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ABSTRACT

Five mesh sizes were used to sample shrimp *Palaemon serratus* at depths of less than 30 m in Bantry Bay, southwest Ireland from June 1996 to March 1997. All of the meshes, with the exception of the smallest (2.5 mm) were made up of polyethylene and they were distributed over a gang of 20 Chinese-hat-ended creels which were fished on fourteen occasions throughout the period which overlapped with the commercial fishing season. Some 5,000 shrimp were captured and the size distribution of the total catch per month reflected the growth of the species so it is supposed that the population was representatively sampled throughout. Selection was calculated using the alternate hauls method. Shrimps did not enter the pots in any numbers below the length of 50 mm (total length) and mesh selection could not be demonstrated at a mesh size of 5.2 mm. Thereafter, as the mesh sizes were ascended, selectivity became more significant. It was however weak; *Lc* values ranged between 58-75 mm for females and 71-88 mm total lengths for males for mesh sizes of 7.5 – 13.5 mm. These lengths coincide with the centre of the length frequency distribution of shrimp. As the mesh size increased, the ratio of females to males rose, but the numbers per haul declined abruptly in the 13.5 mm mesh.

INTRODUCTION

A creel fishery for shrimp came into operation in the south west of Ireland in the mid- 1970s and subsequently extended along the west and south coasts. *Palaemon serratus* (Pennant) comprises the bulk of landings although there is a small contribution by *P.elegans* Rathke (Fahy, Forrest and Gleeson, in prep.). The fishery for *Palaemon* at present has two centres of greater production, in Co Kerry and in Connemara, south Co Galway. Shrimp are not fished commercially in the Irish Sea or, to any extent, along the west coast north of Co Galway.

Landings statistics, collected from 1975, indicate that the annual yield of the *Palaemon* fishery did not exceed 150 tonnes nationally until 1989 (see Fig 2 in Fahy and Gleeson, 1996). In the following year 333 tonnes were recorded and the catches have remained high throughout the 1990s and fishing effort is regarded as heavy and increasing.

Concern about the sustainability of shrimp stocks prompted a review of the fishery in an effort to ascertain its conservation status and to devise appropriate measures to obtain optimum yield. *Palaemon serratus* has a life expectancy of two years, hence it is not a suitable candidate for age based population predictions. In these circumstances a precautionary approach to managing the fishery is the one most likely to succeed; in this the fishing season is defined and the fishing effort, methods and landings carefully monitored in order to identify problems, like local stock collapse, as they arise.

Sprimp are harvested at between 50 and 120mm in length. The largest, exclusively berried females, are the most valuable fetching three to four times the price of the smallest, youngest animals. Most valuable shrimp are in their second growth season (from August to November, approximately) and they may, depending on location, exceptionally account for more than 50% of landings, by weight. Catches from Co Galway tend to contain a higher proportion of berried females than those from Co Kerry or along the southern coastline (Fahy and Gleeson, 1996). However, berried females are generally considerably fewer in the catches and the disposal of large quantities of small shrimp on the commercial market can be a slow and relatively unrewarding business.

Investigations of the mesh selection characteristics of shrimp in Irish waters were undertaken in order to ascertain how mesh size might be used to regulate the quality of landings as part of a management strategy.

MATERIALS AND METHODS

Experimental creel fishing trials were carried out in the inner, eastward end of Bantry Bay, in South west Ireland, the location of a commercial shrimp fishery, at depths of less than 30 m, on fourteen occasions between 24 June 1996 and 20 March 1997 inclusive. A train of 20 commercial polyethylene Chinese-hat-ended barrel type shrimp creels which had been modified by the substitution of various meshes was fished on each occasion. All of the substitute meshes were polyethylene except for the smallest mesh which was fibre glass.

Mesh shape was slightly off-square/rectangle and the plastic rounded the corners and provided in some cases an elliptical shape. Mesh types are described as having a long and a short axis, the latter being interpreted as the obstacle to escape. The mesh characteristics of each creel are set out in Table 1 and the meshes are referred to by the shorter axis.

The creels were baited with whiting *Merlangius merlangus*.

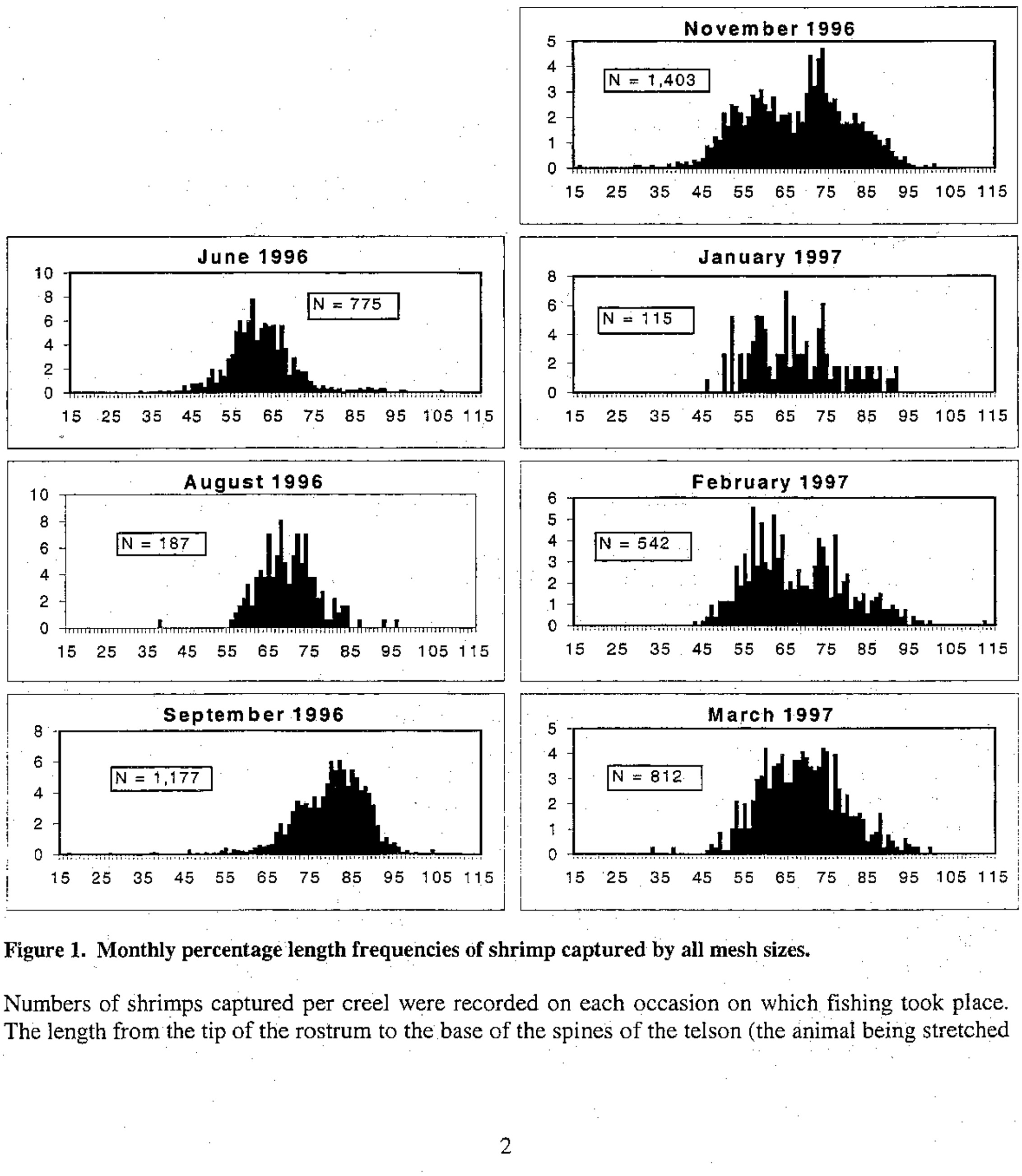

Figure 1. Monthly percentage length frequencies of shrimp captured by all mesh sizes.

Numbers of shrimps captured per creel were recorded on each occasion on which fishing took place. The length from the tip of the rostrum to the base of the spines of the telson (the animal being stretched back along a rigid surface) was recorded as were weight and sex of each shrimp. Some additional measurements of carapace length and depth were recorded from small sub-samples.

Probability of capture was estimated by the alternate hauls method. The approach was similar to that used by Takeuchi (1987a).

RESULTS

The numbers and length frequencies of shrimp captured per month in which fishing took place are set out in Figure 1. Autumn is the growing period for this species (Fahy and Gleeson, 1996) and the single length frequency mode shifted to the right as the year advanced. From November growth had apparently ceased. The larger catches in November and February had two peaks in the length frequency distribution. The left one was largely composed of males and some, possibly, 0-group, females while that on the right was made up mainly by berried females. Thus, the principal growing characteristics of shrimp are visible in the samples obtained by the gang of experimental creels.

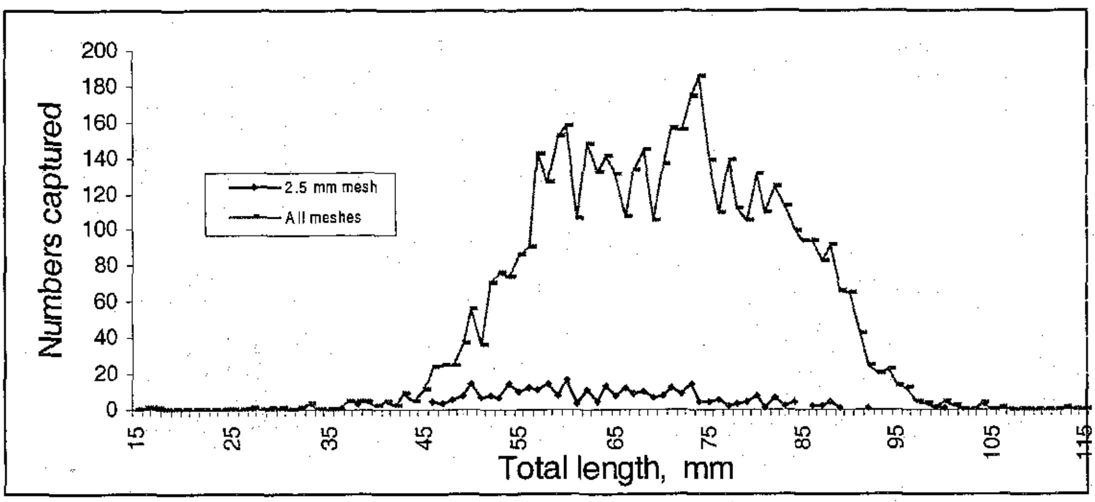

Figure 2. Length frequencies of shrimp captured by the 2.5 mm mesh and by all meshes.

Numbers of shrimp captured per creel at each fishing are set out in Table 1, the order of the creels as fished, identified according to the short mesh. Fishing success fluctuated possibly in response to local weather conditions; the role of seasonal migrations in the abundance of shrimp in Bantry Bay is not clear (Fahy and Gleeson 1996).

In Table 2 the order of creels has been rearranged to group similar mesh sizes in order to demonstrate their relative success. The creel with the smallest mesh size, 2.5 mm, captured an average of 7.9 shrimps. The catch increased through 21.7 shrimps in the 5.2 mm mesh to a maximum of 24.2 in the 7.5 mm and thereafter decreased to 20.8 in the 8.5mm mesh. Averaged catches of the 5.2, 7.5 and 8.5 meshes did not differ significantly. As the mesh size further increased from 8.5 mm to 13.5 mm, the catches declined through 20.8 shrimp per fishing to a minimum of 4.4.

Numbers of female and male shrimp taken throughout the year by the five mesh sizes are set out in Table 3 which also includes the total of each sex per mesh size, the average weight of shrimp taken and the sex ratio of captures per mesh.

Males were of smaller average length and weight than females in the catches. The incidence of larger shrimp and of females tended to rise as the mesh size increased but the average weight of shrimp (sexes combined) was greatest at the 7.5 mm mesh size. In order to demonstrate the range in size of shrimp captured the total length frequency distribution is set out in Fig 2 along with the length frequency distribution of shrimp taken in the smallest mesh. In both cases shrimp recruit to the creels at between 45 and 50 mm total length; in these experiments the length was taken to be 50 mm. Fincham (1983) described larval development of this species which entered the post-larval stage at between 7.0 and 8.6 mm. The size range of captures recorded here would suggest that smaller animals either did not frequent the areas in which fishing took place or that they have a different feeding regimen.

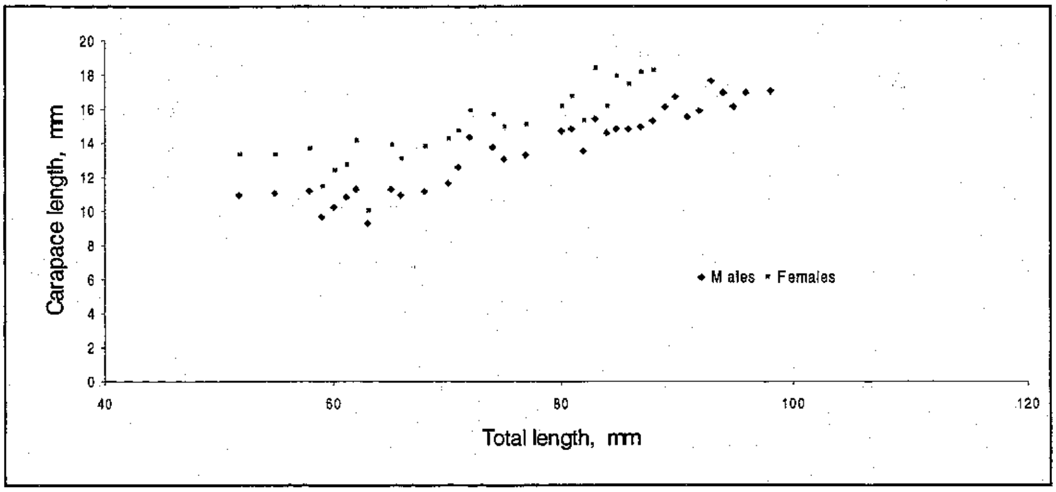

Figure 3. Regression of carapace length on total length for males and females

Investigation of selectivity in terms of the total length of shrimp may be misleading. The critical dimension for escape, should there be one, is more likely to be an aspect of the carapace, the widest part of the body. Takeuchi (1987a) working on *Pandalus borealis*, described his catches by their carapace length and that approach is fairly widespread in such investigations (Garcia and le Reste, 1981). The dimension used in this case was carapace length, measured from the base of the eye notch to the mid-dorsal carapace hind border. Cole (1958) regarded this measurement as more reliable than total length because of the bend in the shrimp abdomen. Establishing the length of the carapace is also more time consuming however and had been criticised by some workers as more likely to distort results because a relatively small error will have greater consequences than a similar mis-reading of total length.

In this case, the carapace lengths of a limited number of individuals throughout the range of the captured animals were measured and these measurements were regressed on their total lengths. The carapace of females is larger than males (Figure 3) so that values for the genders were calculated separately. They are:

Sex	*Number*	*Intercept*	*X variable*	R^2	*P*
Female	26	-0.71	0.8	0.68	<0.001
Male	35	-1.48	0.94	0.87	<0.001

These regressions were then applied to all shrimp and the data in Table 3 were re-presented as carapace rather than total lengths (Table 4).

Selectivity

Selectivity was estimated using the alternate haul method (Takeuchi, 1987a), assuming the carapace length frequency from the smallest (2.5 mm) mesh as representative of the shrimp population, the probability of capture (P) was calculated as shown in Table 5. The values of $\text{Ln}((1-P)/P))$ were regressed against L (length) to provide estimates of r (-slope) and Lc (intercept/slope). The selection curve was then calculated using the formula

$$P = 1/(1+\text{EXP}[-r(Lc-L)])$$

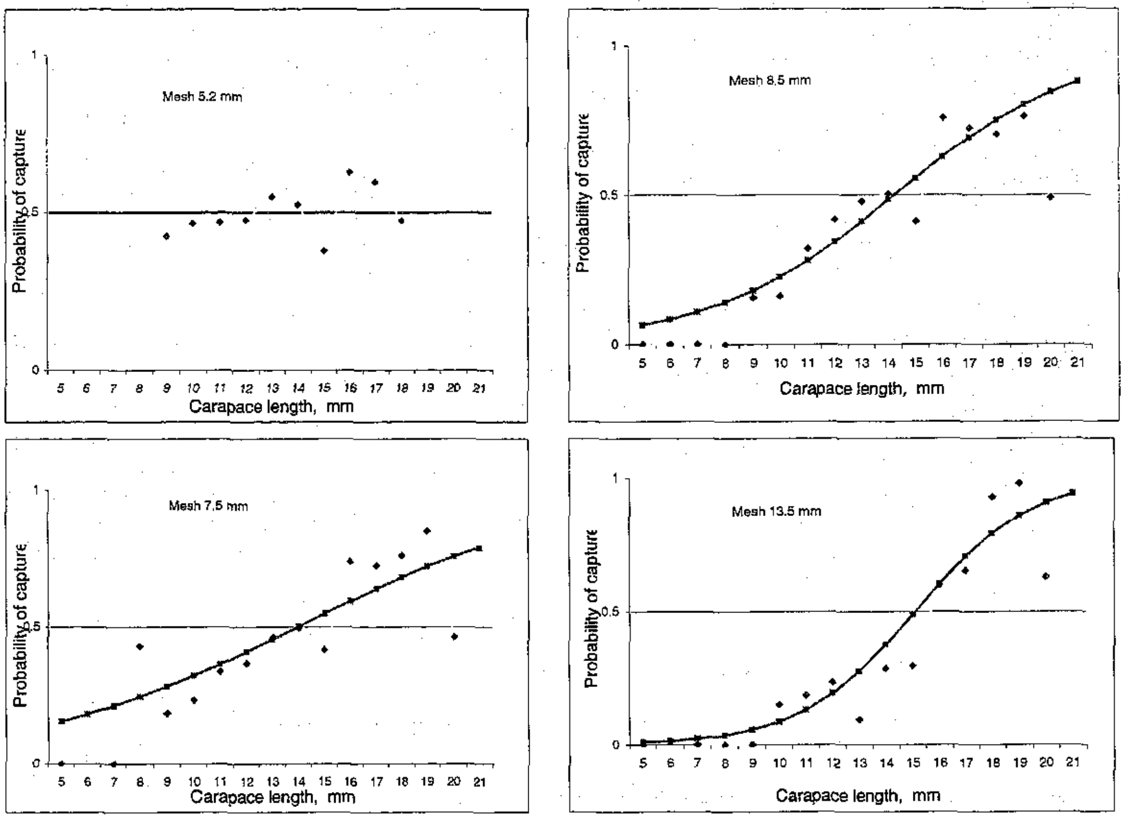

Figure 4. Raw data points and selectivity curves for four mesh sizes.

The method required a judgement about the carapace length at full selection. It was reckoned to be 50 mm (Fig 2), corresponding to an approximate carapace length of 11 mm (Fig 3). Numbers captured from 11 to 21 mm carapace length determined the ratio by which the raw data were raised. Any raised number of 5 or less was disregarded in the calculations.

The resulting selection curves are shown in Figure 4 and the variables used in the calculation are set out in Table 6.

Limiting factors

Depth of the carapace is greater than its width and so is likely to inhibit movement of shrimp through a narrow mesh. Readings of carapace depth were regressed on total length with the following outcome:

No observations	R^2	*Intercept*	*X-variable*
46	0.98	-0.73	0.16

On the basis of these calculations, which are established on measurements from both sexes combined, the following mesh sizes would have constrained the corresponding total lengths:

Mesh size, mm	*Total length, mm*
2.5	15.5
5.2	32.0
7.5	46.0
8.5	52.5
13.5	83.0

DISCUSSION

The five mesh sizes used in the experiments described here provided a similar size range of catch which displayed growth characteristics of shrimp in inshore waters suggesting that the population was representatively surveyed by the gang of experimental creels. The animals did not however enter the creels in appreciable numbers until they had reached a total length of 50 mm. The critical dimension preventing escape through a narrow mesh is not known: carapace depth is greater than its width but a greater width than depth might be required to allow for movement of the legs. Had depth of carapace been the constraining factor, shrimp as small as 15 mm, and possibly at metamorphosing size, would have been retained by the smallest mesh. Their absence from the catches may indicate that shrimps of this small size were either not available in the vicinity or that their feeding behaviour did not make them vulnerable to capture. The size range encountered in the course of these investigations was similar to that recorded in the commercial catches throughout the fishery (Fahy and Gleeson, 1996).

Comparison of the smallest meshes, 2.5 and 5.2 mm, did not yield a significant regression of probability of capture against carapace length (Table 6) and the probability of capture points which are shown without a calculated selection curve (Fig 4) do not display any trend, indicating that no selectivity operates below a mesh size of 5.2 mm.

The range of mesh sizes used in this experiment demonstrates that selection for *Palaemon serratus* is weak and that while the population was probably representatively sampled, and individual meshes for several possible reasons took larger or smaller proportions of the available size range, ***Lc*** values varied little, from 13 – 15 mm carapace length, corresponding with total lengths of 58-75 mm in the females and 71-88 mm in males. These values coincide with the most abundant length frequencies captured (Fig 2).

It was observed that the largest mesh retained small shrimp which were retained across the meshes when the creel was drawn from the water, so that a precise escape mechanism depending on a critical mesh size may not always operate. Shrimp creels are unlike the cod ends of trawls in which retention of undersized fish across the meshes occurs, in that there is invariably room to manoeuvre within the creel.

According to Gulland (1972) selectivity curves for shrimp are not sufficiently defined to justify regulations for mesh size and Mistakidis (1958) pointed out that trawls always retained a proportion of small prawns; in other words that selectivity did not operate in a knife-edged way. However Kurk et al (1965) demonstrated that well defined selectivity curves exist for *Crangon crangon* and various authors have shown that mesh regulation has management application for crustaceans (Garcia and le Reste, 1981).

In the experiments described here, selection did indeed operate by the escape of smaller shrimp through the largest meshes. The sex ratio (females/males) tended upwards (Table 3) as the mesh size increased although the average weight of capture did not change consistently; most significantly, the numbers per haul were considerably reduced in the largest mesh size, making its adoption an unattractive management option.

ACKNOWLEDGEMENTS

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Table 1. Numbers of shrimp taken per creel haul, creels in order as set; below mesh dimensions.

Creel number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total	Mean	st d
24-Jun-96	41	15	43	50	8	11	49	41	101	3	36	7	128	17	31	58	7	29	68	43	786	39.3l	32.1
07-Aug-96	2	2	2	27	1	13	12	7	17	2	15	0	10	6	21	4	0	14	10	22	187	9.4l	8.1
09-Aug-96	8	6	5	29	7	6	23	2	32	0	35	1	27	12	35	11	0	27	26	16	308	15.4l	12.5
24-Sep-96	1	4	3	28	3	0	49	0	53	11	33	11	55	19	28	50	7	26	10	31	422	21.1l	19.1
25-Sep-96	10	5	8	23	0	29	24	28	18	2	19	2	18	27	16	13	17	38	37	43	377	18.9l	12.4
26-Sep-96	1	6	0	53	4	8	36	8	22	3	50	0	31	45	22	23	3	24	22	17	378	18.9l	17.0
19-Nov-96	6	210	50	41	49	133	18	205	48	1	5	0	55	50	66	67	2	5	8	6	1025	51.3l	62.9
21-Nov-96	8	2	3	8	0	68	60	57	15	2	28	5	26	17	2	25	3	20	21	9	379	19.0l	20.5
21-Jan-97	1	1	2	6	2	0	14	10	22	0	4	0	11	5	1	8	1	0	0	16	104	5.2l	6.4
22-Jan-97	0	0	0	0	0	0	2	1	0	0	3	0	0	0	0	2	0	0	3	0	11	0.6l	1.1
25-Feb-97	14	10	14	69	23	9	7	8	9	24	53	6	72	40	21	28	12	14	11	32	476	23.8l	20.1
26-Feb-97	0	0	1	5	5	0	8	5	16	9	10	0	3	1	1	1	1	0	1	0	67	3.4l	4.4
18-Mar-97	0	1	3	10	2	0	3	2	6	6	33	6	34	91	99	47	29	0	54	36	462	23.1l	30.0
20-Mar-97	0	0	1	2	2	0	3	0	0	1	2	0	0	0	0	1	0	2	12	2	28	1.4l	2.7
Total	92	262	135	351	106	277	308	374	359	64	326	38	470	330	343	338	82	199	283	273	5010		
Average	6.6	18.7	9.6	25.1	7.6	19.8	22.0	26.7	25.6	4.6	23.3	2.7	33.6	23.6	24.5	24.1	5.9	14.2	20.2	19.5			
Standard deviation	10.90	55.22	16.10	21.60	13.31	37.36	19.27	54.11	26.76	6.52	17.41	3.60	34.99	25.57	28.22	22.73	5.39	13.18	20.25	15.35			
Mesh characteristics																							
Short axis, mm	2.5	5.2	2.5	7.5	2.5	5.2	7.5	5.2	7.5	13.5	7.5	13.5	7.5	8.5	8.5	7.5	13.5	8.5	7.5	7.5			
Long axis, mm	3.2	6.4	3.2	8.5	3.2	6.4	8.5	6.4	8.5	17	8.5	17	8.5	11	11	8.5	17	11	8.5	8.5			

Table 2. Numbers of shrimp taken per pot haul, according to mesh size..

Mesh size	2.5			5.2			7.5								8.5			14		
24-Jun-96	41	8	43	15	11	41	50	101	36	49	128	58	68	43	29	17	31	7	3	7
07-Aug-96	2	1	2	2	13	7	27	17	15	12	10	4	10	22	14	6	21	0	2	0
09-Aug-96	8	7	5	6	6	2	29	32	35	23	27	11	26	16	27	12	35	1	0	0
24-Sep-96	1	3	3	4	0	0	28	53	33	49	55	50	10	31	26	19	28	11	11	7
25-Sep-96	10	0	8	5	29	28	23	18	19	24	18	13	37	43	38	27	16	2	2	17
26-Sep-96	1	4	0	6	8	8	53	22	50	36	31	23	22	17	24	45	22	0	3	3
19-Nov-96	6	49	50	210	133	205	41	48	5	18	55	67	8	6	5	50	66	0	1	2
21-Nov-96	8	0	3	2	68	57	8	15	28	60	26	25	21	9	20	17	2	5	2	3
21-Jan-97	1	2	2	1	0	10	6	22	4	14	11	8	0	16	0	5	1	0	0	1
22-Jan-97	0	0	0	0	0	1	0	0	3	2	0	2	3	0	0	0	0	0	0	0
25-Feb-97	14	23	14	10	9	8	69	9	53	7	72	28	11	32	14	40	21	6	24	12
26-Feb-97	0	5	1	0	0	5	5	16	10	8	3	1	1	0	0	1	1	0	9	1
18-Mar-97	0	2	3	1	0	2	10	6	33	3	34	47	54	36	0	91	99	6	6	29
20-Mar-97	0	2	1	0	0	0	2	0	2	3	0	1	12	2	2	0	0	0	1	0
Total	333			913			2708								872			184		
Average	7.9			21.7			24.2								20.8			4.4		
sd	13			48			23								23			6.5		

Table 3. Length frequencies according to mesh size.

Mesh	2.5 mm		5.2 mm		7.5 mm		8.5 mm		13.5 mm		Total
	f	m	f	m	f	m	f	m	f	m	
length (mm)											
10-19	1	0	0	0	0	0	0	0	0	0	1
20-29	1	0	0	0	1	0	0	0	0	0	2
30-39	2	1	6	2	4	1	1	0	1	0	18
40-49	12	10	30	27	27	28	6	6	1	0	147
50-59	35	71	66	172	174	270	38	79	2	9	916
60-69	47	48	56	163	339	385	88	157	9	10	1302
70-79	27	42	76	205	397	340	141	158	7	8	1401
80-89	23	8	77	21	565	49	175	17	64	6	1005
90-99	1	0	11	0	118	1	25	0	52	0	208
100-109	1	0	0	0	6	0	3	0	0	0	10
110-119	0	0	0	0	1	0	0	0	0	0	1
Totals	150	180	322	590	1632	1074	477	417	136	33	5,011
Average weight, g	2.2	1.6	2.6	1.7	3.3	1.8	3.3	1.9	4.8	2.1	20,064
Average weight per mesh	1.9		2		2.7		2.6		4.2		
Ratio females:males	0.8		0.6		1.5		1.1		4.1		
Average length, mm	64.9	62.3	68.1	64.6	74.7	65.6	75.6	67.0	85.8	68.8	
Standard deviation	13.3	9.5	13.9	9.6	11.9	8.7	10.5	7.8	9.7	10.4	

Table 4. Carapace length (both sexes) taken in five mesh sizes.

	Mesh sizes				
Carapace length (mm)	2.5 mm	5.2 mm	7.5 mm	8.5 mm	13.5 mm
5	1	0	0	0	0
6	0	1	0	0	0
7	1	1	0	0	0
8	1	5	7	0	0
9	12	25	25	7	0
10	38	94	107	23	4
11	59	147	279	87	8
12	50	129	272	111	9
13	49	169	390	140	3
14	42	131	383	133	10
15	40	69	265	87	10
16	9	43	236	88	8
17	17	71	414	139	19
18	9	23	266	66	69
19	1	4	53	10	28
20	1	0	8	3	1
21	0	0	1	0	0
Totals	**330**	**912**	**2706**	**894**	**169**

Table 5. Probability of capture (P) for shrimp taken in 7.5 mm mesh. Raised data = number in 2.5 mm mesh * 9.3 (ratio of total in 7.5 mm to 2.5 mm mesh).

Carapace length (mm)	Numbers caught Mesh 2.5 mm	Numbers caught Mesh 7.5 mm	Raised data	P
5	1	0	9.3	0.00
6	0	0		
7	1	0	9.3	0.00
8	1	7	9.3	0.43
9	12	25	111.2	0.18
10	38	107	352.2	0.23
11	59	279	546.8	0.34
12	50	272	463.4	0.37
13	49	390	454.1	0.46
14	42	383	389.2	0.50
15	40	265	370.7	0.42
16	9	236	83.4	0.74
17	17	414	157.5	0.72
18	9	266	83.4	0.76
19	1	53	9.3	0.85
20	1	8	9.3	0.46
21	0	1	0.0	
Totals	277	2,567	2,567	

Table 6. Characteristics of selection of shrimp by four mesh sizes, based on the adjusted data. (Lc = intercept/slope).

Mesh size	Observations	R^2	*P*	Significance	Intercept	Slope	Lc
5.2	10	0.19	>0.05	ns			
7.5	13	0.58	0.05<0.02	*	2.63	-0.19	13.00
8.5	11	0.88	<0.001	**	4.14	-0.29	14.22
13.5	11	0.66	0.02<0.01	*	7.00	-0.46	15.10