Scallop Dredge Selectivity

Contribution of tooth spacing, mesh size and ring size; Part I West of Scotland sea trials

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Seafish Report No. 509 Authors: W. Lart, R. Horton, R. Campbell[1]
Date: October 1997

Executive Summary

Currently most of the dredge fisheries for scallops (both the great or king scallop *Pecten maximus* and the queen scallop *Aequipecten opercularis*) are unregulated by technical measures prescribing design features of the dredge. Concern about the capture of undersized scallops resulted in the Seafish Scallop Working Group recommending that technical measures be introduced in dredges targeting *Pecten* in order to increase size selectivity. The purpose of this study was to assess the extent to which tooth spacing, mesh size and ring size could be used to effect size selection in dredges targeting *Pecten*.

Objectives

The objectives of this study were to:

- Gain an understanding of the use of scallop dredges in selectivity research.

- Describe the effect of the three factors on the relative selectivity and catch per effort of the gear.

    - tooth spacing,
    - mesh size,
    - ring size.

- Describe the shape of the scallops in relation to the size and shape of likely selection features of the gear.

- Investigate the feasibility of studying other physical parameters of the gear and their relationship to catch composition.

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[1] Ross Campbell of Mallaig Marine Environment Resource Services

Experimental Design

Two levels of each of the three factors were investigated in various combinations. The levels were:

Teeth spaced at 67 and 77mm (10 and 9 teeth/76cm dredge respectively)
Mesh sizes of 82 and 102mm
Ring sizes of 63 and 74mm

All eight possible combinations of these levels were used in order to examine the extent and significance of these factors on selectivity and catch per effort. The results were also analysed to establish whether there was any significant interaction between them. That is, whether for example, large ring sizes selected scallops differently when in combination with small tooth spacing or with large tooth spacing.

This experiment was carried out on the dredger *MFV Kelly (BCK 303)* fishing in the Tiree Passage and in the Sound of Arisaig. Six valid hauls were made each day with two days being spent in each location. Mesh size was varied between dredges on the same bar, ring size between bars and teeth spacing between days. This means that there were 24 comparisons for teeth spacing, mesh and ring size and twelve replicates of each combination. The experiment was designed and the data analysed to minimise or eliminate the effect of unwanted variables.

Results

Results are presented as:

- Aggregate length-frequency distributions of scallops (all scallops captured were *Pecten maximus*) for each of the combinations of factors. The results indicate that ring size had an important influence on selectivity.

- Aggregate length-frequency distributions for both levels of the three experimental factors: teeth spacing, mesh and ring size. These results indicate that ring size and possibly tooth spacing had an influence on selectivity.

- Mean discard rates per haul (% scallops by number below the minimum landing size [MLS] of 100mm shell length) to show the influence of each factor. Ring size and tooth spacing had a significant effect on discard rate contributing 11% and 3.5% respectively to discard rate reduction. No significant interaction between these three factors was found. Discard rates are specific to this area because the length-frequency distributions of the populations of scallops vary between areas as does the MLS.

- The mean catches per haul of scallops above the MLS by weight and number. No significant reduction was found in the catch per haul of these scallops in the larger ring size but larger tooth spacing resulted in significant reductions in terms of weight and numbers of around 10%. There was no significant difference between the catch per effort of the large and small mesh sizes. As above, no significant interaction was detected.

- A discussion of the relationship between the shape and size of scallops shells, especially for individuals around the MLS, in relation to the size of the apertures in the rings and the spaces between the teeth. These results suggest that there may be scope for further increases in ring size and still enable the retention of 100mm scallops. However, more investigations are needed to fully describe the interrelationship between the shape of the scallops and selectivity and to take into account wear on the gear.

- An analysis of the warp tension data which showed a significant increase over the course of each haul. This was combined with information on the catch composition because scallops only constituted 11% by volume of the total catch. It revealed the extent to which stones and other benthic material build up in the dredge causing increasing drag. This suggests that there may be environmental and energy saving benefits which could be obtained from construction of a dredge designed to catch a reduced proportion of stones.

Conclusions

- The study has shown that it is possible to use scallop dredges to compare relative selectivity. Care has to be taken to examine the data for sources of unwanted variation.

- In the locations, and with these combinations of tooth spacing, ring and mesh sizes; ring size followed by tooth spacing contributed most to selectivity in terms of reducing the percentage of discards. Mesh size did not appear to contribute to selectivity at the mesh sizes used.

- There was a significant reduction in catch per effort of scallops larger than 100mm (the MLS) attributed to the larger tooth spacing. Increasing the ring size did not significantly reduce catch per effort of this size range.

- It is suggested that there may be scope for reducing the energy input into the seabed by finding means for reducing the quantity of stones taken. This could also have environmental and energy saving benefits.

Acknowledgments

The Seafish Scallop Working Group conceived the need for this investigation and provided the initial parameters. Thanks are due to the Chairman Dick James and the members of this group.

The authors would especially like to thank the Skipper of *MFV Kelly* John MacAlister. His contribution was substantial in helping to design the experiment and ensuring that it was accurately executed. The crew, Alec, Davy, Charlie and Willy also deserve thanks for their careful deckwork which ensured that the catch from each dredge was correctly assigned.

Allan Reese of Hull University and Chris Tucker of Seafish Hull provided help with experimental design. Trevor Howell of SOEAFD Marine Laboratory Aberdeen provided background information. Alan Dean of Seafish Hull invented and constructed the tooth bar spring tension measuring device.

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1. Introduction

Currently most of the UK dredge fisheries for scallops (both the king, or great scallop *Pecten maximus* and the queen scallop *Aequipecten opercularis*) are not regulated by technical measures prescribing aspects of gear design. The minimum landing size (MLS) for *Pecten maximus* is 110mm shell length in the Irish sea and 100mm shell length elsewhere in UK waters, but there is no MLS for queen scallop.

The Seafish Scallop Working Group has recommended the introduction of technical measures in dredges targeting *Pecten* because of the need to avoid unnecessary capture of sub-legal scallops. In order to establish a rational basis for these measures there is a need to describe the factors affecting the selectivity of scallop dredges and to understand how selection occurs.

Whilst many features of the design and operation of scallop dredges may affect their selectivity, there is a need to focus on those aspects which could be regulated by technical measures. There is also a need to assess the effect of these measures on catch composition and catch per effort. Three features which are possible to define and control by technical regulations are:

- the spacing between the teeth,
- the size of the mesh on the back of the dredge, and
- the size of the chain mail rings on the back and belly of the dredge.

Previous work (Drinkwater 1974) investigated the selectivity of dredges in relation to tooth spacing, mesh and ring size. However, this work was oriented towards the use of dredges as a survey tool for small scallops. There was no intention to use it as basis for the study of technical measures and the type of dredge used is now obsolete.

The purpose of this work was to investigate the use of dredges in selectivity studies and to gain an understanding of the effects of the above features on dredge selectivity and catch per effort. The study also investigated the feasibility of studying other physical parameters of the gear; warp tension, speed over the ground and through the water, and their relationship to catch composition. Analysis of the results of these parameters could be useful in guiding further work on the physical environmental effects of scallop dredging. It may be possible to design means for reducing the environmental effects of scallop dredging and increasing energy efficiency.

This work was carried out in Scottish waters using gear in use in this fishery; the intention is that similar studies should be carried out in other fisheries in UK waters using appropriate gear.

2. Objectives

The objectives of this study were to:

- Gain an understanding of the use of scallop dredges in selectivity research.

- Describe the effect of the three factors on the relative selectivity and catch per effort of the gear:

    - tooth spacing,
    - mesh size,
    - ring size.

- Describe the shape of the scallops in relation to the size and shape of likely selection features of the gear.

- Investigate the feasibility of studying other physical parameters of the gear and their relationship to catch composition.

Table 1
Gear Specification Details

Component	Specification	Measured dimension: *mean mesh size or **ring internal diameter in mm ± ***standard deviation
Dredge bars	6.7m with 6 x 76cm dredges attached (normal arrangement is 8 x 76cm dredges (see Fig 5).	
Dredge frames	Standard 76cm	
Tooth bar	705mm hardened bar	
Teeth	Both large and small spacing used hardened French teeth. Teeth were 150mm x 10mm x 20mm (Figs 35 & 36).	
Tooth spacing	Large: 9 teeth/bar, between centres 87mm, between teeth 77mm. Small: 10 teeth/bar, between centres 77mm, between teeth 67mm.	
Mesh	Both large and small meshes were 6mm 'Blue Steel' cod end material rigged with 2 mesh in selvedges on either side. Large: 102mm (internal) rigged 11 mesh down, 14 mesh across. Small: 82mm (internal) rigged 13 mesh down, 15.5 mesh across.	101.1 ± 1.4 81.7 ± 2.6
Bellies	Large: 11 rings long Small: 13 rings long	
Belly rings	Large: nominal internal diameter = 74mm, bar thickness=10mm Small: nominal internal diameter = 60mm, bar thickness = 10mm.	73.1 ± 2.2 62.8 ± 1.7
Belly washers	Both large and small: external diameter=45mm, internal diameter=22mm, thickness=9mm	
Backs	Large: 6 rings long - nominal internal diameter = 74mm bar thickness = 8mm. Small: 7 rings long - nominal internal diameter = 60mm bar thickness = 8mm	74.2 ±1.0 62.9 ± 1.5
Back washers	Both large and small: external diameter=38mm, internal diameter=18mm, thickness=7mm	

Measurements taken before study:

* Mean mesh sizes were estimated from sample of 24 of each mesh size measured with an ICES gauge.

** Mean internal diameters of the rings were estimated from a sample of rings of each type measured with callipers.

*** Standard deviation is a measure of the spread of values about the mean.

3. Materials and Apparatus

3.1 Tooth spacing, mesh size and ring size

For this investigation it was decided that two levels (small and large) of the three factors: tooth spacing, mesh size and ring size should be investigated.

The two ring sizes commonly used in this fishery are nominally 60 and 75mm internal diameters. On investigation, the mean internal diameters of these rings were found to be 63 and 74mm for small and large rings respectively. In order to weight the selectivity of the three components equally it was decided to keep the ratios between the small and large components as close as possible within the constraints of available materials.

The ratio between the large and small rings' internal diameters was 0.85. The larger mesh and tooth spacings normally used in the fishery were 100mm and 77mm (9 teeth/bar) respectively. The ratio of large to small tooth spacing and mesh sizes were as shown in Table 2. These are not exactly ratios of 0.85 small/large. For the teeth, this was due to the requirement to ensure that there were no gaps at the end of the tooth bar which would have resulted in changing the effective length of the bar containing teeth. The mesh size was constrained by the sizes available in the hard wearing Blue steel™ mesh; 82 and 102mm mesh were available.

Table 2
Ratio of small to large for tooth spacing mesh and ring size

Component	Measurement (mm)	Large	Small	Ratio Small/Large
Tooth spacing	Between teeth	77	67	0.87
Mesh	Mesh size	101	82	0.81
Ring back and bellies combined	Internal diameter	74	63	0.85

Other gear dimensions - teeth size, twine diameter, ring thickness, and washer sizes - were kept constant between the two sizes. This avoided changing two variables at the same time. However, it did result in the small size not being an exact proportion of the large one in all aspects. This may have implications for selectivity and this aspect is covered in the section.

3.2 Gear specification

The dredges used in this work were spring loaded dredges constructed by Oban Scallop Gear Ltd. Detailed dimensions are described in Table 1.

3.3 Vessel specification

The vessel used for this study was *MFV Kelly*. She is described in Table 3 (overleaf).

Table 3
Vessel Details

Vessel name:	KELLY
Registration number:	BCK 303
Built:	1982 Mackenzie
L.O.A.:	18.1 metres
Registered length:	16.28 metres
Gross tonnage:	40.4
Engine:	Kelvin 535 b.h.p.
Gearbox reduction:	4.5 : 1
ELECTRONICS	
Echo-sounders:	2 Furuno colour video 886 1 Koden CVS 8811
Plotter:	Decca CVP 3500
G.P.S. Navigator:	Furuno GP70 Mk.11
Radar:	Koden MDC410AT Koden MD300
Radio:	Sailor

4. Data Acquisition Systems

4.1 Vessel/surface data

A number of parameters were recorded synchronously on the Delta-T data-logger. The acquisition scheme is shown in Figure 1 (p9). At the end of each tow the following data were downloaded onto a PC spreadsheet for later analysis:

i. *Port and starboard towing loads:* using strain-gauged loadcells connected in-line with the main towing wires (warps). These load cells were calibrated before and after the sea trip and found to be consistent.

ii. *Vessel speed through the water:* using an impellor type log deployed via a telescopic towing boom off the starboard side of the vessel. Care was taken to ensure that the impellor was not influenced by the vessel wake or other ship's noise.

iii. *Vessel speed over the ground*: this parameter was logged autonomously by the GPS. Positions were logged every 30 seconds and at the end of each tow the total data was downloaded onto the PC. It was then analysed in a specifically designed spreadsheet which computed speed over the ground and total distance traversed over each towing period.

iv. The following parameters were recorded manually for each haul and the data are shown in Table 6 (p23):

- Location
- Time shot/hauled
- Wind and sea state
- Warp length and depth recorded at the start of each tow

4.2 Tooth bar spring tension

The tooth bar spring tension was estimated using an adapted torque wrench as shown in Figures 2 and 3 (p10). Tensions were measured with the dredges hung freely below the dredge bar, above the rail of the vessel whilst in port. Torque was applied as in Figure 2 until the tooth bar just began to move relative to the frame. There is a small component of torque due to movement of the dredge itself. Thus, these measurements are not directly comparable with those taken with the dredge in a fixed position. However it was possible to reproduce the results and the technique corresponded to the Skipper's method of adjustment.

4.3 Scallop length

Scallop lengths were measured to the nearest 5mm below using the apparatus described in Figure 4 (p11). The results were recorded initially on the white plastic plate attached to the slider arm of this apparatus and then onto paper records for entry into spreadsheets.

In order to describe the relationship between scallop length, width and height, a sub-sample of scallops was measured in these three dimensions - see Figure 4 for definitions. A further sub-sample of these was also weighed; numbers of scallops and the length and weight ranges of these samples are shown in Table 4.

Table 4
Numbers of scallops measured to compare length-weight and length-width-height relationships

Parameters	Number of scallops	Length range (mm)		Weight range (g)	
		Max	Min	Max	Min
Length-width-height	184	140	69	-	-
Length-weight	100	140	69	34	251

4.4 Weight
Owing to the difficulties involved in weighing accurately small quantities of scallops at sea, it was decided to weigh only the aggregate catch of landed and discarded scallops from the dredges on each bar for each haul. This was carried out using a spring balance. These data were used to check the results obtained from the length-weight relationship.

4.5 Bulk
The total bulk of the catch from each dredge, including scallops, stones and benthos was estimated by eye after it had been placed in the 50 litre fish boxes.

Figure 1: Vessel/surface data aquisition block diagram

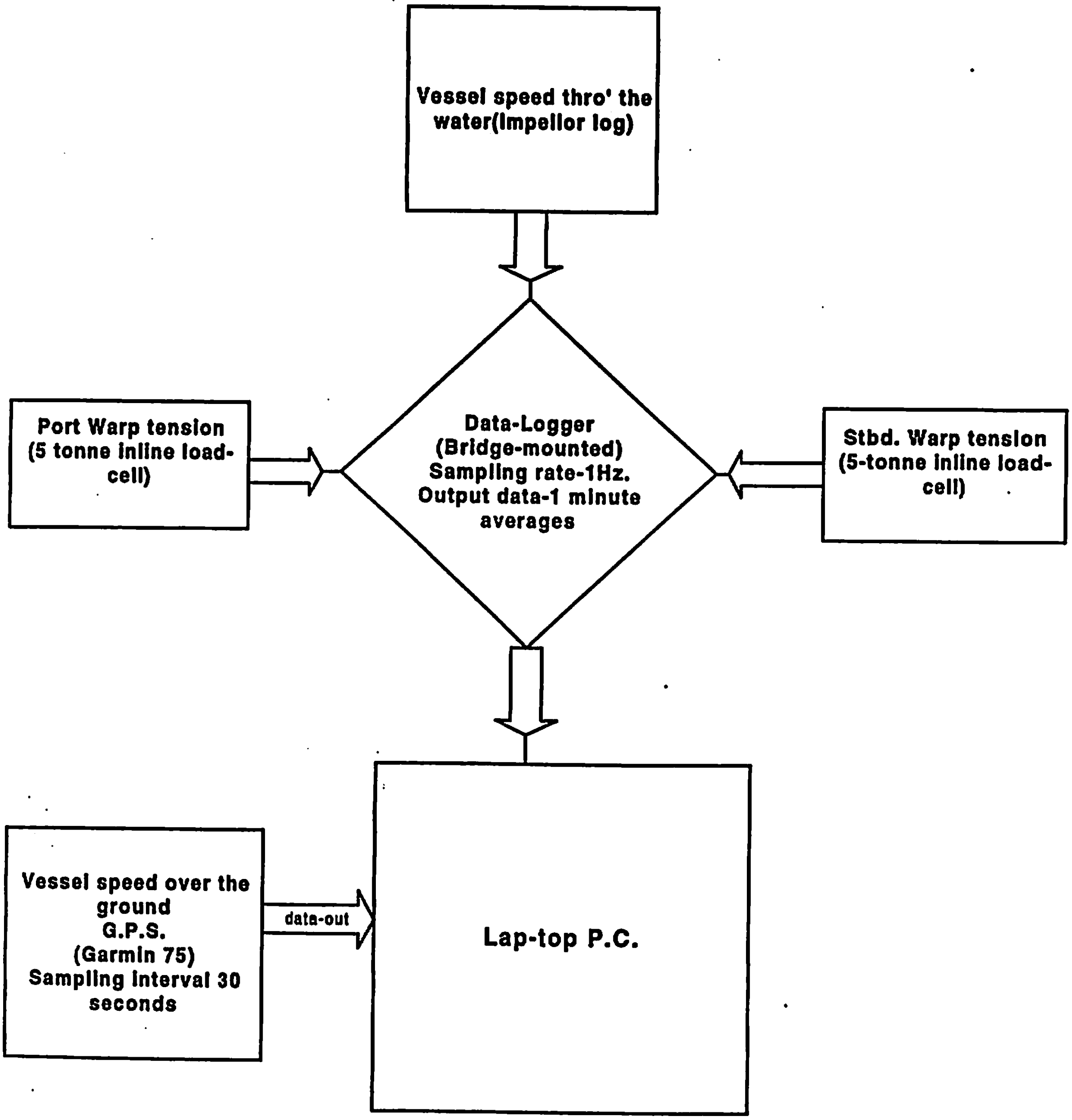


Figure 2: Adapted torque wrench

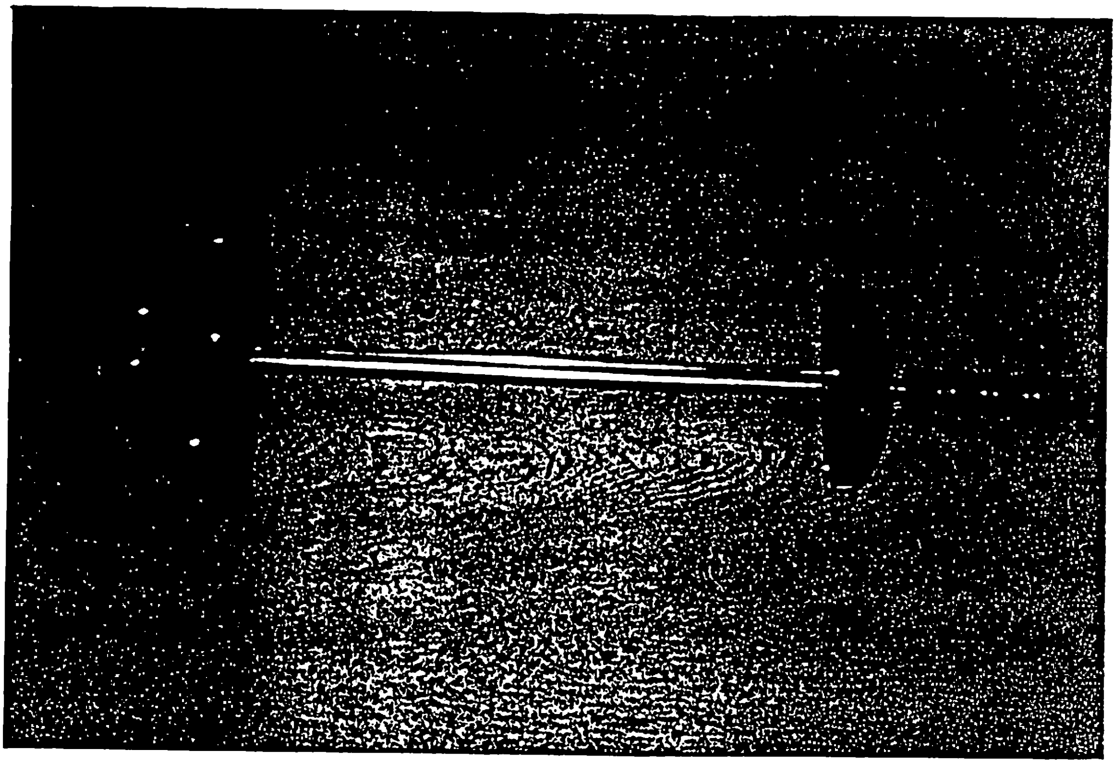


Figure 3: Adapted torque wrench in operation

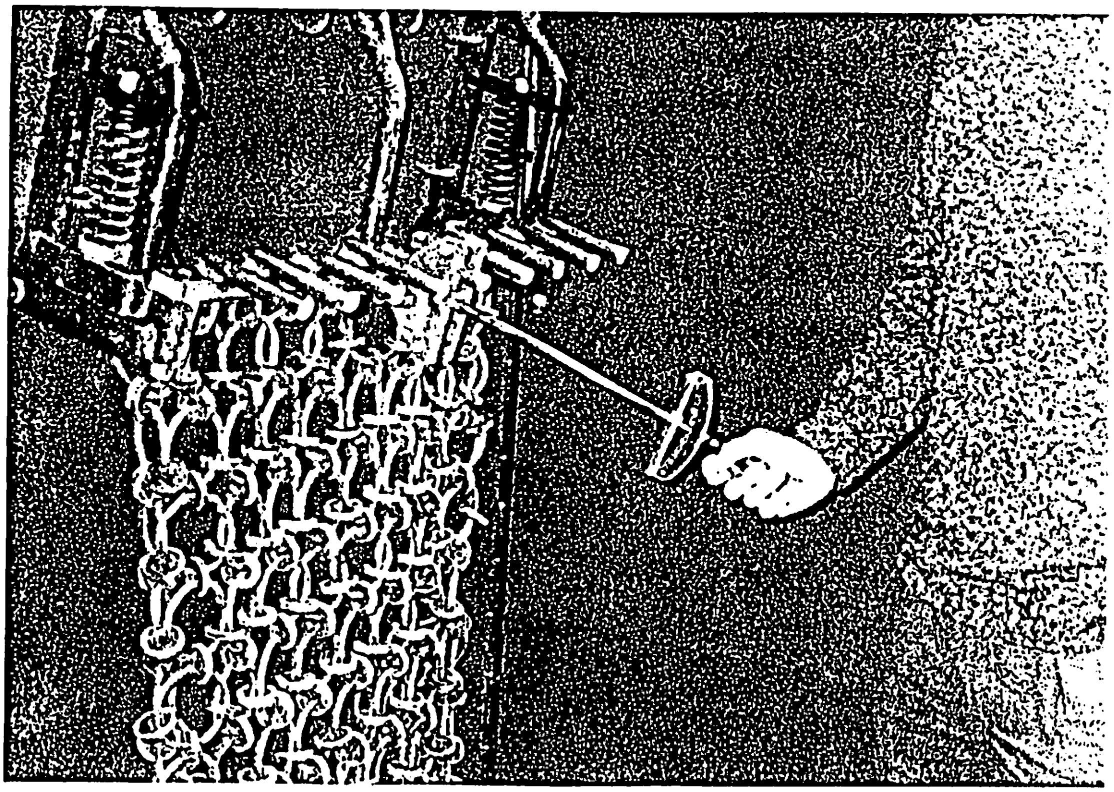


Figure 4: Scallop measuring device and dimensions

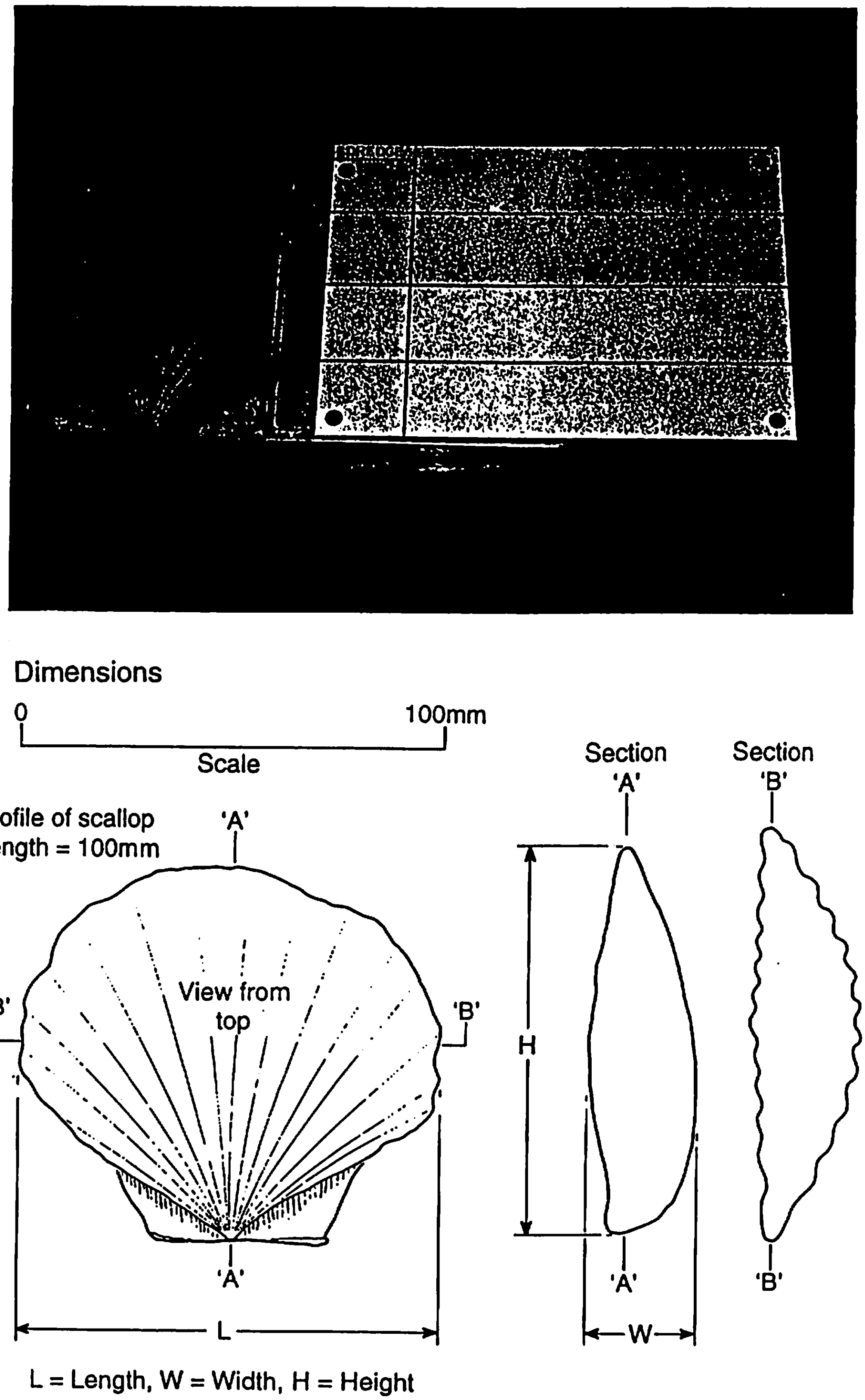


Table 5
Combinations of tooth spacing, mesh size and ring size used in the study

Tooth spacing	Mesh size	Ring size
L	L	L
L	L	S
L	S	L
L	S	S
S	L	L
S	L	S
S	S	L
S	S	S

L = Large

S = Small

5. Method

5.1 Experimental design

In designing the sea trials a number of considerations had to be taken into account. Most were necessary because this type of experiment had not been undertaken before. This meant that the influence of unwanted variables had to be identified and minimised. Achieving this would make it possible to attribute catch variations with confidence to the dredge variants being studied. The major sources of unwanted variation were considered to be:

- the way in which the scallop population is naturally distributed on the seabed and therefore available to the gear, and

- the conditions under which each dredge configuration is deployed; its position on the bar, whether the bar was the lead bar or the lag bar; the side (port/starboard) that it is worked and the fishing area which it is worked in.

Both of these were accommodated in the experimental design and in the way in which the data were analysed. The measures taken were as follows:

- Control dredges were used which exerted constant fishing effort. This gave a reference against which the experimental dredges' catches could be compared regardless of the number of scallops on the ground.

- Care was taken to ensure that the same number of hauls were made with each dredge configuration in each set of conditions; for analytical purposes these conditions are termed 'block structures'.

- The data was analysed by a statistical package called Genstat™ (Version 5.3.2). This package was used to incorporate information from the controls as 'covariates' and minimise variation between block structures. This improves the detection of significance in the factors being investigated.

5.2 Gear configurations

There was a total of eight possible combinations the tooth spacing, mesh and ring size to be compared (Table 5). Comparing all of these within one experiment enabled observations to be made of the main effects due to tooth spacing, mesh or ring size and any effects due to interactions between these factors. If, for example, there were differences in the way in which the small rings selected scallops dependent upon whether they were on dredges with large teeth spacings as compared with small ones, then interaction between these two factors would have taken place.

In planning this experiment the objective was to obtain catches of scallops from equal quantities of fishing effort for all of the combinations described in Table 5. A number of constraints emerged:

1 Adjacent dredges on the same bars may interact; there was a risk that scallops pushed forward or selected out by a dredge may be captured by its neighbour. Thus, it was considered necessary to avoid placing dredges with different experimental combinations together. However dredges are not normally used as singletons so it was decided that the experimental dredges should be deployed in pairs of replicates.

2 There was a risk of physically unbalancing the dredge bar if variants in tooth spacing or ring size were used on the same bar. These parameters were considered likely to affect the catch of stones; large variations in the quantity of stones in dredges in different positions on the bar may risk unbalancing the bar. This would be expected to be particularly so if they were on the ends of the bar.

3 The dredges were fished from two bars with a capacity of eight dredges and towed from booms on the quarters of the vessel (Figure 5). The dimensions were such that the paths of the two dredge bars could potentially overlap by approximately one metre with the vessel towing in a straight line. The warps were always of different lengths with the lead dredge bar's warp always 9m (5 fathoms) shorter than the lag dredge bar. The extent of the overlap could be expected to change during the vessel's manoeuvres; sharp turns were always executed towards the lag dredge to avoid entanglements.

The implications of these arrangements were that the population of scallops available to the dredges on the lag bar, particularly its inboard end, could be affected by the passage of the lead bar catching scallops or disturbing them on the seabed before the arrival of the lag bar. Also, the angle of incidence of the two dredges could be different due to the different warp to depth ratios.

4 There may be some inherent variation in the selectivity or catch per effort between individual dredges, or dredges in different positions on the same bar, or between the two bars. This may arise from a number of sources such as mechanical factors or the distance over the ground travelled as the vessel turns; dredges on the outside of the turn are likely to travel further than those on the inside.

The experimental design accommodated these constraints in the ways described in the following Sections 5.3 to 5.10.

5.3 Dredge deployment

The dredges were deployed on each bar in three groups of two (each pair chained together in the normal way) leaving the 3rd and 6th positions on the bars vacant (Figure 5). The outboard and inboard dredges were the experimental dredges, and middle two dredges on each bar were the control dredges.

5.4 Experimental dredges

The duration of the experimental fishing was 4 days. The dredges were deployed on the bars as shown in Figures 6 to 9 (pp18-21). In order to avoid mixing tooth spacing and ring size on the same bar (apart from the control, see below) the ring size was varied between port and starboard dredges and the tooth spacing was varied by day. The mesh size was varied between the outboard and inboard ends of the bars. During the first two days, the large rings were to starboard and the small rings to port (Figures 6 and 7).

Figure 5

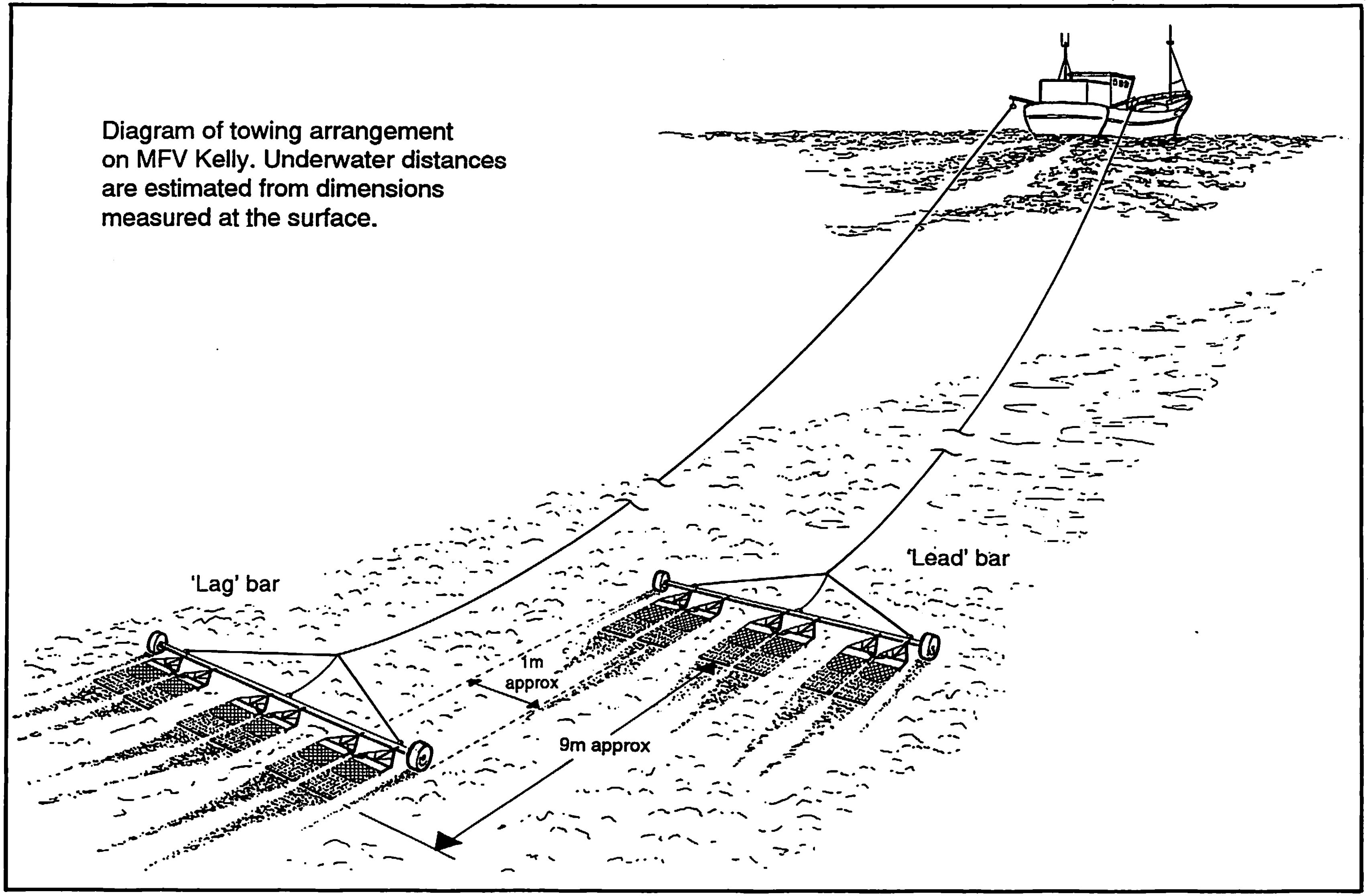


Diagram of towing arrangement on MFV Kelly. Underwater distances are estimated from dimensions measured at the surface.

The tooth spacing on all experimental dredges was small on the first day and changed to large on the second but otherwise remained the same. At the end of the second day the experimental dredges were rearranged (Figures 8 and 9, pp20 and 21) so that those which had been inboard on the port dredge were placed outboard on the starboard dredge and *vice versa*. The tooth spacing on all experimental dredges was small for day 3 and large for day 4.

5.5 Control dredges
The function of these dredges was to provide a consistent index of the catch available to the most and least selective dredges on both bars. The middle two dredges on each bar were the control dredges. These consisted of dredge configurations which were anticipated to be the most and least size selective:

- large tooth spacing, large mesh size and large ring size,
- small teeth spacing, small mesh size and small ring size.

Each pair of control dredges consisted of one each of these dredges set side by side as shown in Figures 6 to 9. Although this means that there is a possibility that the two dredges in the pair may influence each other, the intention was, for most analyses, to combine the results of these control dredges. Apart from adjustments of the springs (Section 4) and necessary repairs, these control dredges were not altered through the entire experiment.

5.6 Day and haul routine
The daily routine consisted of six 50 minute hauls per day. Fishing commenced approximately 1 hour later each day so as to keep tidal conditions as constant as possible. The number of times the two bars lead per location was equal. As far as was feasible the two hauls of each pair of hauls were in the same location but they did not cover the same track. The vessel would normally make sharp turns towards the lagging dredge to avoid entanglements.

At the end of each day, the tooth bar spring tension on each dredge was readjusted to 7.5kgfm using the apparatus described in Section 4. The changes in spring tension were such that adjustments only up to 1-1.5kgfm were necessary.

5.7 Locations fished
The first two days' fishing were in the Tiree passage (Figure 10, p22). Preliminary analysis of these data showed the proportion of small scallops to be low and the catches were relatively low in numbers. It was therefore decided to move location to the Sound of Arisaig for the second two days of the experiment.

5.8 Catch monitoring
The contents of each dredge were carefully tipped into 50 litre plastic fish boxes and the bulk volume including stones assessed by eye. The scallops from each dredge were placed in pre-labled plastic fish baskets and the shell length measured using the apparatus described in Section 4. All scallops captured were measured; there was no requirement to sub-sample. All scallops captured were king scallops *(Pecten maximus)* there were no queen scallops *(Aequipecten opercularis)*. A note was kept of any fish caught which consisted of only a few topknots *(Zeugopterus punctatus)*.

5.9 Haul parameters
Table 6 (p23) shows the haul parameters for all the valid hauls of the experiment. Note that due to weather constraints the final day's fishing was carried out over a period of two days instead of one. The timing and locations of the hauls were designed to be as close as possible a match to those on day three.

5.10 Block structures
Over the course of the experiment there was equal effort expended by all combinations of the experimental dredges in each of the following:

- Locations - Tiree Passage and the Sound of Arisaig.
- Inboard and outboard positions on the bars.
- Port and starboard bars.

Potentially therefore, any of these factors could be used as block structures. Some of them could not be used in combination with others. For example although each of the combinations of experimental dredges was fished on the port and starboard bars they were not fished on the inboard and outboard end of each (port and starboard) bar.

5.11 Tests for significance
Tests for significance were carried of out as described in the results. The following types of analysis were used:

1. ***Pearson's Chi-Squared.*** This test calculates an expected value based on the observations and examines the probability of differences between two observations occurring by chance. In these results it is used to compare length-frequency distributions; the overall chi-squared is the sum of each of the individual chi-squareds for all the 5mm length groups.

2. ***Generalised Linear Modelling (GLM) and Analysis of Variance (ANOVA).*** These methods describe the variation due to the main effects which is compared for significance with the overall variation in the results. This enables a hierachy of the factors examined in terms of their level of significance to be established by the use of GLM. Analysis of Variance, as available on Genstat™, also enables the incorporation into the analyses of the variation due to block structures and covariates which improves the abilty to detect significance with increased confidence. Both these analyses allow investigation of potential interactions between factors. If two factors acting together have a different effect from the factors acting singly then interaction can be said to have taken place.

The quoted level of significance is given as the probability of a result being due to chance; if a result is not due to chance then it is due to the experimental factor being investigated. For example P=0.05 indicates that there is a 1 in 20 probability of this result being due to chance. Probability levels less than this figure (e.g. P=0.01) indicate a lower probability of obtaining the result by chance that is, the results are more significant. Higher levels of probability (e.g. p=0.09) indicate less significant results. P=0.05 is usually considered the threshold for significance in work of this kind.

Figure 6: Dredge configurations - days 1 and 2

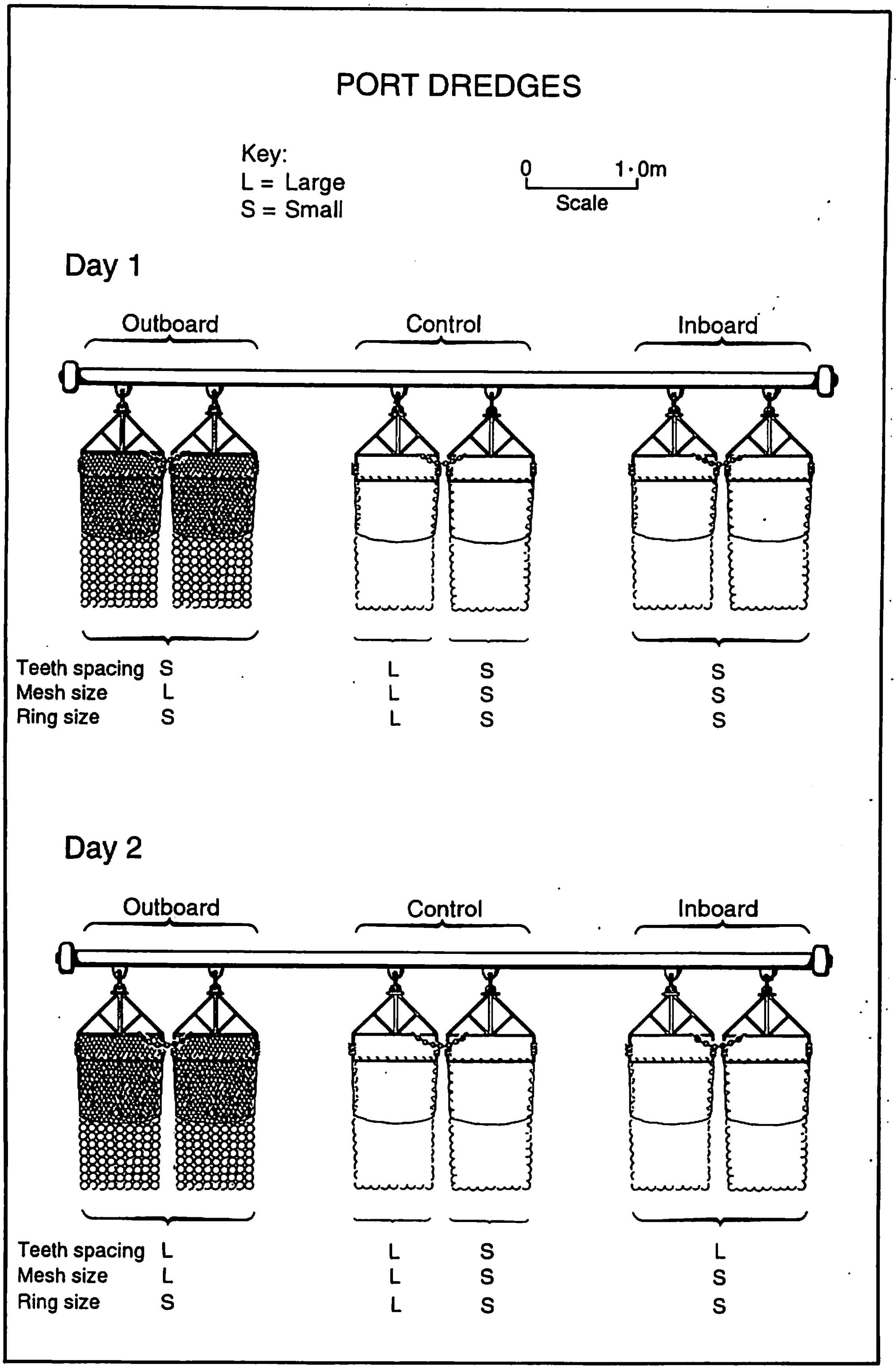


Figure 7: Dredge configurations - days 1 and 2

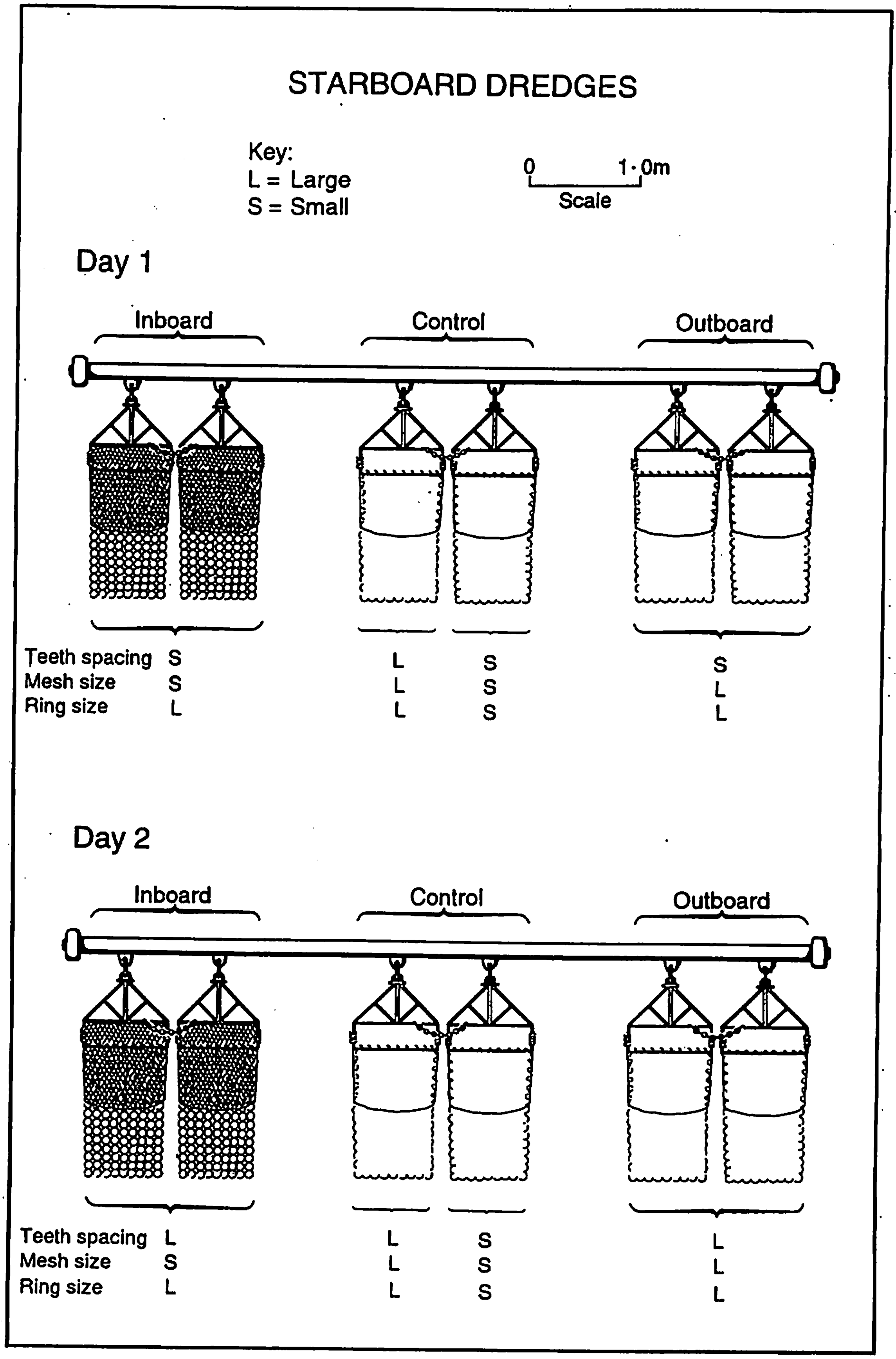


Figure 8: Dredge configurations - days 3 and 4

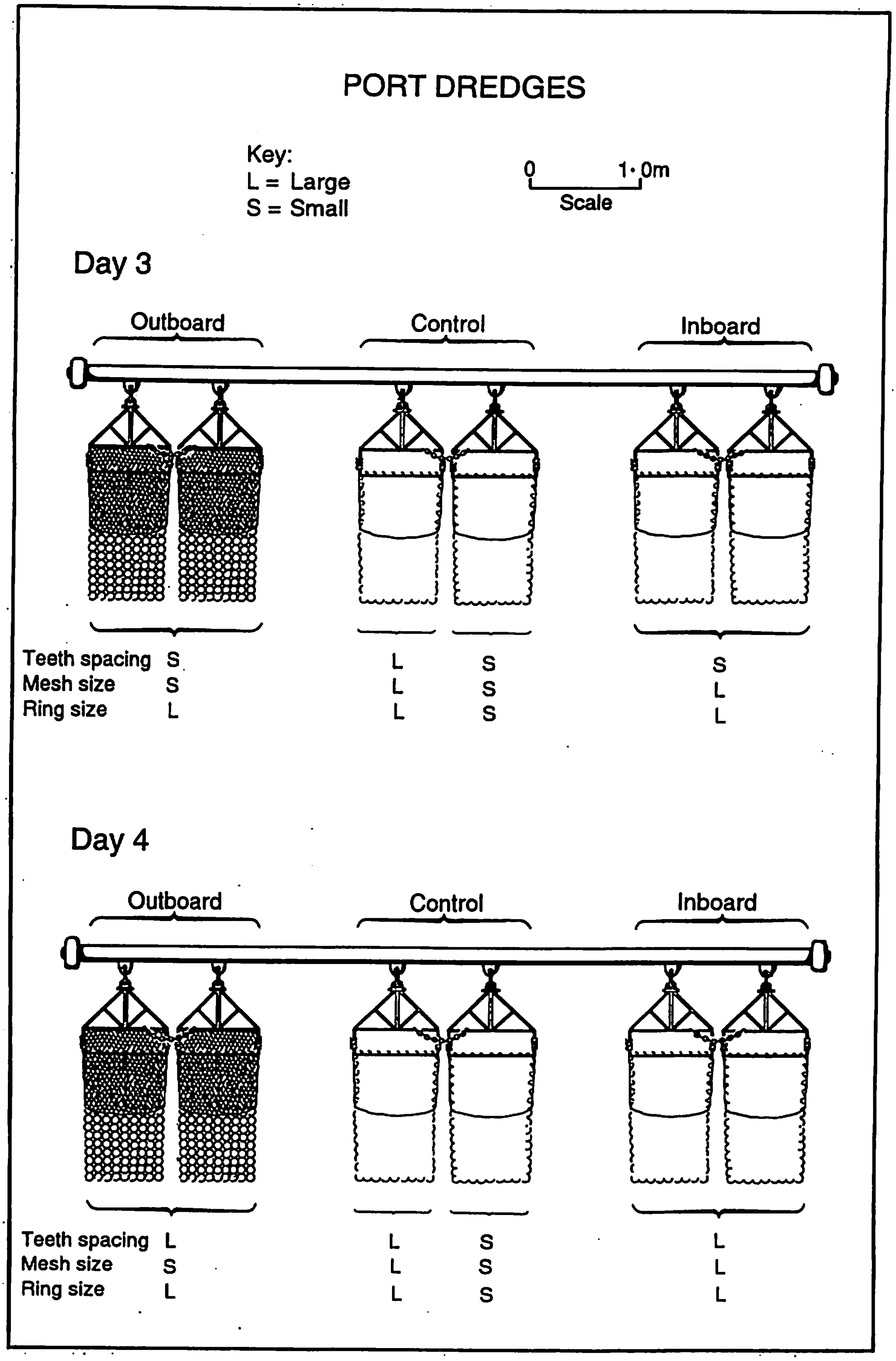
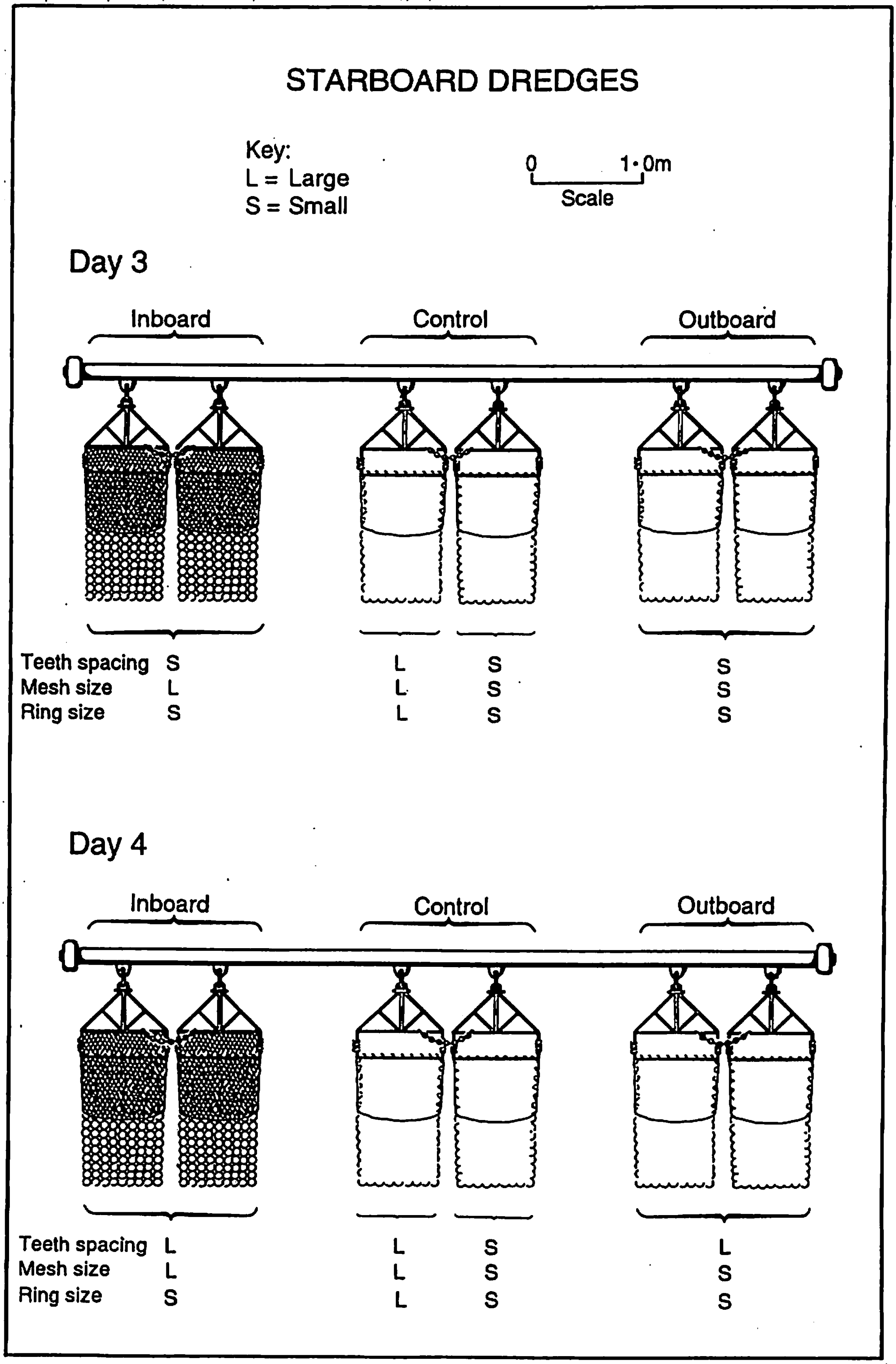


Figure 9: Dredge configurations - days 3 and 4



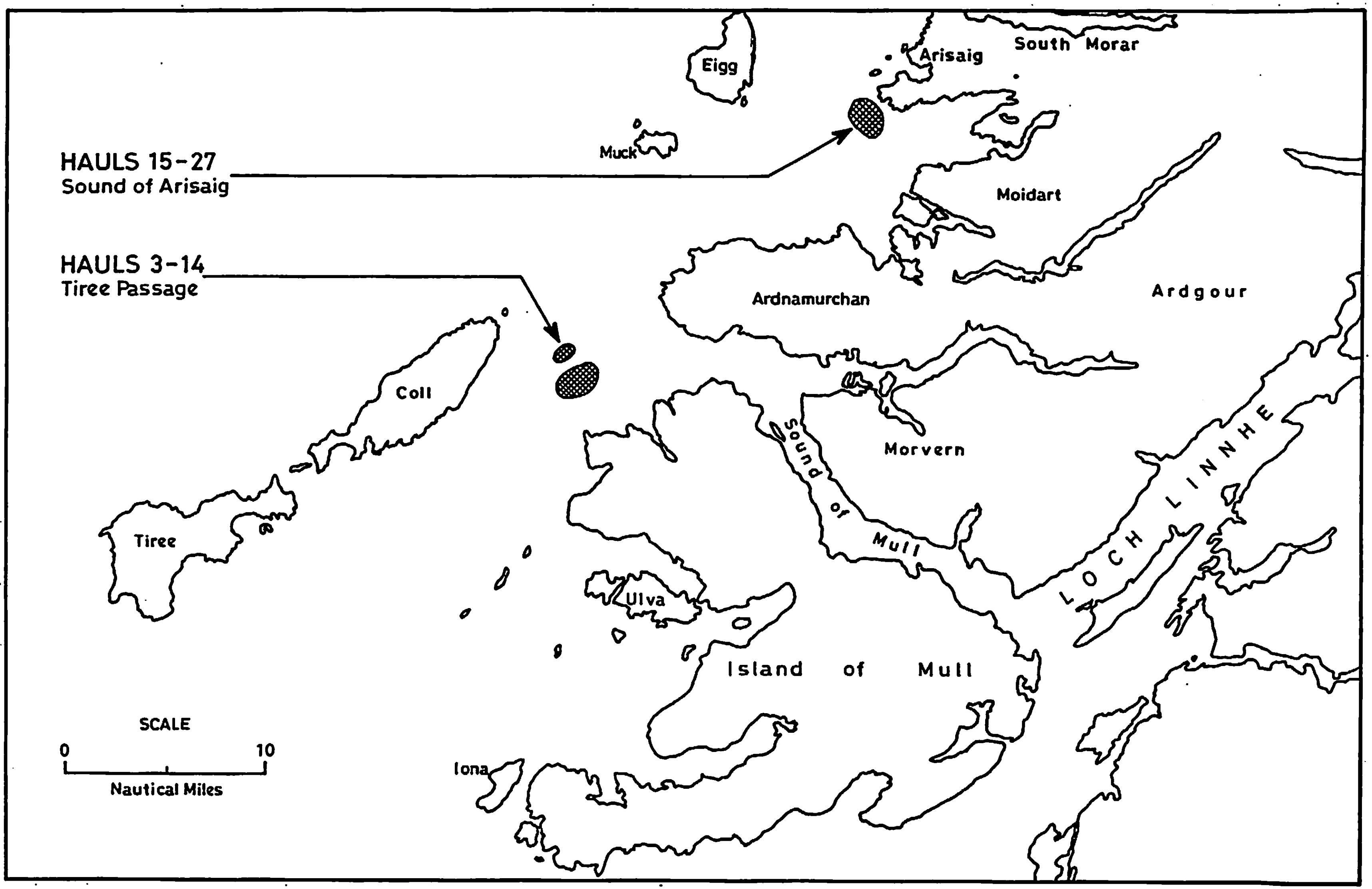


Figure 10: Locations fished

Table 6
Log of Haul Parameters (1/4/97 – 5/4/97)

Day No.	Location	Haul No.	Time		Wind state	Sea state	Towing bars		Warp-out Port (fathoms)	Warp-out Starboard (fathoms)	Depth (fathoms)	Mean speed over ground (knots)	Mean speed thro' water (knots)	Distance traversed (nautical miles)	General comments (ground type etc.)
			Shot	Hauled			Lead	Lag							
1	Tiree Passage	3	07:15	08:05	SW-5	5	Port	Starboard	85	90	33	2.42	2.56	2.01	Sand/rocks
1	Tiree Passage	4	08:35	09:25	SW-4	5	Port	Starboard	85	90	37	3.95	2.56	3.29	
1	Tiree Passage	5	10:20	11:10	SW-4	4	Starboard	Port	95	90	37	2.99	1.73	2.49	
1	Tiree Passage	6	11:33	12:30	SW-5	5	Port	Starboard	90	95	37	1.98	2.57	1.65	
1	Tiree Passage	7	13:00	13:50	SW-6	6	Port	Starboard	85	90	37	1.98	3.34	1.65	Hard - rocks/sand
1	Tiree Passage	8	14:20	15:10	SW-5	6	Starboard	Port	90	85	37	2.99	2.62	2.49	Hard - rocks/sand
2	Tiree Passage	9	08:28	09:20	NW-6	6	Port	Starboard	85	90	33	2.87	2.71	2.39	
2	Tiree Passage	10	09:50	10:40	NW-6	7	Starboard	Port	90	85	33	2.56	2.79	2.13	Hard - rocks/sand
2	Tiree Passage	11	11:15	12:05	NW-7	7	Starboard	Port	95	90	37	3.06	2.97	2.55	Hard - rocks/sand
2	Tiree Passage	12	12:28	13:20	NW-7	6	Starboard	Port	95	90	85	3.00	2.67	2.50	Hard - rocks/sand
2	Tiree Passage	13	13:40	14:30	NW-6	6	Port	Starboard	85	90	33	2.88	2.83	2.40	Port loadcell chain parted
2	Tiree Passage	14	15:05	16:38	NW-5	5	Starboard	Port	90	85	33	2.33	2.58	1.94	Fastener 15:35hrs
3	Sound of Arisaig	15	07:00	07:50	SE-2	3	Starboard	Port	65	60	21	2.89	2.87	2.41	
3	Sound of Arisaig	16	08:19	09:10	SE-2	3	Port	Starboard	55	60	21	2.64	2.88	2.20	
3	Sound of Arisaig	17	09:47	10:37	SW-4	4	Starboard	Port	65	60	21	2.46	2.49	2.05	
3	Sound of Arisaig	18	11:47	12:40	SW-5	4	Port	Starboard	60	65	21	2.78	2.67	2.31	
3	Sound of Arisaig	20	15:25	16:36	SW-4	4	Port	Starboard	60	65	21	-	-	-	Fastener at 15:45hrs
3	Sound of Arisaig	21	16:57	18:05	SW-5	4	Port	Starboard	60	65	17	1.83	3.09	1.52	
4	Sound of Arisaig	22	13:55	14:52	SW-6	6	Starboard	Port	65	60	17	2.46	2.72	2.05	
4	Sound of Arisaig	23	15:15	16:15	NW-4	5	Starboard	Port	60	55	17	2.71	2.84	2.25	Hard sand/stones
4	Sound of Arisaig	24	16:30	17:30	NW-5	5	Port	Starboard	55	60	17	3.05	2.99	2.54	Digging hard loads up to 8.5t
4	Sound of Arisaig	25	07:35	08:30	NW-4	4	Starboard	Port	65	60	17	2.63	2.74	2.20	Sand stones
4	Sound of Arisaig	26	08:50	09:50	SW-2	2	Starboard	Port	65	60	17	3.07	2.61	2.56	Sand stones
4	Sound of Arisaig	27	10:18	11:10	SW-2	2	Port	Starboard	60	65	17	-	-	-	Sand stones

Table 7
Experimental dredges, total number of scallops caught by location and gear combination

Location	Gear combination – tooth spacing, mesh and ring size in that order								
	LLL	LLS	LSL	LSS	SLL	SLS	SSL	SSS	Total
Tiree	171	191	169	165	232	305	257	237	**1727**
Arisaig	497	537	574	631	571	709	585	790	**4894**
Total	**668**	**728**	**743**	**796**	**803**	**1014**	**842**	**1027**	**6621**

L=Large
S=Small

Table 8
Control dredges, total number of scallops caught by location and gear combination

Location	Gear Combination		
	LLL	SSS	Total
Tiree	480	477	**957**
Arisaig	1379	1672	**3051**
Total	**1859**	**2149**	**4008**

6. Results

6.1 Overall catches

Table 7 shows the total number of scallops captured by location and gear combination and Table 8 shows the totals by location for the control. Within the two locations the number of scallops captured in each gear combination was generally well balanced.

These results indicate that the gear was performing reasonably consistently throughout the experiment. However, there was a substantial difference between the two locations for both the control and the experimental results.

6.2 Variation in catch composition - gear and locations

In order to make valid observations of selectivity and catch per effort in this experiment it was necessary to ensure that there were no serious sources of bias due to:

1. ***Differences between the inboard and outboard positions on the dredge bar and between lead and lag bar.*** The dredges on the inboard end of the lag bar may be more affected by the lead dredge disturbing or catching scallops than the dredges on the outboard end of the bar (Figure 5). There may be mechanical or other differences between the lead and lag bars.

2. ***Differences between the two dredge bars on the port and starboard sides of the vessel.*** There may be slight differences in the mechanical features of the two bars or, during the course of the day's fishing, one dredge may encounter different fishing conditions for operational reasons.

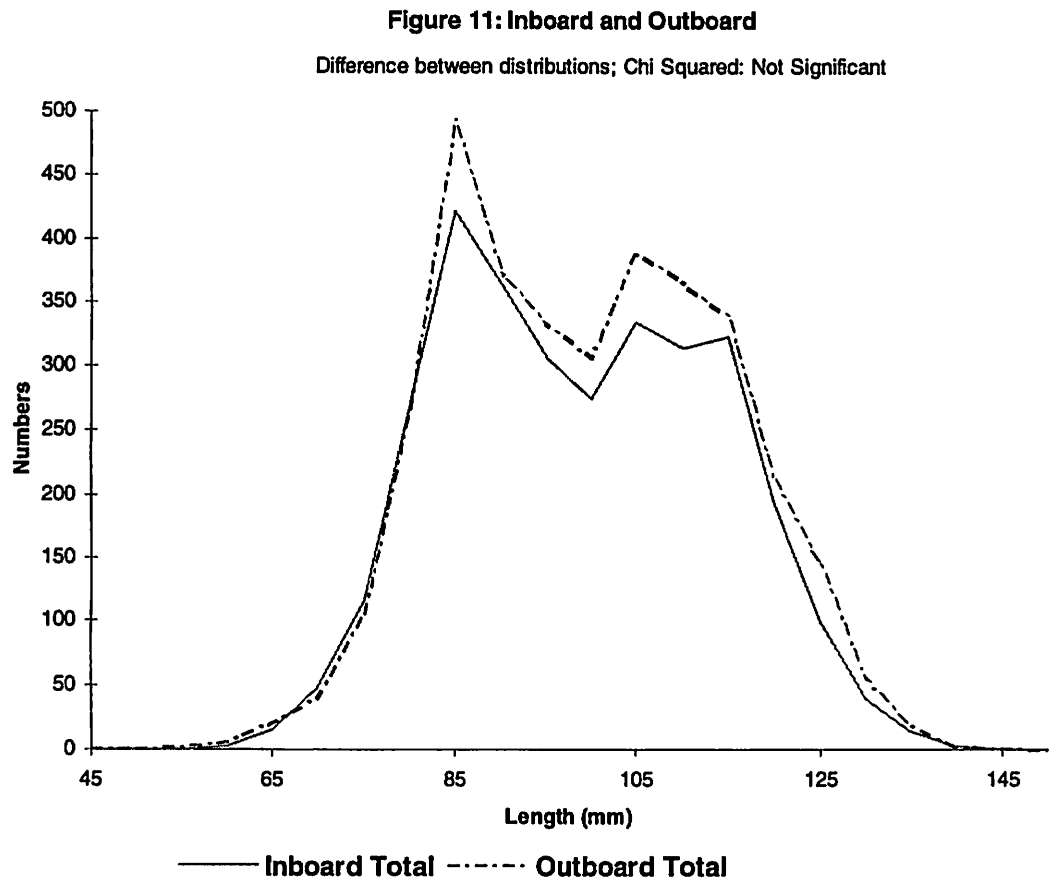
3. ***Differences in the population of scallops available to the dredge on different days.*** This is of particular importance for investigation of the effect of tooth spacing since the teeth were varied by day.

In order to determine whether these factors were affecting the size composition of the catches, length-frequency distributions for each were aggregated for the whole study and examined for differences. The significance of any differences observed were then assessed using Pearson's chi-squared test (see Section 5).

6.2.1 Inboard and outboard

The total effort for each of the experimental dredge combinations (controls were left out of this part of the analysis) in the inboard and outboard positions was the same. A comparison between the aggregate length-frequency distributions for the inboard and outboard dredges should thus determine whether there is any bias arising from that source. This is shown in Figure 11 (overleaf). The chi-squared test indicates that there is no significant difference between these two distributions. Therefore, the dredge position is not considered a source of bias in these results.

Aggregate Length-Frequency Distributions for Scallops



6.2.2 Lead and lag and dredge position

The lead dredge was alternated between port and starboard throughout this experiment (hauls 4, 6, 10, 12, 20, 21, 22 and 23 were exceptions to this rule and so were omitted from this part of the analysis). Therefore the total effort for each dredge permutation in the lead position was equal to that for the lag. Thus comparisons of the length-frequency distributions of the resulting catches should indicate whether this factor was of significance. Comparison between lead and lag dredges in the same positions on the bar should indicate whether there was an effect from the overlap between the two dredges.

The length-frequency distributions from the lead and lag dredges are compared in Figures 12-15 overleaf. The chi-squared test detected no significant difference between the length-frequency distributions of scallops captured in the lead and lag dredges overall and in the inboard, outboard and control positions respectively (Figures 12 to 15 overleaf). Tests of the significance of differences in the discard rate using a GLM also showed no significant difference between the positions of the dredges on the bar but there was a very small difference (Table 9), only just significant at P=0.05 between the lead and lag dredges.

Table 9
Comparison between the mean discard rates for lead and lag catches

Status	Mean discard Rate/Haul % by number	Standard Error
Lag	36.2	0.8
Lead	38.4	0.8

The cause of this difference could be the effect of the lead dredge disturbing or catching scallops before the lag dredge as discussed above. Alternatively these could be an operational or mechanical effect. The vessel always turned more sharply towards the lag dredge and the angle of declination of the wire would be expected to be greater on the lead dredge than the lag dredge.

Whatever the cause of this effect it appears to be independent of the position of the dredge on the bar. Thus the experimental dredges could be analysed independently of their status as inboard/outboard thus there should be no implications for the mesh size results. Overall within each location the number of hauls in which each bar was leading was equal. Thus since the ring size was varied between bars the effect of the small difference between the lead and lag dredge would be cancelled out. Tooth spacing was only varied between days and not between sides so there would be no effect on the results for tooth spacing.

Aggregate Length-Frequency Distributions for Scallops

Figure 12; Lead and Lag; Inboard

Difference between distributions; Chi Squared: Not Significant

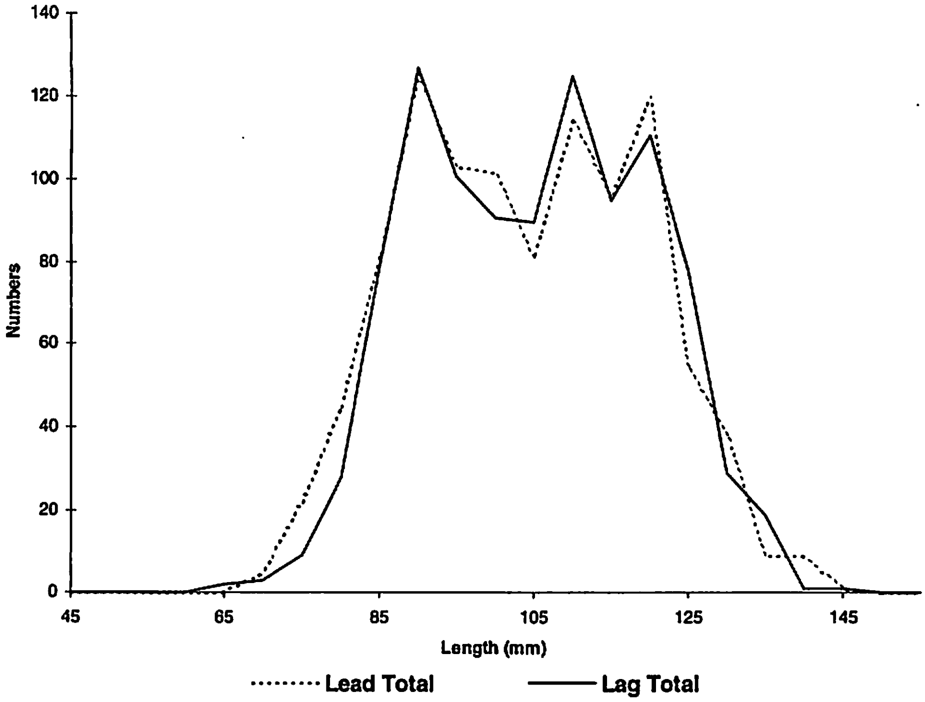
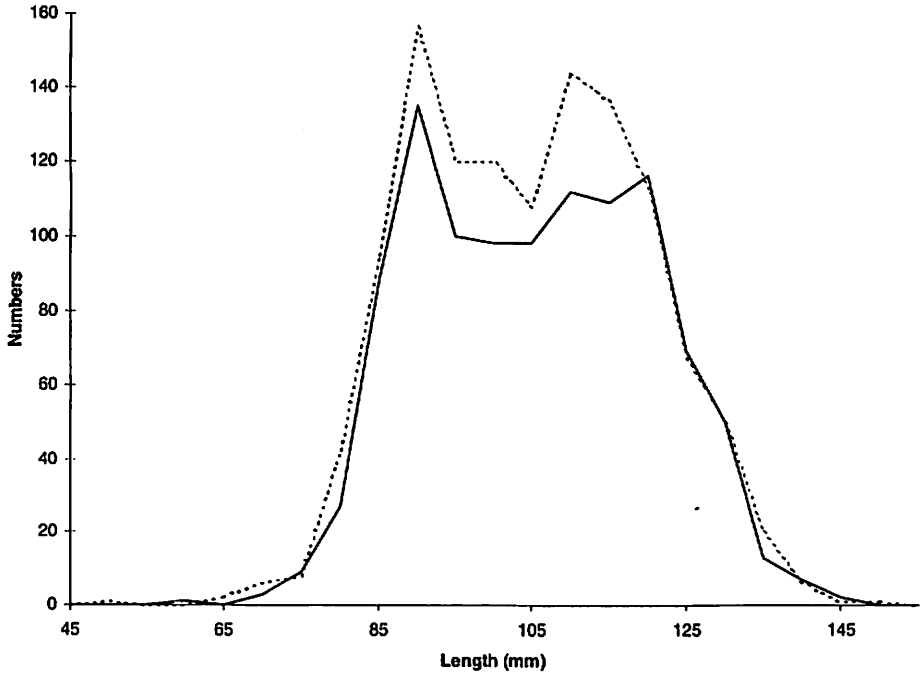


Figure 13; Lead and Lag Outboard

Difference between distributions; Chi Squared: Not Significant



Aggregate Length-Frequency Distributions for Scallops

Figure 14; Lead and Lag; Control only

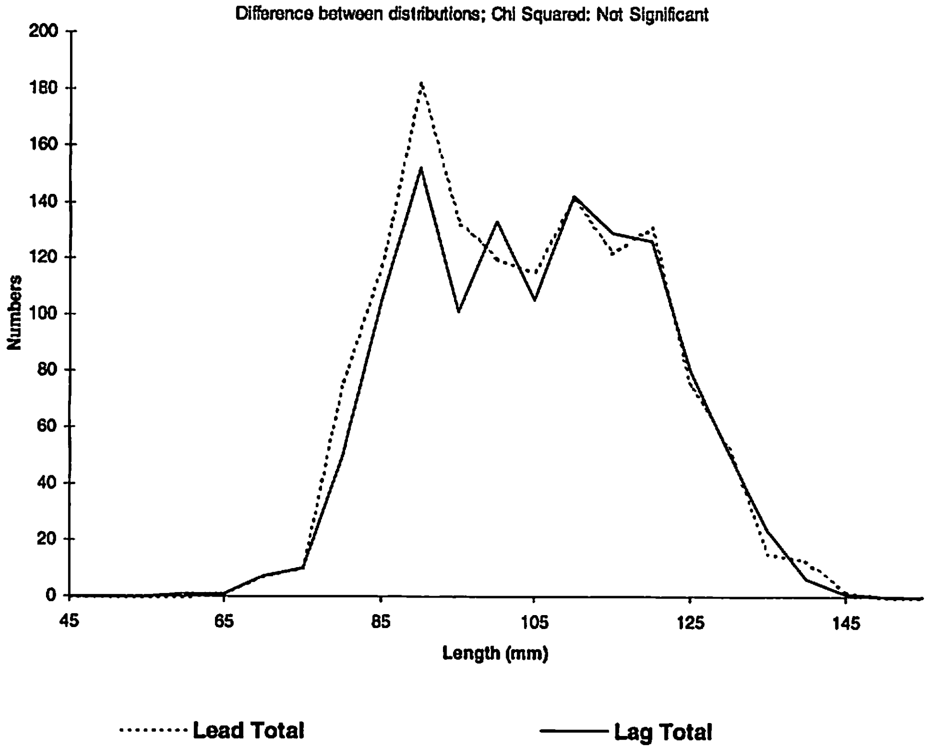
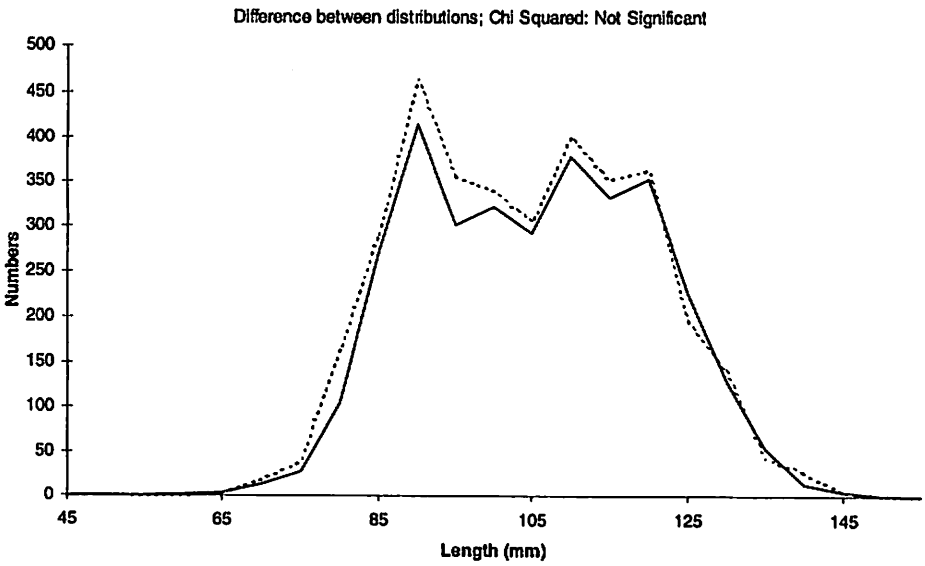


Figure 15; Lead and Lag; Whole sample



6.2.3 Port and starboard

The control dredges were in a constant configuration throughout the experiment. Thus they should provide a comparison between the two sides - port and starboard.

Figure 16 (overleaf) shows the aggregate length frequency distributions for the port and starboard control dredges. The chi-squared test shows there to be a significant difference between the distributions from the two sides. However, they are of the same general shape and the effect was probably due to operational or mechanical differences between the two sides; the port bar produced significantly more warp tension than the starboard bar (Section 6.5).

6.2.4 Locations

The control dredges enable comparisons to be made between locations and days on a consistent basis. The aggregate length-frequency distributions from each pair of control dredges (both large and small tooth spacing mesh and ring sizes combined) from the two locations are shown in Figure 17 (overleaf). These results indicate that there were substantial differences in the length frequency distributions between locations; a much higher proportion of small scallops were captured in the control dredges at Arisaig than at Tiree.

6.2.5 Days

The aggregate length-frequency distributions of scallops from the control from each day are shown in Figures 18 and 19 (overleaf). The distributions were compared by chi-squared and the mean discard rate (Table 10) by GLM (see Section 5.11). These comparisons were made between days at each location.

Table 10
Mean discard rate of the control

Location	Day	Mean Discard Rate/Haul % by number	Significance Location/Days
Tiree Passage	1	11.6	Difference = Not significant
Tiree Passage	2	13.3	
Sound of Arisaig	3	49.1	Difference = Not significant
Sound of Arisaig	4	49.7	

The results of the control indicate that in general the length-frequency distributions were similar for each of the days within each location. Although the chi-squared test indicates a significant difference between the days 3 and 4 at Arisaig there is no significant difference in the mean discard rates for these two days and the overall shape of the length-frequency distributions are very similar. A large and significant difference in the control between the days within each location would have implications for the comparison between the two tooth spacings since these were varied by day. These results suggest that these differences were not important and therefore the comparison between tooth spacings was valid.

Aggregate Length-Frequency Distributions for Scallops

Figure 16: Port and Starboard; Controls only

Difference between distributions; Chi Squared: Significant at P=0.005

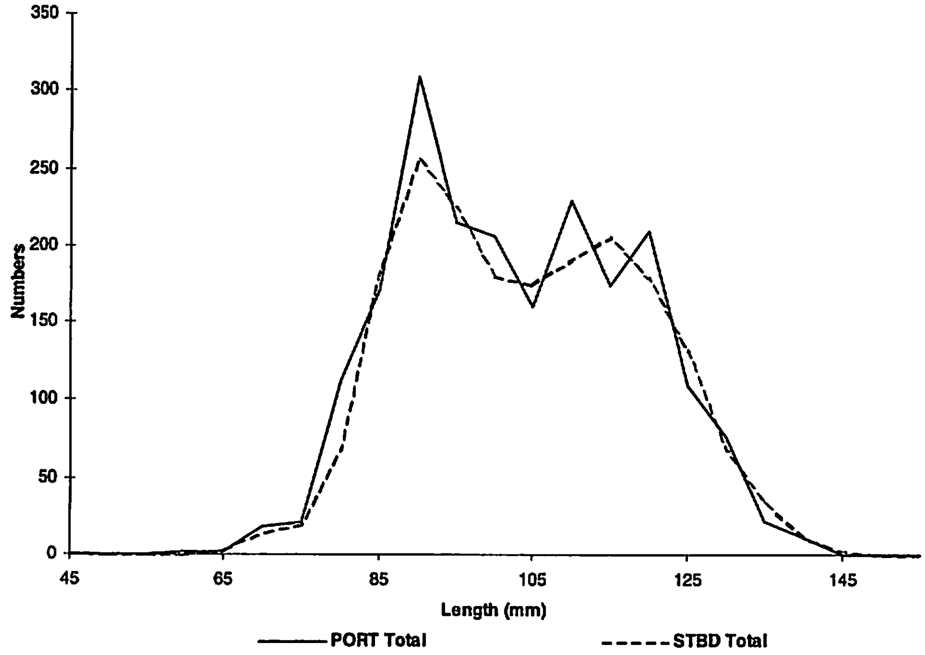
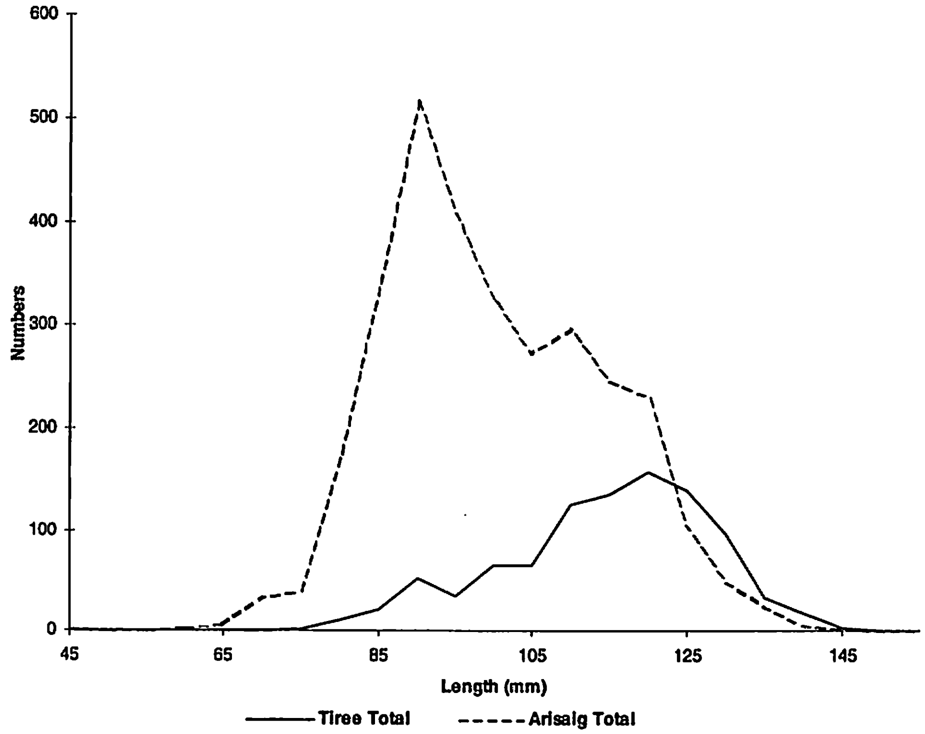


Figure 17: Tiree and Arisaig; Controls Only

Difference between distributions; Chi Squared: Significant at P<0.001



Aggregate Length-Frequency Distributions for Scallops

Figure 18: Tiree; Days 1 and 2
Difference between distributions; Chi Squared: Not Significant

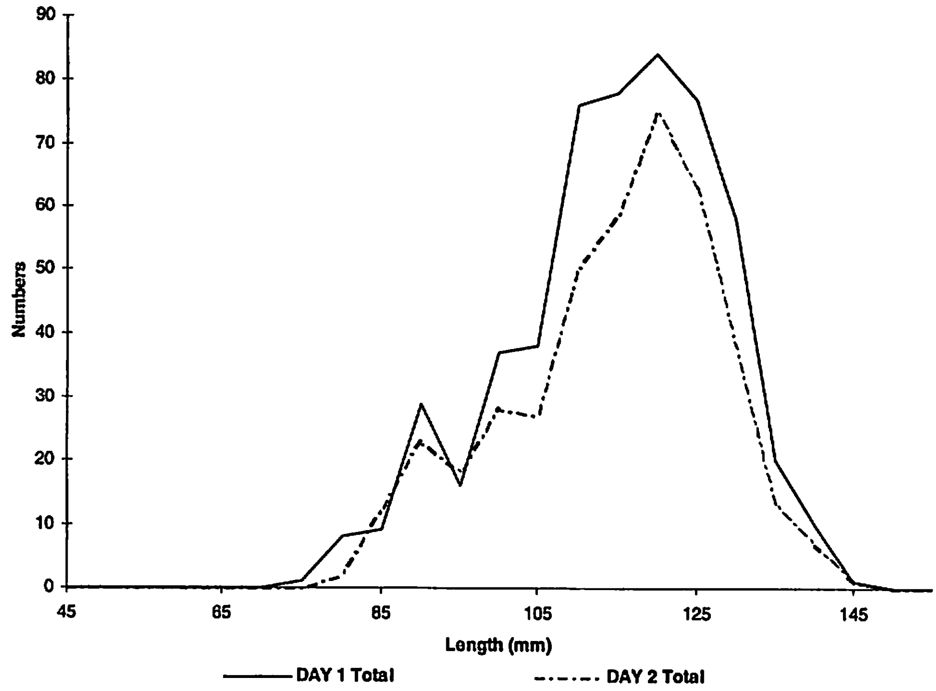
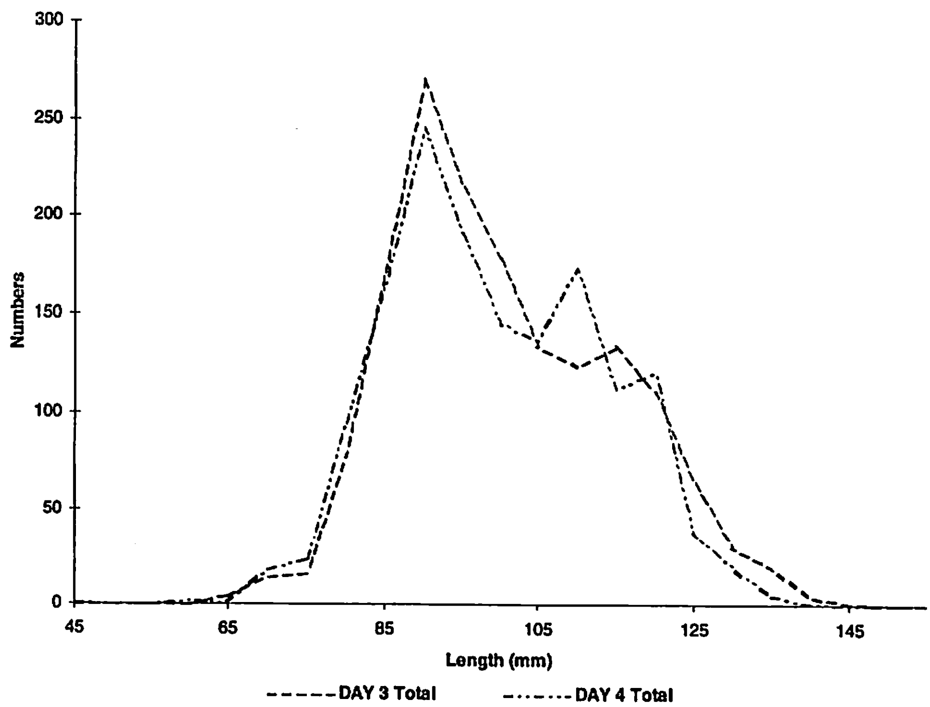


Figure 19: Arisaig; Days 3 and 4
Difference between distributions; Chi Squared: Significant at P<0.001



6.3 Relative selectivity and catch per effort

6.3.1 Aggregate length-frequency distributions

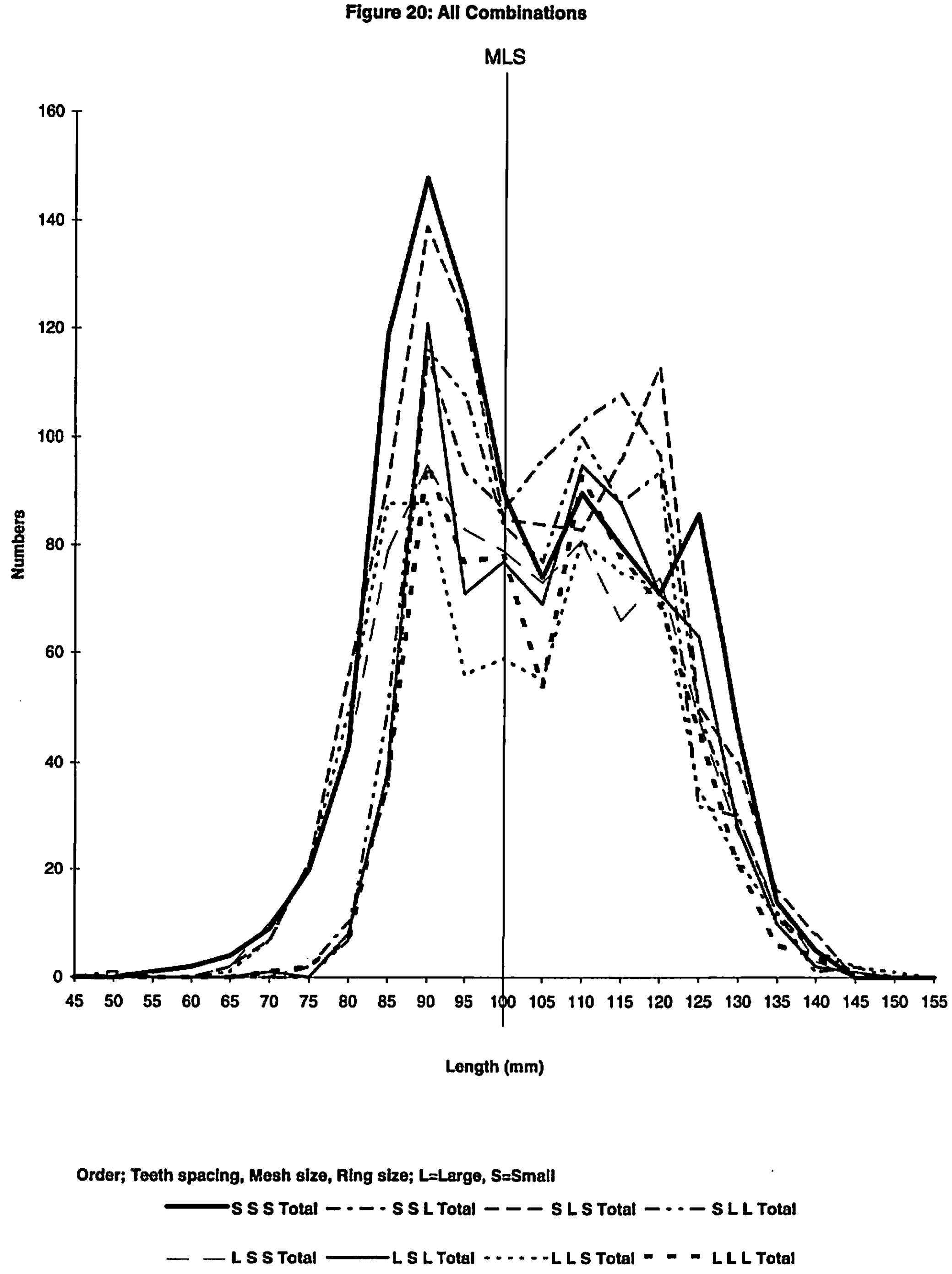
Aggregate (over the whole trip) length-frequency distributions of all the combinations of tooth spacing, mesh and ring size from the experimental dredges were plotted separately (Figure 20 overleaf). The main trends are visible in this graph; there are two distinct groups of ascending limbs of the curve corresponding to large and small rings. However, because of the large number of variations it is difficult to discern other trends.

Aggregate length-frequency distributions of each of the factors are then plotted individually in Figures 21 to 23 (p37) showing the differences between small and large tooth spacing, ring and mesh sizes. The difference between the distributions in each of these graphs is an indication of the influence of these factors on the resulting length-frequency distributions. There is evidence in these results that ring size and possibly tooth spacing had an effect on the proportion of discards. Although there was a significant difference between the aggregate results obtained for the large and small mesh sizes, it is not clear whether it is the discard rate or the overall catch per effort of the dredges which were affected.

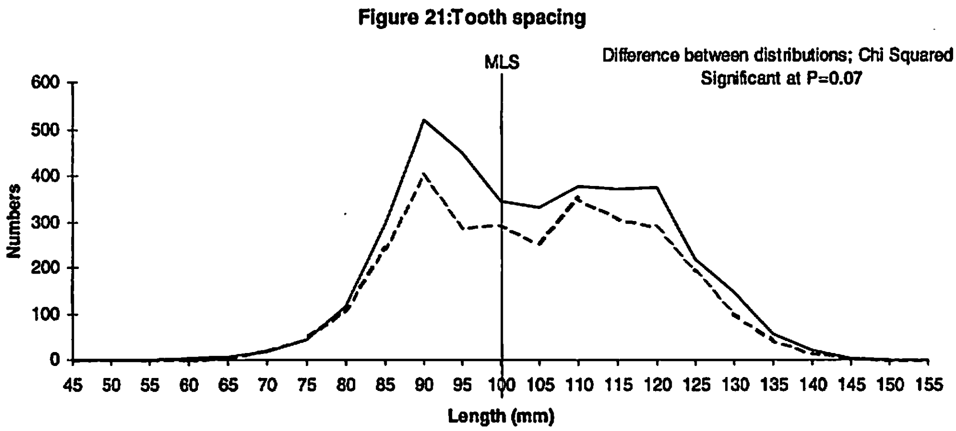
Interpreting the data in Figures 21 to 23 in this way assumes that there were no interactions between the components of the dredges. If, for example there were differences in the way in which the small rings selected scallops dependent upon whether they were on dredges with large or small tooth spacings then interaction could be said to have taken place. This would mean that it would be difficult to separate the effect of the interaction from the selectivity due to teeth spacing, mesh or rings size. Therefore a method is required to examine interactions

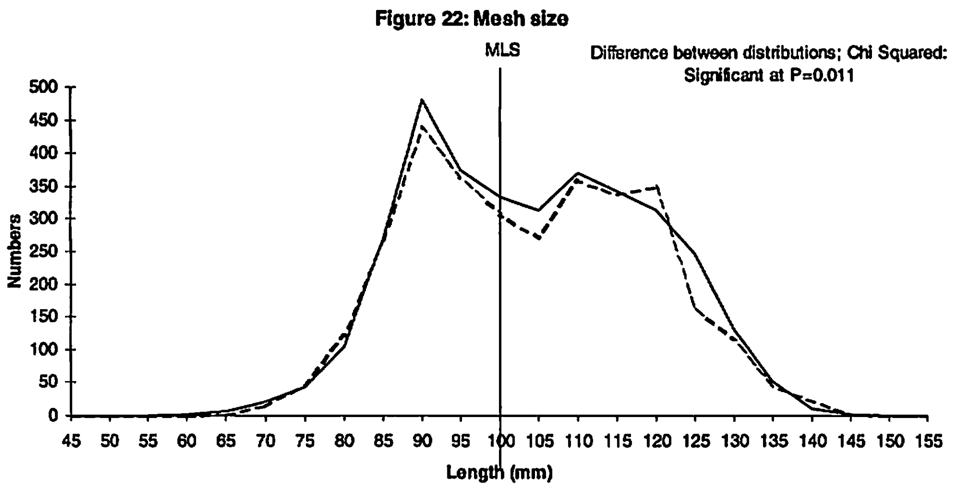
There is also a requirement to take into account variations between location and haul. This is particularly important for the variation in tooth spacing since this factor was compared between sets of hauls on successive days. Thus, further analysis of these data was carried out taking these requirements into account. This is described in Sections 6.3.2 and 6.3.3.

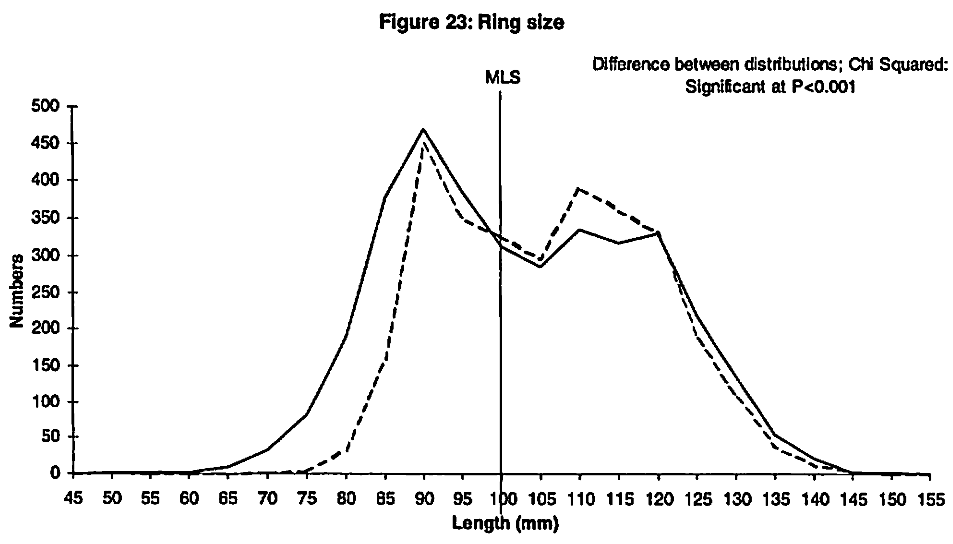
Aggregate Length-Frequency Distributions for Scallops



Aggregate Length-Frequency Distributions for Scallops







Estimates of Discard Percentages

Figure 24 Percentage Discards by Number

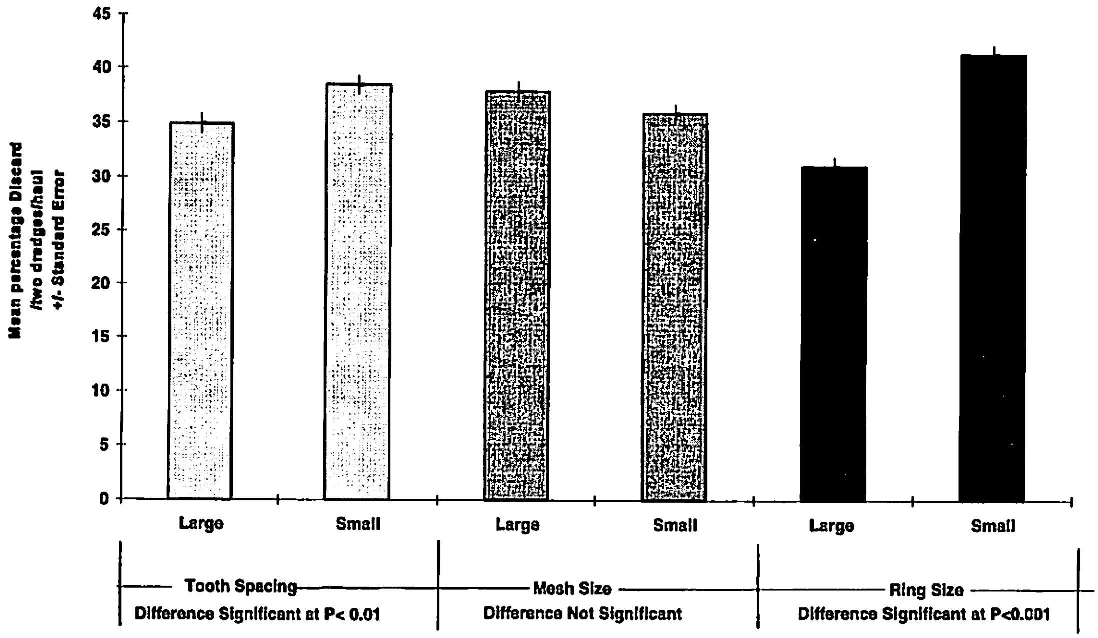


Table 11
Mean Percentage Discard Rates

Effect	Large	Small	% difference
Tooth spacing	35	38.5	3.5
Ring size	31	42	11

6.3.2 Selectivity

Since none of the dredges can be assumed to have captured the whole size range of scallops in the population the length-frequency distribution of the total population remains unknown. These results are therefore described in terms of relative selectivity for the particular population of scallops encountered. The results obtained elsewhere would probably be different.

The proportion of sub-legal scallops (length below the MLS of 100mm) was calculated for the aggregate catch (for both replicates) for each gear permutation for each haul:

$$\%\ Discard = \frac{Number\ of\ scallops\ below\ MLS}{Total\ number\ of\ scallops} \times 100\%$$

The results are described as changes in discard rates due to the three factors (the main effects) under consideration. The effect of these factors on the proportion of discarded scallops were examined by Generalised Linear Modelling (GLM: see Section 5.11). The use of the GLM allowed the significance of interaction between the main effects to be tested and this was found to be not significant. Because there was no interaction, all of the results obtained for the main effects could be used.

Figure 24 describes results of this analysis as the differences in percentage discards due to tooth spacing, mesh and ring size. This bar chart also shows the standard error, which is an indication of the amount by which the results are spread about the mean. This shows that both ring size and tooth spacing had a significant effect on selectivity ($P<0.001$ and $P<0.01$ respectively). Mesh size had no significant effect. Table 11 shows these results in percentage terms. Ring size had by far the largest effect with the larger size accounting for an 11% reduction in the discard rate. The contribution of larger tooth spacing was a 3.5% reduction in the discard rate.

6.3.3 Catch per effort

For comparisons of catch per effort, the weights and numbers of scallops larger than the MLS were calculated (using the length-weight relationship, Section 6.4):

Weight of landed catch = Total weight of scallops above MLS

Number of landed catch = Total number of number of scallops above MLS

The total number of scallops was also calculated.

These figures were calculated for the aggregate catch for each gear combination for each haul and also for the aggregate catch of the controls on each bar.

The effects of tooth spacing, mesh size and ring size, and interactions between these factors, on the total weights and numbers of landed catch of scallops were examined by analysis of variance (ANOVA).

Of the possible block structures listed in Section 5, location was chosen. This was because of the large differences in the length-frequency distributions found between the two locations. The results from the control dredges for each bar were used as covariates for the experimental dredges on that bar thus reducing the effect of between-haul variation.

The results are shown in Figures 25 and 26 and in Table 12 and 13 (overleaf). Although in all cases the smaller of the two factors (small tooth spacing, mesh size or ring spacing) produced a higher mean weight and numbers of scallops per haul, the only one which showed any significance was tooth spacing. There was no interaction; small mesh or ring size did not behave differently when in combination with small or large tooth spacing.

The differences in mean catch per haul attributable to tooth spacing are shown in Tables 12 and 13. At $P=0.056$ for estimated weight and $P=0.04$ for numbers they were not as significant as the differences in the discard rates (see above). However these results imply that there is a reduction in the catch per effort of the dredges of around 10% if the larger tooth spacings are used.

The total catch by numbers was also analysed in the same way (Table 14, overleaf). Both tooth spacing and ring size showed significance ($P<0.0001$ and $P=0.008$ respectively). This was to be expected since these factors affect size selection and therefore the numbers of small scallops captured. Mesh size did not have a significant effect on total catch in terms of numbers. There was no interaction between tooth spacing, mesh or ring size.

Estimates of Catch by Weight

Figure 25
Landed Catch by weight

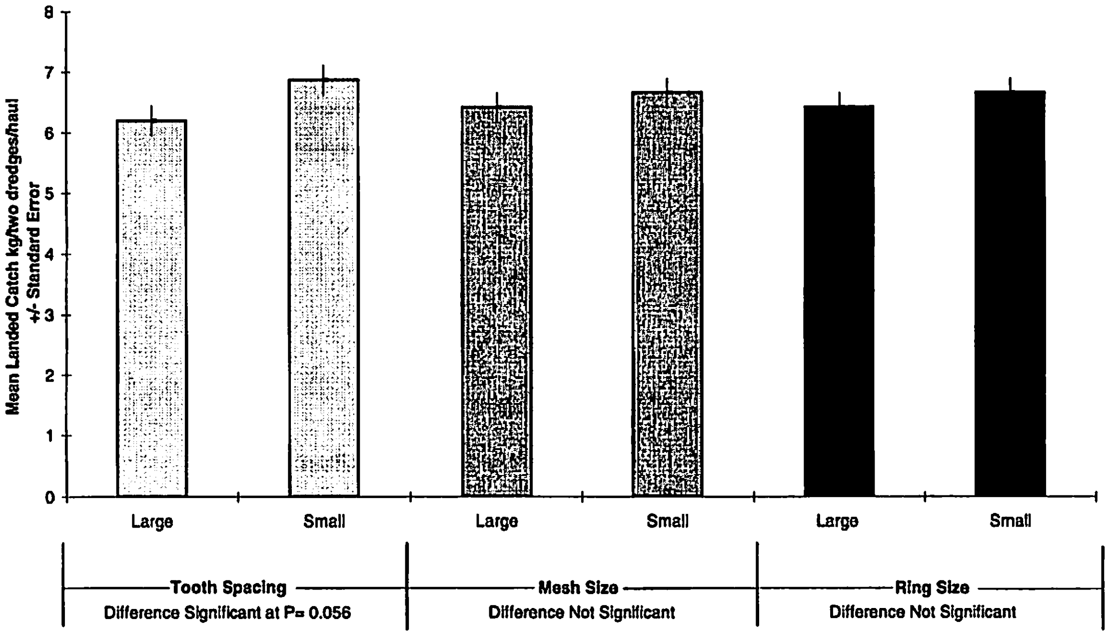


Figure 26 Landed Catch by Number

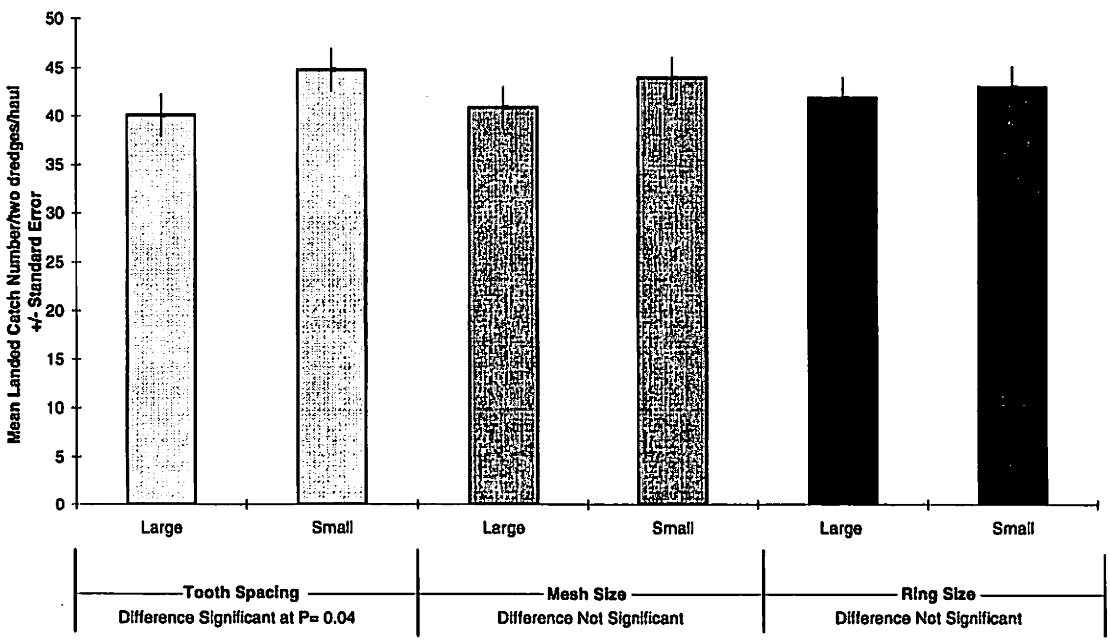


Table 12
Mean landed catch kg/two dredges/haul

	Large	Small	% Difference	Significance
Tooth spacing	6.2	6.87	9.8	p=0.056
Mesh size	6.3	6.77	6.9	Not sig
Ring size	6.41	6.65	3.6	Not sig
Interactions				Not sig

Blockstructure = Location
Covariate = Landed catch in kg from control

Table 13
Mean landed catch numbers/two dredges/haul

	Large	Small	% Difference	Significance
Tooth spacing	40.1	44.8	10.5	p=0.04
Mesh size	40.9	44	7.0	Not sig
Ring size	41.9	43	3.6	Not sig
Interactions				Not sig

Blockstructure = Location
Covariate = Landed catch in numbers from control

Table 14
Mean total catch numbers/two dredges/haul

	Large	Small	% Difference	Significance
Tooth spacing	61.1	76.8	20.4	p=<0.001
Mesh size	66.9	71	5.8	Not sig
Ring size	63.7	74.3	3.6	p=0.008
Interactions				Not sig

Blockstructure = Location
Covariate = Total catch in numbers from control

6.4 Scallop size and shape

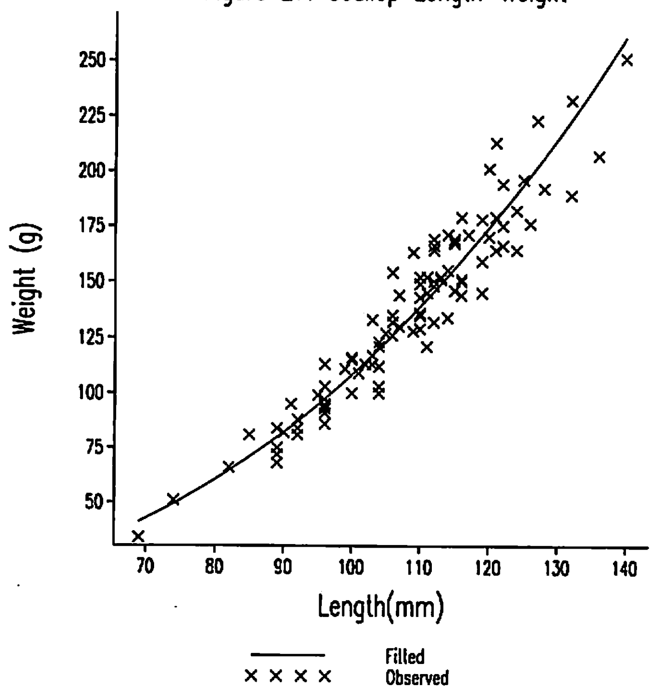
6.4.1 Length-weight relationship

The length-weight relationship shown in Figure 27 was used to calculate the weights of the catches.

6.4.2 Length, width and height

The width and height of the sample of scallops were plotted against length and regression lines obtained. These are shown in Figures 28 and 29 (overleaf). These results were obtained in order to describe the extent of the variation of these parameters with length. This could lead to comparison with the sizes of the apertures in the dredges available for selection of the catch.

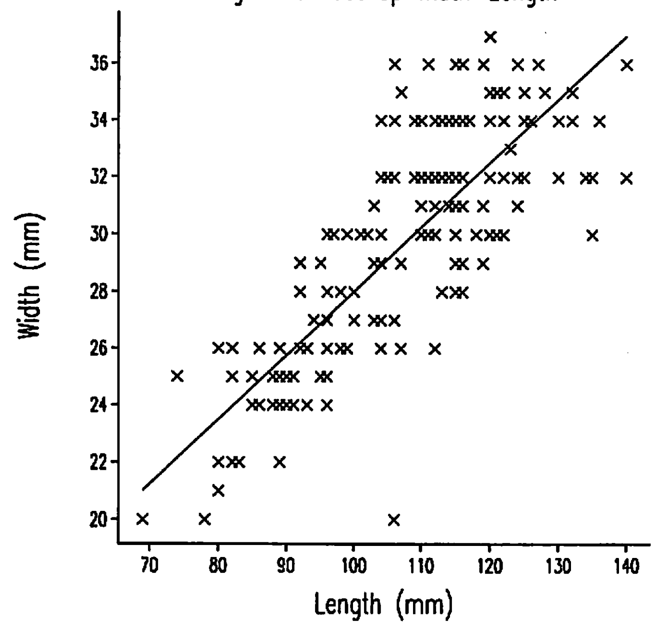
Figure 27: Scallop Length-Weight



Fitted Length-Weight Relationship

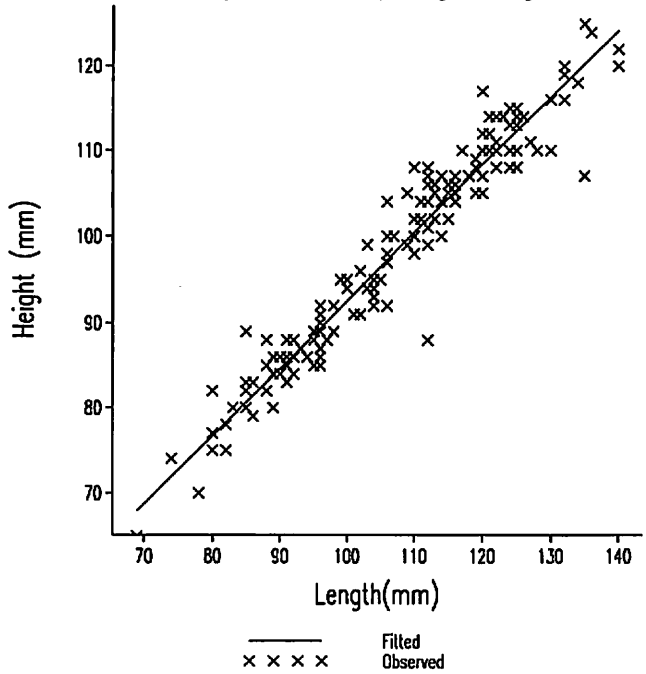
Width(g) = 0.006653 x Length(mm)$^{2.6}$

Figure 28 Scallop Width-Length



Width(mm) = 0.22 x Length(mm) + 5.5

Figure 29 Scallop Height-Length



Height(mm) = 0.8 x Length(mm) + 13.3

6.5 Vessel/Surface Parameters

6.5.1 Warp tension

The results of the monitoring of warp tension were analysed for:

1. Differences between the port and starboard dredges.

2. Differences over time from the start of the haul (the first and last 5 minutes of each haul were removed from each of the hauls).

3. The effects of the changes in teeth spacing and ring size on the experimental dredges.

A significant difference ($P<0.001$) was found between the two sides port and starboard. This amounted to a mean difference of 0.101 tonnes(t) (101kg) in favour of the port side. The mean tensions were 1.390t on the port side and 1.289t on the starboard side. One possible partial explanation is the presence of a steel triangle at the apex of the chains on the port side dredge which may have caused an increase in the drag compared with the shackle on the starboard side.

There was a significant linear relationship with time for both sides of gear amounting to a total of 0.0085t (8.5kg) per minute (both sides added together), see Figure 30 (over). This is probably accounted for by the catch of stones and scallops accumulating in the dredges over the course of the haul.

There was no significant relationship between warp tension and tooth spacing for either port or starboard dredges. The tension on the port side generated by the small rings on the experimental dredge showed a mean increase of 0.031t (31kg) (significant at $P=0.01$) when compared with the large rings. However, there was no corresponding relationship for the starboard dredge.

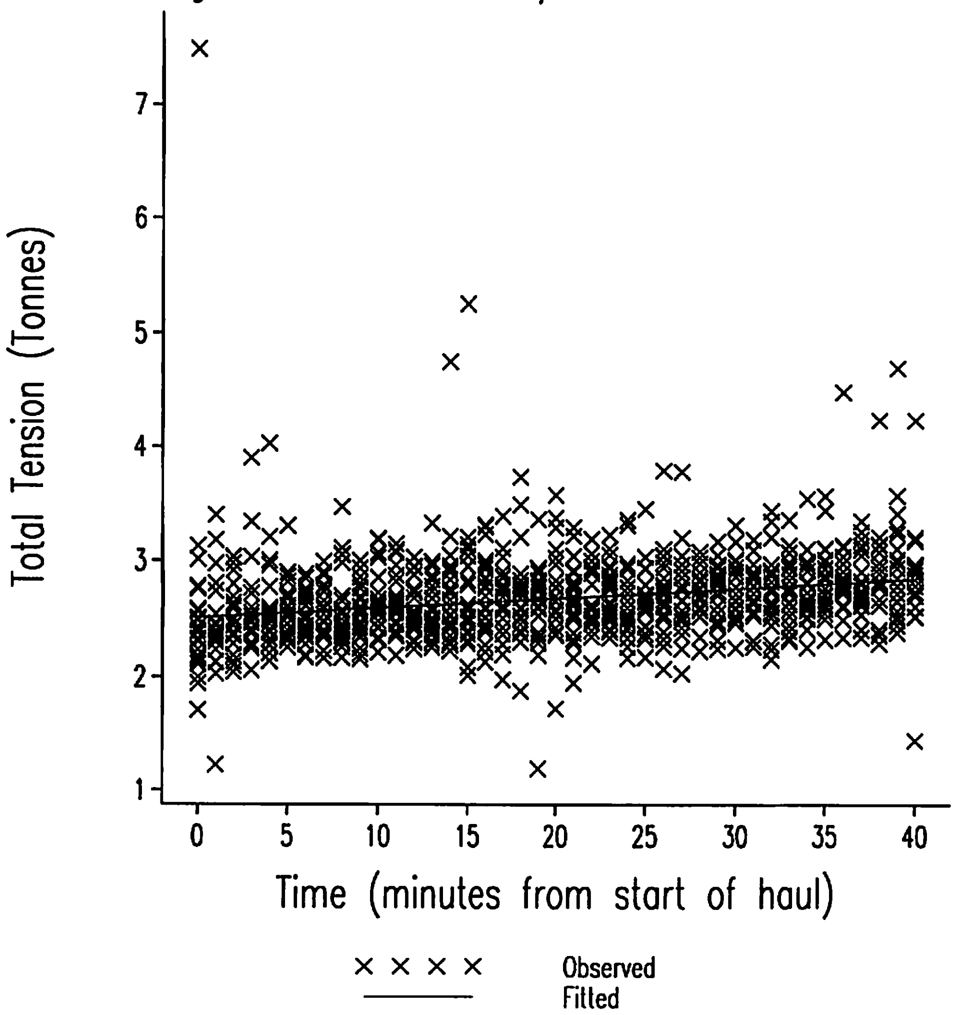
6.5.2 Composition of catches

The mean volume of total bulk in boxes is shown in Table 15 together with the mean percentage of scallops. These results show that of the total bulk volumes, the scallops only constituted a mean of 11% by volume.

Table 15
Mean volume of bulk per haul ± max, min and percentage scallops

Mean volume boxes			Percentage scallops		
Mean	Maximum	Minimum	Mean	Maximum	Minimum
12.5	19.3	7.6	11	18.7	5.7

Figure 30 Total tension/Time from start of Haul



Fitted Tension-Time Relationship

Total Tension(t) = 0.0085 x Time(minute) + 2.51

This is equivalent to 8.5kg/minute increase in tension

7. Discussion

7.1 Scallop dredges in selectivity research

These results indicate that it is possible to compare selectivity between the dredges on a dredge bar. There does not appear to be any serious interference between the lead and lag dredges, although each boat may be different in this respect. There were differences between the port and starboard dredges in respect of warp tension and the length-frequency distributions of scallops captured in the controls. The movement of the experimental dredges from one side to the other at the end of day 2 of the experiment and the use of the control as a covariate should have reduced the influence of these effects.

The lack of a significant difference in warp tension produced by the two tooth spacings suggests that this parameter did not have a significant effect on dredge behaviour. This is of relevance since it is assumed that the control dredges fished in an equally efficient manner throughout the experiment. If they had been affected by the tooth spacing on the experimental dredges then this assumption may not be valid. The significant difference in the warp tension of the two dredge bars in response to ring size is assumed to be an anomaly. Since the small ringed dredges were fished on the opposite sides in the different locations there could be a location effect. However this should not affect the results too seriously since the large and small rings were always fished together on opposite sides of the vessel allowing direct comparisons to be made.

7.2 Selectivity and catch per effort

These results show that for these particular tooth spacings, mesh and ring sizes, the ring size makes the most important contribution to selectivity. The results indicate there was no significant difference in the catch per effort on scallops larger than the MLS between the two ring sizes. The tooth spacing also showed a contribution to selectivity but there was a reduction in the catch per effort on scallops larger than the MLS. The mesh size of these dredges did not appear to have an effect on selectivity or catch per effort.

The lack of significant interactions in terms of discard rate or catch per effort indicates that the aggregate length-frequency distributions shown in Figures 21 to 23 (p37) may be considered valid representations of the main effects.

7.3 Shapes of scallops and selectivity

Although the larger ring sizes and tooth spacings were shown to increase selectivity there may be scope for a further increase in these parameters, particularly ring sizes, in order to increase selectivity. In order to visualise the relationship between the shape and size of the scallop and the teeth and rings, Figures 31 to 36 (overleaf) were drawn. These illustrations suggest that there may be scope for further increases in ring size and still enable the retention of 100mm scallops.

Figure 31: - Ring profile compared with Scallop profile – small belly

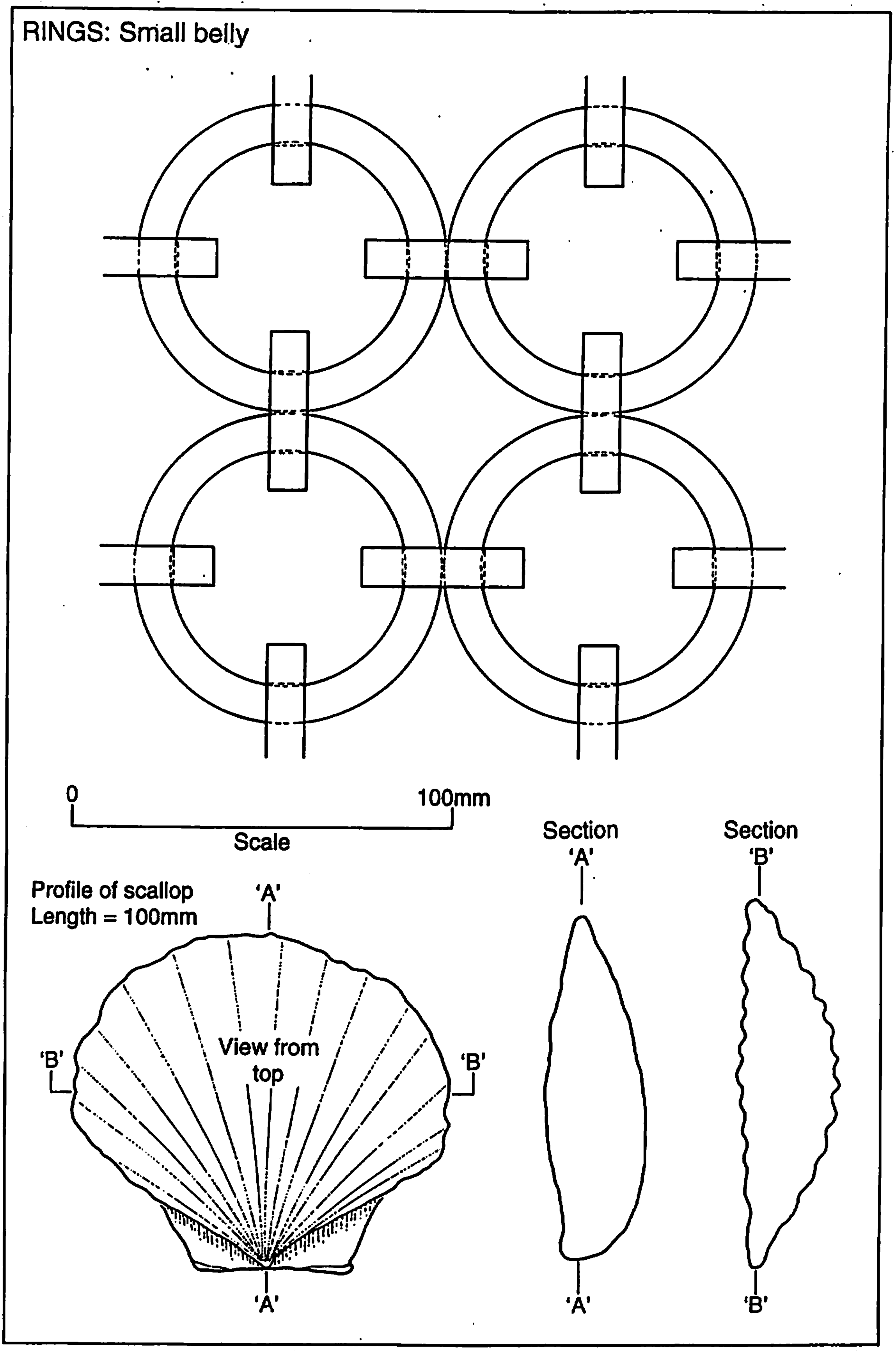


Figure 32: Ring profile compared with Scallop profile – large belly

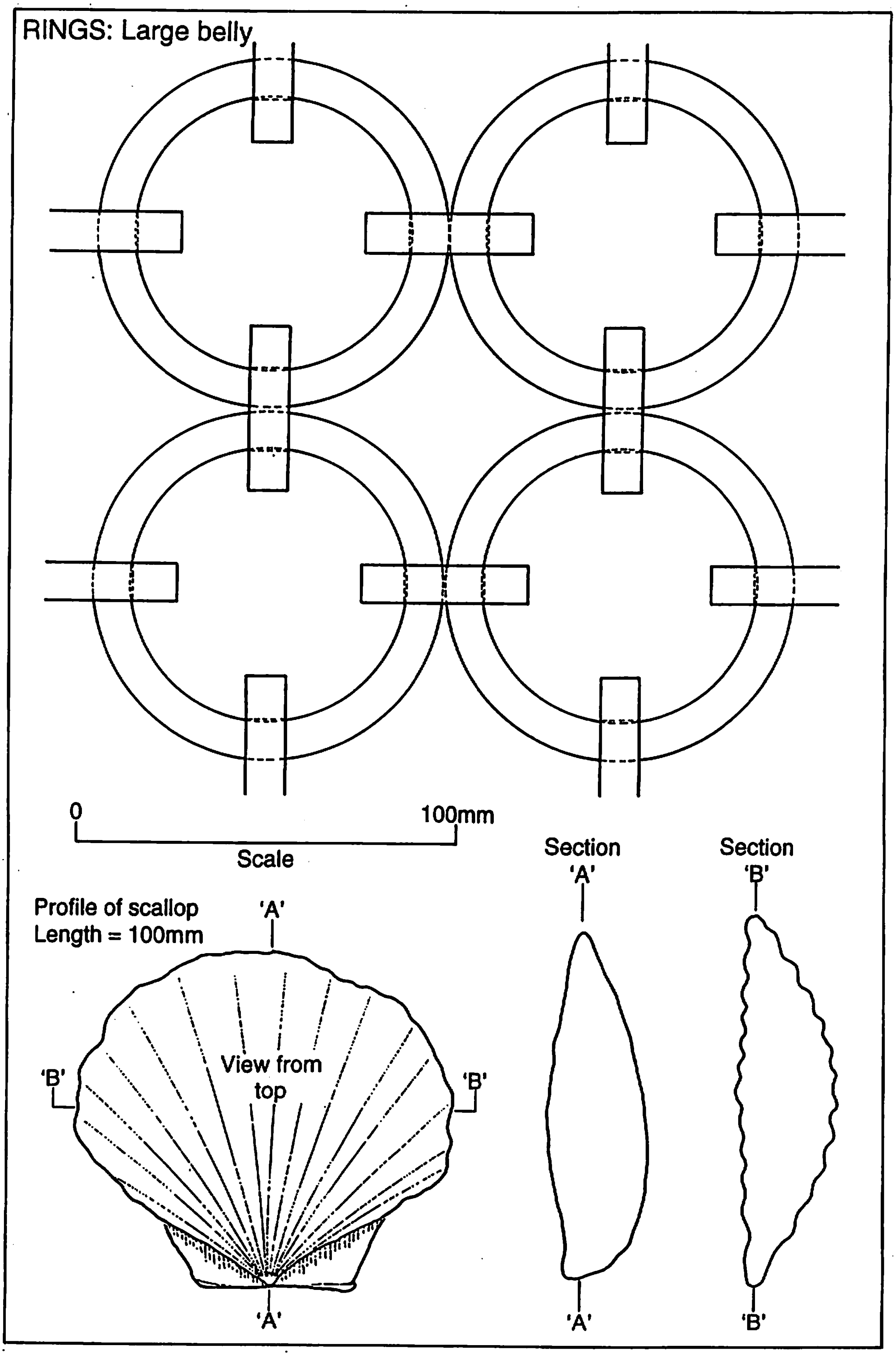


Figure 33: Ring profile compared with Scallop profile – small back

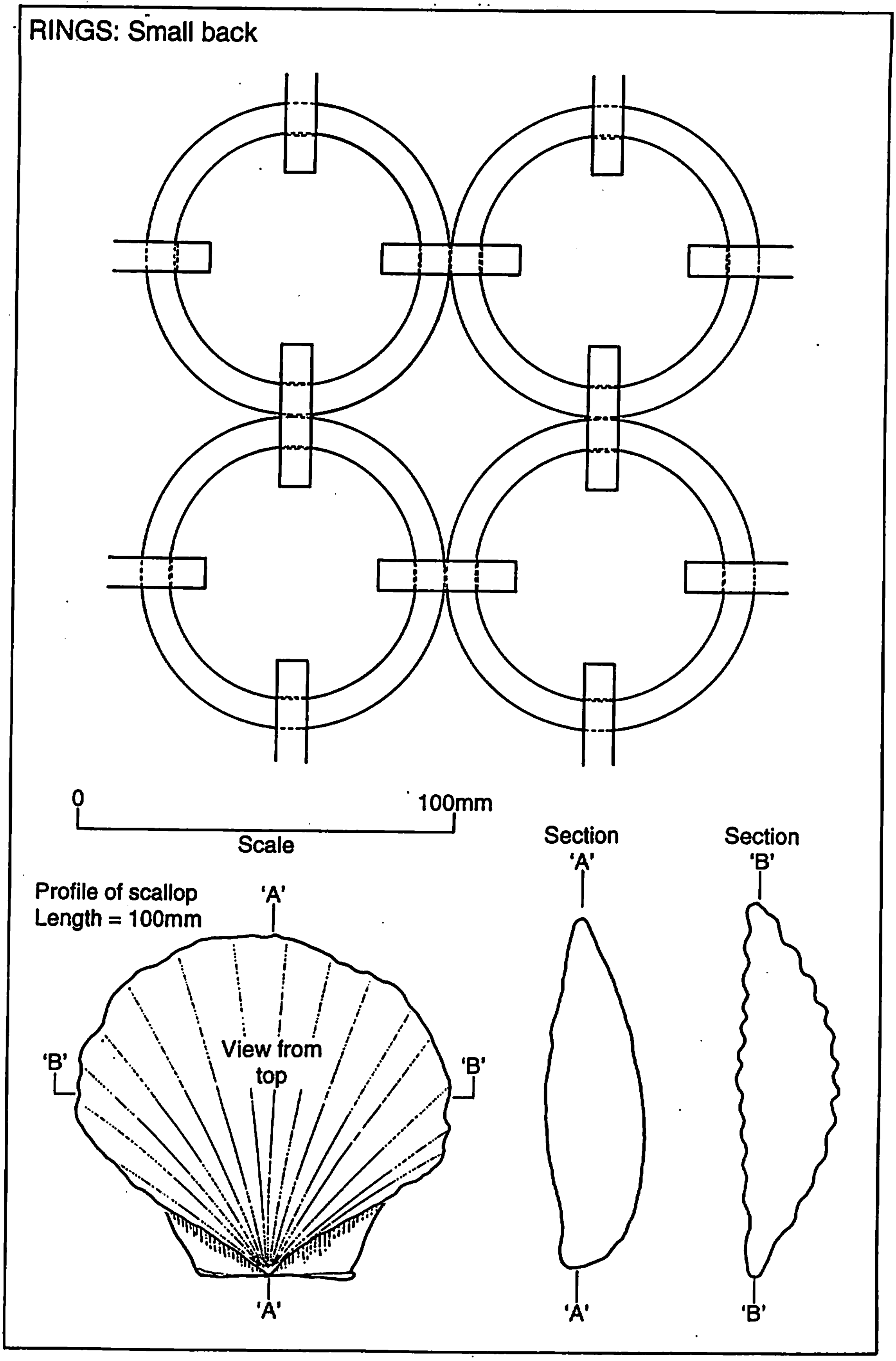


Figure 34: Ring profile compared with Scallop profile – large back

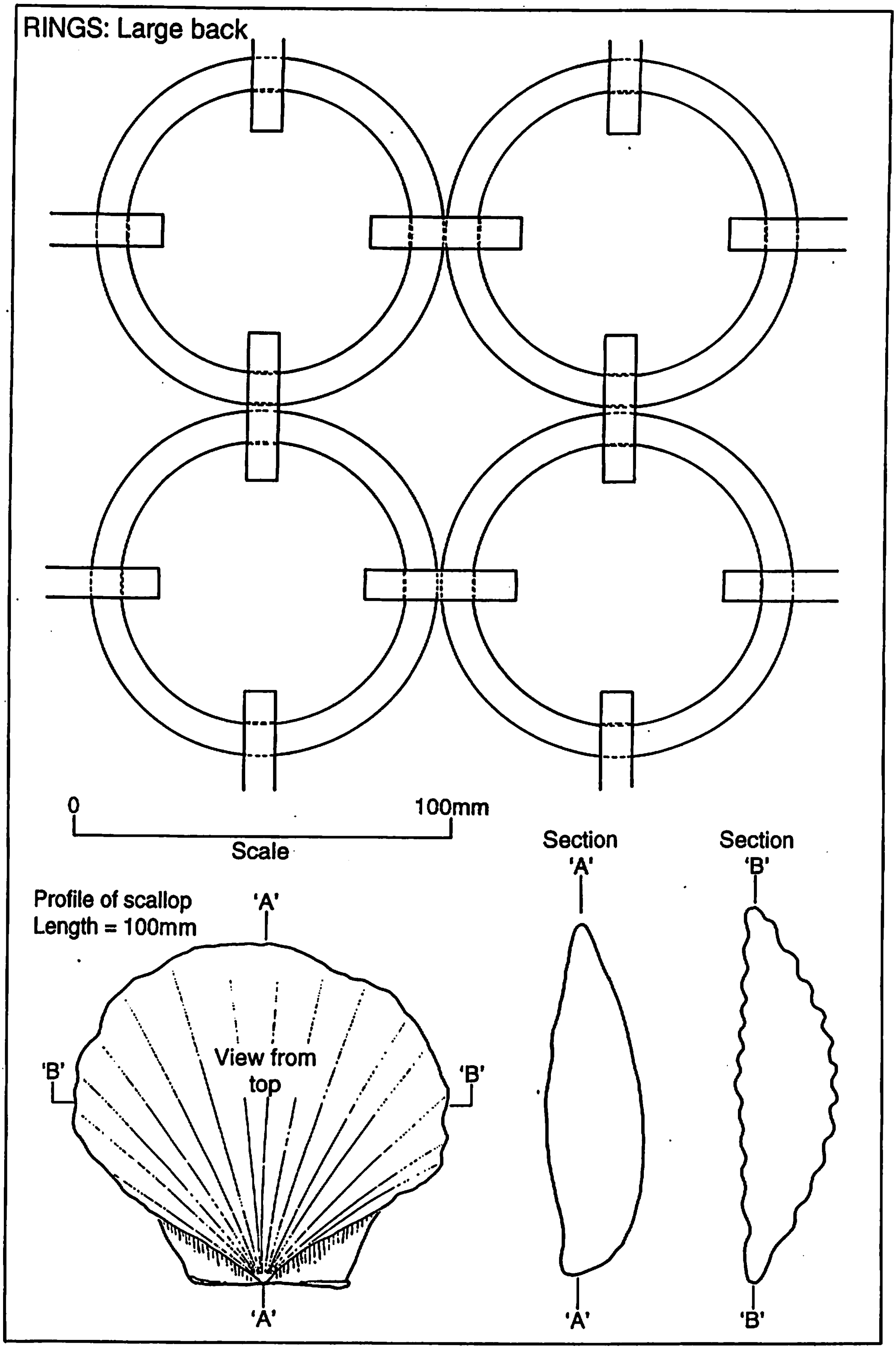


Figure 35: Tooth profile compared with Scallop profile – small tooth spacing

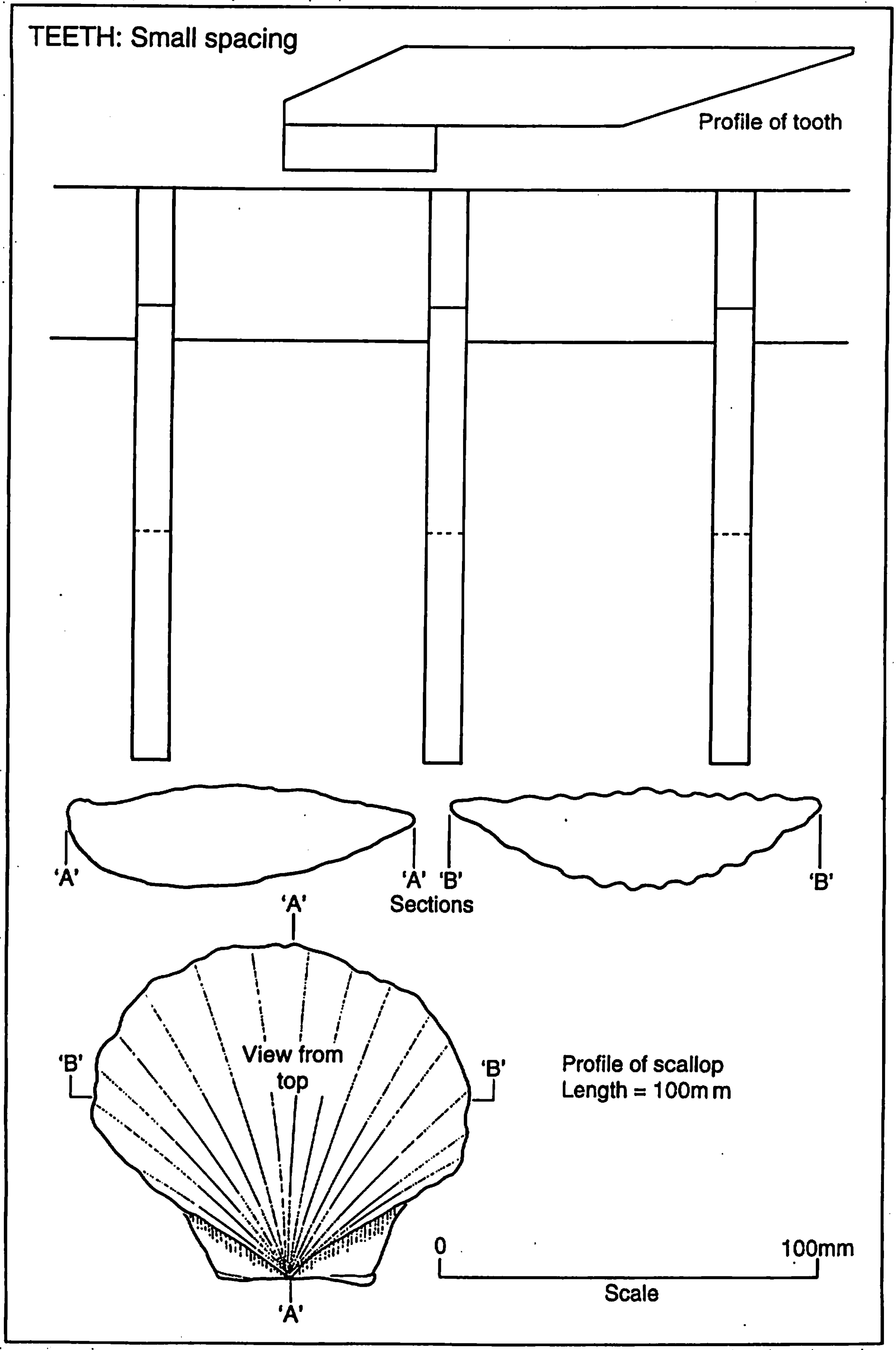
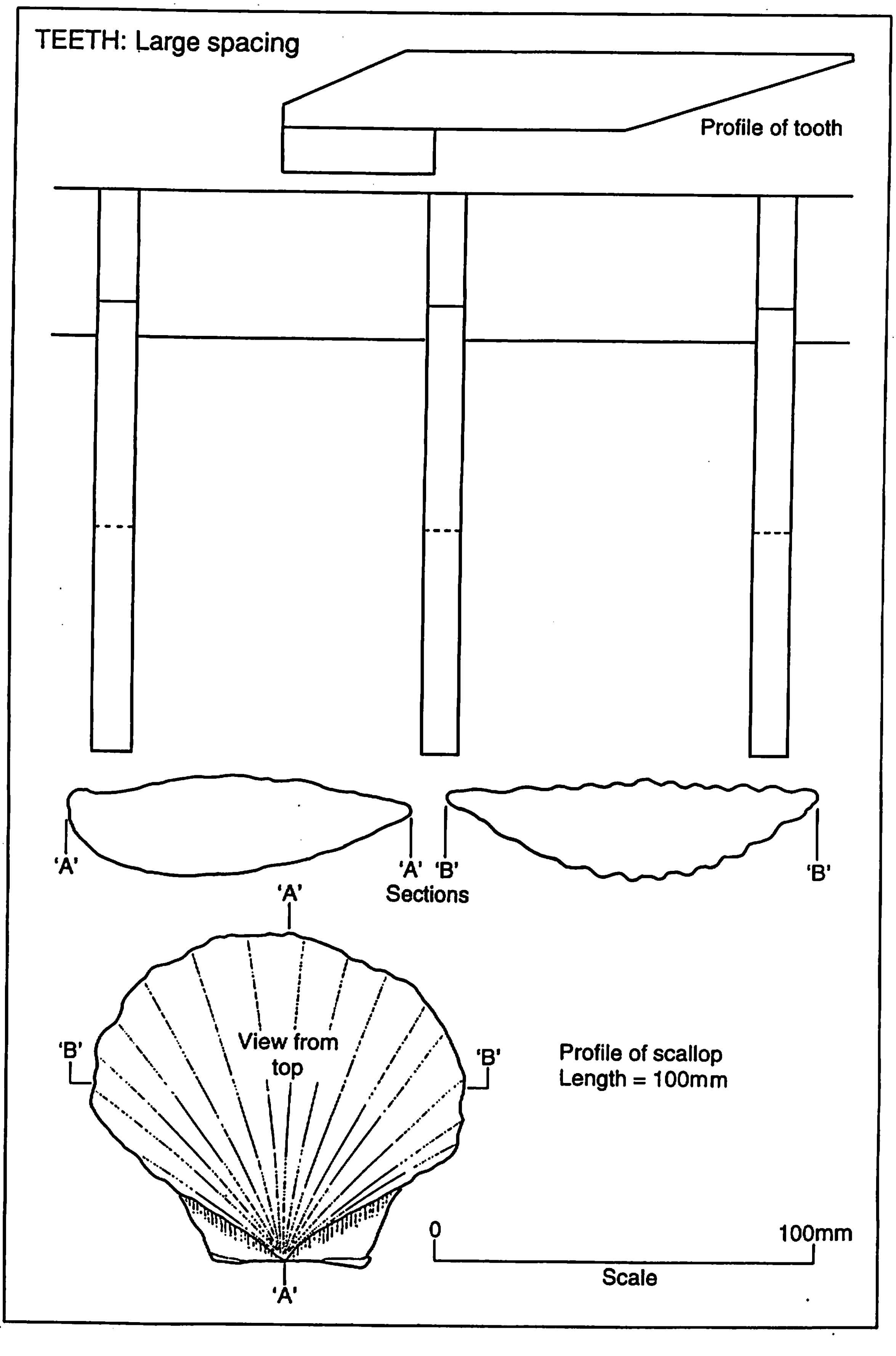


Figure 36: Tooth profile compared with Scallop profile – large spacing



Some important factors must be taken into account when considering the geometrical relationships:

1. It is unknown which part of the rings select the scallops. The scallops could pass through the rings or pass between them or a combination of both.

2. The rings are not static structures. There is scope for the scallops to work their way through the apertures between the rings. Their performance may also change over time and the rings may also allow larger scallops to pass between them or through them as they become worn.

3. The profiles of the scallops shown in these illustrations may not be that which is smallest in cross sectional area. Also, there is some variation in the profile of the scallops in terms of their length/width and length/height ratios (Section 6.4); the profile shown in the figures is close to the mean.

Another consideration is the size of the washers connecting the rings together. In this experiment the same washers were used both in the large and small ring sizes. Thus, the apertures between the washers are not in proportion to the ring size. Both components would therefore need to be defined in any proposed technical measure.

7.4 Proportion of stones
The large proportion of stones by volume captured by the dredges, and the increase in warp tension over the course of the haul suggests that a proportion of the vessel's power is being used to move stones over the seabed. There may be environmental and energy saving benefits if means can be found of reducing the volume of stones captured whilst retaining the scallops.

8. Conclusions

- The study has shown that it is possible to use scallop dredges to compare relative selectivity. Care has to be taken to examine the data for sources of unwanted variation.
- In the locations and with these combinations of tooth spacing, ring and mesh sizes, ring size followed by teeth spacing contributed most to selectivity in terms of reducing the percentage of discards. Mesh size did not appear to contribute to selectivity at the mesh sizes used.
- There was a significant reduction in catch per effort of scallops larger than 100mm (the MLS) attributed to the larger tooth spacing. Increasing the ring size did not significantly reduce catch per effort of this size range.
- It is suggested that there may be scope for reducing the energy input into the seabed by finding means for reducing the quantity of stones taken. This could also have environmental and energy saving benefits.

9. Further work

- Examination of the geometrical and mechanical relationships involved in selection. This would be focussed on optimising the ring size and possibly tooth spacing for a given minimum landing size.
- Selectivity experiments carried out in different fisheries using appropriate gear.
- Examination of design features of the dredge which could reduce the retention of stones and, possibly, the benthic impacts of dredging.

10. References

DRINKWATER J., 1974
Scallop dredge selectivity experiments. International Council for Exploration of the Sea. ICES CM 1974/K:25