11. TRAWL GEAR PERFORMANCE TRIALS

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11.1 Introduction

An accurate estimate of abundance is essential for fisheries management. Abundance estimates are often limited, due to insufficient information regarding the catch efficiency of the sampling gear. A measure of sampling gear efficiency will enable a realistic estimation of abundance. Trawl sampling gear efficiency, is the proportion of animals retained in the net relative to the total number in the path of the trawl (Kjelsohn and Johnson 1978).

Estimating the efficiency of the sampling gear often causes serious problems for the analysis of trawl survey data. Gear efficiency involves many complex variables that are often insufficiently understood to predict their cumulative effects. The efficiency of trawl sampling gear varies not only for each species but also for different size classes and with varying environmental conditions (Kjelsohn and Johnson 1978). This unmeasured variability in trawl sampling gear efficiency, results in an error in estimating population size. Measuring this error remains a major and largely unresolved challenge in fishery science.

Selectivity is closely related to gear efficiency and includes components of net mesh selectivity and fish or prawn behaviour. Mesh selectivity is the variation in fishing mortality with age, which is the differential escape of certain sizes of fish or prawns after they enter the mouth of the net (Gulland 1983). Both efficiency and selectivity describe in some way the performance of gear. The distinction made is that efficiency is a measure of the gear's catch relative to the total population present in the area swept by the net. Mesh selectivity is a measure of the gear's catch relative to the number of prawns that entered the mouth of the net. Gear efficiency includes the effects of mesh selectivity and any other processes of selectivity that occur when fish or prawns are initially stimulated from the sea bed into the mouth of the trawl.

Errors that occur in these calculations affect the estimates of absolute abundance and the shape of length-frequency distributions. Errors in length-frequency distributions are due to the size-specific nature of sampling trawl gear efficiency. Errors in estimates of absolute abundance are due both to the size-specific nature of the trawl, and to species-specific factors such as diurnal and seasonal variations in behaviour.

Other factors that affect trawl efficiency are associated with the physical aspects of the fishing gear itself (Table 1). These factors have an importance that is often not fully appreciated in fisheries research. It is imperative that these factors are closely monitored during survey work to ensure that inter-sample variation of trawl efficiency is minimized.

Table 1. Aspects of otter trawl equipment used commercially and for survey work in the Australian prawn industry that influence gear efficiency.

Primary Factors	Secondary Factors
mesh size	
fishing line height	drop chain length and weight
	tickler weight
	warp length to depth ratio
	otterboard settings
	headline length to spread ratio
tickler chain lead	
headline lead	
headline height	
trawl speed	

Commercial trawl gear designs compromise gear efficiency to achieve a practical and safe operation. The designs are selective for commercial species and sizes. They may be strongly biased against catching trash species and collecting debris even to the extent of having a negative effect on their commercial catch. If using commercial gear in fisheries research it may be necessary to be aware and correct for any bias that may exist.

We conducted two separate experiments for efficiency and selectivity in order to investigate sample bias. Experiment 1 was designed to measure the size-specific trawl efficiency. Experiment 2 investigated mesh selectivity in greater detail. Experiment 1 is reported in full. The results presented for Experiment 2 incorporate data from only the first two monthly surveys and provides a preliminary examination of the selectivity performance of a standard port net relative to a small mesh starboard net.

11.2 Materials and Methods

Our trawling surveys utilized three-fathom wide prawn nets of a design commonly used by commercial operators. All net mesh sizes quoted were measured from centre of knot to the centre of the adjacent knot. The standard net for both experiments was always on the port side and the modified nets on the starboard side of the boat.

11.2.1 Experiment 1 - Gear Efficiency

The experimental design consisted of a comparison of catch of all prawn species from our standard 48 mm mesh sampling trawl (Figure 1) with that of a trawl designed to be as efficient as possible (Figure 2). To produce these qualities three design features were implemented on the non-standard trawl: 29 mm mesh size, zero fishing line height, and a tickler chain well forward of the fishing line (Figure 2). Other aspects of the non-standard net design were unchanged from the standard port net. The nighttime catch of this non-standard net was assumed to measure approximately the total trawl path biomass in the area swept by the net. By comparing the catches of both nets we determined the efficiency of the Torres Strait Prawn Project's standard otter trawl.

The two nets were towed from our 14 m research vessel R.V. 'Lumaigul' in a dual net system (Figure 3). This system ensured that similar grounds were covered by both nets and that bottom times were identical. The spread of each trawl was continuously recorded with side-scan sonar and the results used to correct for differences in swept area trawled.

Comparing the catches of the two nets, when appropriately corrected for differences in swept area, theoretically yields size-specific trawl efficiencies for any species.

The data analyzed was taken from a 30 minute trawl made at station 21, west of Warrior Reef (Section 5 - Figure 1) in November 1987. At this time of year this station typically returns a sample containing a high abundance of medium-sized commercial prawns (Section 5 - Figure 6). All prawns were frozen and returned to the laboratory where they were identified, measured and sexed.

There were insufficient numbers of any single commercial species common to both nets to provide species-specific results. Analysis of the sample was made with all species pooled. The frequency distribution of prawns for each net was determined for 1 mm carapace length (CL) classes. For each carapace length class the proportion caught in the standard net relative to the non-standard net was calculated and corrected for swept area differences giving the efficiency of the sampling trawl gear for that particular prawn carapace length class. Nonlinear regression analysis was used to fit a logistic model to the variation of gear efficiency with carapace length. The equation of the model is of the form:

$$y = x_1 \ / (1 + e(x_2 (CL - x_3)))$$

Where: y is the proportion captured by the standard net relative to the non-standard net

- x_1 is the upper asymptote
- x_2 determines the slope of the curve
- CL is the carapace length of prawns in mm
- x_3 is the value of CL where the curve reaches half of the upper asymptote

The three parameters (x_1, x_2 and x_3) were estimated with their standard errors and regression coefficient. Length classes represented by ten or fewer prawns caught in the non-standard net were not included as observations in the regression as it was thought that they were non-representative of the size class.

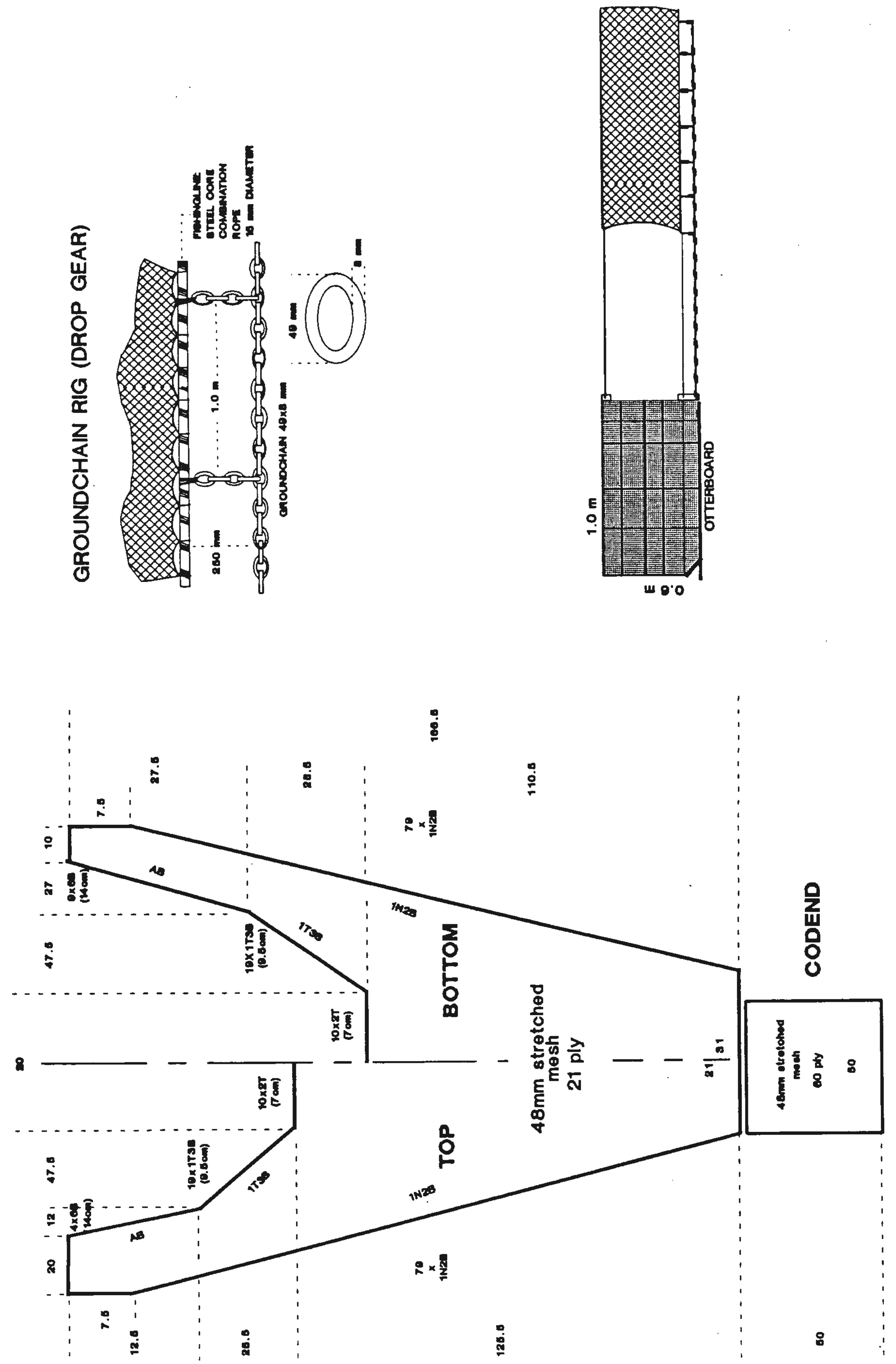

Figure 1. Netting plan and drop gear arrangement of the 48 mm mesh 3-fathom sampling net.

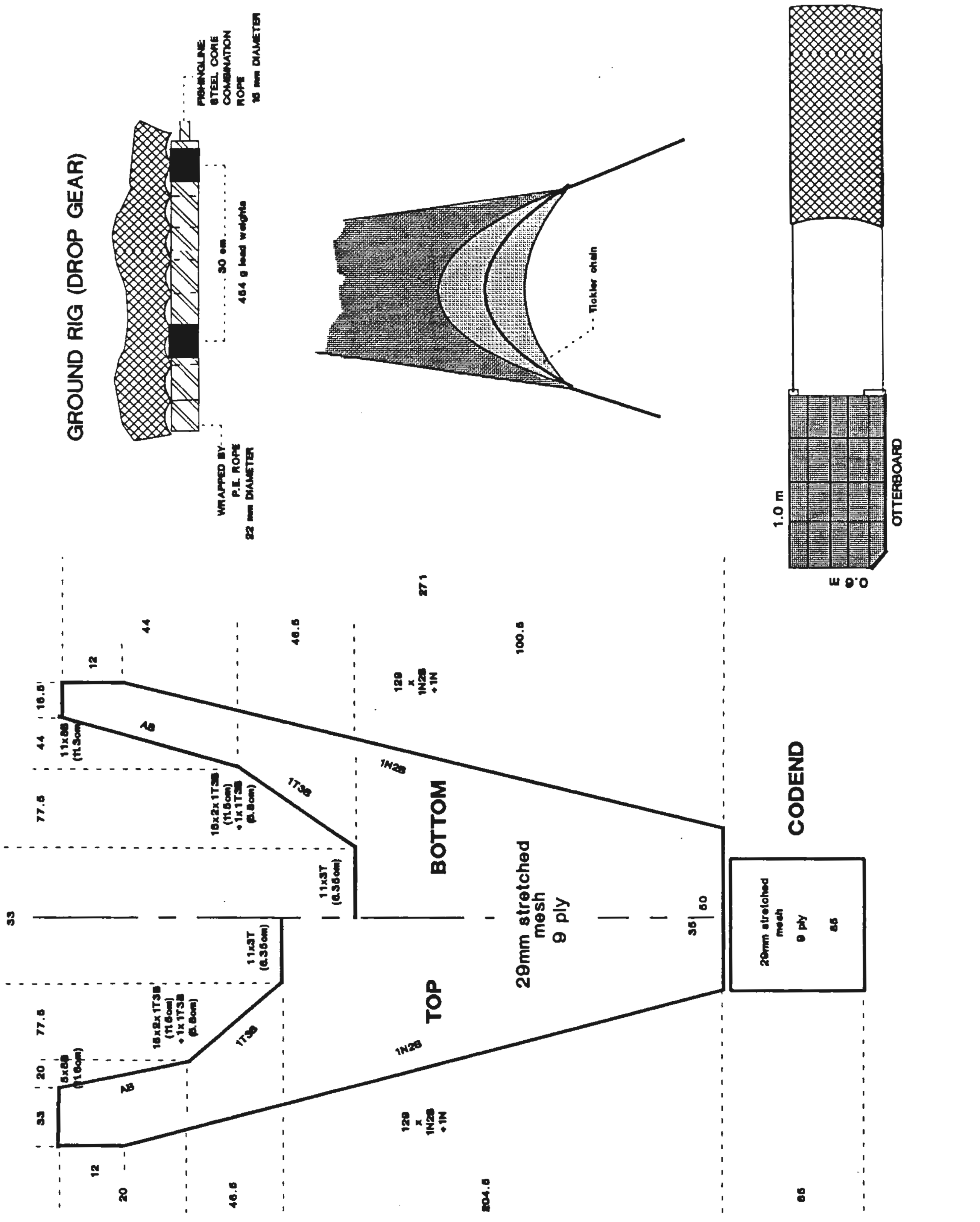

Figure 2. Netting plan and ground line arrangement of the 29 mm mesh 3-fathom trawl designed for low catch bias.

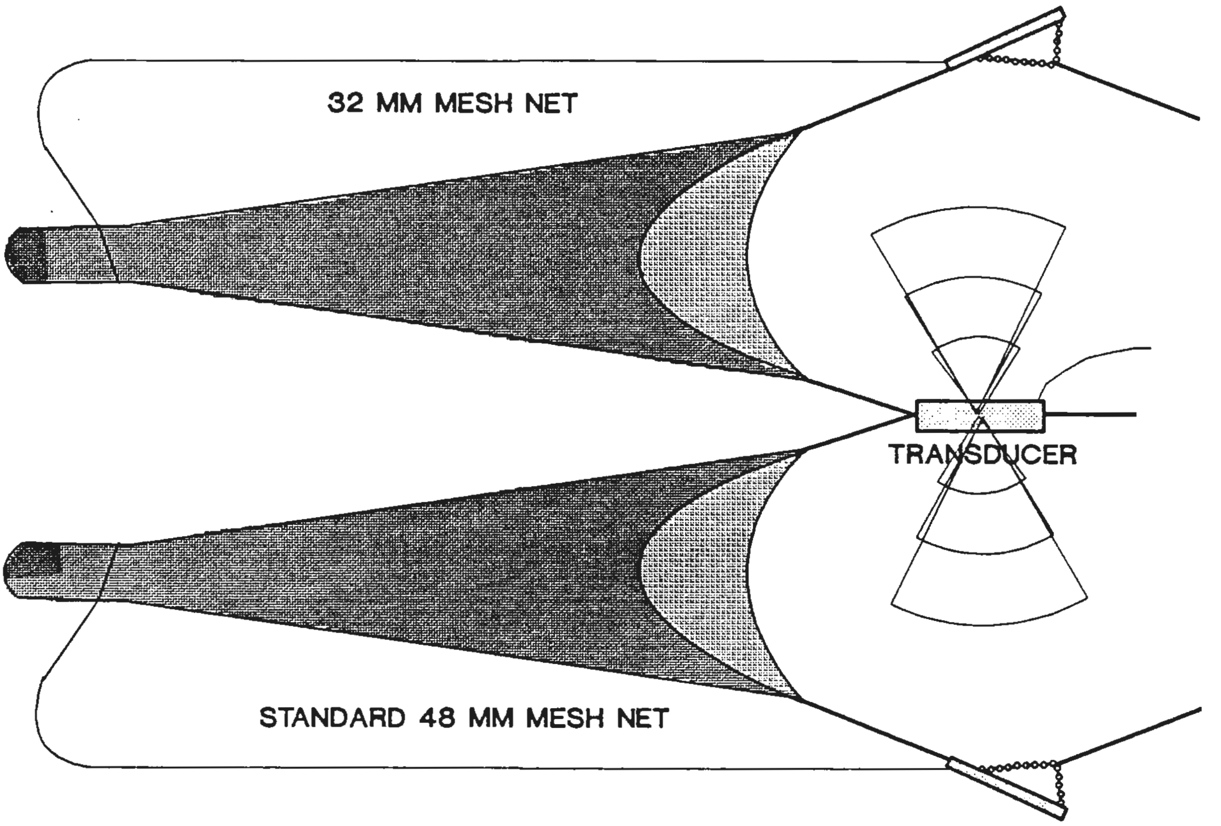

Figure 3. General arrangement of the dual-net sampling rig designed for trawl comparison.

11.2.2 Experiment 2 - Gear Selectivity

The traditional method of determining selectivity of a trawl is by using a small mesh cover over the cod-end of a net (King in press). This method for calculating selectivity assumes that prawns escape exclusively through the cod end. Selectivity of nets can also be determined by comparative fishing experiments (Royce 1972). In these type of experiments, nets of different construction are fished side by side. This method is more exacting as it assumes that prawns can escape through the mesh at any point along the net.

Whatever method is used, the results can be expressed as the proportion of prawns at each length class entering the net which are retained in the cod-end (Gulland 1984). When these proportions are plotted against length, the selection curve for the species is obtained.

In September 1988, the RV 'Lumaigul' was fitted with a dual-net system incorporating the standard 48 mm mesh net on the port side and a exact 1:1 scale copy using 32 mm mesh (Figure 4) on the starboard side. This gear was primarily designed to enhance the project's data for growth and recruitment analysis from the monthly survey work, by improving the performance of the overall gear for smaller-sized (< 20 mm CL) prawns.

Prawn samples were treated identically to those in Experiment 1, although only commercial species (*Penaeus* and *Metapenaeus* spp) were processed. Selectivity analysis was for three groups: (1) all species pooled, (2) *Metapenaeus endeavouri*, endeavour prawns and (3) *Penaeus esculentus*, brown tiger prawns.

The analysis for the three groups was identical to Experiment 1, although this experiment measured the selectivity of the standard trawl and not its efficiency. No spread difference correction was applied. The spread difference used in Experiment 1 would not be appropriate because of the difference in netting material and ground chain arrangement used in Experiment 2.

It was assumed that a catch of at least 10 prawns by the starboard net was necessary to represent a particular length class accurately.

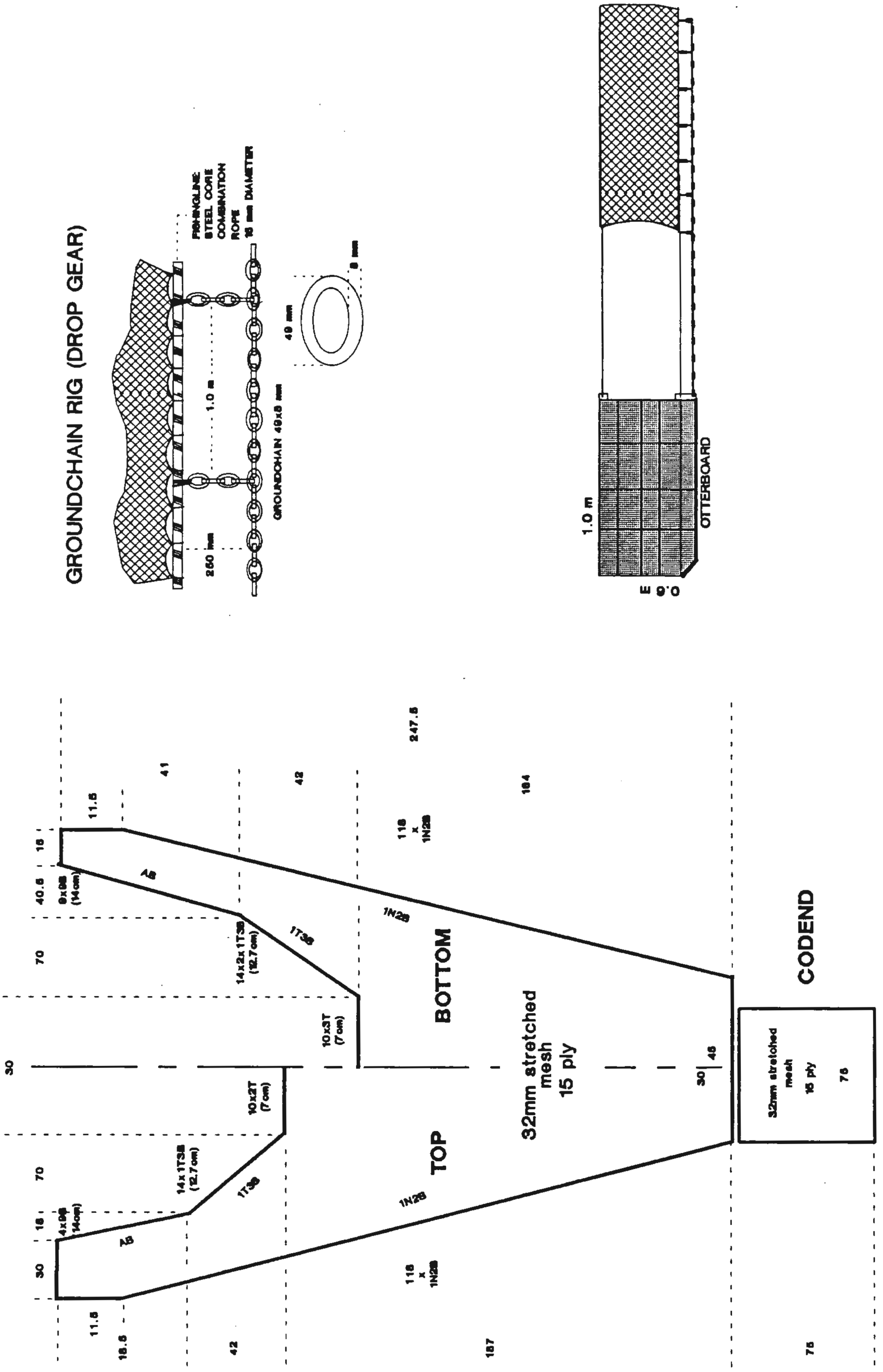

Figure 4. Netting plan and drop gear arrangement of the 32 mm mesh 3-fathom sampling net.

11.3 Results and Discussion

11.3.1 Experiment 1 - Gear Efficiency

An estimate of the average spread ratio of the standard net relative to the non-standard net was calculated as 1.13 based on sonar measurements taken during earlier trials. The accuracy of this ratio was confirmed by repeated trials.

Eleven species of prawns were collected including several non-commercial species. The prawns caught in the non-standard trawl ranged in size from 5 to 45 mm CL (Figure 5). Sizes of the commercial species: *P. esculentus, M. endeavouri* and *P. longistylus* only overlapped slightly with the smaller non-commercial species.

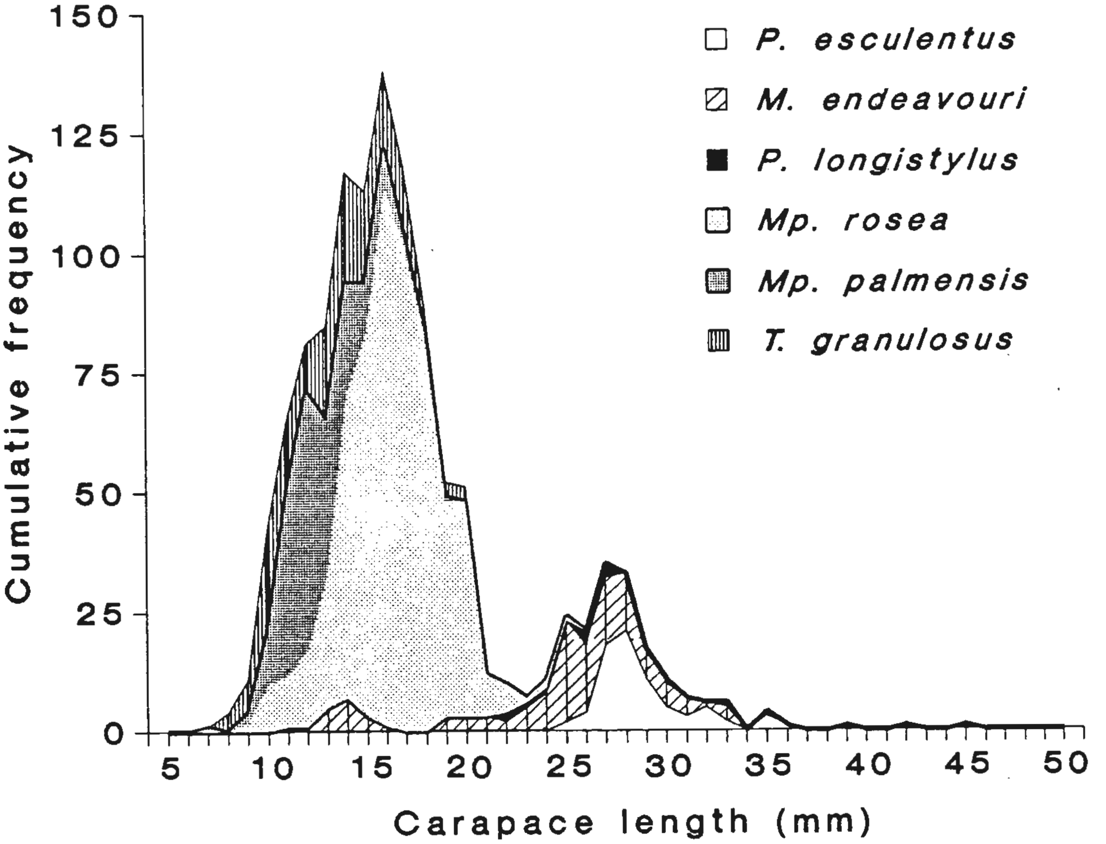

Figure 5. Length-frequency distribution caught by the non-standard net in Experiment 1, showing the contributions made by the six most abundant species.

There was a positive correlation between efficiency and carapace length (Figure 6). A logistic curve fitted by nonlinear regression adequately represented the trend in the data (Table 2). The parameter x_1 (0.812, Table 2) was significantly less than 1, where 1 would be the asymptote of a curve of a net 100% efficient ($p < 0.05$, Student t-Test)). This shows that the standard net never attained 100% efficiency relative to the non-standard net, even at the largest prawn sizes. This result probably reflects the percentage of large prawns (> 27 mm CL) that can escape through the drop gear (Figure 1) of the standard trawl (QDPI unpubl. data).

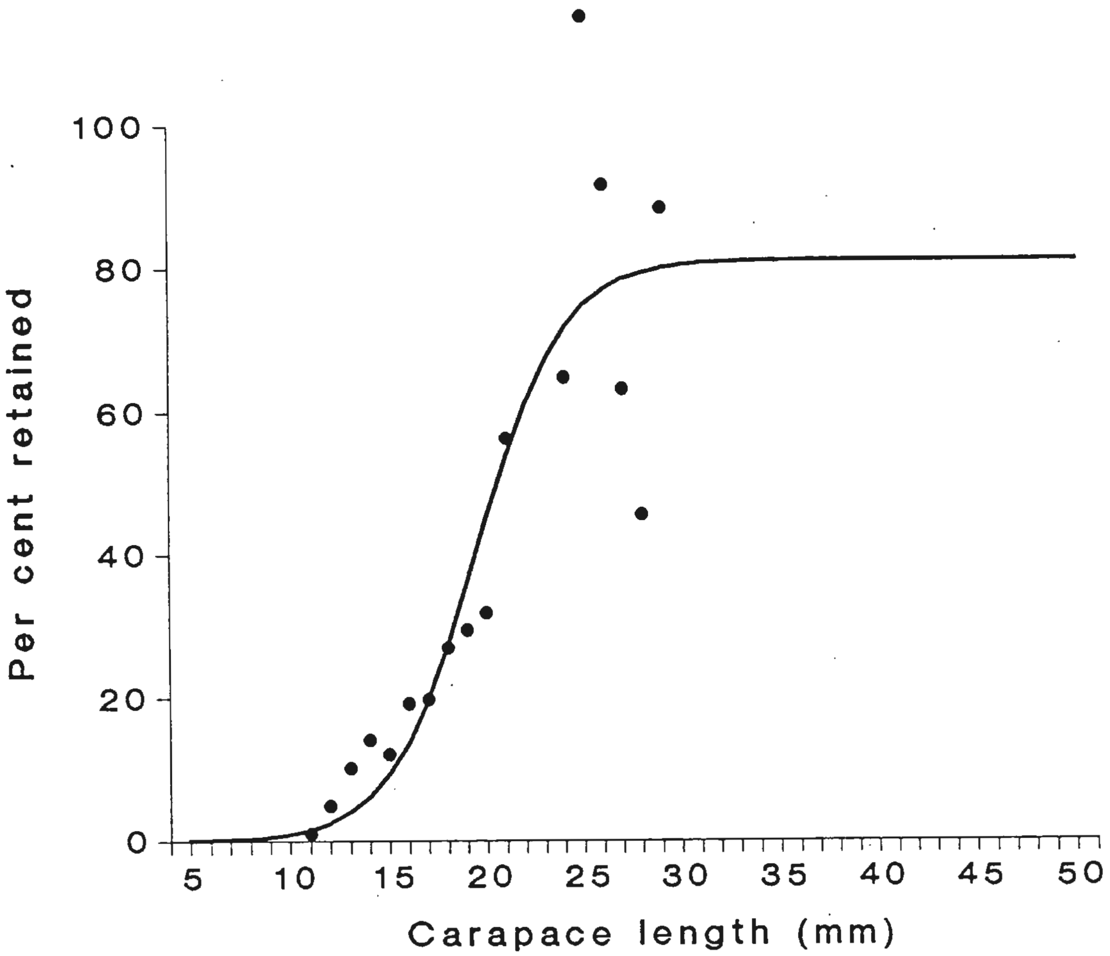

Figure 6. Size-specific gear efficiencies for all species pooled measured for the standard 48 mm mesh trawl with the fitted logistic curve.

Table 2. Parameters for the relationship between efficiency and prawn carapace length.

	Estimate	Standard Error
x_1	0.812	0.096
x_2	-0.452	0.185
x_3	20.0	1.12

$CL_50\%$ = 21.1 mm $\qquad$ $r^2 = 0.83$

11.3.2 Experiment 2 - Gear Selectivity

All Species Pooled. The commercial prawn species caught did not have the same size ranges (mm CL). Individuals of *P. esculentus* were on average larger than *M. endeavouri* (Figure 7).

The relationship between selectivity of all species pooled and carapace length was well represented by a logistic curve (Figure 8). The upper asymptote, x_1 of 1.105 (Table 3) was statistically larger than 1 ($p < 0.1$, Student t-Test). This shows that it is likely that the small mesh net is catching fewer large prawns than the standard net, (10% fewer), through comparison of the upper asymptotes of 1.105 to 1. Theoretically calculations of selectivities can yield values that range from zero to 100%. In practice when selectivity is greater than 100% the value is set at 100% (Kjelsohn and Johnson 1978). However it was felt that if this conditional 100% was applied to our data it would mask the actual performance of the trawl sampling gear. One reason for a 10% difference could be an average spread difference of the otter boards of around 10%. If so, this reduction would have occurred over all the length classes and species. This was not the case.

Another reason could be that the performance of the small mesh net allows larger prawns to either escape from the net or avoid the net, as there is evidence that jumping height and consequently the ability to escape a net is size dependent (QDPI unpubl. data).

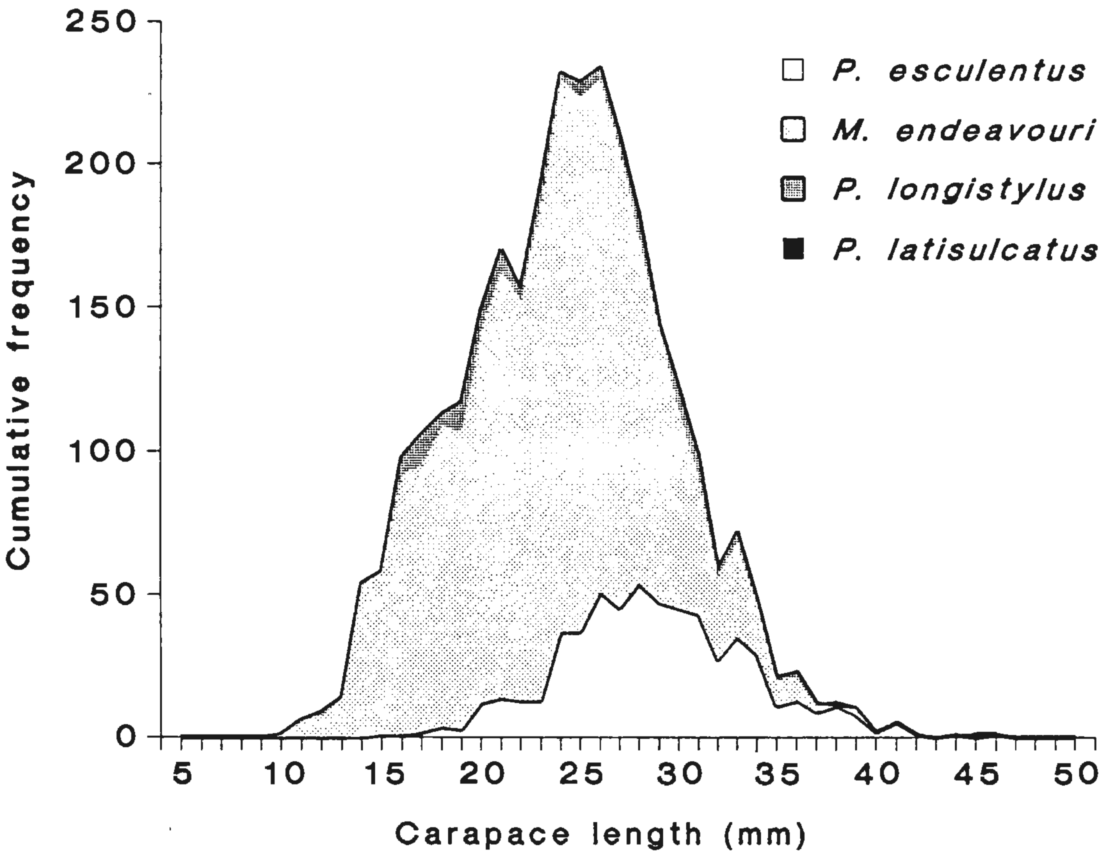

Figure 7. Prawn length-frequency distribution caught by the starboard net in Experiment 2, showing the contributions made by the four commercial species processed.

Table 3. Parameters for the relationship between the selectivity of all species pooled and their carapace length.

	Estimate	Standard Error
x_1	1.105	0.064
x_2	-0.396	0.103
x_3	20.4	0.739

$CL_50\%$ = 19.9 mm $r^2 = 0.84$

King (1979) measured the proportion of western king prawns, *P. latisulcatus,* retained in the codend of a 50 mm mesh trawl by using a fine mesh cover which caught all prawns escaping the codend. $_0$ur $CL_50\%$ value of 19.9 mm (Table 3) was considerably less than 29.88 mm as determined by King (1979). Several factors may account for the different $CL_{50\%}$ between these two studies. One explanation may be that as King (1979) used a larger mesh net than that used in this study, his $CL_{50\%}$ was greater. The use of a codend cover by King (1979) may have changed his net's performance allowing more escapement through the net and into the cover. Greater escapement from the cod-end is possible if the fine-mesh cover reduced codend water flow. Reduced codend water flow may allow prawns to move more freely inside the net and escape. It may also cause an increase in the effective size of codend mesh openings permitting prawns to pass through the mesh into the codend cover. It should also be remembered that the $CL_{50\%}$ for this study was determined for all species pooled and not one species as in King's study. The smaller $CL_{50\%}$ of our study may have been influenced by the high proportion of small *M. endeavouri* prawns in the catch (Figure 7). It could also be attributed to different net avoidance behaviour of different species.

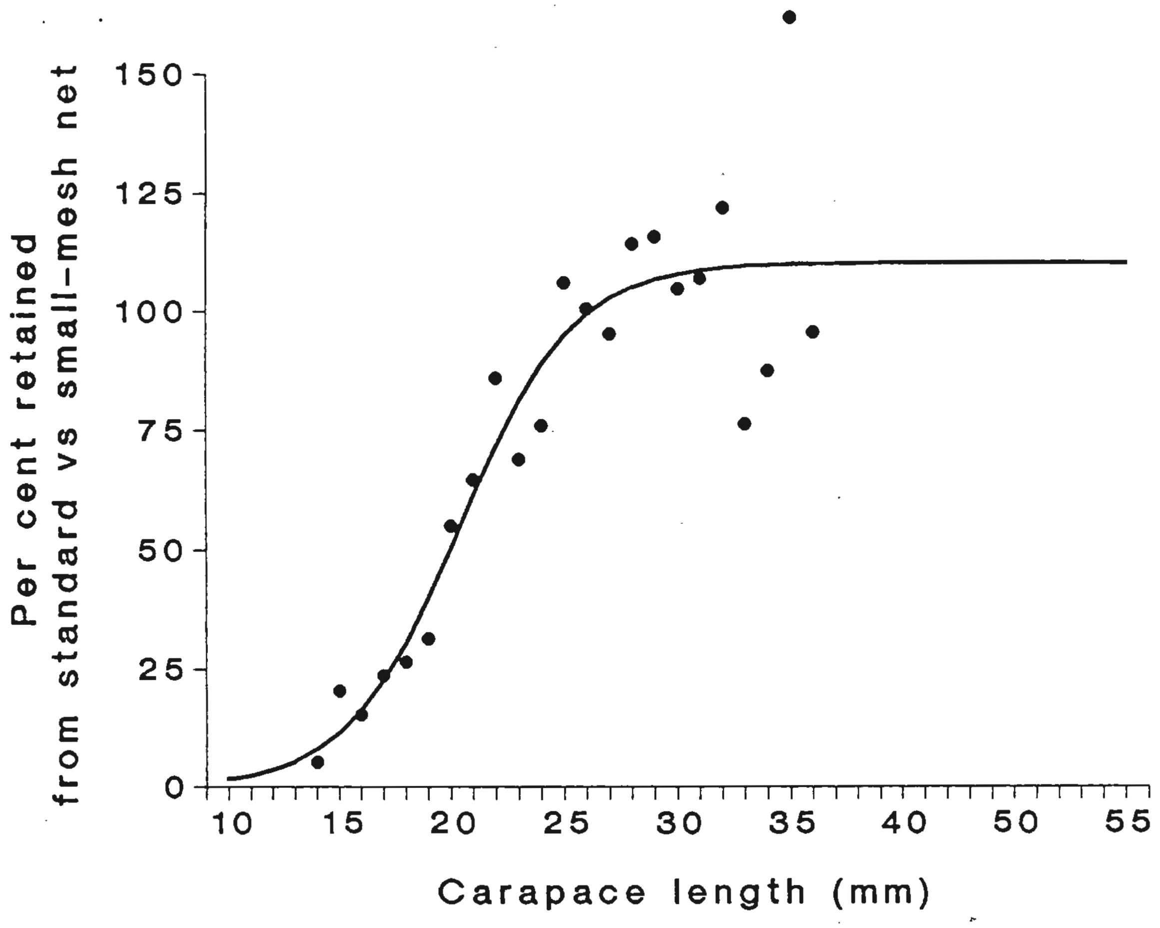

Figure 8. Selectivity data and fitted logistic curve, based on pooled species catches obtained from port and starboard nets in Experiment 2.

Metapenaeus endeavouri. A logistic relationship between trawl selectivity and carapace length for *M. endeavouri* prawns was determined (Fig. 9). and the logistic parameters estimated (Table 4).

Estimated parameters for the fitted logistic curve were not statistically different ($p > 0.05$, Student t-Test) from those parameters estimated for the pooled species (Table 3 and Table 4). This was expected as the majority of prawns in the pooled analysis were *M. endeavouri* (Figure 7). Parameter x_1 (1.203, Table 4) was significantly greater than 1 ($p<0.05$, Student t-Test).

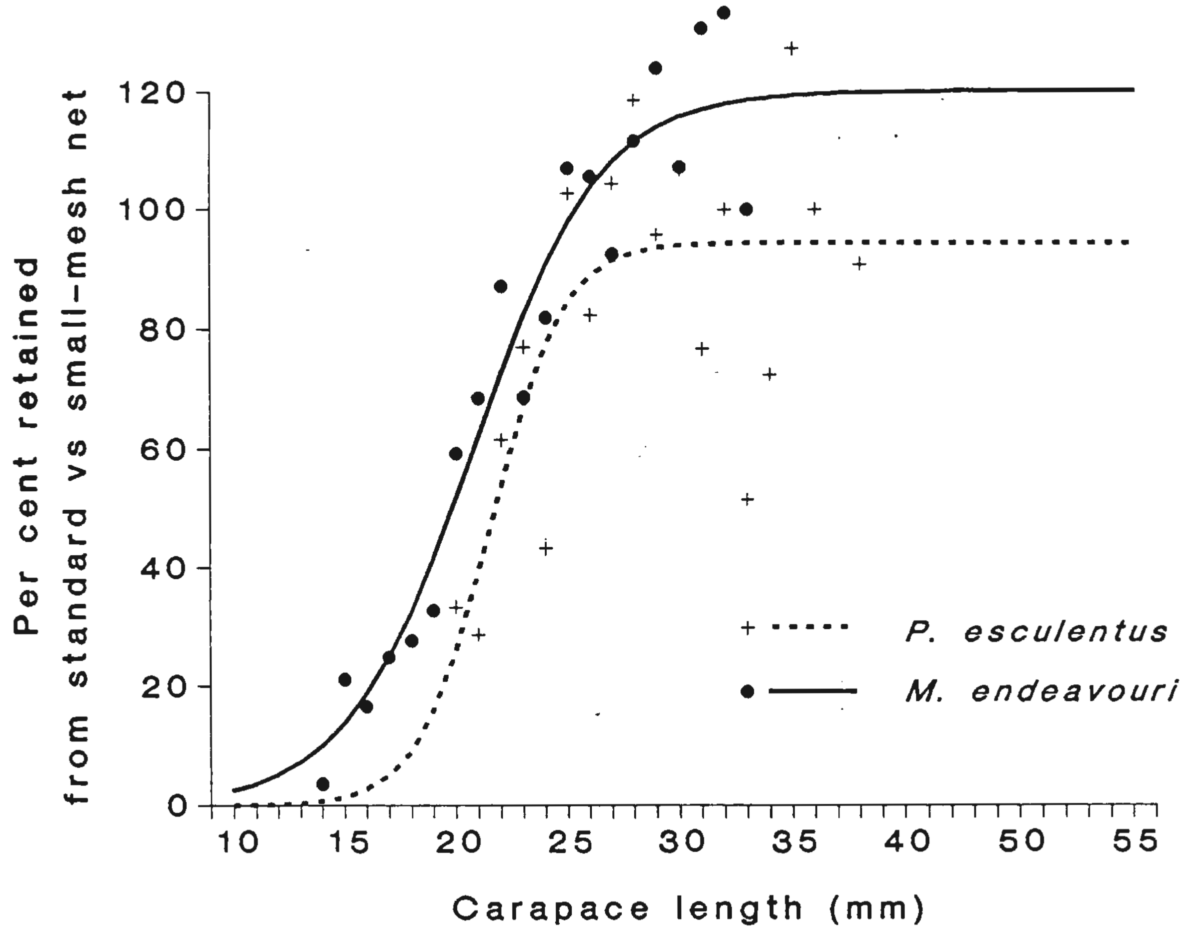

Figure 9. Selectivity data and fitted logistic curve for *P. esculentus* and *M. endeavouri*, based on catches obtained from port and starboard nets in Experiment 2.

Table 4. Parameters for the relationship between the selectivity of *M. endeavouri* and their carapace length.

	Estimate	Standard Error
x_1	1.203	0.0616
x_2	-0.353	0.0596
x_3	20.8	0.562

$CL_50\%$ = 19.8 mm $r^2 = 0.94$

Penaeus esculentus. A logistic curve was fitted to the *P. esculentus* selectivity data (Figure 9). The numbers caught were low and the majority of prawns caught were in size classes above the 50% selectivity level.

The asymptote of the selectivity curve was lower for *P. esculentus* than it was for *M. endeavouri* (Figure 9). The asymptote x_1 (0.945, Table 5) for *P. esculentus* was not significantly different from 1 ($p > 0.05$, Student t-Test). This suggests that there was no difference in the spread of the two nets, which is contrary to our explanation for mesh selectivity curve asymptotes being greater than 1 for *M. endeavouri*. The average number of *M. endeavouri* > 26 mm CL retained was compared with the average number of similar-sized *P. esculentus* retained (Figure 7) and was found to be significantly different ($p < 0.1$, Student t-Test).

Table 5. Parameters for the relationship between the selectivity of *P. esculentus* and their carapace length.

	Estimate	Standard Error
x_1	0.945	0.068
x_2	-0.628	0.349
x_3	21.6	0.808

$CL_{50\%}$ = 21.7 mm $r^2 = 0.52$

11.3.3 General Discussion

The parameters calculated in Experiment 1 can be used to correct the bias associated with the use of commercial trawls as sampling devices for all species of prawns. This correction may have to be species-specific as indicated by the different selectivity results for *M. endeavouri* and *P. esculentus.*

Results from Experiment 1 on gear efficiency showed that up to 20% of large-sized prawns (> 26 mm CL; comparison of catches from both nets) are lost through the ground chain rig. It would be possible to isolate the size-specific effects of drop gear by comparing the results of Experiment 2 with those of Experiment 1. This has not yet been possible due to the small sample size in Experiment 1. Further trials of Experiment 1 would be required to achieve an adequate sample size for this comparison.

The results from Experiment 2 showed that the proportion of *P. esculentus* retained in the standard net for a given carapace length class was consistently lower than that for *M. endeavouri.* Differences in the $CL_{50\%}$ between these two species would suggest differences in mesh selectivity. The fact that a common upper asymptote was not shared by these species would suggest that the set of the trawl sampling gear selects differently for individual species. If this does cause the different asymptote values for the different species, it may also explain the differences in the other estimated selectivity parameters of x_2, x_3 and $CL_{50\%}$. The behaviour of prawns when approached by trawl gear is likely to differ between species. This behaviour in turn may be affected differently by such factors as ground chain lead ahead of the net, a factor which is affected by net spread. Investigations into details of net settings and animal behaviour was beyond the scope of this study, however there is a definite need for further investigation before species-specific mesh selectivity effects can be determined.

11.4 Acknowledgements

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11.5 References

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QDPI, Rural Credits Project on the net avoidance behaviour of prawns. (unpublished data)