

Effect of tooth spacing and mesh size on the catch of the Portuguese clam and razor clam dredge

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Experiments on the selectivity of the clam and razor clam dredges were carried out during July 1995, on the south coast of Portugal. The effects of mesh size and tooth spacing were investigated for both the clam and razor clam dredges. Four different mesh sizes (25, 35, 40, and 50 mm) and three different tooth spacings (15, 20, and 25 mm for the clams *Spisula solida* and *Venus striatula*, and 10, 15, and 20 mm for the razor clam *Ensis siliqua*) were used. The results indicated that the tooth spacing did not have an effect on the selectivity. The best mesh sizes were 40 mm for the clam fishery (*S. solida* and *V. striatula*) and 66 for the razor clam (*E. siliqua*). These mesh sizes will result in considerable reduction in the numbers of small- and medium-sized individuals in the catch.

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Introduction

An important bivalve fishery takes place along the south coast of Portugal. Among the Portuguese, bivalve fishing is an ancient and traditional activity. Until the 1960s the harvesting of bivalves was restricted to estuaries and lagoons. In ancient times bivalves were harvested by hand or by hand rakes at low tide. At the beginning of the twentieth century, small dredges were introduced to the fishery. The dredges were very similar to those used nowadays but smaller and with a bag made of leather (Ruano, 1997). The gear was towed from rowboats with a cable or with a long-handled pole (Silva, 1893). The exploitation of bivalve ocean beds along the Portuguese coast is recent and was initiated in 1969 by the Spanish fleet under the auspices of the “Portuguese-Spanish Fishery Agreement”. The Spanish fleet directed its fishing effort mainly towards two species *Ensis siliqua* and *Venus striatula*. The high economic value of these species in the external market soon aroused great interest in the Portuguese fleet. Thus, the fishing effort as well as the gear efficiency increased and as a consequence bivalve beds soon showed signs of depletion. By that time

Instituto de Investigação das Pescas e do Mar (IPI-MAR) had started a research programme in order to study the distribution, biology, and ecology of the species.

Unfortunately no reliable statistical data are available since, until 1997, fishermen were not obliged to declare their catches. However, the last bivalve survey carried out by IPIMAR showed that bivalve beds were over-exploited. Thus, it is important to introduce or modify some management measures in order to overcome the present situation.

At present the most important commercial species are the clams *Spisula solida* and *Venus striatula*, and the razor clam *Ensis siliqua*. All three species inhabit sand bottoms at depths between 3 and 12 m where they form extensive and dense beds, sometimes strips that reach several miles. These populations constitute the target of a specific fishing activity carried out by an artisanal fleet. The boats involved in the fishery are 4–15 m long, with engines of 17–150 hp and a crew of 1–5 fishermen. Dredges are the gear used in this fishery.

The basic structure of the Portuguese clam and razor dredge is a small, heavy semicircular iron structure, with

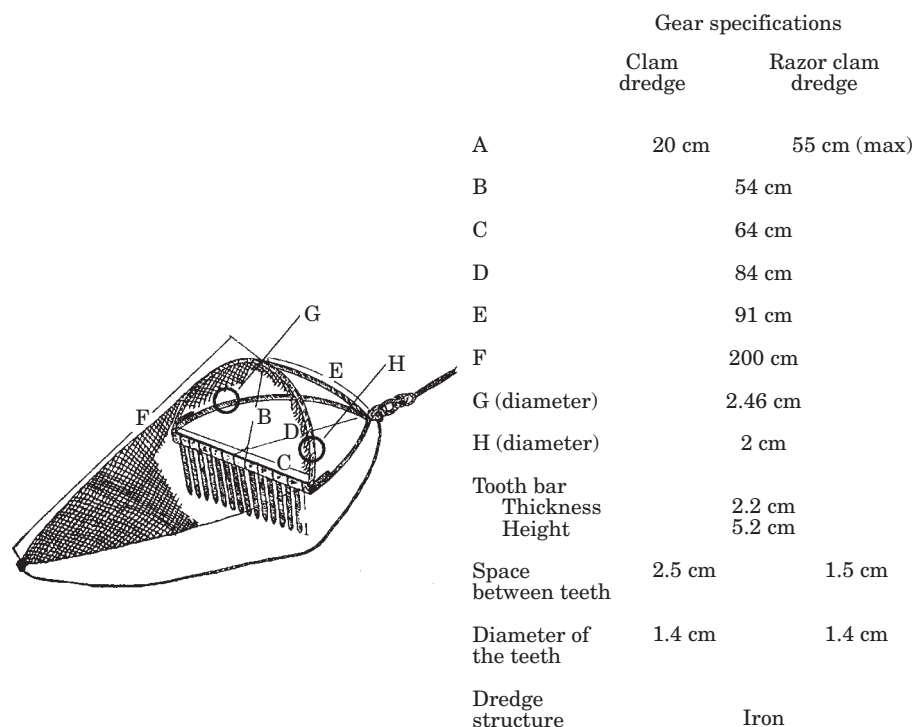


Figure 1. Diagram of a Portuguese dredge and its specifications (adapted from Monteiro, 1985).

a net bag and a toothed lower bar at the mouth. The lower bar has 12–14 teeth with a maximum length of 55 cm spaced 1.5–2.5 cm apart, acting as the lower leading edge of the dredge. Welded to this iron structure are three metal shafts forming a kind of hen's foot where the towing cable is attached (Fig. 1).

Large yearly fluctuations in the recruitment of these species are observed (Gaspar, 1996). In such resources the classical approach of maximizing yield-per-recruit is less important than conserving the spawning stock at densities that allow these species to take advantage of future favourable environmental conditions (Caddy, 1989). With this objective, several management measures were applied to this fishery. These measures included minimum legal landing length (MLL) and minimum mesh size (MMS). A MLL of 25 mm for *S. solida* and *V. striatula*, and 100 mm for *E. siliqua* was introduced to allow spawning at least once before capture. Minimum legal banding lengths were based on the size/age of first maturity, life span, and growth of the species (Gaspar et al., 1994, 1995; Gaspar, 1996). Nevertheless, the capture of undersized individuals is still a great problem. There are high discard rates in this fishery because adults and juveniles are found in the same areas.

The mortality due to fishing is affected by the survival rates of discarded individuals. Recently Gaspar and Monteiro (unpubl.) showed that undamaged juveniles of

S. solida are extremely sensitive to the time of exposure on the deck. These authors estimated a fishing mortality rate of 0.003 min^{-1} out of water. As catches are usually sorted at the end of the trip, mortality is high. This is a problem of particular importance during summer, when high temperatures increase mortality and densities of undersized individuals are higher. A good management option would be to avoid a large by-catch of undersized clams and razor clams in the first place.

According to Drinkwater (1974), mesh size and tooth spacing are the most important dredge features that affect selectivity. The effect of these two characteristics was studied with the objective of quantifying the catch of undersized individuals retained and estimating a minimum mesh size.

Methods

Experimental design

The selectivity experiments were conducted during groundfish surveys, off the south coast of Portugal, carried out on board the "NI DONAX" in July 1995. The vessel is of similar size and power of the commercial ones as well as the dredges used. For experimental purposes the dredges were fitted with interchangeable tooth bars. The specifications of the gear used in the experiment are summarized in Figure 1.

Four different mesh sizes 25, 35, 40, and 50 mm were investigated. These sizes were chosen to cover a range of mesh sizes and include the one in current use (25 mm). All meshes were measured across the diagonal of fully stretched nets. Three different tooth spacings were used: 15, 20, and 25 mm for *S. solida* and *V. striatula*; and 10, 15, and 20 mm for *E. siliqua*. These sizes included tooth spacing in current use and narrower and wider spacings for comparison. For each gear combination (teeth and mesh size) 10 hauls were made. This gave a total of 240 hauls, 120 hauls for *S. solida* and *V. striatula*, and 120 hauls for *E. siliqua*.

The dredge selectivity experiments were conducted by attaching to the gear a cover bag with a 20 mm mesh. This bag was 1.6 times longer and wider than the primary net bag and did not impede the natural flow of water through the net. Two dredges with equal teeth and different bag meshes were towed side by side. All fishing hauls were conducted at a towing speed of 1–1.5 knots at depths between 5 and 10 m with duration of 3 min. After each haul the catches in the bag and in the cover were sorted separately. For all species the standard length was measured to the millimetre and subsequently grouped into 2 mm classes, in the case of *V. striatula* and *S. solida*, and into 5 mm classes in the case of *E. siliqua*.

Data analysis

It was assumed that the selection curves followed a logistic model, which is expressed by the following equation (Paloheimo and Cadima, 1964):

$$P(L) = \frac{1}{1 + \exp^{-(a + bL)}} \quad (1)$$

Where: L is the centre of the length class; P(L) is the retention proportion for length cases L; and a and b are parameters.

The logistic curves were fitted using non-linear regression with the routine PROC NLIN, part of the statistical package SAS (SAS Institute Inc., 1989). This iterative curve fitting procedure employs a non-linear least-square regression method (Gauss-Newton) and estimates a and b from the above equation. Useful parameters of a selection curve are $L_{50\%}$ (theoretical length at which 50% of the individuals are retained) and the selection range, SR (difference between $L_{75\%}$ and $L_{25\%}$). These two parameters are related to the parameters of the logistic equation by the expressions:

$$L_{50\%} = -\frac{a}{b} \quad (2)$$

and:

$$SR = 2 \times \frac{\ln 3}{b} \quad (3)$$

To compare the selection curves, the vectors of estimated parameters were tested for equality using

the multivariate Hotelling's T^2 -test (Bernard, 1981; Hanumara and Hoenig, 1987). It was assumed that the distribution of the estimated parameters was normal (Morrison, 1976). This T^2 statistic was used to test the null hypothesis $H_0: P_1 = P_2$ vs. $H_a: P_1 \neq P_2$ where P_1 and P_2 are the parameter vectors for both selectivity curves. T^2 has a modified F-distribution (Bernard, 1981). The variance-covariance matrices, necessary for the calculation of T^2 , were resulted from the iterative procedure with convergence, part of the non-linear fit. According to Hanumara and Hoenig (1987) these matrices can be used in the test, as an approximation of true variance-covariance matrices, without the introduction of significant error or bias. The statistic of the test (T^2) is compared with the modified F-values (T^0). The null hypothesis is rejected whenever $T^2 > T^0$.

Results

The effect of tooth spacing on the selectivity of the dredges was analysed first. In these experiments mesh size was ignored and catches in the bag and cover were added together for hauls with the same tooth spacing. The length distributions of the catch, for each of the species studied, are represented in Figure 2.

If tooth spacing had a selective effect in the size range caught, the length frequencies obtained for each tooth spacing would be different. One would expect that narrower tooth spacing would correspond to length distributions with a higher proportion of smaller individuals. This hypothesis was not confirmed, and in one of the species, *S. solida*, the opposite was found, the wider tooth spacing corresponded to higher proportion of small individuals. These results led to the conclusion that tooth spacing, within the ranges studied here, does not affect the selectivity of the dredge.

After establishing that tooth spacing was of no importance for the selectivity of these dredges, the effect of mesh size was studied ignoring this factor, that is, data from the hauls with the same mesh size were pooled, ignoring the tooth spacing used. Figure 3 shows the estimated selectivity curves for *S. solida*, *V. striatula*, and *E. siliqua*, respectively. Table 1 summarizes the parameters obtained for the three species studied, and Figure 4 shows the length distributions for different mesh sizes and species.

The Hotelling's T^2 -test was applied to pairs of curves of the same species corresponding to different mesh sizes. The results of the test as well as the values limiting the rejection area for $\alpha=0.01$ are presented in Table 2.

The 50% retention lengths for mesh sizes 25, 35, 40, and 50 mm and for the species *S. solida* are 13.9, 16.6, 20.5, and 23.3 mm, respectively. All these values are below the 25 mm MLL for this species. However, the selection range for the 40 and 50 meshes includes the

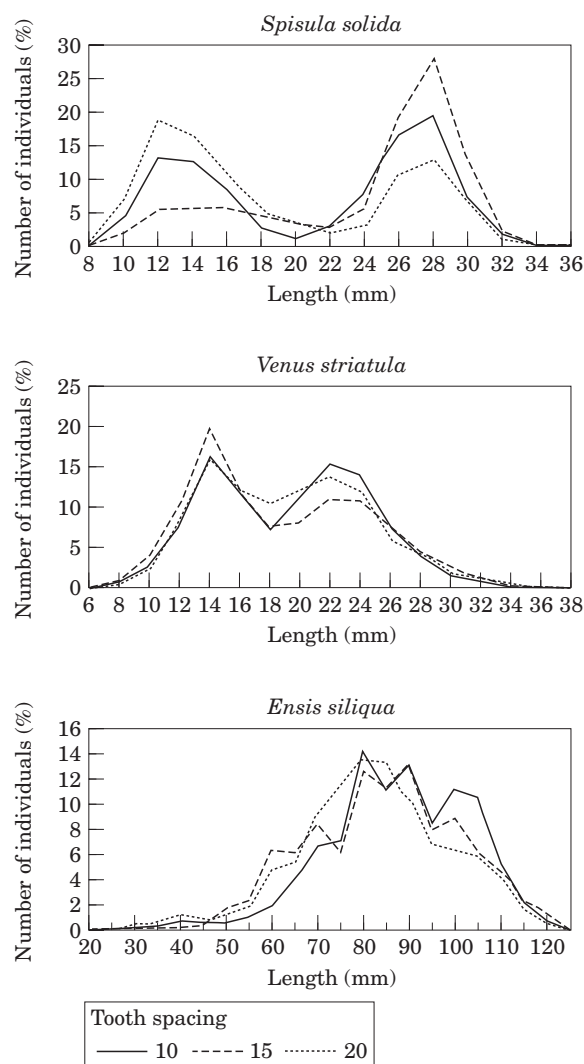


Figure 2. Length frequency distributions by tooth spacing obtained for all experiments and for the three species studied.

MLL. For the 35 mm mesh, the MLL was very close to $L_{75\%}$. The selection range for this mesh is very wide, which leads to the capture of a high proportion of undersized individuals. The 50% retention lengths for *V. striatula* were 14.0, 18.8, 18.0, and 21.4 mm, for mesh sizes 25, 35, 40, and 50, respectively. Only the selection range estimated for mesh size 50 includes the MLL for this species, which is also 25 mm.

The 50% retention lengths for *E. siliqua* were 39.3, 57.2, 61.9, and 65.4 mm, for mesh sizes 25, 35, 40, and 50 mm, respectively. All these values are considerably below the MLL for this species, which is 100 mm.

Discussion

Management of these species usually combines a minimum legal landing length (MLL) with a minimum mesh

size (MMS). The objective is to aid enforcement by discouraging fishermen from using very small meshes that lead to the rejection of a large proportion of the catch. For the present study, a 50% selection length of approximately 25 mm was the target for the clam dredge because this value is the current minimum landing size for *S. solidus* and *V. striatula*. Similarly, for the razor clam dredge, our target was a 50% selection length of 100 mm, the minimum legal length for *E. siliqua*.

Data from the present study suggests that the estimated $L_{50\%}$ values are markedly below the stipulated MLL for *S. solidus* and *V. striatula*. As both species are caught together, the mesh size recommended will be a compromise between the two species. Figure 5 shows the observed proportion of retention of individuals with lengths below and above the MLL. The effect of mesh sizes on the catches is clear for *S. solidus*; the retained proportion of undersized clams decreasing with the increasing mesh. The same pattern was not seen for *V. striatula*, for example the mesh size of 40 mm caught more undersized clams than the 35 mm mesh size. This can be explained because, at the larger mesh size the bag became blocked by *S. solidus* decreasing the escapement of *V. striatula*. The present experiments suggest that the 40 mm mesh size would be a reasonable compromise. This mesh size retains a high proportion of adult individuals as well as allowing the escapement of a high percentage of undersized clams.

One aspect of the selectivity parameters estimated is the wide selection range for all species studied. This may be related with the way the gear is operated, as observed by divers during the experimental phase of this work. While the dredge is being towed, there is very little escapement from the bag into the cover, because the mesh closes as it is stretched. It is when the dredge is hauled vertically and washed that most of the escapement through the bag occurs. In such a situation the escapement affects individuals of a wide length range, in particular for the species *E. siliqua*, the razor clam. For this species, the selectivity parameters are largely the result of the morphology of the shell. In fact, adult razor clams rapidly block the meshes and make selection ineffective. Therefore a larger number of undersized individuals are caught. As a consequence, the values of both $L_{50\%}$ and selection range are the largest of the three species. The mesh to be adopted for the *Ensis* fishery should be different from that used for the other two clams. A 40 mm mesh and its corresponding $L_{50\%}$ of 61.9 mm is markedly below the stipulated MLL for the species. Assuming the selection factor is more or less constant for a given gear and species, and is approximately equal to the ratio $L_{50\%}/\text{mesh_size}$, the indicated mesh, chosen to obtain a $L_{50\%}$ close to 100 mm, would be 66 mm. If experimental observations confirm this hypothesis, the adoption of a different pattern of exploitation would be justified also because this species does

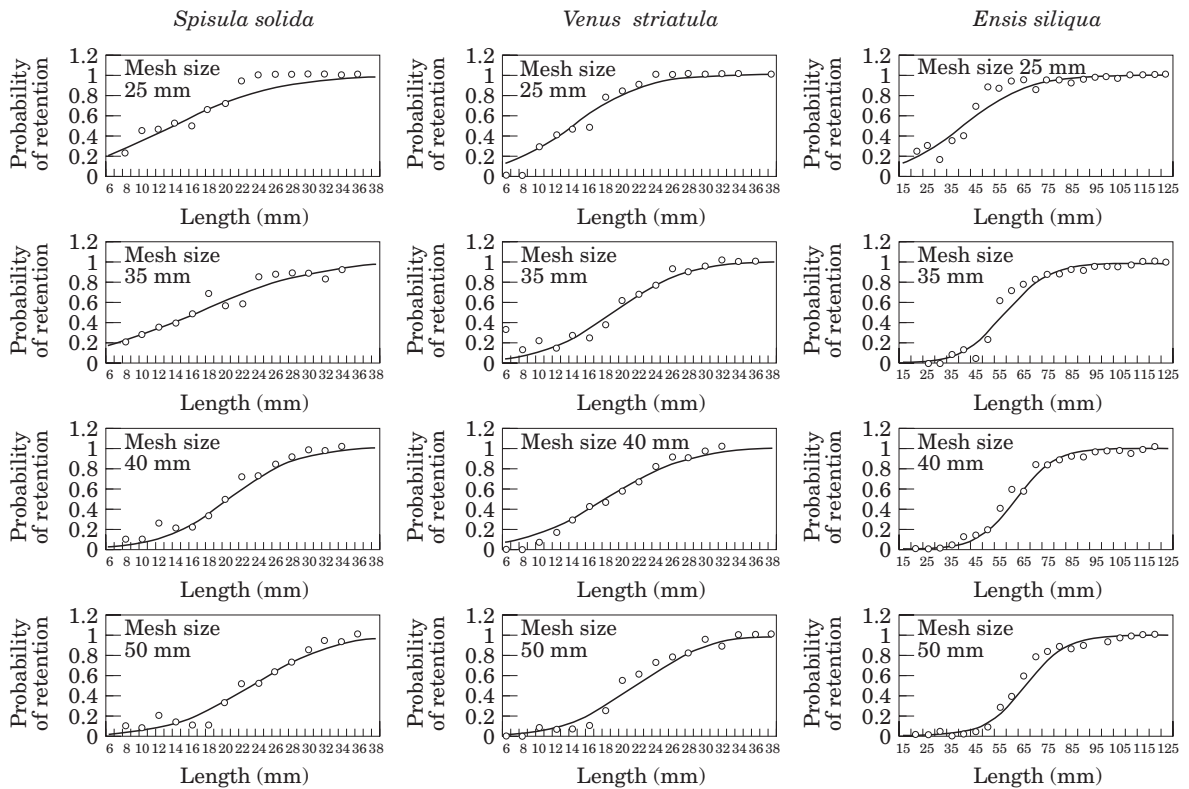


Figure 3. Selectivity curves estimated for *Spisula solidida*, *Venus striatula*, and *Ensis siliqua*. The vertical line represents the minimum legal landing length (MLL) of this species. The horizontal line represents $L_{50\%}$.

Table 1. Selectivity parameters for the three species studies where: a and b are the parameters of the logistic curve, r is the coefficient of determination, $L_{50\%}$, $L_{75\%}$, and $L_{25\%}$ are the lengths at which 50%, 75%, and 25% of the individuals are retained, SR is the selection range ($L_{75\%} - L_{25\%}$), and SF is the selection factor ($L_{50\%}/\text{mesh_size}$).

Mesh	a	b	r	$L_{25\%}$	$L_{50\%}$	$L_{75\%}$	SR	SF
<i>Spisula solidida</i>								
25 mm	-2.215	0.156	0.941	7.0	13.9	20.7	13.7	0.6
35 mm	-2.351	0.142	0.956	8.8	16.6	24.3	15.5	0.5
40 mm	-5.003	0.244	0.948	16.0	20.5	25.0	9.0	0.5
50 mm	-4.771	0.205	0.978	17.9	23.3	28.7	10.7	0.5
<i>Venus striatula</i>								
25 mm	-3.275	0.234	0.869	9.3	14.0	18.7	9.4	0.6
35 mm	-4.285	0.228	0.964	14.0	18.8	23.6	9.3	0.5
40 mm	-3.641	0.202	0.988	12.6	18.0	23.5	10.9	0.5
50 mm	-4.908	0.229	0.987	16.6	21.4	26.2	9.6	0.4
<i>Ensis siliqua</i>								
25 mm	-2.289	0.074	0.962	24.3	39.3	54.2	29.9	1.6
35 mm	-6.144	0.107	0.987	47.0	57.2	67.5	20.5	1.6
40 mm	-7.780	0.126	0.991	53.2	61.9	70.6	17.5	1.6
50 mm	-7.780	0.119	0.996	56.1	65.4	74.5	18.5	1.3

not coexist with the other two species which were studied.

Several factors have been known to affect dredge selectivity. These factors include the nature of the

bottom, the duration of the tow and the design of the dredge. Drinkwater (1974) stressed the importance of the nature of the bottom in the scallop fishery. This author reported that the dredge is likely to bounce in

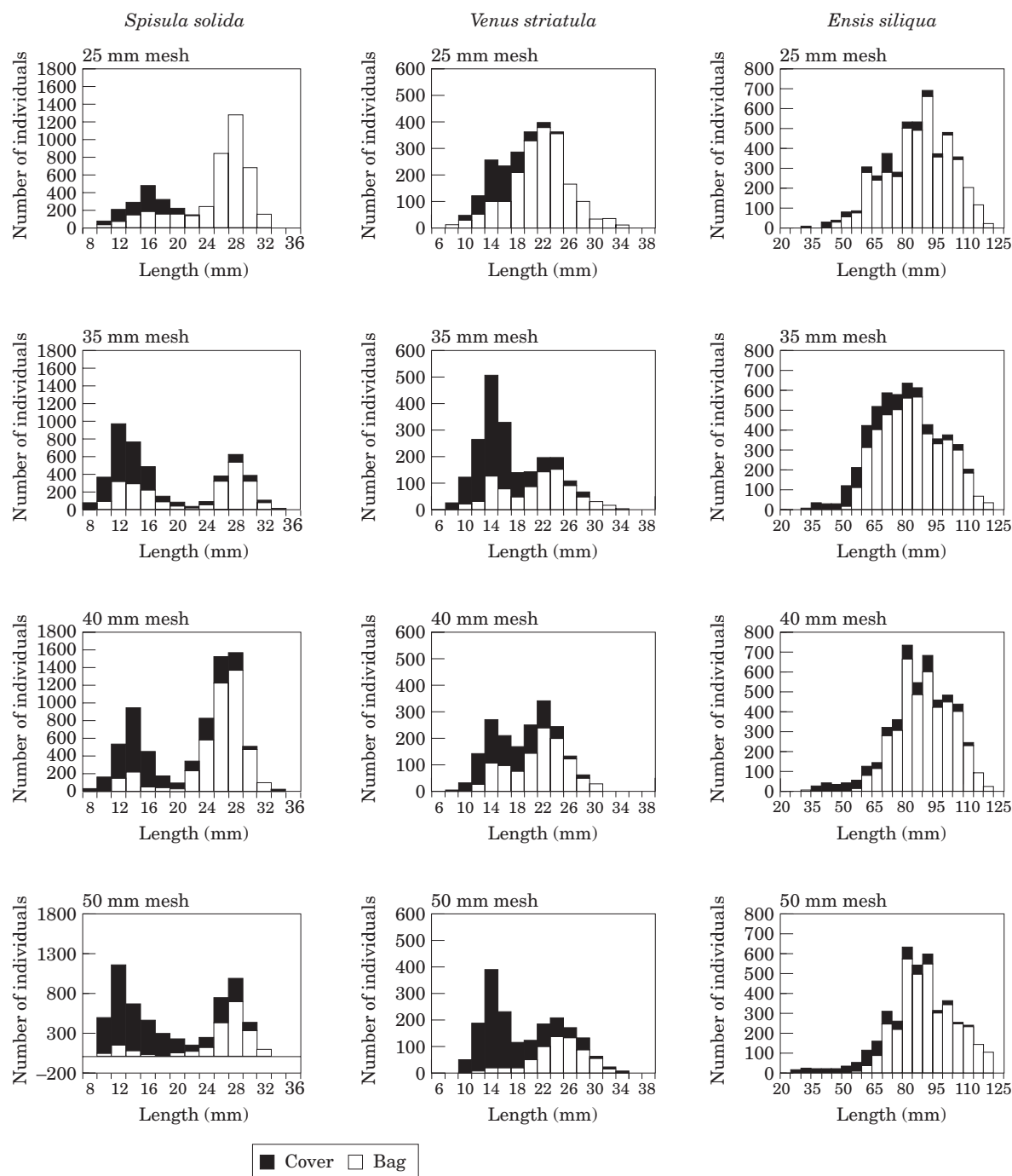


Figure 4. Length frequency distributions by mesh size obtained for all experiments and for the three species studied.

some places and fill with mud and stones in others. Thus selectivity will depend partially on the nature of the bottom deposits scraped up by the dredge. In the Portuguese dredge fishery, the nature of the bottom does not constitute a problem, since the exploited species only

forms extensive and dense beds on very clean sandy bottoms (Gaspar, 1996).

The second factor affecting selectivity reported by Drinkwater (1974), was the duration of the tow, which was not studied in the present work. However, the

Table 2. Results of the Hotelling's T^2 -test, where T^0 is the modified F-statistic value limiting the rejection area for $\alpha=0.01$. The null hypothesis $H_0: P_1=P_2$ (vs. $H_a: P_1 \neq P_2$) is rejected when $T^2 > T^0$.

	Mesh	35 mm	40 mm	50 mm
<i>Spisula solida</i>	25 mm	$T^2=211.29$ $T_0=10.12$ H_0 Rejected	$T^2=718.52$ $T_0=10.23$ H_0 Rejected	$T^2=1618.96$ $T_0=10.12$ H_0 Rejected
	35 mm		$T^2=642.62$ $T_0=9.97$ H_0 Rejected	$T^2=1968.37$ $T_0=9.91$ H_0 Rejected
	40 mm			$T^2=358.74$ $T_0=9.98$ H_0 Rejected
<i>Venus striatula</i>	25 mm	$T^2=701.53$ $T_0=10.32$ H_0 Rejected	$T^2=395.21$ $T_0=10.66$ H_0 Rejected	$T^2=930.07$ $T_0=10.36$ H_0 Rejected
	35 mm		$T^2=51.91$ $T_0=10.27$ H_0 Rejected	$T^2=362.97$ $T_0=10.11$ H_0 Rejected
	40 mm			$T^2=476.01$ $T_0=10.32$ H_0 Rejected
<i>Ensis siliqua</i>	25 mm	$T^2=1873.05$ $T_0=9.95$ H_0 Rejected	$T^2=4405.30$ $T_0=9.94$ H_0 Rejected	$T^2=1980.12$ $T_0=10.00$ H_0 Rejected
	35 mm		$T^2=105.26$ $T_0=9.87$ H_0 Rejected	$T^2=557.40$ $T_0=9.91$ H_0 Rejected
	40 mm			$T^2=1065.23$ $T_0=9.90$ H_0 Rejected

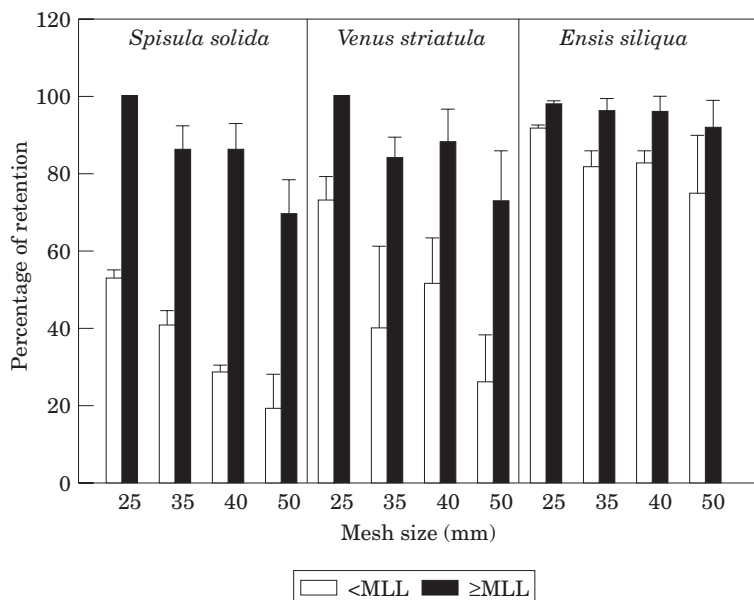


Figure 5. Percentage of retention of the individuals with lengths below and above the minimum legal landing length (MLL) for each mesh size and species. The error bars represent 2 standard deviations.

experiments were designed so that this factor would be constant. The duration of the tows was a constant 3 min. Of the other factors inherent to the dredge itself, tooth

spacing and the mesh size were considered to be potentially the most important. Tooth spacing was analysed first. The present work showed that, with the dredge

design used, the spacing of the teeth was of no importance. The tooth bar must act as a hoe. As a result of this bulldozing effect the Portuguese dredge has a high efficiency of capture (Gaspar, 1996). Although the effect of tooth spacing has been found to be significant in other studies (Baird and Gibson, 1956; Drinkwater, 1974; Nashimoto, 1984; Nashimoto *et al.*, 1983), these authors recognized that the effect of tooth spacing on selectivity was of minor importance when compared to mesh size.

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