Effects of twine diameter and mesh size in the body of prawn trawls on bycatch in Gulf St. Vincent, Australia

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Abstract.—The influences on catches and bycatches due to 1) an increase in size of mesh and 2) a reduction in twine diameter in the body of prawn trawls were investigated in Gulf St. Vincent, Australia. Compared with a conventional trawl body (mesh size 45 mm) attached to a composite square-mesh codend, two new trawl bodies, made with 53-mm mesh but with different twine diameters (1 and 1.7 mm, respectively) and each attached to identical composite square-mesh codends, were equally effective in significantly reducing the numbers of a range of small fish (by between 23.7% and 67%) and in not significantly reducing the weight of targeted prawns. Because there were no significant differences in the selectivity parameters of both new trawl bodies, these results indicated that the main cause of bycatch reduction was the increase in size of mesh in the body of the trawl. The escape of large numbers of unwanted small fish and prawns is discussed in terms of their probable behavior in the body of the trawl and the extent to which this behavior was influenced by the operational characteristics of the gear.

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In many of the world's prawn-trawl fisheries, large numbers of organisms are captured incidentally with the targeted catch (collectively termed "bycatch" *sensu* Saila, 1983). This bycatch comprises a diverse assemblage of small fish, cephalopods, and crustaceans, including prawns that are smaller than optimum size (for reviews see Saila, 1983; Andrew and Pepperell, 1992; Alverson et al., 1994). Concerns over the negative effects that the mortality of these fish and small organisms may cause on the yield of stocks has led to the application of various management strategies designed to minimize bycatch (Andrew and Pepperell, 1992). The most common approach has been to change the conventional trawls to improve overall selectivity of the gear. Depending on the sizes and species to be targeted and excluded, these changes have involved the sizes and types of mesh used, and the application of physical modifications, collectively termed bycatch reducing devices (BRDs) (see Broadhurst, 2000, for review).

Inherent variations among the characteristics of different prawn-trawl fisheries have resulted in a range of modifications to conventional trawls. Regardless of design, however, the majority of functional modifications have been applied within or immediately anterior to the codend (e.g. Isaksen et al., 1992; Thorsteinsson, 1992; Broadhurst and Kennelly, 1997; Rogers et al., 1997) mainly because observations suggest that most of the selection process for many species occurs in this area (Armstrong et al., 1990; MacLennan, 1992; Wileman et al., 1996). Moreover, because codends often are similar among the different trawl designs within a particular fishery (e.g. Broadhurst and Kennelly, 1997), any modifications to improve selectivity are more easily implemented, adopted, and regulated throughout the fishery.

Although alterations to codends have been successful in reducing various subsets of bycatch, there is evidence suggesting that individuals of some species, particularly those of prawns, escape from the bodies of prawn trawls (High et al., 1969; Sumpton et al., 1989; Vendeville, 1990). For example, High et al. (1969) attached various covers to the upper, lateral, and posterior bodies of trawls to isolate areas that could be modified to passively separate fish from prawns (*Pandalus* sp.). Although there was little evidence of fish escaping, large numbers of small prawns were retained in the covers, particularly in the posterior sections. Similarly, in one of the few studies on the effects of changes in the types of twine used in the body of trawls on catches, Sumpton et al. (1989) showed that compared with multifilament twine (1.1 mm diameter), significantly more smaller-size prawns (*Penaeus* spp.) and squid (*Loligo* spp.) escaped through the bodies of trawls made from monofilament twine (0.9 mm diameter).

Despite these results and although nearly all prawn-trawl fisheries are regulated by means of legally defined minimum mesh sizes (typically ranging from 40 to 50 mm stretched mesh, Vendeville, 1990), there is a paucity of information on the effects of different sizes of mesh used in the bodies of trawls on selectivity. This is particularly the case in Australian prawn-trawl fisheries, where despite extensive research to develop BRDs (see Broadhurst, 2000), no published studies have quantified the effects of different sizes of mesh. In a recent experiment in Gulf St. Vincent, South Australia (Broadhurst et al., 1999), we provided evidence to suggest, however, that the minimum size mesh (45 mm) throughout the trawls was too small. As a first step in addressing this issue, we investigated modifications to the codends and demonstrated that new designs comprising composite panels of different-size square-shape mesh (52 and 80 mm mesh hung on the bar) were effective in significantly reducing bycatches of undersize western king prawns (*Penaeus latisulcatus*) and small fish without reducing the weight of the commercial catch.

These results, combined with the simplicity of the new codend, led to the immediate and unanimous adoption of a design, based on those tested, by Gulf St. Vincent prawn trawlers. Encouraged by the performance of simple changes in mesh type and size to improve selectivity, commercial fishermen sought assistance to examine other refinements to their trawls. Given evidence to suggest that the mesh size used in Gulf St. Vincent was inappropriate and that selection for some species may occur in the body of prawn trawls, our aims in the present study were to quantify the influences on selection in this area due to 1) increasing the mesh size (from approx. 45 mm to 53 mm) and 2) reducing the diameter of twine used.

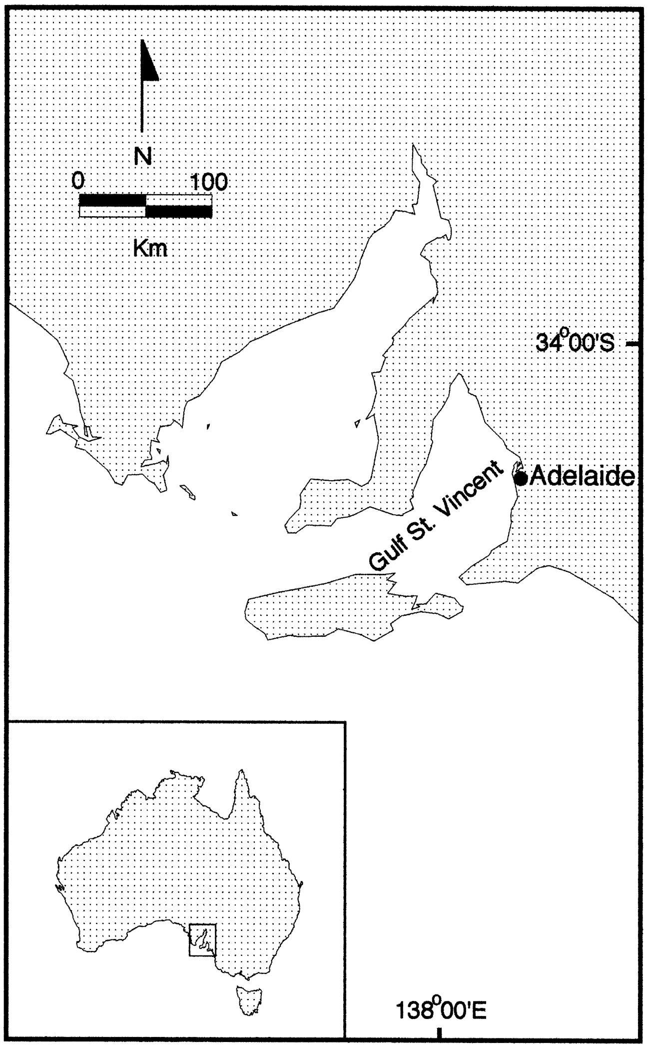

Figure 1

Location of study at Gulf St. Vincent, South Australia.

Materials and methods

Our work was done in Gulf St. Vincent, South Australia (Fig. 1), in October, 1998, with a chartered commercial prawn trawler rigged to tow three trawls in a standard triple gear configuration (see Andrew et al., 1991, for details). Three different trawl bodies were examined. The first (termed the "control") represented conventional trawl bodies (see Broadhurst et al., 1999, for specifications) and was constructed of 1.7-mm-diameter, 24-strand, polyethylene twisted twine with a mean mesh size (stretched distance between the knots) of 44.42 mm (see "Results" section). The second and third trawl bodies (termed "spectra-1-mm" and "momoi-1.7-mm") were identical in design, in headrope and footrope length, in rigging and tapers to the control trawl body but were made from 1-mm-diameter, polyethylene cabled twine (brand name "spectra") and 1.7-mm-diameter, 30-ply, polyethylene twisted twine (brand name "momoi"), respectively, with mean mesh sizes of 52.43 and 52.96 mm, respectively (see "Results" section).

All three trawl bodies were attached to identical composite square-mesh codends (Broadhurst et al., 1999) consisting of two sections, each measuring 80 bars in circumference, 70 bars in length, and constructed of 52-mm mesh (3-mm-diameter, braided polyethylene twine) cut on the bar (Fig. 2, A–C). Each square-mesh section consisted of an upper and lower panel sewn together so that the direction of the knots on the upper panel were opposite those on the lower panel (Fig. 2A). A panel of 104-mm netting, measuring 6 bars × 10 bars, was inserted into the tops of the posterior sections of each square-mesh codend, starting at the leading edge and ending about 1.3 m anterior to the last row of meshes (Fig. 2, A and B). Lengths of 12-mm-diameter, polyethylene 3-strand rope (termed "last-ridge ropes") were firmly laced at a hanging ratio of 0.9 to each of the two lateral seams of the codends (to provide length-wise strength) (Fig. 2B).

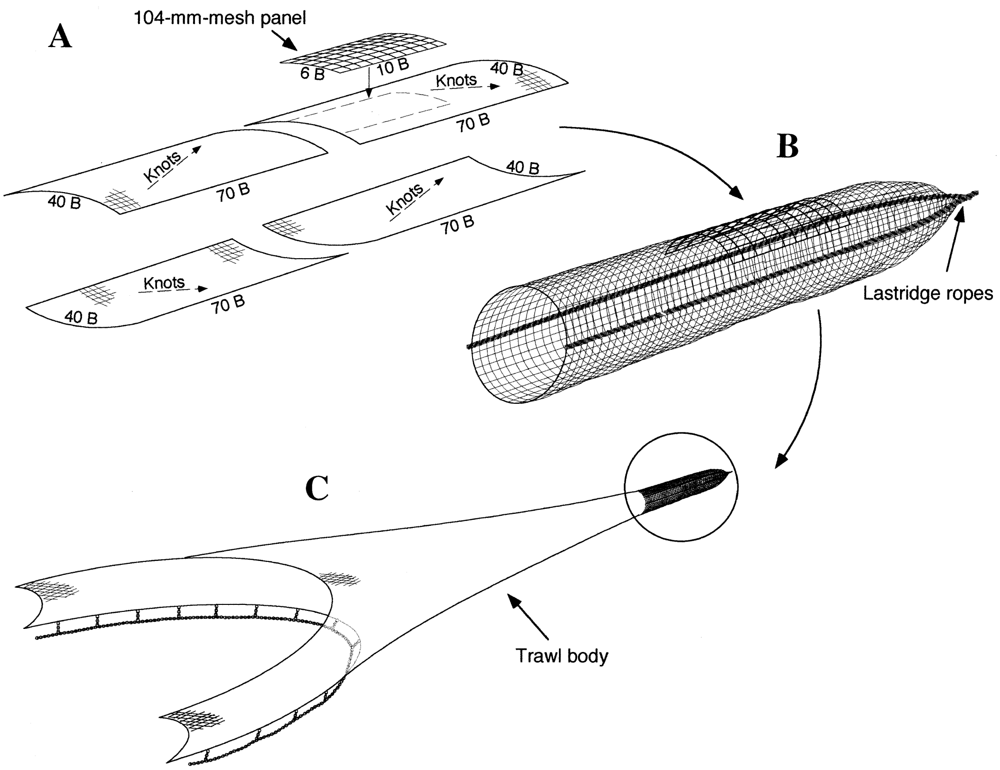

Figure 2

Diagrammatic representation of (**A**) panels and sections of the composite square-mesh codend (B=bars), (**B**) completed composite square-mesh codend, and (**C**) prawn-trawl body and codend used in the study. B = bars.

Experimental procedure

Before starting the experiment, all trawls were towed for a short period to allow knots and bindings to stretch. To obtain accurate information on mesh sizes, a set of dial calipers was used to measure 30 randomly located meshes (stretched length in mm, between the inside knots) at four separate locations (starboard wing, footrope, headrope, and posterior body) in each trawl body.

The spectra-1-mm and momoi-1.7-mm trawls were compared separately against the control trawl. In each paired comparison, the trawls were shackled to the outside sweeps of the sleds and otterboards of the triple rigged gear and towed simultaneously. A conventional trawl body was used as the center net in all comparisons, but because it was not rigged in exactly the same manner as the outside nets, its catch was excluded from analysis. The triple gear was towed in normal commercial tows of 25-min duration at 3 knots (1.5 m/s) over a combination of sandy and light coral bottoms. Each of the outside trawls were randomly assigned after each tow (to eliminate any potential biases), so that three paired comparisons of each new trawl against the control trawl were made on each night (i.e. a total of six tows per night). Over five nights, we completed a total of 15 replicate comparisons of each configuration.

After each tow, the catches from the two outside trawls were emptied onto a partitioned tray. Data collected from each tow were the following: the total weight of western king prawns and a subsample (100 prawns from each trawl) of their carapace lengths (to the nearest 1 mm); the total number of prawns (estimated from the weight of the subsample); the total weight of discarded bycatch and discarded noncommercial bycatch; the weights and numbers of commercially or recreationally (or both) important bycatch species; and the sizes (to the nearest 0.5 cm) of commercially or recreationally (or both) important fish. A random sample of prawns (approximately 12 kg) from each trawl in each tow was separated and sent to A. Raptis & Sons PTY LTD (seafood processing plant) in Adelaide for grading into "commercial categories" (based on a system of numbers per pound) with a locally built "dynamic grading machine."

Several commercially important species were caught in sufficient quantities to enable meaningful comparisons. These were western king prawns (*Penaeus latisulcatus*), blue swimmer crabs (*Portunus pelagicus*), sand trevally (*Pseudocaranx wrighti*), red mullet (*Upeneichthys porosus*), leatherjacket (*Thamnaconus degeni*), southern sand flathead (*Platycephalus bassensis*), small-toothed flounder (*Pseudorhombus jenynsii*), and southern calamari (*Sepioteuthis australis*). With the exception of western king prawns and southern calamari (which fishermen are legally permitted to retain), all remaining species comprised those that are considered commercially important bycatch (e.g. to other fisheries) and that are normally discarded.

Analysis of mesh sizes

The mesh-size measurements collected from the trawl bodies were analyzed for heteroscedasticity with Cochran's test and a two-factor, balanced analysis of variance (ANOVA) with trawl body and location of meshes considered fixed and random factors, respectively. Significant differences detected in these analyses were investigated by Tukey's multiple comparisons of means test.

Analysis of catch data

Catch data for all replicates that had sufficient numbers of each variable (i.e. 1 individual in at least 10 replicates) were analyzed with paired *t*-tests ($P \leq 0.05$). Except for the weights and numbers of blue swimmer crabs and small-toothed flounder (species that could not pass through the meshes in any of the trawls), all variables were analyzed with one-tailed tests to test the hypothesis that the larger-mesh trawl bodies retained fewer individuals than the control. Catches of blue swimmer crabs and small-toothed flounder were compared with two-tailed tests. To examine the relative effectiveness of the spectra-1-mm and momoi-1.7-mm trawl bodies, differences in catches (between each trawl and their respective controls) for those variables that had data in all tows were analyzed by using Cochran's test for homogeneity of variances and a balanced, two-factor ANOVA. In these analyses, trawl-type and nights were considered fixed and random factors, respectively. Where there were sufficient data ($n > 25$ in each trawl, pooled across all tows), size frequencies of commercially or recreationally important fish (or both) were plotted and compared with two-sample Kolmogorov-Smirnov tests ($P = 0.05$).

Analysis of prawn sizes

Size-frequencies of prawns retained in each of the three trawls were combined across all tows. Using an estimated split model (Millar and Walsh, 1992), we fitted logistic curves to these data by maximum likelihood method (Pope et al., 1975). Logistic curve parameters, associated standard errors and 95% confidence limits were calculated for each large-mesh trawl body. Model deviance values were determined for a goodness-of-fit hypothesis (i.e. to test H_0: that the curves were logistic). Size categories of commercially graded prawns from each trawl were plotted and analyzed with two-sample Kolmogorov-Smirnov tests ($P = 0.05$).

Results

Analysis of mesh sizes

There were significant differences detected in size of mesh between the three trawl bodies (Table 1). Tukey's comparison of means test showed no significant differences between the spectra-1-mm and momoi-1.7-mm trawl bodies (mean mesh sizes ±SE of 52.43 ±0.08 mm and 52.96 ±0.09 mm, respectively). The mean size of mesh in the control trawl was significantly less at 44.42 ±0.13 mm. Mesh size was not significantly different among the various locations (e.g. wing, footrope, head rope, and posterior body) examined in any of the trawl bodies.

Table 1

Summaries of *F* ratios from two-factor analysis of variance to determine differences in size of mesh in the trawls and at various locations and results of Tukey's comparison of means test for the significant difference detected in size of mesh between trawls (spectra-1-mm=momoi-1.7-mm>control). Data were treated in the raw form. ** = $P < 0.01$.

Treatment	df	Mesh size (mm)
Trawls (T)	2	2494.7**
Location of mesh in trawl (L)	3	0.85
$T \times L$	6	1.4
Residual	346	

Analysis of catch data

Compared with the control, the spectra-1-mm and momoi-1.7-mm trawl bodies significantly reduced the numbers of western king prawns caught (means reduced by 13.7% and 15.6%, respectively), without significantly reducing the weights of prawns (although mean catch from the spectra-1-mm was 6.3% lower than that from the control) (Table 2; Fig. 3, A and B). The spectra-1-mm and momoi-1.7-mm trawl bodies also significantly reduced the weights of total discarded bycatch (by 29.3% and 20.3%); numbers of leatherjacket (by 32.5% and 23.7%) and their weights (by 24.2% and 19.6%); numbers of sand trevally (by 56.2% and 40.4%) and their weights (by 52.8% and 40.4%); and the numbers of southern sand flathead (by 59.8% and 40.2%) and red mullet (by 67.2% and 59.3%) (Fig. 3, C, E, F, G, and I; Table 2). The spectra-1-mm trawl body also significantly reduced the weights of southern sand flathead (by 31.8%), red mullet (by 57%), and the numbers of southern calamari (by 33.6%) (Fig. 3, H, J, and L; Table 2). ANOVA of the differences in catches between the new trawl bodies and their controls showed no significant interactions nor main effects for any of the variables examined (Table 3).

Two-sample Kolmogorov-Smirnov tests for comparing the size-frequency distributions of fish measured from the control and new trawl bodies detected significant differences in the relative size compositions of southern sand flathead retained by both new trawl bodies and in the relative size compositions of sand trevally retained by the momoi-1.7-mm trawl body (the new trawl bodies retained proportionally fewer small-size fish) (Fig. 4, A and B). There were no other significant differences detected.

Table 2

Summaries of paired t-tests in which the control and the new trawl bodies were compared. Weights and numbers of blue swimmer crabs and small-toothed flounder were analyzed with two-tailed paired t-tests whereas the remaining variables were analyzed with one-tailed paired t-tests. pt-v = paired t-value; n = number of replicates; disc = discarded; n-comm = noncommercial. * = $P<0.05$; ** = $P<0.01$.

	Spectra-1-mm versus control			Momoi-1.7-mm versus control		
	pt-v	P	n	pt-v	P	n
No. of prawns	–2.368	0.016*	15	–2.389	0.016*	15
Wt. of prawns	–1.755	0.051	15	–0.044	0.483	15
Wt. of total disc bycatch	–4.127	0.0005**	15	–2.662	0.009**	15
Wt. of disc n–comm bycatch	–1.709	0.055	15	–1.38	0.095	15
No. of leatherjacket	–3.627	0.001**	15	–2.447	0.014*	15
Wt. of leatherjacket	–4.542	0.0002**	15	–2.181	0.023*	15
No. of sand trevally	–1.987	0.033*	15	–2.491	0.013*	15
Wt. of sand trevally	–1.960	0.035*	15	–2.253	0.020*	15
No. of southern sand flathead	–3.516	0.002**	14	–2.939	0.006**	14
Wt. of southern sand flathead	–2.994	0.005**	14	0.445	0.668	14
No. of red mullet	–3.116	0.004**	15	–2.610	0.013*	11
Wt. of red mullet	–2.157	0.024*	15	–0.882	0.199	11
No. blue swimmer crab	1.505	0.156	14	0.725	0.482	13
Wt. of blue swimmer crab	1.524	0.152	14	1.462	0.169	13
No. of small–toothed flounder	–0.395	0.699	13	–1.977	0.068	15
Wt. of small–toothed flounder	–0.082	0.936	13	–0.150	0.883	15
No. of southern calamari	–2.210	0.022*	15	–0.846	0.206	15
Wt. of southern calamari	0.026	0.510	15	–0.837	0.208	15

Table 3

Summaries of F ratios from two-factor analyses of variance to determine effects on variables due to fishing with different trawl bodies on different nights. The transforms used to stabilize the variances where required are listed. N-comm = noncommercial, disc = discarded.

				Bycatch (wt. in g)							
		Prawns		Total	N-comm	Leatherjacket		Trevally		Southern calamari	
Treatment	df	no. $1/(x+1)$	wt.	disc	disc	no. $\ln(x+1000)$	wt.	no.	wt.	no.	wt.
Trawl bodies (T)	1	0.01	3.97	0.64	0.44	0.64	0.64	1.36	1.36	1.15	1.31
Nights (N)	4	1.50	1.79	0.40	0.41	0.40	0.42	0.72	0.72	1.47	0.18
$T \times N$	4	1.00	0.48	0.86	1.27	0.86	0.23	0.73	0.29	2.20	0.36
Residual	19										

Analysis of prawn sizes

The logistic length selection curves derived for each of the new trawl bodies are provided in Figure 5. Model deviance indicated sufficient goodness of fit for both curves (Table 4). The 95% confidence limits of the selectivity parameters showed that there were no statistically significant differences between the two new trawl bodies (Table 4).

Significant differences were detected in Kolmogorov-Smirnov tests on the commercial-size categories of prawns graded from the control and new trawl bodies (Fig. 6). Both trawls with the larger meshed bodies retained proportionally fewer smaller prawns.

Discussion

The results from this study showed that both new trawl bodies were effective in excluding under-size prawns and large numbers of small fish (by up to almost 60%) and in not reducing the weight of targeted prawns. These results provide evidence to suggest that simple changes to the body of prawn trawls can have a contributing effect on overall trawl selectivity. The escape of large numbers of small fish and prawns from this area may be due to their behavior in the trawl and the extent to which they were influenced by the operational characteristics of the gear.

It is well established that fish exhibit specific responses to stimuli from trawls and attempt to avoid contact with the trawl body by maintaining position at the opening (Wardle, 1983; Watson, 1989). After some period, depending on species- and size-specific swimming abilities (Wardle, 1975), fish invariably tire and turn towards the codend, allowing the trawl to pass around them (Watson, 1989) or alternatively, maintain swimming in the direction of the tow, but gradually fall back along the taper of the body panel towards the codend opening (Wardle, 1983). As the taper of the trawl body narrows and the density of fish increases, some fish may rise in the trawl and attempt escape through the meshes or pass into the codend and resume swimming immediately anterior to the catch (Wardle, 1983). In contrast, benthic invertebrates like prawns tend to display limited responses during capture. SCUBA observations by Watson (1976) showed that after contact with the leading edge of the trawl, penaeid prawns contracted their abdomens ventrally, propelling themselves backwards. This initial response was repeated three to five times but because prawns are not capable of maintaining such activity, the speed of the trawl through the water quickly forced them against the meshes of the trawl body and they eventually tumbled down the net into the codend.

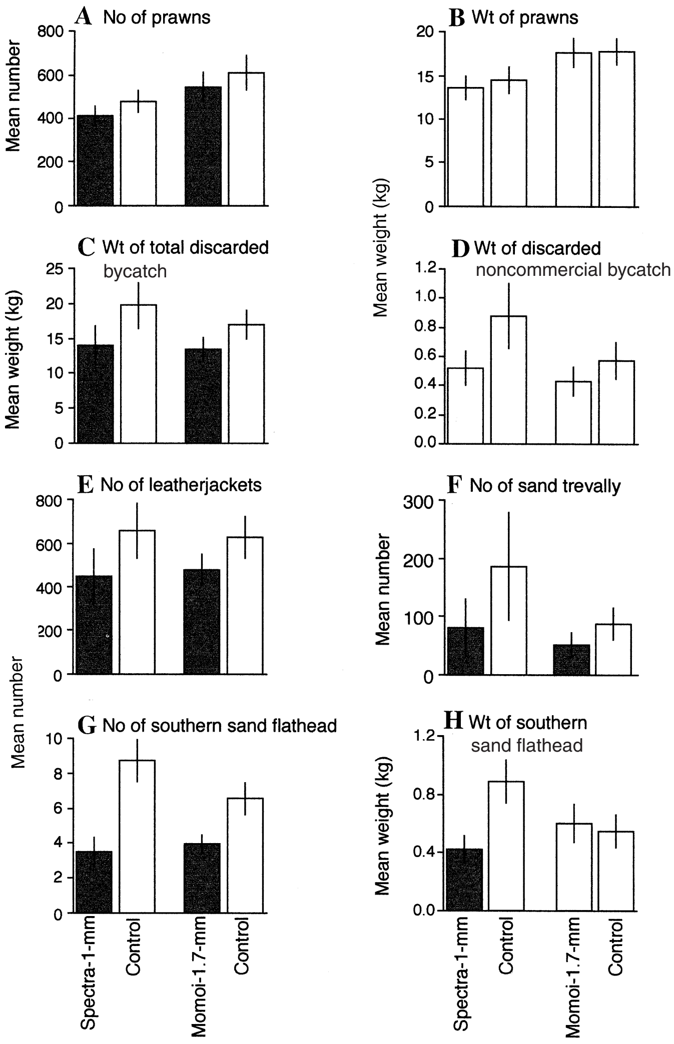

Figure 3

Differences in mean catches (per 25 min tow ±SE) between the new trawl bodies and control for the (**A**) numbers and (**B**) weights of king prawns (*Penaeus latisulcatus*); the weights of (**C**) total discarded bycatch and (**D**) discarded noncommercial bycatch; the numbers of (**E**) leatherjackets (*Thamnaconus degeni*), (**F**) sand trevally (*Pseudocaranx wrighti*) and (**G**) southern sand flathead (*Platycephalus bassensis*); the weights of (**H**) southern sand flathead; the numbers (**I**) and weights (**J**) of red mullet (*Upeneichthys porosus*); the numbers of (**K**) blue swimmer crabs (*Portunus pelagicus*); the numbers (**L**) and weights of (**M**) southern calamari (*Sepioteuthis australis*); and the numbers of small-toothed flounder (*Pseudorhombus jenynsii*). Significant differences are indicated by shaded histograms.

In view of these behavioral patterns, gear-related factors, such as the fast towing speed (1.5 m/s) and taper of the trawl body in our study, may have increased the probability of small fish and prawns being selected in this area. For example, the sizes of most of the fish encountered, and particularly sand trevally, leatherjackets, and small southern sand flathead (5–15 cm, [Fig. 4]), means that they would have been unable to maintain position in the moving trawls. Studies quantifying the swimming speeds of teleost fish suggest that although individuals 5 and 15 cm long may be expected to have burst speeds of 0.5 m/s and 1.5 m/s over very short periods, their normal maximum swimming performance (or maximum cruising speed, Wardle, 1983) would be much less (Bainbridge, 1958; Wardle, 1975, 1983; Beamish, 1978). As a consequence, in our study some fatigued individuals probably came in contact with meshes in the body panels as they were herded towards the codend opening. Further, the relatively steep tapers (i.e. 1N4B—see Broadhurst et al., 1999) of the trawl bodies (compared with those used in most other prawn-trawl fisheries, FAO,

Table 4

Computed selectivity parameters for prawns (carapace length in mm) from the two new trawl bodies and deviance values for the goodness-of-fit logistic curve. Standard errors are given in parentheses. *a*, *b* = logistic parameters (Pope et al., 1975). *P* = split proportion from estimated split model

	Momoi-1.7-mm		Spectra-1-mm	
a	–8.99		–13.00	
b	0.26		0.39	
P	0.59		0.56	
		95% confidence limits		95% confidence limits
25% retention (L25)	30.26 (0.67)	25.43–34.91	29.92 (0.49)	26.72–32.92
50% retention (L50)	34.47 (0.92)	32.93–37.06	32.68 (0.57)	31.69–34.13
75% retention (L75)	38.68 (1.56)	34.11–45.51	35.44 (0.92)	32.46–39.55
Selection range (SR)	8.42 (0.44)	5.48–11.42	5.52 (0.16)	3.71–7.33
Deviance	22.58		29.49	
df	34		32	
P-value	0.932		0.594	

1972), probably contributed to contact of both fish and prawns with meshes in this section of the trawl. A combination of the above effects in the larger-mesh spectra-1-mm and momoi-1.7-mm trawl bodies may have facilitated the escape of smaller individuals.

It is also likely that a reduction in twine area associated with the larger mesh sizes in both new trawl bodies allowed a faster release of water than did the control trawl body,[1] possibly contributing to the effects discussed above. In partial support of this hypothesis and although no significant differences were detected between the spectra-1-mm and the momoi-1.7-mm trawl bodies for those variables examined (Table 3), the narrower-twine spectra-1-mm trawl body consistently reduced a larger percentage of bycatch across a greater range of variables. These variables included the weights of southern sand flathead and red mullet and the numbers of southern calamari (Table 2; Fig 3). Further investigation, involving a greater number of replicate tows would be required, however, to validate the potential for this effect.

A contributing operational factor towards the escape of fish from both large-mesh trawl bodies may have been the period between the time when the vessel was slowed and when the gear was hauled to the surface (termed "haulback") (Watson, 1989; Broadhurst et al., 1996). Watson (1989) showed that differences in geometry of the trawl and associated water flow during haulback caused fish (that were still swimming in the trawl) to become disorientated and to attempt escape through the surrounding meshes. More specifically, Workman and Taylor (1989) observed that numerous small individuals of schooling species such as Carangidae (e.g. *Trachurus lathami* and *Decapterus punctalus*) escaped during this period and that larger individuals were often caught by their gills in

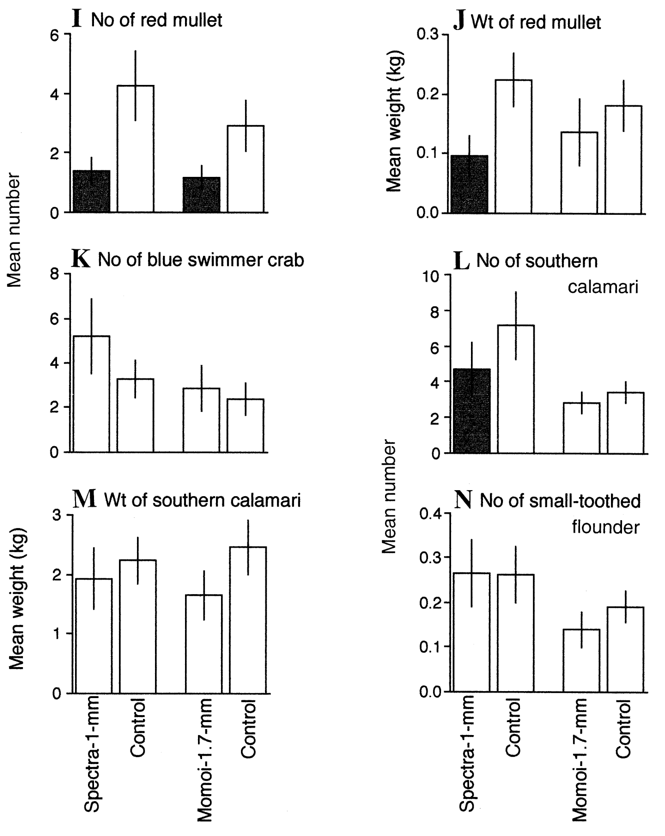

Figure 3 (continued)

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[1] Harrington, D. L., J. W. Watson, L. G. Parker, J. B. Rivers, and C. W. Taylor. 1988. Shrimp trawl design and performance, 37 p. University of Georgia Marine Extension Service, 715 Bay St., Brunswick, Georgia 31520-4601.

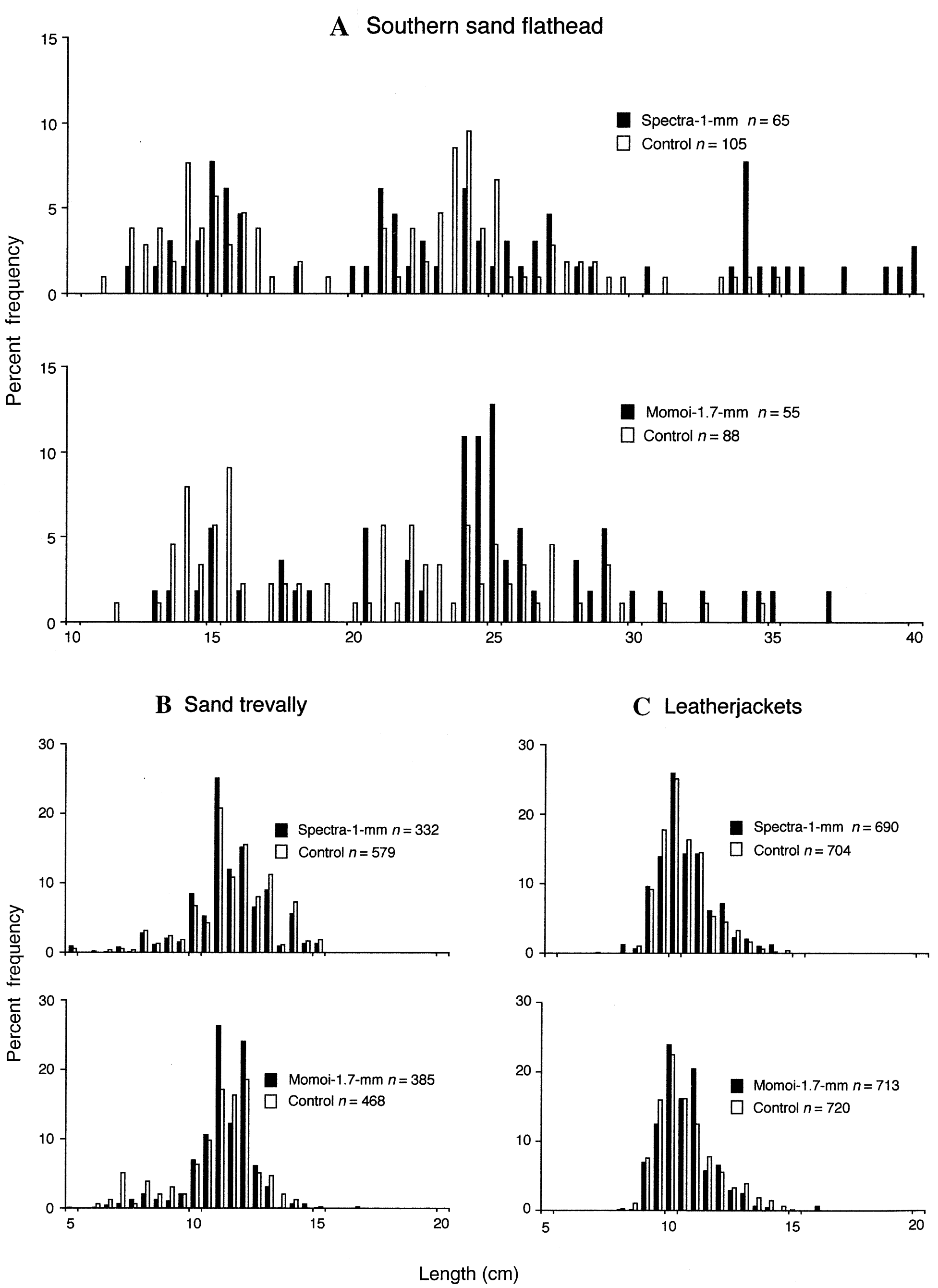

Figure 4

Size-frequency distributions of the new and control trawl bodies for (**A**) southern sand flathead (*Platycephalus bassensis*), (**B**) sand trevally (*Pseudocaranx wrighti*) and (**C**) leatherjacket (*Thamnaconus degeni*).

the meshes of the body panels. Likewise in our study, we observed numerous larger individuals of southern sand flathead, leatherjackets, and particularly larger sand trevally (10–15 cm) trapped in the meshes of the posterior sections of both large-mesh trawl bodies.

Although the results showed that significantly more smaller prawns escaped from the new trawl bodies than from the control trawl body, the selectivity parameters and associated 95% confidence limits (Fig 5; Table 4) were within the range calculated in a previous study (Broadhurst et al., 1999) for a

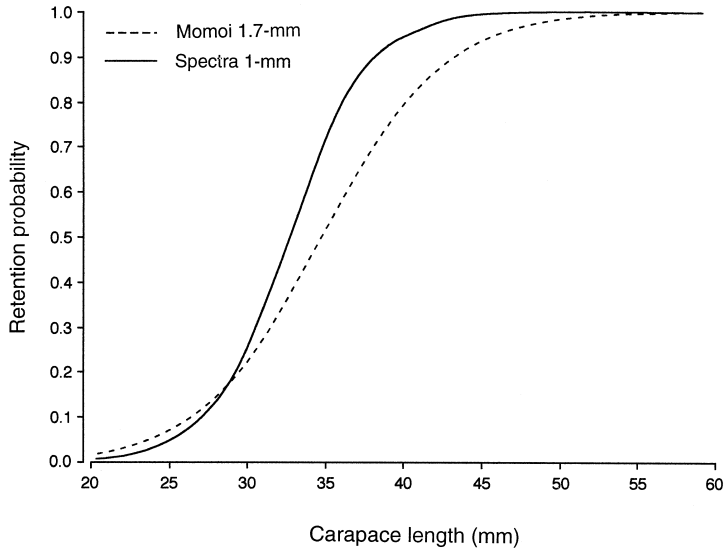

Figure 5

Plots of the selection curves of western king prawns (*Penaeus latisulcatus*) for the spectra-1-mm and momoi-1.7-mm trawl bodies.

trawl comprising a body of 45-mm mesh attached to a similar composite square-mesh codend. During this previous study, the codend that showed the most appropriate size-selectivity for prawns tapered from a circumference of 70 bars at the start of the anterior section to 58 bars at the end of the posterior section. After extensive commercial testing, however, it was reported that the slight taper in this codend occasionally "wedged" the catch in the posterior section, making it difficult to remove the catch when the codend was retrieved and the draw-strings were opened. To address this problem, fishermen widened the circumference to 80 bars throughout the codend. Although such an alteration solved the problems associated with buildup of catch in the codend (by allowing it to distribute more horizontally), it probably lowered the selectivity for prawns (Broadhurst and Kennelly, 1996). Any contributing effects on trawl selectivity due to the larger mesh in the spectra-1-mm and momoi-1.7-mm trawl bodies may have been slightly negated by a reduction in overall selectivity of the composite square-mesh codends. This result illustrates the need for ongoing assessments of influences on selectivity of trawls due to subtle modifications to facilitate operational procedures.

Like the results from other related studies, the significant reduction in numbers of prawns caught, but not in their weights, has shown that increases in mesh sizes or in openings (or in both) can facilitate an increase in catches of target-size individuals (Walsh et al., 1992; Broadhurst and Kennelly, 1997; Broadhurst et al., 1999). Possible hypotheses to explain this effect include 1) a faster release of water from the larger-mesh trawls resulted in prawns quickly passing into the trawl after initial contact, with less chance of escaping over the head rope and out through the mouth of the trawl or alternatively, 2) less drag in the larger-mesh trawls, due to less twine area and amount of bycatch, allowed the mouth of the trawl to spread wider, thereby covering more of the sea bed and capturing more prawns. Of these two hypotheses, the potential for an increase in spread is less likely because there were no significant differences in the catches of blue swimmer crabs or small-toothed flounder (species that could not pass through either the trawl bodies or composite square-mesh codends) between any of the trawls examined.

Because there were no significant differences detected in the weights of prawns captured between the various trawls, a further increase in the size of mesh in the body of the trawl (e.g. 60 mm) warrants investigation. Given the results presented in our study, this increase in mesh size could facilitate a greater release of small fish and further improve size selectivity for the targeted prawns. Alternatively, it may be feasible to examine the utility of trawl bodies comprising composite panels of larger mesh, particularly in the posterior section, because it is apparent that as fish are herded together in this area their densities increase, resulting in random attempts at escape through the sides of the trawl (Wardle, 1983). In addition, any fatigued fish still swimming in the posterior section of the trawl during haulback may have an opportunity to escape through these larger meshes.

Although not mandated, the results from our study have led to the use of large-mesh trawl bodies by many of the fishermen operating in Gulf St. Vincent. Combined with the contributing effects on bycatch reduction due to the composite square-mesh codend, this modification should result in a comparatively more selective prawn-trawl fishery. For example, in a review of literature quantifying bycatches from prawn-trawl fisheries throughout the world, Andrew and Pepperell (1992) reported that typical bycatch-to-prawn ratios in similar temperate fisheries were in the order of 5:1. From the mean catch per tow from the control and the new trawl bodies in our study,

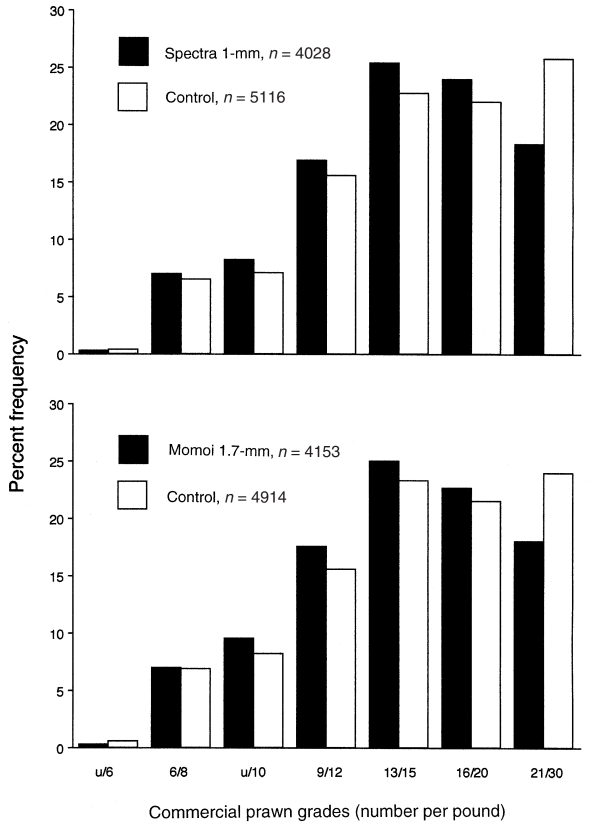

Figure 6

Commercial size categories of western king prawns (*Penaeus latisulcatus*) caught with the (**A**) spectra-1-mm and control trawls and (**B**) momoi-1.7-mm and control trawls (u=under).

discarded bycatch-to-prawn ratios were 1:1 for the spectra-1-mm and 1:1.3 for the momoi-1.7-mm trawl bodies. Ongoing monitoring is still required, however, to assess any potential effects on selectivity associated with operational refinements to the current trawl configurations.

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