Fisheries Research, 15 (1993) 301–313
Elsevier Science Publishers B.V., Amsterdam

Use of a semi-pelagic trawl in a tropical demersal trawl fishery

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(Accepted 29 June 1992)

ABSTRACT

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

A fork rigged semi-pelagic trawl was modified to meet Australian regulations and its performance was evaluated against that of a demersal trawl commonly used in a tropical trawl fishery. The catch rates and sizes of commercial species (mainly *Lutjanus* spp.) and production costs were found to be similar in both nets. However, the semi-pelagic trawl caught less unwanted species, had less impact on the substrate and produced higher quality product. It is a viable commercial alternative for the demersal trawl fishery.

INTRODUCTION

Australia's northern trawl fishery on the continental shelf between 114–140°E is a multi-species finfish fishery of major commercial importance (Edwards, 1983; Sainsbury, 1987). This fishery underwent drastic changes in species composition on the Northwest Shelf (114–123°E) during the 1970s, possibly induced by trawling (Sainsbury, 1987; Hutchings, 1990). Indeed, trawling may alter the morphology of substrates (e.g. Krost et al., 1990), modify or damage seagrass meadows (e.g. Peres, 1984), sponge and coral beds (e.g. Dolah et al., 1987) and other benthos (Reise and Schubert, 1987), increase the turbidity of the water column overlying the fishing ground (e.g. Churchill, 1989) and even affect sea birds and seals (Ryan and Moloney, 1988). Further, poor selectivity of demersal trawls results in the capture of numerous unwanted species which reduces the efficiency of commercial operations and inflicts physical damage to target species.

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The environmental implications of demersal trawling have led us to find alternative methods for harvesting Lutjanidae which are selective, have considerably lower impact on benthic structures, and have comparable or reduced production and operation costs. While passive, selective and less damaging fishing methods are suited for some species, such as droplines for *Pristipomoides* spp. and traps for *Lutjanus sebae* (D.C. Ramm, unpublished data), red snappers (*Lutjanus malabaricus* and *L. erythropterus*) are taken more cost-effectively using trawls. The use of mid-water trawls meet the environmental criterion. However, their high production cost (more than 20 000 Australian dollars), requirement for power (>600 kW) and netsondes presently exceed the capability of the fishery. We modified a semi-pelagic trawl to meet our criteria. In this paper, we describe the net and its performance, and outline its application in a tropical demersal fishery.

MATERIALS AND METHODS

The semi-pelagic trawl used was based on designs of high-opening trawls with fork rigging (e.g. Maucorps and Portier, 1971; Garner, 1978; J.C. Brabant, personal communication, 1990) and modified by R.P. Mounsey to meet local fishery regulations. It uses fly wires (upper bridles) to lift the headline to target fish 8–15 m above the substrate, and the footrope is raised off the bottom reducing both damage to the net and benthic habitats; there is no bobbin line.

The modified semi-pelagic trawl (Fig. 1), locally known as 'Julie Anne', is a four-seam box trawl with equal length (38 m) headline and footrope. The net was scaled to suit trawlers of 23–27 m and 300–400 kW operating in finfish and shrimp fisheries in northern Australia. The headline was buoyed with 13 floats of diameter 280 mm providing a total lift of 115 kg. The footrope was weighted by two 60 kg (in air) steel weights, one at each extremity of the wings, and 7 lengths of chain spread over a distance of 4 m at the centre. Each length (0.5 m) of chain weighed 10 kg (in air). The fly wires (length, 92 m; diameter, 16 mm) and their points of connection to the warps (37 m ahead of the boards) were adjusted during gear trials so that the height of the footrope was set at a minimum distance of 0.3 m above the substrate, and the opening height of the trawl was approximately 10 m. The lower bridles (diameter, 20 mm) were 65 m long.

The performance of the semi-pelagic net was compared with that of a demersal trawl (Paulegro) commonly used in the northern finfish trawl fishery. This contrast net was a two-seam trawl with an overhanging headline and cutaway wings (Fig. 2). The 46-m headline had 54 floats of diameter 200 mm; the total buoyancy was 160 kg. The bobbin line had rubber disks of diameter 150 mm, lead weights, chains and steel cable with a total weight of approxi-

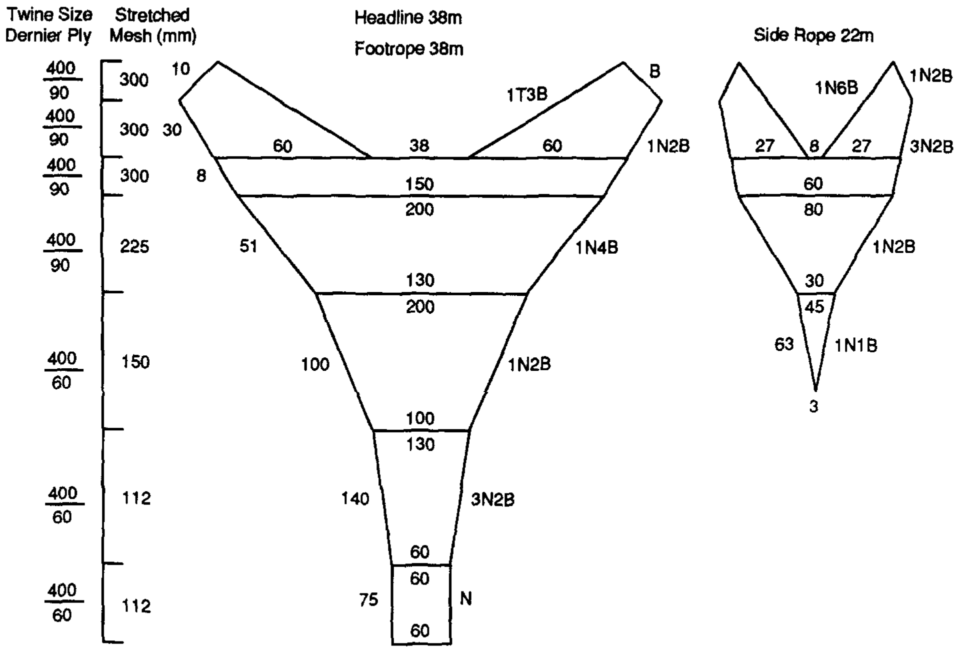

Fig. 1. Schematic diagram of the Julie Anne trawl.

mately 500 kg (in air). The rigging assembly was similar to that used in the northern trawl fishery, with sweeps of 50 m (diameter, 16 mm) and upper and lower bridles of 50 m (diameter, 16 mm). The opening height of the trawl was 4–5 m.

Both trawls were constructed of polyethylene netting and had codends of similar volume made from 5 mm braided netting with a stretched mesh size of 112 mm. The nets were rigged with 1.5 m×2.3 m steel boards ("V-doors"). The trawl path widths were adjusted to 65 m during gear trials using light cords of varying lengths stretched between the boards (e.g. Edwards, 1983).

Following the successful testing of a scale model (approximately 1 : 10) and the fine tuning of the full-scale net, the performance of the Julie Anne trawl was compared with that of the Paulegro trawl in terms of catch rate, species composition, size of fish, product quality, impact on the substrate and power requirement. The comparison was conducted within an extensively fished trawl ground in the Arafura Sea (9°40′–10°50′S and 136°40′–137°30′E) at a depth of 43–55 m and over a substrate ranging from soft mud to low-lying reef. Data for the comparison were acquired from 14 tows with the Julie Anne net (8–11 March 1991) and 14 corresponding tows with the Paulegro net (13–16 March 1991) conducted under similar tidal amplitudes and weather conditions. Tow durations (bottom time, 3 h), sorting of the catch into commercial and non-commercial categories and processing followed the current practice in the fishery.

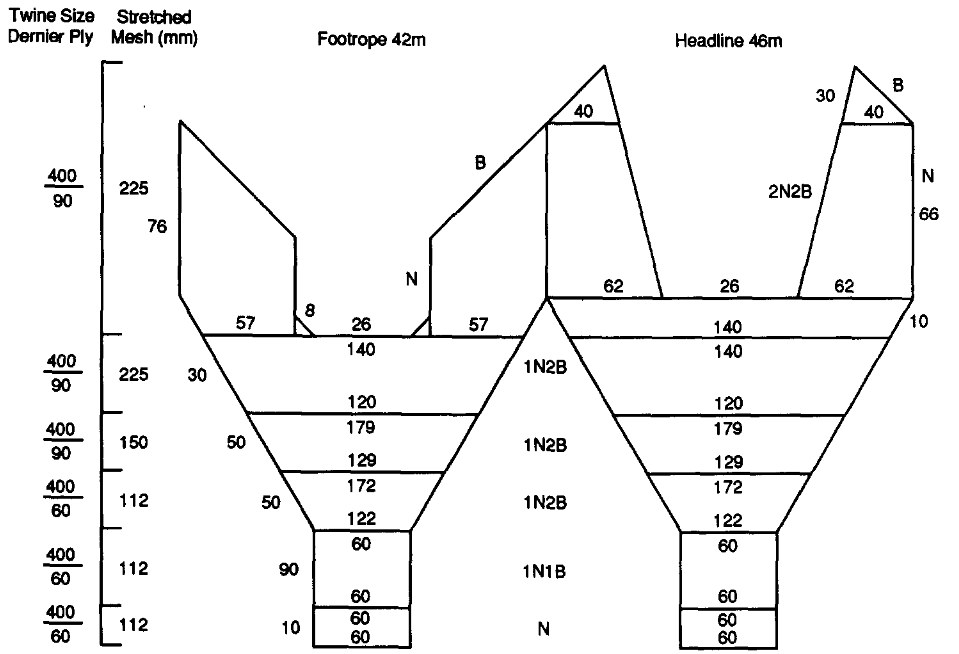

Fig. 2. Schematic diagram of the Paulegro trawl.

Both nets were deployed from a chartered trawler powered by a Callesen main engine developing some 370 kW and driving a variable pitch propeller. Main engine revolutions (410 r.p.m.) and propeller pitch (80%) were held constant throughout; the bollard pull was rated at 6 t. Positions and towing speeds were obtained from a global positioning system (Furuno) and depths and fish marks were recorded using a colour sounder (Koden). The ground tackle and its impact on the substrate were monitored using a neutrally buoyed underwater video camera and light unit (Sony CCD-TR55E; Amphibico, Dorval, Que.). The 'shine' on the rigging of the nets was also used to gauge the performance of the ground tackle over the bottom.

All fish and invertebrates were identified to species, where possible, and each taxon was weighed on board to the nearest 0.05 kg. All individuals from 21 abundant species of fish were measured to the nearest cm. For each of 7 commercial species, 3 individuals from each type of gear were randomly chosen from the catches, bled in water at an ambient temperature of 25–30°C for about 30 min, frozen at −40°C and transported to the International Food Institute of Queensland (Brisbane) for evaluation of product quality. The fish were maintained at −40°C for 4 weeks and then thawed to +4°C over a period of less than 24 h. Three trained judges assessed the general appearance (resilience of the flesh and gill and eye appearance), body colour, scale condition (presence of scales and mucous) and physical condition (external damage) on a scale from 1 (poor) to 5 (excellent).

RESULTS

Nineteen commercial taxa of fish and invertebrate were caught during the comparison. Overall, the 14 Julie Anne tows produced 5490 kg of commercial species, and the Paulegro tows netted 4480 kg. A total of 7500 kg of red snappers were caught during the 28 3-h tows. The mean catch rates of commercial species are given in Table 1. Catch rates were similar ($P>0.1$) in both nets for 10 taxa (e.g. *L. malabaricus, L. erythropterus, Lutjanus johni*). However, the mean catch rate of *Carcharhinus tilstoni* was higher ($P<0.1$) in the Julie Anne trawl, and 5 taxa (*Diagramma pictum, C. dussumieri, L. sebae, Pristipomoides multidens* and *Sepia* spp.) had greater ($P<0.1$) mean catch rates in the Paulegro trawl.

TABLE 1

Mean catch rates (kg 3 h^{-1}) of commercial fish and invertebrates caught in the Julie Anne ($n=14$) and Paulegro ($n=14$) trawls in the Arafura Sea in March 1991

Taxon		Julie Anne		Paulegro		*F*	*P*
Scientific name	Common name	Mean	s.e.	Mean	s.e.		
No difference between nets							
Lutjanus malabaricus	Saddletail snapper	293.3	54.3	192.9	36.1	2.373	0.136
Lutjanus erythropterus	Scarlet snapper	27.3	27.1	22.2	9.8	0.031	0.861
Lutjanus johni	Golden snapper	10.5	10.0	2.5	1.5	0.631	0.434
Scomberomorus commerson	Spanish-mackerel	6.2	3.5	0.6	0.4	2.547	0.123
Lutjanus russelli	Russell's snapper	6.1	1.6	6.9	2.8	0.060	0.808
Rhizoprionodon acutus	Milk shark	2.3	1.0	2.5	0.6	0.040	0.843
Carcharhinus sorrah	Sorrah shark	1.5	0.9	0.1	0.1	2.333	0.139
Hemigaleus microstoma	Weasel shark	0.9	0.9	1.5	0.7	0.247	0.623
Lutjanus argentimaculatus	Mangrove-jack	0.5	0.5	0.4	0.2	0.003	0.957
Loligo spp.	Squid	0.1	0.0	0.1	0.0	0.139	0.713
Higher rates in the Julie Anne net							
Carcharhinus tilstoni	Blacktip shark	14.3	4.6	3.5	1.6	4.977	0.035
Carcharhinus macloti	Shark	0.1	0.1	0.0	0.0	-	-
Higher rates in the Paulegro net							
Diagramma pictum	Painted sweetlip	11.7	4.1	35.4	10.2	4.669	0.040
Carcharhinus dussumieri	Blackspot shark	10.6	2.6	28.8	5.7	8.538	0.007
Lethrinus lentjan	Red-spot emperor	4.8	1.5	12.3	3.9	3.303	0.081
Lutjanus sebae	Red emperor	1.6	0.6	7.6	2.0	8.191	0.008
Pristipomoides multidens	Gold-band snapper	0.2	0.1	1.2	0.4	7.335	0.012
Sepia spp.	Cuttlefish	0.3	0.1	1.2	0.2	13.417	0.001
Lethrinus fraenatus	Blue-lined emperor	0.0	0.0	0.1	0.1	-	-

TABLE 2

Mean catch rates (kg 3 h^{-1}) of non-commercial fish caught in the Julie Anne ($n=14$) and Paulegro ($n=14$) trawls in the Arafura Sea in March 1991. Species with both mean catch rates <0.05 kg 3 h^{-1} are not included; +, >0.0 to <0.05 kg 3 h^{-1}

Taxon		Julie Anne		Paulegro		*F*	*P*
Scientific name	Common name	Mean	s.e.	Mean	s.e.		
No difference between nets							
Carangoides uii	Onion trevally	32.1	5.0	34.6	10.7	0.045	0.833
Carangoides chrysophrys	Long-nosed trevally	19.9	4.0	21.4	4.3	0.062	0.805
Himantura sp.B	Brown stingray	14.1	14.1	27.3	11.1	0.542	0.468
Mene maculata	Moon-fish	11.9	6.2	11.6	5.5	0.001	0.975
Apolectus niger	Black pomfret	10.0	4.1	17.4	7.5	0.744	0.396
Carcharhinus plumbeus	Sandbar shark	7.0	7.0	3.3	2.4	0.257	0.616
Carangoides malabaricus	Malabar trevally	6.9	2.4	8.5	1.8	0.296	0.591
Leiognathus fasciatus	Broad-banded ponyfish	4.5	4.2	0.9	0.8	0.699	0.411
Caranx bucculentus	Blue-spotted trevally	4.2	2.4	5.7	3.0	0.158	0.694
Hemipristis elongatus	Fossil shark	3.8	2.9	6.3	2.1	0.468	0.500
Aetobatus narinari	Spotted eagle ray	2.9	2.9	2.1	2.1	0.040	0.843
Epinephelus suillus	Malabar rock-cod	2.7	0.9	4.6	1.7	0.943	0.340
Rachycentron canadus	Black kingfish	2.5	2.2	4.0	1.8	0.283	0.599
Ulua aurochs	Mirror-mouthed trevally	2.3	1.8	1.3	0.8	0.233	0.633
Stegostoma varium	Leopard catshark	2.1	2.1	1.4	1.4	0.083	0.776
Sphyraena putnamiae	Military sea-pike	1.9	0.5	5.0	2.3	1.811	0.190
Ariomma indica	Indian eyebrow-fish	1.8	0.6	3.3	0.9	1.795	0.192
Selar crumenophthalmus	Big-eye scad	1.5	0.8	0.7	0.3	0.894	0.353
Platax batavianus	Hump-headed batfish	1.5	0.8	6.2	3.7	1.574	0.221
Aetomylaeus nichofii	Barbless duckbill ray	1.4	0.5	3.0	1.3	1.217	0.280
Alepes sp. (*melanoptera*)	Small-mouth scad	1.2	0.4	2.1	0.8	1.017	0.323
Zabidius novemaculatus	Nine-spined batfish	1.2	0.5	0.6	0.2	1.143	0.295
Scomberomorus munroi	Munro's Spanish-mackerel	1.2	0.4	1.2	0.6	0.000	0.994
Alectis indicus	High-brow pennantfish	1.1	0.4	1.8	0.6	0.830	0.371
Scomberomorus queenslandicus	School Spanish-mackerel	1.1	0.5	1.5	0.8	0.259	0.615
Alectis ciliaris	Round-headed pennantfish	0.9	0.5	1.7	0.8	0.702	0.410
Johnius vogleri	Sharp-toothed croaker	0.9	0.9	0.4	0.3	0.308	0.584
Selar boops	Ox-eye scad	0.8	0.7	1.1	1.0	0.056	0.814
Decapterus russellii	Indian scad	0.7	0.7	0.1	0.0	0.872	0.359
Uraspis uraspis	White-tongued jack	0.6	0.2	0.9	0.3	0.607	0.443
Psenopsis humerosa	Black-spot butterfish	0.5	0.2	0.6	0.1	0.116	0.736
Sphyrna lewini	Hammerhead shark	0.4	0.4	2.3	2.1	0.708	0.408
Scomberomorus semifasciatus	Grey mackerel	0.4	0.4	1.5	0.6	2.406	0.133
Seriolina nigrofasciata	Black-banded kingfish	0.3	0.1	0.5	0.1	2.617	0.118
Alutera monoceros	Unicorn leatherjacket	0.3	0.2	0.4	0.2	0.080	0.780
Scolopsis taeniopterus	Red-spot monocle-bream	0.2	0.1	0.3	0.1	2.196	0.150
Epinephelus areolatus	Yellow-spotted rock-cod	0.1	0.1	0.3	0.1	1.459	0.238
Priacanthus macracanthus	Large-spined big-eye	0.1	0.0	0.1	0.0	2.206	0.150
Gazza minuta	Toothed ponyfish	0.1	0.0	+	0.0	1.177	0.288
Rastrelliger kanagurta	Indian mackerel	0.1	0.1	0.3	0.1	1.480	0.235
Rhynchostracion nasus	Small-nosed boxfish	0.1	0.1	0.3	0.1	2.249	0.146
Lagocephalus spadiceus	Half-smooth golden puffer	0.1	0.0	0.2	0.1	1.998	0.169
Echeneis naucrates	Slender suckerfish	+	0.0	0.1	0.1	1.228	0.278
Pomadasys maculatum	Blotched javelin-fish	+	0.0	0.4	0.3	1.768	0.195
Sphyraena forsteri	Blotched sea-pike	+	0.0	0.1	0.0	1.378	0.251
Pseudomonacanthus peroni	Pot-bellied leatherjacket	+	0.0	0.1	0.1	0.899	0.352

TABLE 2 (continued)

Taxon		Julie Anne		Paulegro		*F*	*P*
Scientific name	Common name	Mean	s.e.	Mean	s.e.		
Higher rates in the Julie Anne net							
Megalaspis cordyla	Finny scad	8.0	3.1	2.1	0.9	3.305	0.081
Makaira indica	Black marlin	3.5	3.5	0.0	0.0	–	–
Protonibea diacanthus	Black jewfish	0.2	0.2	0.0	0.0	–	–
Chirocentrus dorab	Wolf-herring	0.1	0.1	0.0	0.0	–	–
Thunnus tonggol	Long-tail tuna	0.1	0.1	0.0	0.0	–	–
Anchisomus multistriatus	Many-striped pufferfish	0.1	0.1	0.0	0.0	–	–
Higher rates in the Paulegro net							
Himantura toshi	Coachwhip stingray	1.3	1.3	82.3	15.2	28.379	0.000
Arius thalassinus	Giant salmon catfish	5.3	1.6	57.9	10.8	23.037	0.000
Rhynchobatus djiddensis	Shovelnose-ray	0.2	0.2	18.3	9.8	3.443	0.075
Himantura sp.A	Leopard-spotted stingray	2.1	2.1	15.0	5.9	4.205	0.051
Priacanthus tayenus	Threadfin big-eye	3.4	0.7	12.5	1.9	19.506	0.000
Abalistes stellaris	Starry triggerfish	3.6	0.7	7.9	0.9	14.436	0.001
Nemipterus hexodon	Ornate threadfin-bream	1.1	0.4	7.4	0.9	38.343	0.000
Nebrius ferrugineus	Tawny nurse shark	0.0	0.0	5.9	5.9	–	–
Trixiphichthys weberi	Long-nosed tripodfish	0.5	0.2	5.9	1.3	17.630	0.000
Saurida micropectoralis	Short-finned lizardfish	0.3	0.1	5.8	1.2	20.391	0.000
Psettodes erumei	Tropical halibut	0.6	0.2	5.7	0.6	71.853	0.000
Lagocephalus lunaris	Rough golden pufferfish	1.1	0.5	4.7	1.8	3.624	0.068
Lutjanus vittus	One-band snapper	1.7	0.4	4.0	0.8	6.613	0.016
Gymnura australis	Rat-tailed ray	0.1	0.1	3.1	1.1	7.355	0.012
Pomadasys kaakan	Yellow-finned javelin-fish	0.0	0.0	2.5	2.5	–	–
Argyrops spinifer	Long-spined sea-bream	0.3	0.1	2.4	0.7	8.582	0.007
Cyclichthys hardenbergi	Plain porcupine-fish	0.4	0.3	1.8	0.7	3.339	0.079
Carangoides humerosus	Epaulet trevally	0.5	0.2	1.3	0.4	3.272	0.082
Mobula diabola	Manta ray	0.0	0.0	1.0	1.0	–	–
Caranx ignobilis	Giant trevally	0.0	0.0	1.0	1.0	–	–
Aetomylaeus vespertilio	Rare eagle ray	0.0	0.0	0.8	0.6	–	–
Amphotistius kuhlii	Blue-spotted stingray	0.0	0.0	0.6	0.2	–	–
Velifer hypselopterus	High-finned veilfin	0.1	0.0	0.6	0.1	17.365	0.000
Fistularia petimba	Rough flutemouth	+	0.0	0.5	0.1	39.837	0.000
Lepidotrigla sp.1	Blue-finned gurnard	0.1	0.0	0.5	0.2	5.956	0.022
Amphotistius sp.3	Black-spotted stingray	+	0.0	0.4	0.2	7.777	0.010
Saurida undosquamis	Checkered lizardfish	+	0.0	0.4	0.1	14.760	0.001
Pseudorhombus diplospilus	Four twin-spot flounder	0.0	0.0	0.4	0.1	–	–
Lagocephalus inermis	Smooth golden pufferfish	0.1	0.1	0.4	0.1	3.834	0.061
Paramonacanthus filicauda	Threadfin leatherjacket	+	0.0	0.3	0.1	16.754	0.000
Sargocentron rubrum	Red squirrelfish	0.1	0.0	0.2	0.1	3.318	0.080
Pentaprion longimanus	Long-finned silver-biddy	+	0.0	0.2	0.0	21.440	0.000
Rhina ancylostoma	Shark ray	0.0	0.0	0.1	0.1	–	–
Dactyloptena papilio	Flying-gurnard	+	0.0	0.1	0.0	3.297	0.081
Epinephelus sexfasciatus	Six-banded rock-cod	0.0	0.0	0.1	0.0	–	–
Epinephelus heniochus	Three-lined rock-cod	0.0	0.0	0.1	0.1	–	–
Gnathanodon speciosus	Golden trevally	0.0	0.0	0.1	0.1	–	–
Selaroides leptolepis	Yellow-striped trevally	+	0.0	0.1	0.1	3.021	0.094
Lutjanus lutjanus	Big-eye sea-perch	0.0	0.0	0.1	0.1	–	–
Nemipterus peronii	Notched threadfin-bream	0.0	0.0	0.1	0.0	–	–
Trichiurus lepturus	Large-headed hairtail	+	0.0	0.1	0.0	3.704	0.065
Arothron stellatus	Starry pufferfish	0.0	0.0	0.1	0.1	–	–
Cyclichthys orbicularis	Short-spined porcupine-fish	0.0	0.0	0.1	0.1	–	–

TABLE 3

Mean catch rates (kg 3 h^{-1}) of benthic invertebrates and debris caught in the Julie Anne ($n=14$) and Paulegro ($n=14$) trawls in the Arafura Sea in March 1991. +, >0.0 to <0.05 kg 3 h^{-1}

Benthic category	Julie Anne		Paulegro		F	P
	Mean	s.e.	Mean	s.e.		
Invertebrates						
Asteroid	0.2	0.1	4.7	1.0	19.944	0.000
Thenus orientalis	0.2	0.1	0.7	0.2	5.065	0.033
Brachyura	+	0.0	0.4	0.1	27.144	0.000
Amusium pleuronectes	+	0.0	0.1	0.0	23.611	0.000
Octopus	+	0.0	+	0.0	0.357	0.556
Penaeid	0.0	0.0	+	0.0	–	–
Other benthos	0.2	0.1	6.8	3.5	3.488	0.073
Debris						
Rock	+	0.0	6.0	1.8	10.819	0.003
Shell	+	0.0	1.4	0.5	7.074	0.013

The series of 14 Julie Anne tows yielded 87 taxa of non-commercial fish (2740 kg), and the 14 Paulegro tows produced 128 taxa (6350 kg). The overall catch rate of non-commercial taxa in the Paulegro net (453 kg tow^{-1}) was higher ($P<0.1$) than that in the Julie Anne tow (195 kg tow^{-1}). The mean catch rates for non-commercial taxa are given in Table 2. The catch rates were similar ($P>0.1$) for 52 species of fish, however, greater catch rates were observed for 7 species in the Julie Anne trawl and 75 taxa in the Paulegro net. Notably, the Paulegro trawl caught more ($P<0.1$) *Arius thalassinus* and *Himantura toshi*. The catch rates for all categories of benthic invertebrate, except octopus, and debris were lower ($P<0.1$) in the Julie Anne trawl than those observed in the Paulegro trawl (Table 3). The overall catch rate of benthos in the Julie Anne trawl (0.6 kg tow^{-1}) was only 3% of that observed for the Paulegro net.

Examination of the shine on the rigging and ground tackle, and videophotography indicated that the height of the Julie Anne footrope above the substrate ranged from approximately 1.0 m at the wings to about 0.3 m at the centre. The sweeps did not come into contact with the bottom and their attachment point to the boards was 0.8 m above the substrate. 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. 1). These contacts caused 9 furrows of width 10–30 cm and depth 5–10 cm, disturbing only 2 m (about 3%) of the 65 m wide trawl path. In contrast, the Paulegro bobbin line, lower bridles and sweeps contacted the substrate along the entire trawl path, often penetrating the substrate and dislodging benthos.

TABLE 4

Results of Kolmogorov–Smirnov 2-sample test (asymptotic) of differences in length (cm) frequency distributions of 21 species of fish caught in the Julie Anne ($n = 14$) and Paulegro ($n = 14$) trawls in the Arafura Sea in March 1991

Taxon	Julie Anne			Paulegro			KSa	*P*
	n	Mean	s.e.	*n*	Mean	s.e.		
Commercial species								
Diagramma pictum	80	48	<1	345	45	<1	1.618	0.011
Lethrinus fraenatus	0	–	–	1	39	0	–	–
Lethrinus lentjan	131	29	<1	341	29	<1	0.841	0.479
Lutjanus argentimaculatus	3	50	5	4	55	5	0.873	0.431
Lutjanus erythropterus	253	47	<1	227	47	<1	1.131	0.155
Lutjanus johni	85	48	1	30	48	1	0.600	0.864
Lutjanus lutjanus	0	–	–	11	16	<1	–	–
Lutjanus malabaricus	1535	43	<1	660	45	<1	3.420	0.000
Lutjanus russelli	148	32	<1	164	31	<1	1.561	0.015
Lutjanus vittus	99	24	<1	253	23	<1	0.663	0.771
Lutjanus sebae	28	35	1	93	36	1	0.982	0.290
Pristipomoides multidens	5	31	3	19	37	1	1.068	0.204
Non-commercial species								
Abalistes stellaris	104	28	<1	260	27	<1	1.856	0.002
Epinephelus areolatus	5	30	1	9	30	1	0.637	0.811
Epinephelus heniochus	0	–	–	5	28	3	–	–
Epinephelus sexfasciatus	0	–	–	6	27	4	–	–
Epinephelus suillus	7	69	2	15	60	4	1.165	0.132
Nemipterus hexodon	106	19	<1	677	20	<1	1.011	0.258
Parupeneus pleurospilus	0	–	–	1	24	0	–	–
Psenopsis humerosa	39	18	<1	41	19	<1	1.057	0.214
Saurida micropectoralis	16	30	1	280	31	<1	0.757	0.615

The production costs of the Julie Anne trawl, and Paulegro trawl and bobbin line, were comparable (approximately 8000 Australian dollars). Although statistically different ($P < 0.1$), the mean towing speed for the Julie Anne net (1.75 m s^{-1} over ground) and the Paulegro net (1.90 m s^{-1}) were within 9%.

Of the 21 species of fish selected for length–frequency analysis (Table 4), 16 occurred in both nets. Twelve species (e.g. *Lethrinus lentjan, L. erythropterus, Nemipterus hexodon,* and *Psenopsis humerosa*) had comparable ($P > 0.1$) distribution patterns and thus similar sizes in both nets. The remaining 4 species had different ($P < 0.1$) distributions; the mean length of *Abalistes stellaris, D. pictum* and *Lutjanus russelli* was 1–3 cm larger in the Julie Anne net, while that of *L. malabaricus* was 2 cm larger in the Paulegro net.

On-deck observations indicated that fish caught in the Julie Anne trawl

TABLE 5

Comparison of four product quality indices for seven commercial species of fish netted in the Julie Anne and Paulegro trawls in the Arafura Sea in March 1991

Species	Julie Anne			Paulegro			*F*	*P*
	n	Mean	s.e.	*n*	Mean	s.e.		
General appearance								
Lethrinus lentjan	9	2.2	0.2	9	1.9	0.2	1.24	0.282
Lutjanus argentimaculatus	3	4.0	0.0	3	3.0	0.6	3.00	0.158
Lutjanus erythropterus	9	1.7	0.2	9	2.0	0.2	2.00	0.177
Lutjanus johni	9	3.1	0.1	9	1.9	0.1	60.50	0.000
Lutjanus malabaricus	9	3.3	0.5	9	1.7	0.2	11.11	0.004
Lutjanus sebae	9	2.3	0.2	9	1.6	0.2	7.00	0.018
Pristipomoides multidens	9	2.1	0.1	6	1.7	0.2	4.16	0.062
Body colour								
Lethrinus lentjan	9	2.8	0.2	9	2.0	0.0	12.25	0.003
Lutjanus argentimaculatus	3	4.0	0.0	3	2.7	0.3	16.00	0.016
Lutjanus erythropterus	9	2.2	0.2	9	2.9	0.3	3.79	0.070
Lutjanus johni	9	3.7	0.3	9	2.0	0.0	33.33	0.000
Lutjanus malabaricus	9	4.7	0.2	9	1.7	0.2	108.00	0.000
Lutjanus sebae	9	2.2	0.1	9	1.8	0.1	4.57	0.048
Pristipomoides multidens	9	2.9	0.3	6	2.2	0.3	2.51	0.137
Scale condition								
Lethrinus lentjan	9	2.1	0.3	9	2.0	0.2	0.10	0.756
Lutjanus argentimaculatus	3	4.7	0.3	3	2.7	0.3	18.00	0.013
Lutjanus erythropterus	9	1.8	0.1	9	1.9	0.2	0.20	0.661
Lutjanus johni	9	4.7	0.2	9	4.0	0.4	2.67	0.122
Lutjanus malabaricus	9	3.6	0.5	9	1.7	0.2	14.10	0.002
Lutjanus sebae	9	1.8	0.1	9	1.3	0.2	4.00	0.063
Pristipomoides multidens	9	2.0	0.0	6	1.7	0.2	3.90	0.070
Physical condition								
Lethrinus lentjan	9	2.1	0.2	9	1.9	0.1	0.94	0.346
Lutjanus argentimaculatus	3	3.3	0.7	3	1.7	0.3	5.00	0.089
Lutjanus erythropterus	9	1.6	0.2	9	1.4	0.2	0.20	0.661
Lutjanus johni	9	4.3	0.2	8	3.1	0.4	7.20	0.017
Lutjanus malabaricus	9	2.4	0.3	9	1.3	0.2	10.81	0.005
Lutjanus sebae	9	1.8	0.1	9	1.2	0.1	7.14	0.017
Pristipomoides multidens	9	1.6	0.2	6	1.2	0.2	2.32	0.152

were clean with little physical damage while those caught in the Paulegro net were at times muddy, noticeably bruised from large rays, sponges and benthic debris, and/or spiked by *A. thalassinus* and *Trixiphichthys weberi*. Results from the laboratory analysis are given in Table 5. All four quality indices for *L. malabaricus* caught in the Julie Anne trawl were higher ($P<0.1$) than those caught in the Paulegro net. Body colour was also greater ($P<0.1$) for *L.*

lentjan, Lutjanus argentimaculatus, L. johni and *L. sebae* in the Julie Anne trawl. In addition, some of these species caught in the Julie Anne net had higher ($P<0.1$) scores for general appearance, scale and physical conditions. The quality of *L. erythropterus* and *P. multidens* was generally comparable ($P>0.1$) in both trawls. Videophotography of fish in the codends of both types of nets revealed that fish in the Paulegro trawl appeared agitated and were continuously showered with sediment and debris raised by the bobbin line. In contrast, fish in the Julie Anne net were swimming with the net; the plume of sediment and the sound of the ground tackle moving over the substrate, recorded by the video unit, were not detected.

DISCUSSION

The semi-pelagic trawl is considered commercially viable in the trawl fishery in the Arafura Sea, as evidenced by the similar catch rates achieved for the targeted red snappers in, and by the similar size of fish retained by, both trawls, and comparable production costs. These catch rates were also realised by the Julie Anne net at a slightly slower trawling speed, indicating a greater fishing efficiency. This trawl also enhances product quality by reducing the unwanted catch of fish, benthos and debris, the associated frequency of contacts, and agitated swimming, and eliminating showering by sediment and debris. Reduced wear and tear on the net and rigging due to limited contact with the substrate further enhance the commercial viability of the Julie Anne net.

The environmental disturbance caused by the Julie Anne trawl was, as predicted from the semi-pelagic design, significantly less than that of the Paulegro net due to much reduced impact on the substrate, damage to the benthos and catch of unwanted components. While our analysis of catch data could not detect the shearing and dislodging of benthic structures by the sweeps, videophotography of the Julie Anne footrope showed no such damage even at the point of the trawl closest to the substrate (centre of footrope, about 0.3 m off the bottom). In our study, the semi-pelagic trawl was configured for light benthic cover since the trawl grounds of the Arafura Sea consist predominantly of sand-silty sand (Jongsma, 1974), and benthic formations typically less than 0.3 m above the substrate (D.C. Ramm, unpublished data). A footrope height of 0.3 m was sufficiently close to the substrate to prevent target species from escaping under the net, and sufficiently high to avoid most benthos. Light benthic cover is also present on the Northwest Shelf (Sainsbury, 1987), and may be found in the Gulf of Carpentaria (137–142°E) where sediments similar to those in the Arafura Sea occur (Jones, 1987). On fishing grounds with dense benthos and large sponges, including the Timor Sea (123–131°E), the fork rigging could be adjusted to raise the footrope to any height required to avoid contact with the substrate. However, fine tuning of the Julie

Anne trawl indicated that over light benthic cover, few red snappers were taken when the footrope was set at greater than or equal to 1 m. Further tests are required to determine the feasibility of using semi-pelagic trawls for targeting lutjanids over dense benthos.

Reduced environmental effects, increased product quality, simplified sorting of the catch and reduced wear and tear on the net and rigging fishing, highlight the commercial advantage of a semi-pelagic trawl over conventional demersal gear in the trawl fishery of the Arafura Sea. Further fine tuning would, however, reduce the number of floats on the headline and the weights and chains on the footrope. The selectivity of the trawl may be improved by using square mesh in the codend.

In March 1991, following this study, the Julie Anne net was loaned by the Australian Fisheries Management Authority (then Australian Fisheries Service) to the FV 'Clipper Bird' for further testing. Preliminary examination of the logbook data has lent strong support to our findings. Based on this study and the success of the FV 'Clipper Bird' in using the Julie Anne trawl, the Authority will require vessels operating in the northern trawl fishery to use semi-pelagic trawls from October 1992.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of Graham Baulch, Christine Julius, Alf Mikolaczyk and other Divisional staff, the expertise of Tracy Hay (International Food Institute of Queensland) in the field and laboratory, and the participation of Jon Abbey and the crew of the FV 'Clipper Bird' (A. Raptis & Sons). We thank two anonymous reviewers for their critical comments. This study was supported, in part, by the former Australian Fisheries Service (Fisheries Development Trust Account 1990–1991).

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