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Use of transparent netting to improve size selectivity and reduce bycatch in fish seine nets

C.A. Gray[a,*], R.B. Larsen[b], S.J. Kennelly[a]

[a]*NSW Fisheries Research Institute, PO Box 21, Cronulla, NSW 2230, Australia*
[b]*University of Tromso, Breivika, N-9037 Tromso, Norway*

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Abstract

Strategically placed panels of transparent mesh improved the size selection of targeted commercial species (primarily sand whiting, *Sillago ciliata*) and reduced the bycatch of other species in an estuarine fish seine net. A cover net was placed over the whole bunt and cod-end to quantify the numbers and sizes of fish that passed through the modified and conventional (control) nets. The average size of sand whiting caught in the modified net was larger than in the control net, but other commercial species (sea mullet, flat-tail mullet and silver biddy) showed only a slight change in size selectivity, possibly due to differing escape responses to visual cues. The cover net used in the study appeared to modify the effectiveness of the transparent panels, with some smaller fish observed to re-enter the main net as hauling ceased. An alternative analysis which treated the data as a series of paired comparisons showed an even greater increase in the selection of larger sand whiting than that obtained in the cover net analyses. The panels of transparent netting tested in this experiment show potential as a means of improving the selectivity of fish seine nets.

Keywords: Beach-seine; Haul net; Size-selectivity; Bycatch reduction; Estuarine fish; *Sillago ciliata*

1. Introduction

Commercial seining for finfish (locally termed fish hauling) is permitted in most estuaries in New South Wales (NSW), Australia and forms the basis of a valuable fishery, landing over 1800 tonnes of finfish valued at $4.5 million in 1997/98. Estuarine hauling is, however, one of the most controversial forms of fishing in NSW, with conservation and angling groups claiming that the nets catch and kill many juveniles of recreational and commercial fish species. Further, increased urban development of coastal areas in NSW in recent years and the high visibility of estuarine haul crews has led to even greater conflicts among various estuarine user groups, including tourist operators and local councils.

Currently, 250 fishers are endorsed to use fish hauling nets in NSW estuaries, with haul crews usually comprising 2–6 persons. This fishery is currently managed by a complex set of spatial and temporal closures and gear restrictions, including minimum and maximum mesh sizes and maximum lengths of nets

* Corresponding author. Tel.: +61-2-95278411;
fax: +61-2-95278576.
E-mail address: grayc@fisheries.nsw.gov.au (C.A. Gray).

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and ropes. The most common net configuration used is termed "the general purpose haul net", which must have a mesh size greater than 80 mm in the wings, less than 51 mm in the bunt, and 38–50 mm in the cod-end. However, the regulations governing the amount of net and rope that can be used vary between estuaries, with a maximum 375 m of net and 375 m of rope permitted in rivers, but up to 1000 m of net and 1000 m of rope permitted in coastal lagoons (in some lagoons, 2000 m of rope can be used in winter). The species of fish targeted by haul crews also vary spatially and temporally. For example, in northern NSW, fishers target sand whiting (*Sillago ciliata*) over shallow sand flats throughout warmer months (September–March), while in cooler months (April–August), fishers target sea mullet (*Mugil cephalus*) and bream (*Acanthopagrus australis*). Although estuarine hauling for fish has a long history in NSW (beginning in 1880s), there have been no studies on the selectivity of the nets used in the fishery, even though current mesh regulations were first introduced in 1940s. It is not surprising, therefore, that the configuration of nets currently used do not exhibit optimum selectivity, often retaining large numbers of small fish, including juveniles of the targeted species (pers. obs.).

Many studies have investigated the selectivity of commercial fishing gears, including demersal and pelagic trawls (Casey et al., 1992; Reeves et al., 1992), Danish seines (Jackobson, 1985) and gill nets (Hamley, 1975), but relatively few have examined beach-seining (or hauling) gears (but see Jones, 1982; Lamberth et al., 1995). These latter studies showed that the mesh sizes used in seine net fisheries in South Africa and South Australia were inappropriate, primarily because many small fish were retained and subsequently discarded (often dead). Both these studies concluded that significant increases in mesh size were required to reduce the quantity of bycatch, and that this would reduce considerably the catch of the target species.

It is generally accepted that selection of fish occurs in the cod-ends of mobile fishing gears (like trawls and Danish seines) (Pope et al., 1975; Wileman et al., 1996) and, therefore, most of the techniques for improving selectivity and reducing bycatches have been made in this section of the net (e.g. Ferno and Olsen, 1994; Wileman et al., 1996; Broadhurst et al., 1999). In contrast, observations made from the surface and underwater of NSWs estuarine haul nets indicated that the selection of fish mainly occurs before the fish enter the cod-end. Fish appear to be herded in front of the fishing gear during hauling but, when the net nears the beach (in water depths of 20–50 cm), and the distance between the wing reduces, captive fish become more active and swim in all directions. Most size selectivity during this operation occurs in the anterior section of the bunt and in the wings immediately anterior to the bunt. Because of these observations, we decided that devices to improve size selectivity and reduce bycatch in this fishery should be placed anterior to the cod-end.

The behavioural responses of fish to fishing gears have been noted to be caused by visual and/or hydrodynamic stimuli (see Glass et al., 1993, 1995; Broadhurst et al., 1999). In particular, Glass et al. (1995) demonstrated that, in reasonable light levels fish seem to prefer to swim through clear passages and away from dark areas. Because selectivity in the daytime estuarine fish haul fishery in NSW occurs in shallow, clear water, we concluded that altering visual cues in the net may provide a means to improve selectivity, rather than simply increasing the mesh size as suggested by Lamberth et al. (1995). In this study we tested the effectiveness of transparent (multi-monofilament nylon) panels of mesh strategically inserted in the anterior region of the bunt as a device to improve the size selection of targeted species (principally sand whiting) while concomitantly reducing the capture of unwanted bycatch species.

Several experimental procedures have been used to examine the selectivities of commercial fishing gears, including alternate trawl/haul, trouser trawl and covered net cod-end comparisons (see Pope et al., 1975; Millar and Walsh, 1992; Wileman et al., 1996). In the present study we decided to use a covered net procedure because: (1) operational constraints during hauling and the way fish behaved at the end of the haul precluded the division of the net into two equal halves with two bunts and cod-ends (the trouser net approach); and (2) the species, diversity, abundances and size compositions of fishes can vary substantially between different sites within an estuary and at different phases of the tide, precluding the alternate haul approach. Previous examinations of the selectivity of beach-seine nets have used a covered net approach (Jones, 1982; Lamberth et al., 1995), but the 'covers' used involved a second smaller-meshed net encircling the main net which was deployed only during the last 100 m of the haul — assuming that fish escaped only during the last part of the haul. To remove this assumption, in the present study we used a cover that was attached to the study net, therefore catching and quantifying all escaping fish throughout the entire haul.

2. Materials and methods

2.1. Study area

This study was done during the daytime on commercial fishing grounds in the Bellinger River, in northern New South Wales, Australia (30°30′; 153°02′) in January and February 1998, using a chartered commercial fish haul crew. Throughout the study, individual hauls were done over nine distinct haul sites in a 15 km section of the river, the lowest being 2 km upstream of the river mouth. The bottom type varied from sand to mud from downstream to upstream, and the maximum depth of water ranged from 3–8 m. Visibility in the estuary at the time of sampling was up to 3 m.

2.2. Net configurations

The conventional (control) net used in this study conformed to NSW Fisheries regulations, having a total headline length of 375 m, with 102 mm mesh in the 120 m wings, 51 mm mesh in the 30 m bunt and 38 mm mesh in the cod-end. The net was 2 m deep and was negatively buoyant so that it remained on the substratum at all times. The entire net was made of blue multifilament polyamide, with the bunt and cod-end dyed black. The modified net (see Fig. 1) was the same net, but two panels of 57 mm mesh of transparent multi-monofilament polyamide of 100 meshes (N direction) in length (4.95 m) and 50 meshes (T direction) in depth (1.43 m) were inserted (mesh by mesh) along each side of the anterior section of the bunt using a hanging ratio of approximately 0.45.

The cover net surrounded the entire bunt and cod-end of the control and modified nets and was used to catch and quantify the fish that passed through the meshes of these parts of the gear (see Fig. 1). The cover was made of 32 mm multifilament polyamide, but where it covered the transparent panels it was constructed of 32 mm transparent multi-monofilament polyamide. Small floats were attached to the cover to stop it from digging into the substratum.

2.3. Sampling procedure

Three treatments were compared in this study: the conventional net with the cover (i.e. control), the modified net with the cover, and the modified net without the cover. A comparison of the data gathered

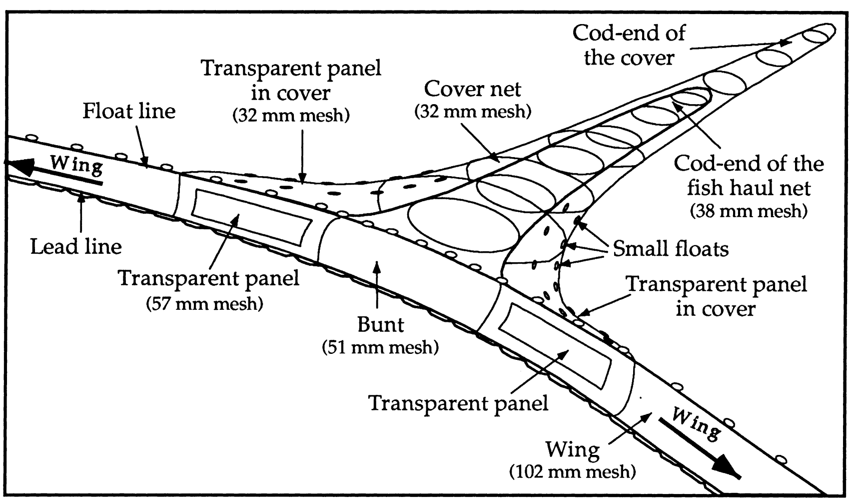

Fig. 1. Diagrammatic representation of the modified net and the cover net.

from the hauls done with the modified net with and without the cover examined any confounding effects of the cover on catches. A total of five replicate hauls were done for each treatment over a period of 10 days. However, the five hauls with the modified net with no cover were done after the 10 hauls with the cover, as it was impractical to remove and re-attach the cover between individual hauls or days. The order in which hauls of each covered-net treatment were done was haphazard, with the panels inserted or removed between sampling days. Depending on the site of each haul, replicates were taken at low or high tide when water movement was minimal.

The hauling procedure usually took approximately 20 min to complete. The rope and net were set from a small boat in a semi-circular shape starting and ending at the shoreline (Fig. 2). After setting, the gear was hauled at approximately 2 km/h (0.5 m s^{-1}) by two small petrol powered 5 kW engines which were staked into the substratum approximately 5 m apart and 1 m shoreward of the water level. The length of rope deployed during each haul varied from approximately 100 m to the maximum 375 m.

Fish caught in the main net and in the cover were kept separate, sorted, identified, counted and measured (fork length) to the nearest 0.5 cm below. When excessive quantities (>200 individuals) of any particular species were captured, a subsample was measured (approximately 100–200 fish). The total catch of each species retained in the main net and the cover was weighed to the nearest 50 g.

2.4. Analyses of data

Detailed analyses were done on four species of economically important fish: sand whiting (*Sillago*

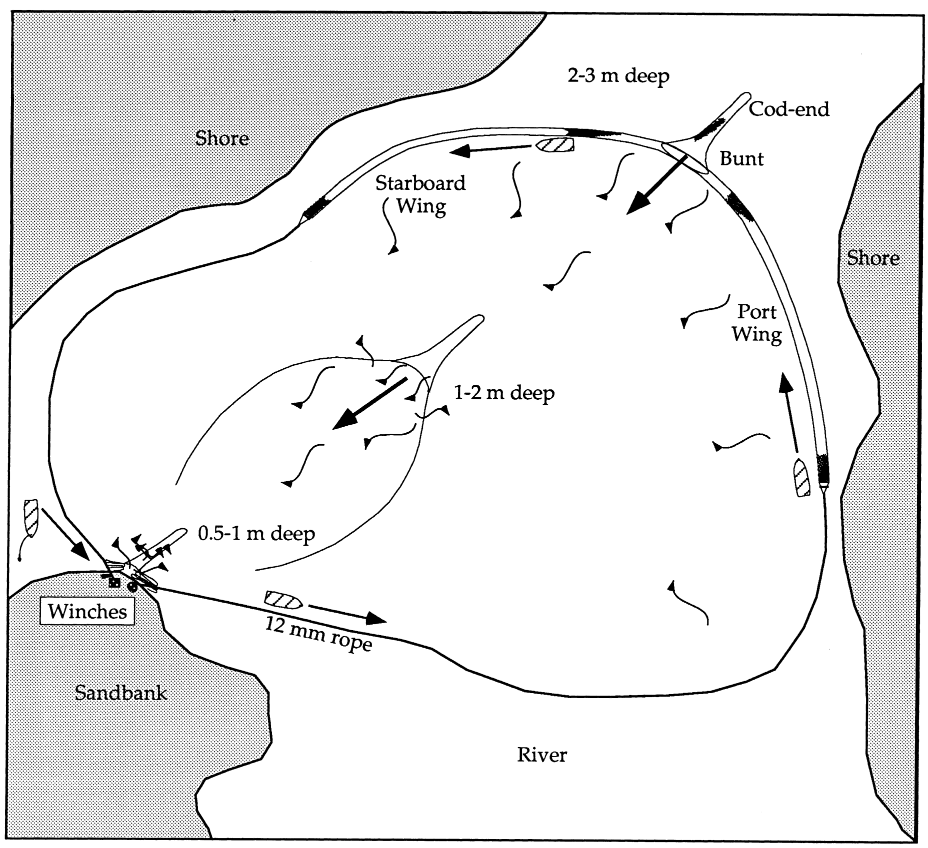

Fig. 2. Diagrammatic representation of the hauling operation as used in this study.

ciliata), sea mullet (*Mugil cephalus*), flat-tail mullet (*Liza argentea*) and silver biddy (*Gerres subfasciatus*). Size-frequencies of each of these species were pooled across hauls for each of the three treatments (control net with cover, modified net with cover, and modified net without cover) and compared using two-sample Kolmogorov–Smirnov tests ($p = 0.05$).

The size selection of each net treatment for the four main species of fish caught were determined using the program 'CC Selectivity' (see Wileman et al., 1996). Logistic selection curves were fitted to the data by a maximum likelihood method (Pope et al., 1975) and, where possible, data from individual replicates were used so that variance analyses could be included (see Fryer, 1991). However, because of small catches for some species and difficulties in fitting the data to a logistic curve, analyses for some species were performed on pooled data.

Because the cover appeared to modify the effectiveness of the panels (see Section 3), we also determined the selection of the modified net for sand whiting using a 'pseudo' trouser net comparison. For this analysis we compared the size composition of sand whiting caught in the modified net without the cover with the size composition of all sand whiting caught in the control net with the cover (i.e. in the main net and the cover net) (see Millar and Walsh, 1992). This comparison was based on an alternate haul design and thus the statistical assumptions surrounding its use may not be totally valid.

The data from each haul were also examined to determine the percentage (by weight and number) of fish of each species that escaped through the control and modified nets. For each replicate, the number of each species caught in the cover net was expressed as a percentage of those that were caught in the main net plus those caught in the cover (i.e. the total entering the fishing gear). The mean percentages (and standard errors) across all five replicates were plotted and the data analysed using a one-way ANOVA.

3. Results

3.1. Observations of the gear fishing

Both surface and underwater observations of the fishing gear confirmed that the small-meshed cover net hung back from, and did not interfere with, the main net and so allowed the free passage of fish escaping through the bunt and cod-end of the control net and through the transparent panels of the modified net. These observations confirmed that sand whiting escaped from the modified net through the transparent panels with some legal sized sand whiting meshing in the panel as they tried to escape (see below). However, after the gear was hauled to the point of landing (<1 m deep) and hauling ceased, a small number of fish that had passed through the main net into the cover net but had not travelled to the cod-end of the cover net were observed (from the surface) to swim back and re-enter the main net via the cod-end, bunt and panels. Whilst most of these fish meshed or became entangled on the outside of the main net and could easily be detected, some fish (particularly very small sand whiting) re-entered the main net and became mixed with its catch. We consequently tied off the cover net immediately after hauling but, despite this, a few small fish still re-entered the main net.

3.2. Composition of catches

Table 1 gives the total number of each species of fish caught in each of the three experimental treatments. Sand whiting, sea mullet, flat-tail mullet and silver biddy dominated catches in all the three treatments, and more detailed analyses of the catches of these species are provided below. Few other species were caught in substantial numbers across all net treatments and data for these species were therefore not analysed.

3.3. Size-frequencies of fish captured

A greater proportion of legal sized sand whiting (>25 cm FL) were retained in the main nets of the modified net with the cover (39.3%) and without the cover (63.4%) than in the main net in the control net (33.2%) (Fig. 3). No such trends were evident for the other three species analysed, as the size distributions of the retained catches of each species did not differ significantly between the modified net with cover and the control net with cover (Kolmogorov–Smirnov tests, $p > 0.05$) (Figs. 4–6). The Kolmogorov–Smir-

Table 1
The numbers of each species of fish retained in the main (M) and cover (C) nets of each experimental treatment[a]

	Conventional net with cover		Modified net with cover		Modified net
	M	C	M	C	M
Silliginidae					
Sillago ciliata	1063	863	954	1093	921
Sillago maculata	1	13		7	
Mugilidae					
Mugil cephalus	654	37	519	65	587
Liza argentea	3446	240	483	88	122
Liza vaigiensis					1
Myxus elongatus	14	3	3		1
Myxus petardi					1
Gerreidae					
Gerres subfasciatus	596	659	154	716	70
Pomatomidae					
Pomatomus saltatrix	22	50			1
Sparidae					
Acanthopagrus australis	17	1	12	2	133
Rhabdosargus sarba	26				43
Pagrus auratus	0	2			2
Carangidae					
Caranx sexfasciatus	41				8
Gnathanodon speciosus	12				
Pseudocaranx dentex	7				
Scomberoides lysan	9				2
Girellidae					
Girella tricuspidata	249	3	11		28
Scatophagidae					
Scatophagus multifasciata					6
Monodactylidae					
Monodactylus argenteus	74		92	15	40
Platycephalidae					
Platycephalus fuscus	1		1	1	2
Bothidae					
Pseudorhombus arsius	1				7
Hemiramphidae					
Hyporhamphus regularis	35	148	6	40	
Teraponidae					
Pelates quadrilineatus	422	801			1
Tetraodontidae					
Tetractenos sp.					1
Soleidae					
Synaptura nigra					1
Clupeidae					
Potamalosa richmondia	2354	10 977	13	130	1

Table 1 (*Continued*)

	Conventional net with cover		Modified net with cover		Modified net
	M	C	M	C	M
Fistulariidae					
Fistularia commersonii	2	10			
Sphyraenidae					
Sphyraena obtusata	68	60			
Monacanthidae					
Meuschenia trachylepis	6	1			3
Siganidae					
Siganus fuscescens	61				2

[a] Five hauls were done with each net treatment.

nov tests also showed that a greater proportion of larger sand whiting and sea mullet were retained in the modified net without the cover than in the modified and control nets with the cover (Figs. 3 and 4), suggesting that the cover affected the performance of the panels in the modified net.

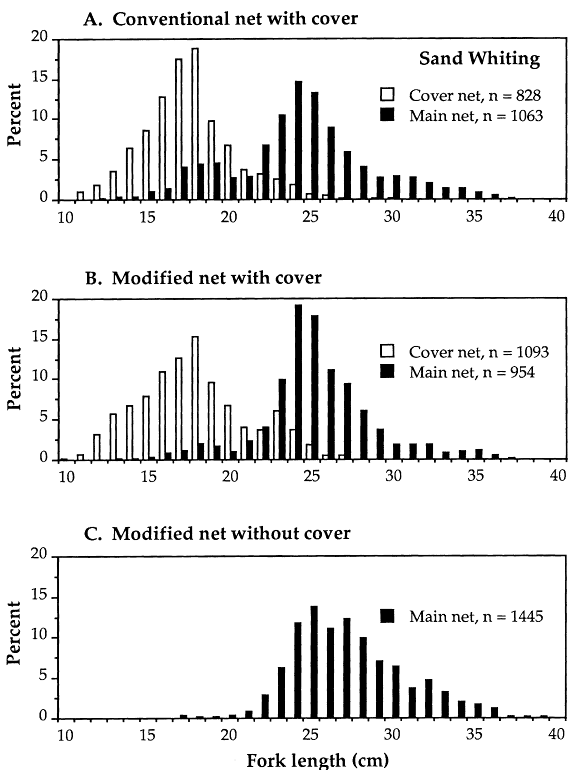

Fig. 3. Size frequencies of sand whiting caught in the modified net with and without the cover net, and in the conventional net with the cover.

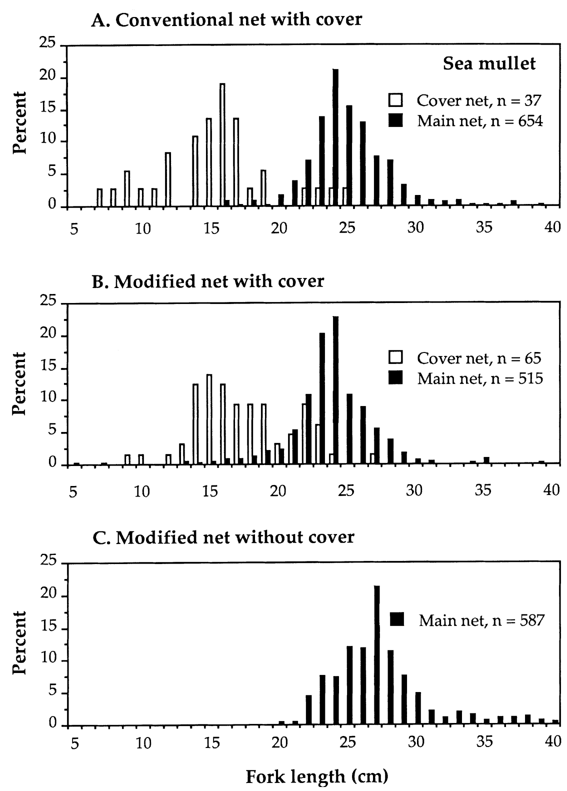

Fig. 4. Size frequencies of sea mullet caught in the modified net with and without the cover net, and in the conventional net with the cover.

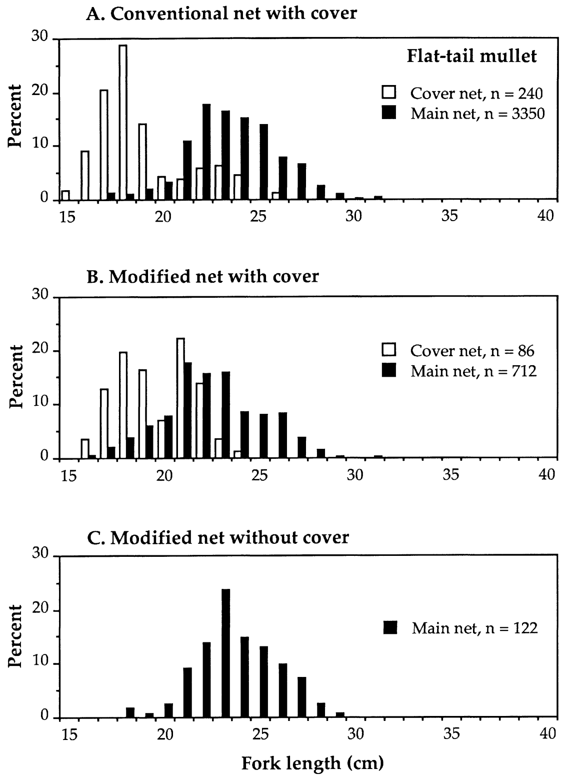

Fig. 5. Size frequencies of flat-tail mullet caught in the modified net with and without the cover net, and in the conventional net with the cover.

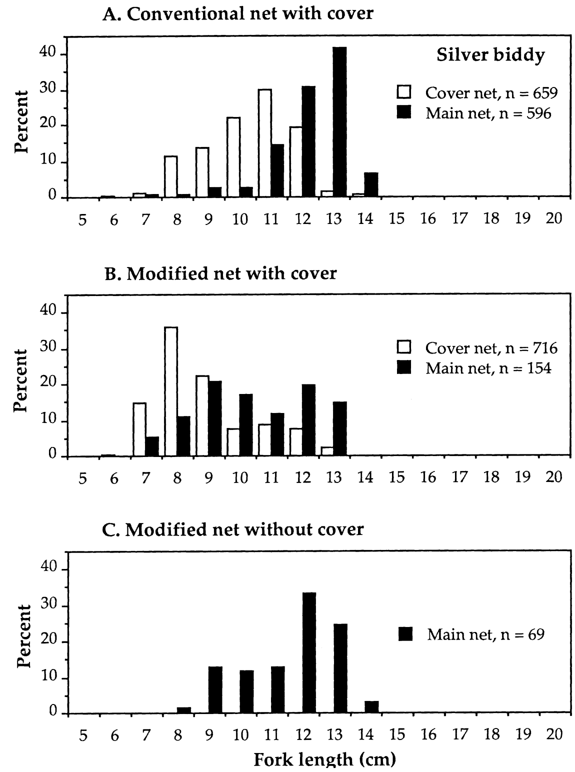

Fig. 6. Size frequencies of silver biddy caught in the modified net with and without the cover net, and in the conventional net with the cover.

3.4. Selectivity of commercial species of fish: covered net comparison

3.4.1. Sand whiting (Sillago ciliata)

One haul from each of the modified and control nets had to be omitted from analysis because the data did not fit the logistic curve. The variance component analyses showed that the 50% selection point of the modified net (22.39 cm FL) was greater than the control net (20.57 cm FL) (9% increase), and the selection range was reduced by 1.52 cm (31%) (Table 2A).

3.4.2. Sea mullet (Mugil cephalus)

Three hauls from the modified net and one from the control net could be included in the analyses, and therefore pooled data were used for the modified net versus the one haul from the control net. Few of the sea mullet captured were within the selection range, but the mid selection point for the modified net was greater (albeit non-significant) than the control net by 0.3 cm (2%), and the selection range was increased by 1.01 cm (36%) (Table 2B).

3.4.3. Flat-tail mullet (Liza argentea)

Three hauls from the modified net and two hauls from the control net could be analysed. The variance component analyses showed that the mid selection point decreased by 2.18 cm (11%), and the selection range increased by 1.82 cm (73%) in the modified net compared to the control net (Table 2C), although these changes were not significant.

3.4.4. Silver biddy (Gerres subfasciatus)

Only two hauls from each gear type were analysed. The mid selection point was virtually the same for both nets, although an increase in the selection range of 0.53 cm (26%) was found for the modified net (Table 2D).

Table 2
Selectivity characteristics (standard errors in parentheses) of four species of fish for the conventional (control) and modified nets[a]

Selectivity	Conventional net	95% CL	Modified net	95% CL
A. Sand whiting (MLL 25 cm FL)				
$l_{25\%}$ (cm)	18.14 (0.67)	15.36–20.92	20.72 (0.50)	18.57–22.53
$l_{50\%}$ (cm)	20.57 (0.68)	19.25–21.95	22.39 (0.37)	21.54–23.02
$l_{75\%}$ (cm)	23.00 (0.72)	20.22–25.88	24.07 (0.25)	22.24–25.77
SR (cm)	4.87 (0.06)	4.38–5.35	3.35 (0.09)	2.77–3.93
SF[b]	4.05 (206 mm/51 mm)		3.92 (224 mm/57 mm)	
B. Sea mullet (MLL 27 cm FL)				
$l_{25\%}$ (cm)	15.99 (0.41)	14.23–17.51	15.79 (0.45)	13.54–17.79
$l_{50\%}$ (cm)	17.38 (0.32)	16.67–17.98	17.68 (0.33)	16.94–18.28
$l_{75\%}$ (cm)	18.77 (0.29)	17.23–20.30	19.57 (0.26)	17.57–21.54
SR (cm)	2.78 (0.08)	2.23–3.33	3.79 (0.10)	3.17–4.41
SF	3.42 (174 mm/51 mm)		3.09 (177 mm/57 mm)	
C. Flat-tail mullet (no MLL)				
$l_{25\%}$ (cm)	18.59 (0.25)	16.74–19.97	15.50 (1.06)	11.85–18.15
$l_{50\%}$ (cm)	19.84 (0.27)	19.45–20.80	17.66 (0.83)	15.61–19.04
$l_{75\%}$ (cm)	21.96 (0.79)	19.75–24.03	19.83 (0.64)	17.05–22.25
SR (cm)	2.51 (0.69)	1.15–3.86	4.33 (0.58)	3.20–5.46
SF	3.91 (198 mm/51 mm)		3.09 (177 mm/57 mm)	
D. Silver biddy (no MLL)				
$l_{25\%}$ (cm)	11.27 (0.33)	0.73–12.40	10.96 (0.99)	7.59–12.88
$l_{50\%}$ (cm)	12.27 (0.22)	12.01–17.97	12.24 (0.80)	9.98–13.55
$l_{75\%}$ (cm)	13.27 (0.67)	12.21–34.63	13.51 (0.67)	11.27–15.32
SR (cm)	2.01 (0.92)	0.12–3.89	2.54 (0.53)	1.50–3.59
SF	2.42 (123 mm/51 mm)		2.14 (122 mm/57 mm)	

[a] Variance component analysis, logit model, MLE estimates on covered net data. MLL — minimum legal fork length; SR — selection range; SF — selection factor.
[b] Calculation of the selection factor of the conventional net used the 51 mm mesh in the bunt, whereas the modified net used the 57 mm mesh in the transparent panels.

3.5. Size selectivity of sand whiting: alternative trouser net comparison

A comparison of the size frequencies of sand whiting caught in the modified net, with and without the cover, showed distinct differences in the proportions of small (<20 cm FL) sand whiting (Fig. 3), suggesting that the cover modified the effectiveness of the panels, and so influenced the 'true' selectivity of the modified net. The trouser net analysis showed that the mid selection point of the modified net was 27.06 cm FL for sand whiting, 6.49 cm greater than the control net (with cover) (24% increase) (Table 3) and the selection range was reduced by 1.23–3.64 cm (34%). Fig. 7 shows the differences in the selectivity of sand whiting between the control and modified

Table 3
Selectivity parameters (standard errors in parentheses) for sand whiting using a trouser net analysis of data from the covered conventional net and the non-covered modified net[a]

Size range (cm)	10.0–39.5
No. fish in selection range	804 (27.1%)
y-intercept (*a*)	−16.34
Slope (*b*)	0.604
Split-value (*P*)	0.727
$l_{25\%}$ (cm)	25.24 (0.28)
$l_{50\%}$ (cm)	27.06 (0.35)
$l_{75\%}$ (cm)	28.88 (0.44)
Selection range ($l_{75\%}$–$l_{25\%}$) (cm)	3.64 (0.20)
Selection factor ($l_{50\%}$/57 mm)	4.73
Model deviance	34.10
Degrees of freedom	55
p-value for fit	0.988

[a] Logit model, MLE estimates on pooled data.

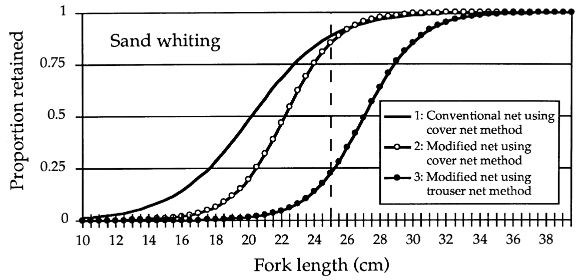

Fig. 7. Selectivity curves for sand whiting caught in the conventional and modified nets using the cover net method and for the modified net using the trouser net method. The dashed vertical line shows the minimum legal size of 25 cm FL for sand whiting.

nets, including that estimated from the trouser net approach.

3.6. Numbers and weights of escapees

The mean (and standard error) of the percentage weights and numbers of fish escaping through the control and modified nets are shown in Fig. 8. There was a trend for more sand whiting, silver biddy and flat-tail mullet to pass through the modified net although this was only statistically significant for the weights and numbers of flat-tail mullet (probably due to the low level of replication).

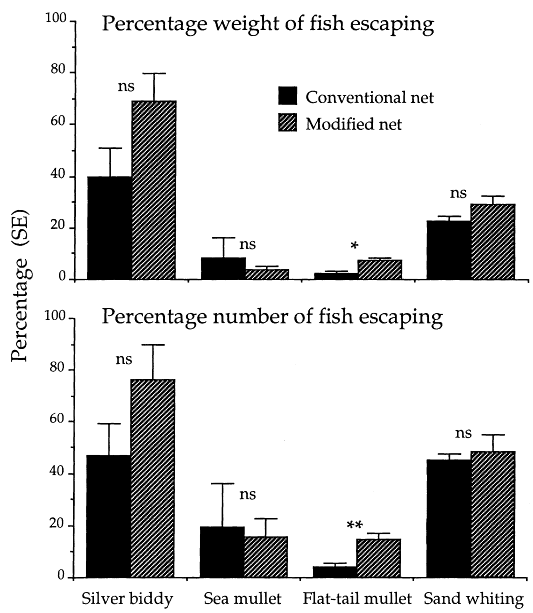

Fig. 8. The percentage (weight and number) of fish that escaped the conventional and modified net. Escapees were captured in the cover net. * — significant difference ($p < 0.05$); ns — no significant difference ($p > 0.05$).

4. Discussion

The work reported in this paper is the first description of the selectivity of haul nets used in estuarine waters in NSW, and is the first assessment of a method to improve the selectivity of these nets and reduce the discards from this fishery. Our experiment showed that many small fish, including species of commercial and recreational significance, were retained in the conventional haul net. The results show that the mid selection point of the target species (sand whiting) using conventional haul nets is much less than the current legal size. Inappropriate selectivities and problems with the capture and subsequent discarding of undersized fish have been recorded for similar types of haul nets used in estuaries in South Australia (Jones, 1982) and on the open coast of South Africa (Lamberth et al., 1995). Clearly, there is a need to address the selection characteristics of haul nets used in the NSW commercial estuarine fishery, particularly since the fate of the discarded component of the catch is unknown, and the conflicts surrounding the use of these nets are significant.

This study showed that the insertion of transparent panels in the haul net was effective in allowing the escapement of small sand whiting and therefore improved the selectivity for this species. Surface and underwater observations of the modified net (with and without the cover) confirmed that the majority of sand whiting were escaping through the transparent panels. Visual cues have been found to play an important role in determining the escape responses of fish to fishing gears (Watson, 1989; Glass and Wardle, 1989; Wardle et al., 1991) and in particular, fish may prefer to pass through clear passages than darker meshes (Glass et al., 1995). Glass and Wardle (1995) showed that fish tried to avoid entering a darkened cod-end (black tunnel) in a trawl net as they escaped through any available openings ahead of the tunnel, and that the insertion of a black tunnel in a net enhanced the escapement of fish through clearer panels. The low visibility of the transparent panels of multi-monofilament netting and their contrast with the highly visible surrounding black multifilament netting could explain why sand whiting chose to escape through the panels. The positioning of the panels at the anterior region of the bunt appeared to offer fish an alternative clear passage to entering the net mouth. The effectiveness of the panels may have been enhanced by a 'black tunnel' effect of the dyed bunt and cod-end (see Glass and Wardle, 1995). If vision was the primary cue for fish escaping from the panels tested here, then these types of panels would probably be less effective in turbid water and would not work as well at night. This needs to be tested as some commercial fishers use similar haul nets to capture sand whiting over shallow sand spits at night in NSW estuaries.

The change in size selectivity of sand whiting in the modified net was not pronounced when the cover was in place, indicating that the cover may have modified the true effect of the transparent panels probably because of some small fish re-entering the main gear when hauling ceased (see Section 3.1). Because of this possible confounding effect of the cover, the trouser net analysis was done which provided results showing a significant increase in the selection mid point. This result probably reflects the true selection characteristics of the modified net, although we note, that the trouser net approach we presented was technically inappropriate as it was based on an alternate haul sampling design (see Section 2.4). The difference in the selectivity curves of sand whiting for the modified net with and without the cover (i.e. covered net versus trouser net method) may have been slightly enhanced by our decision to fit one ogive to each length–frequency distribution, even though these distributions contained a small tail of fish <20 cm FL (see Fig. 3). However, combining two ogives to describe the selectivity of sand whiting in each of these cases would not have altered our conclusions. We believe that the covered net approach will prove the most effective means of testing the selectivity of other modified haul nets but, the design of the cover and its retrieval needs improving to make escaping fish move towards and remain in the covers cod-end and not swim back into the main net. Attaching light weight glass–fibre hoops (see Wileman et al., 1996) to certain parts of the cover may aid in this by keeping the cover well back from the main net, potentially providing a better passage for escaping fish to travel along.

Previous work on Danish seine nets has shown that increasing the mesh size of a net proportionately increases the size of fish selected (e.g. Pope et al., 1975; Jackobson, 1985; Reeves et al., 1992). In theory, the 12% increase in mesh size from 51 to 57 mm panels used in this study should have produced a similar increase in the selection characteristics of the net (provided the selection factor of 50% per mesh size is constant for a given species). This was not observed for any species analysed in our experiment — the mid selection point for sand whiting increased from 20.57 to 22.39 cm FL, whereas it decreased for flat-tail mullet and did not change for silver biddy. Because the 57 mm transparent panels were attached point-to-point (mesh by mesh) to the surrounding 51 mm mesh, the hanging ratio was slightly less in the panels, therefore reducing the mesh openings in the panels which may explain the smaller change in selection of the modified net than that expected. An additional factor which may have influenced the effective hanging ratios of these nets is the fact that at the critical time of selection (when the haul is close to shore), the nets collapse and become convoluted and so reduce the vertical openings of the meshes in the T-direction.

The improved size selection detected for sand whiting compared to the other species (Table 2) may be explained by differences in escape behaviour. Sand whiting exhibited a rapid swimming speed while trying to escape and several legal sized fish became meshed in the transparent panels. In contrast, flat-tail, sea mullet and silver biddies displayed slower responses to the net and became entangled in meshes more easily. Although there were no changes in the size selectivities of these later species, a greater proportion of flat-tail mullet and silver biddy escaped into the cover when the panels were in place, indicating that these panels may reduce the quantity of bycatch landed. Other kinds of modifications (e.g. inclusion of square meshes in the transparent panels) may be required to improve the size selectivities of such species and to reduce bycatch in these nets.

The transparent panels used in this study show potential as a means of improving the daytime selectivity of haul nets for sand whiting by reducing the proportion of smaller individuals that are retained by the net. Panels similar to that tested here may be beneficial in other daytime estuarine and ocean beach-seine fisheries. It is apparent, however, that transparent panels of different dimensions, and possibly those incorporating larger sized meshes and square meshes need to be tested over a range of habitats in different estuaries and time periods to determine the optimal design for the species of interest.

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