Canadian Atlantic Fisheries
Scientific Advisory Committee

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CAFSAC Research Document 89/17

CSCPCA Document de recherche 89/ 17

Gear performance in the Bay of Fundy scallop fishery.
II.- Selectivity studies

By

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ABSTRACT

Following concerns expressed by a component of the Bay of Fundy fleet that the gear used by the vast majority of the fleet was catching scallops at too small a size, a study was carried out jointly with the annual stock survey to look at other gear configurations. This investigation examines the selectivity of different ring sizes 78, 87, and 100-mm and different washer types, rubber and steel on a 78-mm ring which is the size commonly used in the Digby bucket for the Bay of Fundy scallop fishery. It also compares the fishing behaviour of variants of the conventional bucket, one with a ring bale bottom and another one with a side panel of offshore rings. 103 tows were carried out on 4 different bottom types (rock, shell debris, mussel bed, and moss). Bucket configurations of different ring sizes and washer types retain different sizes of scallops until saturation. The larger the ring size and / or the more inter-ring space left by the washers used to knit the rings, a lesser amount of small scallops will be retained. Using ring size as a comparative basis, (i.e. keeping washer type constant) a 78-mm ring has the highest retention values for 71-100 mm shell height (SH) scallops; 87 and 100-mm rings are very similar with best results for SH over 100 mm. Using washer types as a comparative basis, (i.e. keeping the ring size at 78-mm) rubber washers best retention is at 81-90 mm SH, steel washers at 91-110 mm SH. To select against scallops under 80 or 90 mm SH, the 78-mm bucket with rubber washers configuration should not be used. The 78-mm bucket with steel washers was better than the 87 and 100-mm rings at retaining SH classes over 91 mm. For SH under 80 mm, only the 100-mm bucket with rubber washers design was selecting against smalls better than the 78-mm bucket with steel washers.

RESUME

Des membres de la flottille de la Baie de Fundy s'inquiètent du fait que l'engin de pêche couramment employé par la majorité des pêcheurs capture des pétoncles de taille beaucoup trop petite. On a donc entrepris une étude de différentes configurations de paniers de dragues en même temps que l'inventaire de recherche annuel. Ce projet examine la selectivité de différentes grandeurs d'anneaux, 78, 87, et 100-mm et différents types de rondelles, caoutchouc et acier sur un anneau de 78-mm, ce qui est normalement utilisé par cette flottille. On compare aussi le patron de pêche de deux variations du panier traditionel, un panier avec un fond troué et un autre panier avec un panneau latéral d'anneaux hauturiers. On a effectué 103 coups de drague sur 4 types de fond différents (roche, débris coquilliers, moulière, et mousse). Des configurations de paniers avec différentes tailles d'anneaux et différents types de rondelles retiennent différentes grosseurs de pétoncles jusqu'à saturation. Plus large est le diamètre de l'anneau et / ou l'espace entre les anneaux, moins de pétoncles de petite taille seront retenus. Lorsqu'on compare la grandeur de l'anneau (type de rondelles gardé constant) un anneau de 78-mm retient le mieux les pétoncles de hauteur de coquille (SH) de 71-100 mm; les anneaux de 87 et 100-mm sont très semblables avec de meilleurs résultats pour des SH de plus de 100 mm. Lorsqu'on compare le type de rondelles, (taille d'anneau gardé à 78-mm) les rondelles de caoutchouc sont supérieures pour les SH 81-90 mm, les rondelles d'acier pour 91-110 mm. Afin d'éviter la rétention de pétoncles de moins de 80 ou 90 mm de SH, on ne devrait pas employer de paniers avec des anneaux de 78-mm et des rondelles de caoutchouc. Le panier avec des anneaux de 78-mm et des rondelles d'acier était meilleur que ceux avec des anneaux de 87 et 100-mm pour retenir des SH de plus de 91 mm. Le panier avec des anneaux de 100-mm et des rondelles de caoutchouc était le seul panier à éviter la rétention de pétoncles de moins de 80 mm SH d'une façon supérieure au panier avec des anneaux de 78-mm et des rondelles d'acier.

INTRODUCTION

A study of gear fishing behaviour was recommended in the Bay of Fundy Scallop Management Plan resulting from the Inshore / Offshore Agreement (September 1986). The Bay of Fundy fleet has built up considerable fishing power and had been expecting to sustain high landings. During the 1980's, the traditional grounds had been suffering from heavy exploitation and catch-rates were declining substantially (Robert et al 1988). The fleet considered catching scallops at a smaller size, hence the popularity of rubber washers for the gear; they fill the inter-ring space to a greater extent than steel washers and reduce the escapement of small scallops. But, at the same time, another component of the fleet realised that catching a greater number of smalls might maintain present landings but jeopardise future yields, especially if recruitment was not to keep up with such high expectations. Lately, a sizeable recruitment pulse showed up on the traditional grounds, more particularly in the inside fishing zone, the most productive area. It alleviated some of the concerns, but excessive retention of scallops under 90 mm shell height (SH) meant that an important year class was to pass in the fishery and, with considerable loss of yield.

Attention was therefore focussed on the retention aspects of different types of Digby buckets. Our survey work of 1987 had provided the opportunity to look closely at the inter-ring space by testing 2 types of washers, rubber and steel, on a conventional bucket of 76-mm wire rings (Robert and Lundy 1988). With the same ring size, buckets with rubber washers had 100 % retention of much smaller size scallops (71-90 mm Shell Height) than buckets with steel washers (over 100 mm SH). By selecting toward relatively smaller scallops, buckets with rubber washers were only 33 % efficient in terms of meat yield shucked compared to scallops retained in buckets with steel washers.

While the 1987 project was an investigation of opportunity, the present one is a full-fledged study. It compares the selectivity of different ring sizes, approaches the subject of inter-ring space again (washer types) and examines the performance of conventional buckets to which a few design changes were made to the bottom or sides of the bucket.

Numerous studies have looked at different aspects of scallop fishing gears such as the New Bedford offshore rake (Bourne 1965 and 1966; Caddy 1968, 1971, and 1973) used by the Canadian offshore fleet, the toothed scallop dredge commonly used in the United Kingdom scallop fishery (Baird 1959; Mason 1983 for a comprehensive review) but relatively little work has been carried out on the Digby scallop drag per se. An extensive literature search produced few results (Dickie 1955; Medcof 1952; Worms and Lanteigne 1986). Even though Medcof (1952) got interesting results, his study would have been more meaningful if Digby rings would have been used instead of offshore rings. It seems highly probable that effects of ring size and bucket configuration, have yet to be quantified for the Digby type of scallop fishing gear. We feel that it may be highly misleading to compare or project conclusions obtained from a large capacity offshore rake to a Digby bucket which dimensions, mouth design, knitting materials, etc. all differ, hence the need for an appropriate investigation of the Digby drag itself.

As in 1987 the annual stock survey (Robert et al 1988) was combined with investigative work on gear behaviour. The 1988 survey, however, offered more opportunity to fish simultaneously a greater variety of bucket types.

METHODS

Gear specifications

Gear design for scallop dredging in the Bay of Fundy has changed very little since the 1940s. MacPhail (1954) gives excellent descriptions of individual drags or buckets, gang of drags, and of fishing operations. The present day fishery uses individual buckets (usually, 76 cm, inside width) made of rows of wire rings, 7 deep, 9 across, 3 on the side fastened to an angle iron frame at the mouth and a piece of wood (25X50 mm) at the tail end. Wire rings of 4 mm steel wire have an inside diameter of 76 mm; they are linked together with 2-25 mm steel washers or, most commonly, 2-46 mm rubber washers (Figure 1). Under commercial conditions there are numerous variants as to the width of a bucket, from 46 to 76 cm, combination of washers (rubber being used to link top and/or bottom row(s) and sides, steel for the remainder of the bucket), absence or presence of teeth welded to the mouth frame and different configurations of bottom sections, solid to ring-like. In Bay of Fundy waters the maximum overall width of scallop fishing gear is regulated at 5.49 m which means that 7 conventional 76 cm buckets is the widest allowed. Individual buckets are shackled to a steel pipe (bar) at regular intervals along its width. Bridle chains connect each bucket from the bar to the warp via a main swivel.

Buckets were knitted with rings of increasing diameter (inside) and, in some drags, different types of washers following that the retention pattern of small scallops will vary according to the escapement possibilities offered by larger rings and/or inter-ring spaces. Table 1 and Figure 1 describe the pertinent details of bucket configurations evaluated. Buckets were assembled in a gang of seven on the tow bar, one of each of the following: 78-mm lined, 78-mm rubber, 78-mm steel, 100-mm rubber, 2 buckets of 87-mm rubber plus one variant of the 78-mm rubber bucket, either a ring bale bottom or a side panel of offshore rings (75 mm). There may be a variation of 2-3 mm in the diameter of rings used depending on the supplier; it does not appear to be of significance. Rubber washers are most frequently used by the fleet because it saves the gear from some wear and tear. They also gained wide acceptance a few years ago when the stocks were noticeably depressed as they block considerably more inter-ring space than steel washers do.

It is believed that juveniles could escape to a greater degree from a bucket made of a non-solid bottom. A 'ring bale' bottom, instead of a solid piece of wood is made up of 2 rows of offshore rings welded together. Offshore rings are welded in a single piece in contrast to wire rings and of thicker diameter (10 vs 4 mm). It is also perceived that a panel of offshore rings on the bucket sides would play the same role. These 2 variants of the conventional bucket were tried for 58 and 44 tows respectively.

A bucket was lined with 38-mm polypropylene stretch mesh to improve the retention of juvenile scallops. The lined bucket gives an indication of the minimum number of small animals which could enter the bucket but would not be retained in the other types of buckets. A lined bucket would effectively retain scallops with SH over 40 mm.

Possible test combinations are as follows. (A plus sign denotes bucket configurations used for the experiment, see column heading.)

	Increasing ring size (rubber washers only)	Inter-ring space (washer type)	Variants of conventional 78-mm rubber bucket
78-mm lined	+	+	+
78-mm rubber	+	+	+
78-mm steel	-	+	-
87-mm rubber	+	-	-
100-mm rubber	+	-	-
78-mm rubber with ring bale bottom	-	-	+
78-mm rubber with side panel offshore rings	-	-	+

Sampling procedures

For stock assessment purposes, the survey stations are randomly stratified according to the catch distribution on the commercial fishing beds (Robert et al 1984). Although fishery performance has recovered, especially in the inside fishing zone, the fleet has still been covering fishing grounds extensively in the outside fishing zone, from Centreville to Hampton, Nova Scotia. It follows that survey work was also giving wide coverage to the fishing areas. If the nature of the bottom influences the catch, this variable would be encountered although the sampling design was not stratified after bottom types.

Survey tows are 8 minutes long. The distance towed, with the tide, is determined by the continuous recording of LORAN C bearings on a desktop computer (Jamieson, 1982). In this fashion, a position is recorded every 2 seconds while in tow mode which allows to establish quite accurately the area dragged during a tow. Tows are standardised to a 800-m length or 4,267 square meters is the area swept per tow.

For each tow, the following data were recorded: 1) shell heights (SH) in 5-mm intervals for all live scallops and cluckers fished by each bucket; 2) tow location with LORAN C bearings at start and end of tow; 3) depth (m); 4) direction of tow from compass bearing; 5) duration of tow in minutes; 6) bottom type(s) as a subjective volume appreciation of the material fished by the drag in addition to scallops; 7) count of the number of vertical bucket rings which were covered by the catch; and 8) total scallop catch as a round weight.

Shell height is measured as the distance between the hinge (umbo) and the farthest ventral margin of the shell in a straight line. Height measurements record the maximum physical dimension of scallop shells; it should be an adequate observation with respect to degrees of selectivity offered by different sizes of rings used to knit a bucket. Mechanically speaking, the physical dimensions of shell height transfer well to the sizes of bucket rings or inter-ring spaces. For the current study, shell height readings have been grouped in 10-mm intervals (e.g. 31-40, 41-50, etc.). In the graphs, height classes are denoted by the maximum value within that class (e.g. 80 refers to readings between 71 and 80 mm SH).

It is also valuable to group scallops by age classes. Ever since the studies of Stevenson (1935) it has been recognised that scallop growth-rate varies depending on the location of the aggregation in the Bay. Depth is the most easily related factor to growth differences. From materials collected during the 1980s stock surveys, present day growth rates have been established according to three main depth gradients. Table 2 presents a series of shell heights at age with respect to depth. (See also Robert et al 1985, 1987).

For the purposes of this investigation, results are presented both in terms of average number of scallops per standard tow on a shell height basis and on an age basis. The latter is easy to visualise but young ages encompass a large spread of height values due to a fast growth rate at this stage. As such, grouping by age loses a great deal of the information it carries. Furthermore, biomass is estimated according to the allometric relationship between meat weight and shell height which, to approximate a 'year round' value is :

$$\ln \text{meat weight (g)} = -13.291 + 3.401 \ln \text{shell height (mm)}$$

This equation is derived from the analysis of 3,388 measurements collected throughout the year during the 1982 to 1986 commercial fishing operations.

Bottom types

Scallop beds off Digby are found on four different bottom types. The stock survey data was poststratified according to bottom types as we hypothesize that the gear may fish differently on rocky bottoms compared to substrates where large amounts of shell debris were present. In addition scallops are also found over mussel beds off Parker's Cove and Young Cove and in other areas, scallops live in a jungle of bryozoans. The 1988 stock survey had 68 stations on rocky bottom, 13 over mussel beds, 10 on bryozoans, and 12 over shell debris. This ratio is not necessarily representative of the areas covered by the 4 bottom types where commercial scallop beds occur. A schematic map of substrates (Figure 2) observed during the 1985 to 1988 surveys with 456 data points shows that rocky bottoms predominate while the area where bryozoans, commonly referred to as moss, carpet the bottom is much smaller. Caddy et al (1970) give a map of bottom types according to sounder readings which roughly corresponds to ours; theirs does not detail the nature of the substrate though.

Stock profile

Needless to say that to study the retention potential of bucket designs, the scallop stock under study has to carry such size classes in sufficient quantities for meaningful statistical analysis. A stock lacking young sizes will reveal an apparent exclusion of smalls even in a lined bucket. However, it is difficult to find great quantities of old, large scallops in a stock under (heavy) commercial exploitation. A strong recruitment pulse has brought in great numbers of small scallops; the size range 51-100 mm SH is abundantly represented. This is a slightly better size structure than the one observed in 1987 as more scallops over 90 mm SH are present. Abundance of prerecruits makes for ideal conditions to study the exclusion characteristics of different gear designs.

Gear evaluation

To evaluate gear performance from a conservation point of view involves addressing two main points. First, the gear actively selects against small size scallops by not collecting smalls in the path and/or alternatively not retaining smalls if and when they enter the gear. From a yield perspective small scallops produce relatively much less meat per unit compared to large animals. This is the problem of growth overfishing so obvious in scallop fisheries without regulation on minimum size. Second, since the optimum yield resides in large animals, they should become the target of the fishery and the gear used should be efficient at collecting and retaining such large scallops. For example, while 80 mm SH scallops produce about 100 meats per 500 g, only 33 meats from 110 mm scallops will weigh 500 g.

Such general principles may apply to any type of fishery. However, certain elements single out the harvesting of aggregated sedentary invertebrates like scallops from the pursuit of mobile, (disperse) finfish. Fishnets are made of flexible mesh material compared to non-malleable metal rings used to knit scallop drags. Mechanical properties of the two gear types are quite different. When a drag is towed over the bottom in search of scallops, it also collects bottom materials such as other epifauna, rocks of all sizes, shell debris, etc. Depending on the nature and quantity of this extra material, it may line or clog the gear much sooner than the clogging possibilities encountered by a fishnet sieving the water column at mid-depths. Furthermore while fish may swim through the net, given the opportunity; a lack of such mobility prevents scallops from escaping the ring bag as easily, once trapped among other scallop shells, rocks, starfish, etc.

Two main aspects of gear performance will be focussed on. Retention or selection (S_G) expressed as a percentage for each SH class or each age group equals:

$$\sum_{i=50\text{ mm}}^{i=140\text{ mm}} SH_i \ \frac{n\text{ caught}}{n\text{ entered}} \times 100 = \%\, S_{Gith} = \sum_{i=2\text{ years}}^{i=11+\text{years}} Age_i \ \frac{n\text{ caught}}{n\text{ entered}} \times 100$$

The ith class corresponds to one or more 10 mm height interval(s) or one or more year-class(es). Another factor used in studies on selectivity of fishnets is the selection factor (Clarke 1963) which is 50 % retention by the gear / internal mesh size. But in scallop drags there are 2 measures of mesh size: 1) internal ring diameter and 2) inter-ring space which vary depending on the type and number of washers used to link the rings. Under such circumstances the selection factor is the result of multiple mesh sizes and is a more complex derivation than with fish nets.

RESULTS

Gear configuration

Different bucket types were towed simultaneously on a single tow bar. This procedure enhanced the probability that all 7 buckets covered the same scallop aggregation compared to attempts at tow replication by navigational maneuvering using a single bucket type for each tow. The gang configuration of lined and unlined buckets on the same tow bar is equivalent to the alternate tow method mentioned in Clarke (1963). However, the comparison among bucket types and their location within the gang still had to be validated statistically. Jamieson et al (1979) had made extensive comparisons in this respect. Robert and Lundy (1988) verified that the catch of lined buckets is significantly (P 0.05 level) different from the catch of unlined buckets; lined buckets catch significantly more prerecruits under age 5 than unlined buckets; and that the location of buckets in the gang does not have statistical significance. Therefore any bucket type may be located anywhere on the tow bar and lined ones will catch more young scallops than unlined drags. Furthermore, there was no statistically significant difference (P 0.05 level) in the catch of the 2 87-mm rubber buckets for both prerecruits (ages 2-4) and recruits (age 4+) so the data of only one 87-mm rubber bucket is presented.

Frequency distribution

Analysis was carried out according to bucket types used in the gear and bottom types where tows were performed. Tables 3, 4, and 5 represent mean number of scallops per tow according to 10 mm SH increments. Table 3 presents the data stratified according to bottom types while the other set pools all tows together, regardless of bottom types. Since not all 103 tows used the same variant of conventional bucket, the data was further split into 2 sub-groups to compare results of, either tows with a ring bale bottom (Table 4) or tows with a side panel of offshore rings (Table 5). Another series of tables (Tables 6-8) present the same analytical data but grouped on an age basis. Lined buckets are not considered reliable for animals under 40 mm although some were collected in the rocky area. Prerecruit sizes (under 90 mm) are well represented over rocky bottom and shell debris but there are considerably less over mussel beds or mossy areas. However, the number of locations representing bottom types other than rock is up to seven times smaller than the number of rocky locations. In contrast to the preliminary study of 1987 (Robert and Lundy l988), recruited sizes, at least for young ones (91-100 mm SH) contribute significantly to the histogram. Older recruits decrease noticeably beyond 130 mm SH.

According to Figure 3 different bottom types show slightly different stock profiles with the moss bottom having a mode of large scallops at 120 mm SH, both the 78-mm steel and 100-mm rubber buckets retaining these better than other types of buckets but the low number of locations sampled does not make for conclusive results. At the other end of the histogram the profile for smalls is more or less the same regardless of bottom type with the 78-mm rubber catching the most of the 70 mm SH peak. Another peak at 90 mm SH is best represented by 78-mm rubber, over 800 scallops per tow in rocky areas and about 650 scallops per tow when all data are combined. At the 90 mm SH peak, the 78-mm rubber is followed (500 per tow all data) by 78-mm steel and 87-mm rubber; the 100-mm rubber had retained less than half the number of scallops in the 78-mm rubber.

Not all bottom types are graphically represented in Figure 4 because there were too few stations. Tows performed on rocky bottoms show very little difference between a conventional bucket and one with a ring bale bottom. The lower graph with all tow data has an almost identical catch curve. The catch difference for prerecruits and recruits was not statistically significant (P 0.05 level). The same peak at 70 mm SH is obtained from a lined bucket, a conventional one and one with a ring bale bottom. So the perception that such a feature would allow smalls through is not verified experimentally. The retention characteristics at the 90 mm peak from this set of data follows the same pattern than the ones observed above.

Only a small number of stations (7-18) of each bottom types were sampled with a 78-mm bucket with a side panel of offshore rings. Figure 5 has a graph with all data combined (lower half). The stock profiles from a conventional bucket and one with a side panel are nearly identical. There is no significant (P 0.05 level) difference for recruited age groups and a small degree of significance (P 0.15 level) for prerecruits; this is noticeable at the 70 and 80 mm SH intervals. So, more selection would be achieved by using a large ring size instead of modifying a conventional bucket.

The data from the largest number of locations sampled simultaneously (103 tows) (Table 3 and Figure 3) is also used to look at the inter-ring space. Here a conventional bucket with rubber washers is compared to a bucket with the same ring size but linked with steel washers. The catch curves of the two buckets are identical for shell heights over 100 mm but there is a marked reduction in the catch of prerecruits in the bucket linked with steel washers, especially for SH under 80 mm. At these SH intervals, in Figure 3, the 78-mm rubber has retained twice as many scallops as the 78-mm steel bucket. These results are similar to the 1987 study (Robert and Lundy 1988). Comparatively speaking, less juveniles were escaping the 87-mm rubber than the 78-mm steel. For scallops over 100 mm SH, Robert and Lundy (1988) had shown that steel washers were retaining slightly more than rubber washers while in this study, no difference is observed between washer types.

Selectivity and increasing ring size

In the present context retention of smalls or selection against prerecruits (under 90 mm SH) are synonymous. Percentage retention is expressed as a percentage of scallops per standard tow in at least one 10 mm SH class retained in the drag from the total number in that corresponding class caught in the lined bucket. Scallops below a certain size could have entered the unlined bucket but were not retained. It is assumed that lined buckets catch all scallops in the path of the drag with shell height over 40 mm until the buckets are full. Numbers of scallops with shell height under 40 mm are not reliable since the lining material used was 38-mm mesh. Table 9 presents data on which ring size retained the most scallops of the lowest shell height. A wide diversity exists among bottom types. In mussel beds and shell debris smaller scallops are retained whatever ring size is used compared to rock and moss. In shell debris, the 78-mm ring has the highest retention for scallops whose height is almost half the diameter of the ring. In rocky areas and moss the 100-mm ring has a minimum size of full retention at 121-130 mm SH. These results might not necessarily be conclusive except for rocky locations because of the low sampling intensity.

More detailed retention characteristics are further given in table 10 for data from all bottom types pooled together and for rocky areas. For any ring size in particular, the retention of smalls is enhanced from rock bottoms to all tows combined. For example, on rocky bottoms the 78-mm ring retains: 65 % (41-50 mm SH), 82 % (51-60 mm SH), 93 % (61-70 mm SH), and 100 % (over 71 mm SH); these values increase to 76, 88, 99, and 100 % respectively when all tows are combined. Of the three ring sizes, the 78 and 87-mm rings retain 100 % of relatively small scallops at 71-80 mm SH and the 78-mm ring reaches this stage more quickly than the 87-mm ring. The retention profile (figure 6) of the 100-mm ring is much less steep; it retains only 56 % of the 71-80 mm SH class and 100 % of a larger size scallop at 101-110 mm SH. On an age basis, the 78-mm ring excels at retaining age 4 scallops while the 87-mm ring keeps only 60 % age 4 in comparison and the 100-mm ring 40 %. An increasing ring size definitively selects against age 4 scallops. Rings of 78 and 87-mm are relatively comparable for age 6 while the 87 and 100-mm ring are 20 % better at retaining age 7 scallops.

Selectivity and inter-ring space

The Digby scallop dredge bucket is made up of metal rings joined together with washers, the wire rings passing through the washer center hole. The retention potential of the bucket is influenced by the inside diameter of the wire rings but also by the space left between adjacent rings after they have been linked with the washers. Washers may be of two types: rubber and steel. Here we compare the retention potential of two washer types on a 78-mm diameter ring. When bottom types are considered separately, a 78-mm ring with rubber washers always retain 100 % of scallops caught at a much smaller size than a 78-mm ring fitted with steel washers (Table 9). Over mussel beds and shell debris, steel washers select against scallops up to 91-100 mm SH while rubber washers select against a considerably smaller size scallop at 41-50 mm SH. Over rocky areas and moss patches, the difference is less marked; 100 % retention is reached at 71-80 mm SH for rubber washers and 81-90 mm SH for steel washers. Regardless of bottom types steel washers retain 100 % of scallops of a larger size at 91-100 mm SH; therefore, steel washers select against a much wider group of scallop size classes compared to rubber washers.

Selectivity values for steel washers make for a more gradual slope than rubber washers (Table 10, Figure 6). Both washer types retain 100 % of large prerecruits (81-90 mm SH) but rubber washers retain up to 76 % of smaller size prerecruits, at 41-50 mm SH. Steel washers retain only 29 % of that particular size class. The 50 % selection factor for steel washers occurs at the 61-70 mm SH class interval. Whether one examines data from rocky bottoms or from combined tows, percentages of retention are, very similar (Table 10). All scallops over 90 mm are retained regardless of the kind of washers used. On an age basis, age 5 scallops are completely retained by rubber washers and age 6 scallops by steel washers. For any particular SH interval rubber washers always retain a higher percentage than steel washers; from twice as many for 50 mm (2 inches) scallops and more for 70 mm scallops. These results confirm our previous findings (Robert and Lundy 1988).

The selectivity curve of a 78-mm ring with steel washers has a lower slope and a 50 % selection factor at a larger size scallop than a ring of 87-mm diameter. This bigger ring has a steep slope with 50 % selection at the 41-50 mm SH level and complete retention at the 71-80 mm SH level. Full retention is reached much sooner than with a 78-mm ring linked with steel washers. The steel washers configuration is only surpassed in selection potential by the 100-mm ring.

Conventional bucket and its variants

Histograms of shell height classes of the conventional bucket, 78-mm rubber, and its variants with a ring bale bottom or a side panel of offshore rings show very well the high degree of similarity between the three configurations. Moreover, the similarity in gear behaviour has been tested statistically and no significant difference was found. The selectivity curves for such types of bucket would follow the curve of the 78-mm rubber very closely. These curves are not repeated in figure 6.

Efficiency in terms of meat yield

The term efficiency used here does not refer to the usual definition of gear efficiency (a measure of the number of scallops caught with respect to the number that were in the path of the gear) but more importantly, as a measure of selecting against smalls and retaining only large size ones since better meat yields are found in large animals. Meat yield is far from optimum in scallops under 100 mm SH, at 11 g approximately (100 mm). After all the rings and washers combinations examined had reached the 100 % retention level (i.e. SH over 100 mm cf. Table 10), the 78-mm steel was retaining an equal or greater quantity of scallops in the size range 101-130 mm than the 87 or 100-mm rings (Table 3) and certainly more than a 78-mm rubber bucket. With a 15 g meat in a 110 mm scallop, or 33 meats per 500 g, even a small, 10 %, difference in retention potential gets multiplied in terms of meat yield and value (Table 10). With respect to yield, steel washers are more efficient than rubber ones for the same ring size. The smallest ring size tested, 78-mm, but with steel washers stands the comparison with much larger ring sizes, up to 100-mm.

DISCUSSION

Bottom types

Our results indicate that the Digby drag may fish differently depending on the bottom type. There was a large difference between the abundance reported from rocky areas and the paucity found over moss bottoms. Was the difference encountered real or were scallops just as abundant on any bottom type and the gear could not show the true picture? This may not be determined accurately since the number of samples taken on bottoms other than rock was quite small. Another investigation could attempt to elucidate this point. It is of secondary importance however, because the extent of the commercial beds identified as rocky bottom far surpasses the areas covered by the other three bottom types. Rock bottom is a descriptor for a large range of sizes of rocky material, from small gravel particles to rocks of fist size and bigger. Worms and Lanteigne (1986) who segregated gravel from bigger size rocks did not establish a significant difference between the two.

Selection of ring and inter-ring space

Mechanical principles would advocate that retention should be complete for SH classes greater than the diameter of the ring used. Figure 6 shows that this takes place at a much larger size scallop for the 100-mm ring. Large scallops could not have escaped through inflexible metal rings of smaller diameter than themselves. Also, results indicate that the inter-ring space play a selective role, especially when using steel washers. The free inter-ring space is greater for steel washers than rubber washers (Robert and Lundy 1988). While towing, mechanical stress also modify the configuration of the escapement spaces on an on-going basis by stretching the rings. Medcof (1952) had noted the importance of the inter-ring space in the escapement of what he termed "legal-sized" scallops.

Bucket configurations of different ring sizes and washer types retain different sizes of scallops until saturation. The larger the ring size and / or the more inter-ring space left by the washers used to knit the rings, the lesser amount of small scallops will be retained. Using ring size as a comparative basis, (i.e. keeping washer type constant) a 78-mm ring has the highest retention values for 71-100 mm SH scallops; 87 and 100-mm rings are very similar with best results for SH over 100 mm (Table 3b). Using washer types as a comparative basis, (i.e. keeping the ring size at 78-mm) rubber washers best retention is at 81-90 mm SH, steel washers at 91-110 mm SH. To select against scallops under 80 or 90 mm SH, the 78-mm rubber bucket configuration should not be used. To select for scallops over 100 mm SH, rings of 87, 100-mm diameter (with rubber washers) could be used. However, the 78-mm steel was better than the 87 and 100-mm rings at retaining SH classes over 91 mm. But it was also catching more 81-90 mm SH than the larger rings.

For SH under 80 mm, only the 100-mm rubber design was selecting against smalls better than the 78-mm steel. This illustrates very well the meaningful selection brought about by the inter-ring space as was detailed in Robert and Lundy (1988).

Yield efficiency

Since the 78-mm steel is just as good as a much larger ring, 100-mm, for retaining scallops over 100 mm SH and since this configuration is also the second best among the ones tested to select against small scallops, it would contribute the most toward the enhancement of meat yield. Meat yield may be improved substantially by directing fishing effort toward scallops of 110 - 122 mm SH (ages 8 - 10) (low, high effort) as was shown in a yield per recruit analysis (Robert et al 1988). Another point worth noting is the tendency of buckets to fill with trash (rocks, shell debris, and other epifauna of no commercial value) in a bucket with little escapement potential. This same space could be occupied by a more valuable item such as scallops. Also, culling operations are rendered more tedious and performance decreases when there is a lot of trash to sort through.

At 5 g of meat per 80 mm SH scallop, the meat count in a bucket selecting for that size in particular runs in 100 meats per 500 g. But in a bucket selecting for a larger size scallop at 110 mm SH with a 15 g meat, the count is considerably improved at 33 meats per 500 g with optimal yield values under low effort levels.

SUMMARY

1.- This investigation examined the selectivity of different ring sizes 78, 87, and 100-mm and different washer types, rubber and steel on a 78-mm ring which is the size commonly used in the Digby bucket for the Bay of Fundy scallop fishery. It also compares the fishing behaviour of variants of the conventional bucket, one with a ring bale bottom and another one with a side panel of offshore rings.

2.- An important recruitment pulse has increased the relative abundance of prerecruits and created a most appropriate stock distribution to evaluate the retention of Digby buckets with respect to scallops under 90 mm shell height.

3.- Bottom types, rock, shell debris, mussel bed, and moss, may influence the fishing behaviour of the Digby bucket. Too few tows were performed on bottom types other than rock to draw definite conclusions applicable to all bottom types.

4- No significant difference was found in the fishing behaviour of the conventional bucket with 78-mm rings and rubber washers and its variants with a ring bale bottom or a side panel of offshore rings.

5.- Of the three ring sizes tested, the 78 and 87-mm rings retain 100 % of relatively small scallops at 71-80 mm SH and the 78-mm ring reaches this stage more quickly than the 87-mm ring. The retention profile of the 100-mm ring is much less steep; it retains only 56 % of the 71-80 mm SH class and 100 % of a larger size scallop at 101-110 mm SH.

6.- With a ring of 78-mm both washer types retain 100 % of large prerecruits (81-90 mm SH) but rubber washers retain up to 76 % of smaller size prerecruits, at 41-50 mm SH. Steel washers retain only 29 % of that particular size class. All scallops over 90 mm are retained regardless of the kind of washers used.

7.- The selectivity curve of a 78-mm ring with steel washers has a lower slope and a 50 % selection factor at a larger size scallop than a ring of 87-mm diameter. This bigger ring has a steep slope with 50 % selection at the 41-50 mm SH level and complete retention at the 71-80 mm SH level. Full retention is reached much sooner than with a 78-mm ring linked with steel washers. This configuration is only surpassed in selection potential by the 100-mm ring.

8.- After all the rings and washers combinations examined had reached the 100 % retention level (i.e. SH over 100 mm), the 78-mm steel bucket was retaining an equal or greater quantity of scallops in the size range 101-130 mm than the 87 or 100-mm rings and certainly more than a 78-mm rubber bucket.

9.- At 5 g of meat per 80 mm SH scallop, the meat count in a bucket selecting for that size in particular runs in 100 meats per 500 g. But in a bucket selecting for a larger size scallop at 110 mm SH with a 15 g meat, the count is considerably improved at 33 meats per 500 g with optimal yield values under low effort levels.

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Table 1.- Detailed configuration of experimental buckets in a 7-gang Digby scallop drag. All ring measurements are in mm and refers to the inside diameter.

Appellation in text	Ring characteristics			Washer type	Other items
	no. measured	mean diameter	s.d.		
78-mm rubber lined	10	77.5	0.53	rubber	lined
78-mm rubber	15	78.1	1.41	rubber	----
78-mm steel	15	77.8	0.94	steel	----
78-mm rubber, ring bale bottom	15	77.2	1.42	rubber	offshore rings
78-mm rubber, side panel	8	77.5	0.76	rubber	offshore rings panel of 74.6mm on average
87-mm rubber	13	86.5	2.73	rubber	----
87-mm rubber	13	86.9	1.85	rubber	----
100-mm rubber	15	99.8	3.10	rubber	----

Table 2.- Shell height (mm) at age for scallops coming from different depth intervals on the traditional beds off Digby. The data used was collected between 1982 and 1985 for a total of 7,051 shells sampled.

Age	Depth intervals (m)		
(years)	under 85	86-105	over 105
4	63	62	61
5	79	78	76
6	92	90	88
7	102	99	96
8	110	107	103
9	117	112	108
10	122	117	112
11	126	121	116

Table 3a.- Mean number of scallops caught in a standard tow by 10 mm shell height (SH) increments according to drag bucket types and bottom types. SH intervals go from 21 to 30, 31-40, 41-50,...etc.

SH increment	30	40	50	60	70	80	90	100	110	120	130	140	150	160
equivalent in inches						3 1/4	3 1/2	4						
ROCK, 68 locations														
78-mm lined	14	20	20	138	374	302	517	331	65	16	10	3	1	0
78-mm rubber	2	1	13	113	346	499	815	435	66	23	16	4	1	0
78-mm steel	0	1	4	52	157	214	658	440	86	27	12	5	1	1
87-mm rubber	0	1	8	73	214	262	600	430	77	25	16	14	1	0
100-mm rubber	0	0	5	71	154	159	335	271	69	23	16	5	1	1
MOSS, 10 locations														
78-mm lined	0	1	8	12	20	28	23	4	4	10	2	3	0	0
78-mm rubber	2	1	6	10	20	66	52	10	12	17	11	3	1	0
78-mm steel	0	0	3	11	13	47	75	23	30	34	13	4	0	0
87-mm rubber	0	1	3	3	9	48	35	17	29	23	11	1	0	0
100-mm rubber	0	0	0	0	1	5	7	6	22	31	14	3	0	0
MUSSEL, 13 locations														
78-mm lined	0	5	17	20	43	48	69	11	8	3	0	0	0	0
78-mm rubber	0	3	16	42	78	109	175	31	32	12	2	0	0	0
78-mm steel	0	0	6	25	38	117	109	49	58	15	1	1	0	0
87-mm rubber	0	3	11	21	55	165	128	41	35	16	1	0	0	0
100-mm rubber	0	1	6	10	38	34	41	42	72	29	3	0	0	0
SHELL, 12 locations														
78-mm lined	0	10	42	77	121	97	243	172	28	8	3	1	0	0
78-mm rubber	0	12	44	99	218	183	552	329	53	33	7	4	0	0
78-mm steel	0	5	21	50	180	172	515	334	90	26	10	2	0	0
87-mm rubber	0	14	37	79	193	238	529	237	61	31	11	1	0	0
100-mm rubber	0	0	12	46	102	104	395	288	88	42	12	6	0	0

Table 3b.- Mean number of scallops caught in a standard tow by 10 mm shell height (SH) increments according to drag bucket types and ignoring bottom types at 103 locations. SH intervals go from 21 to 30, 31-40, 41-50,...etc.

SH increment	30	40	50	60	70	80	90	100	110	120	130	140	150	160
equivalent in inches						3 1/4	3 1/2	4						
78-mm lined	9	15	21	104	268	219	380	241	48	13	7	3	0	0
78-mm rubber	1	3	16	92	266	371	630	330	55	22	12	3	1	0
78-mm steel	0	1	6	44	131	180	516	337	77	26	11	4	1	1
87-mm rubber	0	3	11	61	171	226	477	318	65	25	13	9	1	0
100-mm rubber	0	0	6	53	119	122	273	218	67	27	14	4	1	0

Table 4a.- Mean number of scallops caught in a standard tow by 10 mm shell height (SH) increments according to drag bucket types on rocky bottoms at 49 locations. A bucket with 78-mm rings, rubber washers and a ring bale bottom is designated by a superscript "B" in italics. SH intervals go from 21 to 30, 31-40, 41-50,...etc.

SH increment	30	40	50	60	70	80	90	100	110	120	130	140	150	160
equivalent in inches						3 1/4	3 1/2	4						
78-mm lined	19	26	20	139	411	334	544	338	73	18	11	3	0	0
78-mm rubber	2	2	16	123	383	547	865	449	69	21	17	4	0	0
78-mm steel	0	1	4	61	176	227	645	469	95	28	15	6	1	0
78-mm rubber*B*	0	1	9	124	355	490	849	418	77	20	15	4	0	0
87-mm rubber	0	1	9	84	230	288	613	433	82	25	16	18	1	0
100-mm rubber	0	0	7	88	183	188	354	282	71	22	18	5	1	0

Table 4b.- Mean number of scallops caught in a standard tow by 10 mm shell height (SH) increments according to drag bucket types ignoring bottom types at 58 locations. A bucket with 78-mm rings, rubber washers and a ring bale bottom is designated by a superscript "B" in italics. SH intervals go from 21 to 30, 31-40, 41-50,...etc.

SH increment	30	40	50	60	70	80	90	100	110	120	130	140	150	160
equivalent in inches						3 1/4	3 1/2	4						
78-mm lined	16	23	21	126	358	290	478	289	63	16	10	3	0	0
78-mm rubber	2	3	18	121	350	484	775	389	60	19	16	4	0	0
78-mm steel	0	2	6	60	171	217	584	408	84	25	14	6	0	0
78-mm rubber*B*	0	2	14	124	344	468	759	360	68	19	14	4	0	0
87-mm rubber	0	3	13	83	217	282	555	375	74	22	15	15	1	0
100-mm rubber	0	1	6	78	161	163	312	249	63	21	17	6	1	0

Table 5a.- Mean number of scallops caught in a standard tow by 10 mm shell height (SH) increments according to drag bucket types. A bucket with 78-mm rings, rubber washers and a side panel of 75-mm offshore rings is designated by a superscript "S" in italics. SH intervals go from 21 to 30, 31-40, ...etc. 18 tows sampled rocky bottom, 7 for moss (bryozoans), 10 for mussels, and 9 for shell debris.

SH increment	30	40	50	60	70	80	90	100	110	120	130	140	150	160
equivalent in inches						3 1/4	3 1/2	4						
ROCK														
78-mm lined	0	5	19	130	282	223	390	271	44	9	5	3	1	1
78-mm rubber	2	1	5	85	248	369	580	379	57	26	13	5	2	1
78-mm steel	0	1	3	30	104	163	594	348	64	25	6	4	2	3
78-mm rubber^{S}	0	1	8	70	172	224	621	387	45	22	6	3	2	0
87-mm rubber	0	1	6	46	172	187	472	411	59	25	13	5	3	1
100-mm rubber	0	0	1	26	84	86	265	224	64	28	9	5	1	2
MOSS														
78-mm lined	0	0	9	16	27	39	30	5	4	10	0	2	0	0
78-mm rubber	0	1	9	15	28	94	73	12	15	20	8	1	0	0
78-mm steel	0	0	4	15	18	67	106	30	39	39	12	0	0	0
78-mm rubber^{S}	0	0	6	12	10	120	57	8	26	36	8	0	0	0
87-mm rubber	0	2	5	4	12	69	50	20	39	32	12	1	0	0
100-mm rubber	0	0	0	0	1	8	10	7	28	38	14	2	0	0
MUSSEL														
78-mm lined	0	6	20	11	39	31	6	9	8	4	0	0	0	0
78-mm rubber	0	4	16	18	68	78	41	27	39	14	2	0	0	0
78-mm steel	0	0	8	14	40	52	39	54	71	19	2	0	0	0
78-mm rubber^{S}	1	6	18	32	70	84	52	47	37	17	1	0	0	0
87-mm rubber	0	4	9	10	43	52	26	46	38	19	1	0	0	0
100-mm rubber	0	1	6	7	41	32	13	46	89	32	3	0	0	0
SHELL														
78-mm lined	0	8	37	67	111	115	301	216	34	9	3	0	0	0
78-mm rubber	0	7	32	68	159	175	662	393	67	41	5	2	0	0
78-mm steel	0	2	10	34	111	176	551	383	98	32	6	1	0	0
78-mm rubber^{S}	0	3	25	68	156	227	658	232	63	30	6	0	0	0
87-mm rubber	0	8	22	47	145	248	620	267	65	38	11	1	0	0
100-mm rubber	0	0	15	42	101	124	490	327	105	51	11	2	0	0

Table 5b.- Mean number of scallops caught in a standard tow by 10 mm shell height (SH) increments according to drag bucket types. A bucket with 78-mm rings, rubber washers and a side panel of 75-mm offshore rings is designated by a superscript "S" in italics. SH intervals go from 21 to 30, 31-40, 41-50,...etc. All bottom types were pooled together. 44 locations were sampled.

SH increment	30	40	50	60	70	80	90	100	110	120	130	140	150	160
equivalent in inches						3 1/4	3 1/2	4						
78-mm lined	0	5	21	72	151	128	227	158	28	8	3	2	1	1
78-mm rubber	1	3	14	55	154	219	394	244	48	26	8	2	1	0
78-mm steel	0	1	6	25	77	125	381	238	69	28	6	2	1	1
78-mm rubber^{S}	0	2	13	52	120	176	410	218	44	25	5	1	1	0
87-mm rubber	0	3	10	32	112	150	334	236	53	27	10	2	1	1
100-mm rubber	0	0	5	21	65	69	213	170	73	35	9	3	1	1

Table 6a.- Mean number of scallops-at-age caught in a standard tow according to drag bucket types and bottom types.

AGE (years)	2	3	4	5	6	7	8	9	10	11+
ROCK, 68 locations										
78-mm lined	38	243	545	614	291	46	11	7	5	10
78-mm rubber	4	196	690	982	366	48	16	10	7	15
78-mm steel	2	91	299	782	371	63	20	11	6	14
87-mm rubber	2	130	387	718	366	57	18	11	7	26
100-mm rubber	1	107	258	411	232	50	16	10	7	17
MOSS, 10 locations										
78-mm lined	22	234	384	269	46	30	57	39	10	46
78-mm rubber	5	19	75	62	9	10	10	8	5	8
78-mm steel	2	13	53	86	23	25	24	11	6	9
87-mm rubber	2	7	49	44	20	24	18	8	5	4
100-mm rubber	0	0	5	8	9	19	21	12	6	9
MUSSEL, 13 locations										
78-mm lined	11	41	68	80	14	6	3	1	0	0
78-mm rubber	6	72	145	203	34	26	11	2	1	1
78-mm steel	2	35	113	150	55	43	16	3	1	1
87-mm rubber	6	37	160	185	42	27	13	5	1	0
100-mm rubber	3	20	60	48	52	58	24	8	3	1
SHELL, 12 locations										
78-mm lined	22	138	168	278	159	24	7	3	1	2
78-mm rubber	28	192	302	639	283	45	25	9	4	8
78-mm steel	9	118	274	614	280	72	22	8	5	5
87-mm rubber	26	142	356	606	209	46	24	8	6	7
100-mm rubber	2	83	161	475	244	68	30	16	7	10

Table 6b.- Mean number of scallops-at-age caught in a standard tow according to drag bucket types and ignoring bottom types at 103 locations.

AGE (years)	2	3	4	5	6	7	8	9	10	11+
78-mm lined	29	184	392	450	213	35	9	5	4	7
78-mm rubber	7	163	516	754	280	41	16	9	5	12
78-mm steel	2	79	249	615	287	58	20	10	5	11
87-mm rubber	5	108	322	572	273	49	18	10	6	18
100-mm rubber	1	83	197	333	189	50	19	11	7	13

Table 7a.- Mean number of scallops caught in a standard tow by age groups according to drag bucket types on rocky bottoms at 49 locations. A bucket with 78-mm rings, rubber washers and a ring bale bottom is designated by a superscript "B" in italics.

AGE (years)	2	3	4	5	6	7	8	9	10	11+
78-mm lined	49	258	601	651	293	50	13	8	5	10
78-mm rubber	5	216	760	1053	370	48	15	10	7	16
78-mm steel	2	104	329	781	389	67	20	12	7	16
78-mm rubber^{B}	3	204	695	1014	349	52	15	10	8	13
87-mm rubber	2	146	420	747	363	57	18	11	7	29
100-mm rubber	2	131	306	444	236	50	15	10	8	18

Table 7b.- Mean number of scallops caught in a standard tow by age groups according to drag bucket types ignoring bottom types at 58 locations. A bucket with 78-mm rings, rubber washers and a ring bale bottom is designated by a superscript "B" in italics.

AGE (years)	2	3	4	5	6	7	8	9	10	11+
78-mm lined	44	231	521	571	251	43	12	7	5	9
78-mm rubber	7	209	678	940	321	41	13	9	6	15
78-mm steel	3	105	311	709	339	60	18	11	7	15
78-mm rubber^{B}	5	209	657	915	301	47	13	9	7	12
87-mm rubber	5	144	400	682	315	52	16	10	6	25
100-mm rubber	2	117	266	391	208	45	14	10	8	18

Table 8a.- Mean number of scallops caught in a standard tow by age groups according to drag bucket types. A bucket with 78-mm rings, rubber washers and a side panel of 75-mm offshore rings is designated by a superscript "S" in italics. 18 tows sampled rocky bottom, 7 for moss (bryozoans), 10 for mussels, and 9 for shell debris.

AGE (years)	2	3	4	5	6	7	8	9	10	11+
ROCK										
78-mm lined	10	204	411	467	239	35	7	4	3	8
78-mm rubber	3	145	504	695	331	48	20	10	6	12
78-mm steel	1	57	209	684	303	52	19	9	3	9
78-mm rubber^{S}	3	114	317	736	323	35	17	7	2	6
87-mm rubber	3	88	298	553	356	57	16	11	6	15
100-mm rubber	0	43	141	308	207	52	19	10	4	14
MOSS										
78-mm lined	2	31	53	36	5	4	6	4	0	2
78-mm rubber	3	26	107	87	12	12	13	9	4	3
78-mm steel	2	18	75	122	30	33	30	12	6	1
78-mm rubber^{S}	1	17	116	74	11	21	24	13	4	2
87-mm rubber	2	10	71	63	24	32	24	10	6	2
87-mm rubber	2	10	76	48	17	26	18	10	5	3
100-mm rubber	0	0	8	12	12	25	26	15	7	5
MUSSEL										
78-mm lined	14	32	57	10	10	7	3	0	0	0
78-mm rubber	7	42	124	55	30	31	13	3	1	0
78-mm steel	2	26	79	51	63	53	20	4	1	0
78-mm rubber^{S}	14	53	129	70	50	28	13	3	1	0
87-mm rubber	6	22	86	36	48	29	15	6	1	0
100-mm rubber	3	17	64	17	58	73	28	8	2	0
SHELL										
78-mm lined	17	125	172	342	201	29	8	3	1	2
78-mm rubber	20	142	241	761	339	57	31	11	3	5
78-mm steel	3	72	227	661	320	80	28	8	2	4
78-mm rubber^{S}	10	114	306	747	203	50	25	8	4	2
87-mm rubber	15	90	321	708	232	51	30	10	6	7
100-mm rubber	2	78	178	583	278	81	37	19	8	4

Table 8b.- Mean number of scallops caught in a standard tow by age groups according to drag bucket types. A bucket with 78-mm rings, rubber washers and a side panel of 75-mm offshore rings is designated by a superscript "S" in italics. All bottom types were pooled together. 44 locations were sampled.

AGE (years)	2	3	4	5	6	7	8	9	10	11+
78-mm lined	11	121	225	269	142	23	6	3	1	4
78-mm rubber	7	102	301	466	213	40	19	8	4	6
78-mm steel	2	47	162	446	209	55	23	8	3	5
78-mm rubber^{S}	7	85	240	481	187	34	19	7	3	3
87-mm rubber	6	61	218	389	208	45	20	9	5	8
100-mm rubber	1	37	110	251	157	58	26	12	5	7

Table 9.- Minimum size of scallops (10-mm SH interval) fully retained by buckets of increasing ring size linked with rubber washers on 4 bottom types. The last column pertains to 78-mm ring with steel washers.

Bottom types	Shell height interval (mm)			
	78-mm ring	87-mm ring	100-mm ring	78-mm ring steel
Rock	71-80	91-100	121-130	91-100
Moss	71-80	101-110	121-130	81-90
Mussel	51-60	71-80	101-110	91-100
Shell	41-50	71-80	111-120	91-100

Table 10.- Percentage retention of scallops in 10 mm SH classes for increasing ring sizes, rubber washers for the first three ring diameters from all types of bottoms and for rocky locations The last column refers to a 78-mm ring with steel washers. Given the meat yield for each size class, an equivalent meat count per 500 g is also shown.

All tow data

Shell height	Meats	78-mm ring	87-mm ring	100-mm ring	78-mm steel
41-50	495	76	52	29	29
51-60	266	88	59	51	42
61-70	157	99	64	44	49
71-80	100	100	100	56	82
81-90	67	100	100	72	100
91-100	47	100	100	90	100
101-110	33	100	100	100	100

Rocky bottoms

Shell height	Meats	78-mm ring	87-mm ring	100-mm ring	78-mm steel
41-50	495	65	40	25	20
51-60	266	82	53	51	38
61-70	157	93	57	41	42
71-80	100	100	87	53	71
81-90	67	100	100	65	100
91-100	47	100	100	82	100
101-110	33	100	100	100	100

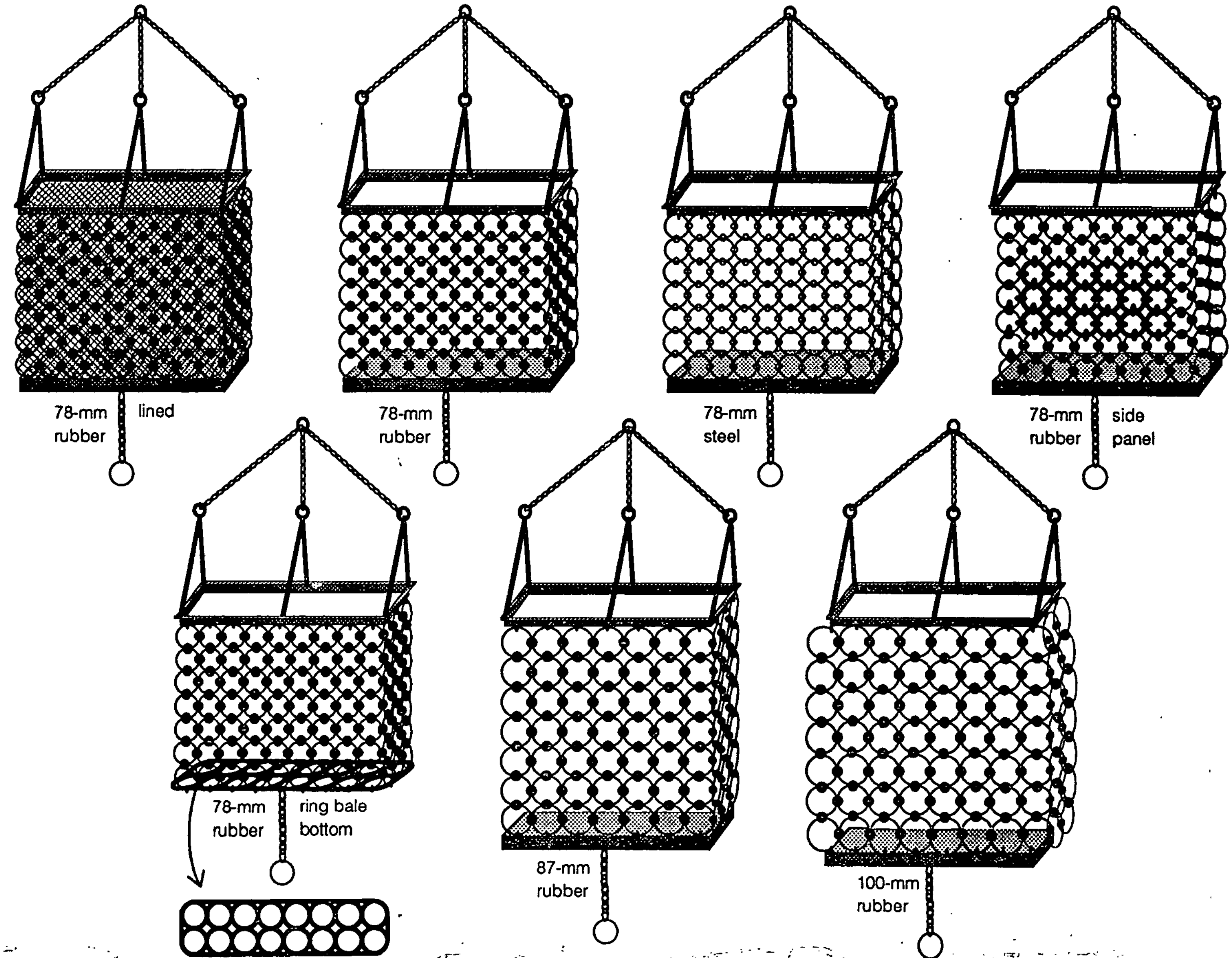


Figure 1.- Schematic representation of the bucket configurations under study. Seven are simultaneously towed on a bar under commercial conditions.

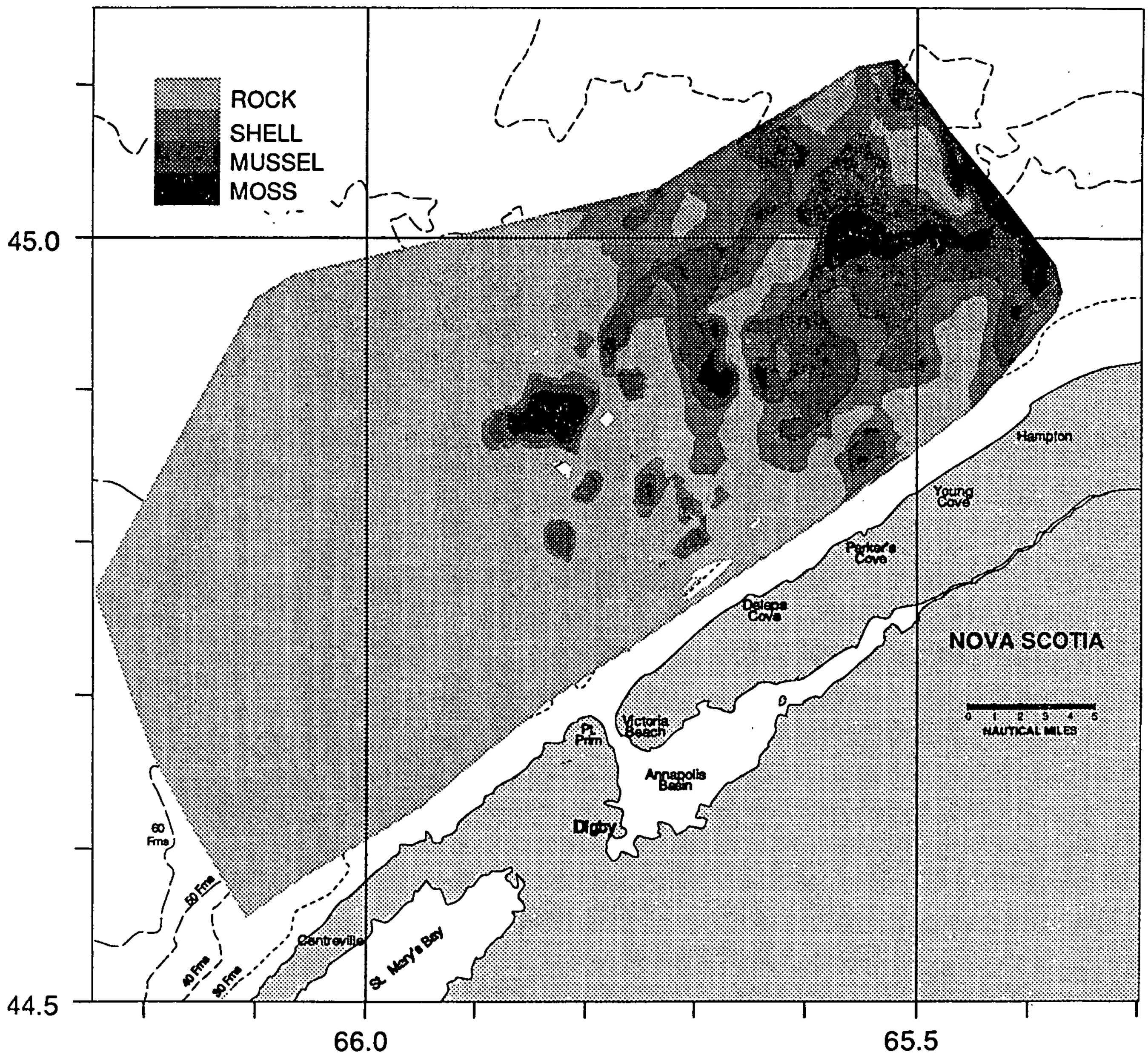


Figure 2.- Illustration of the main bottom types on the commercial scallop grounds off Digby, N.S. according to 456 observations taken during the 1985-88 annual stock surveys.

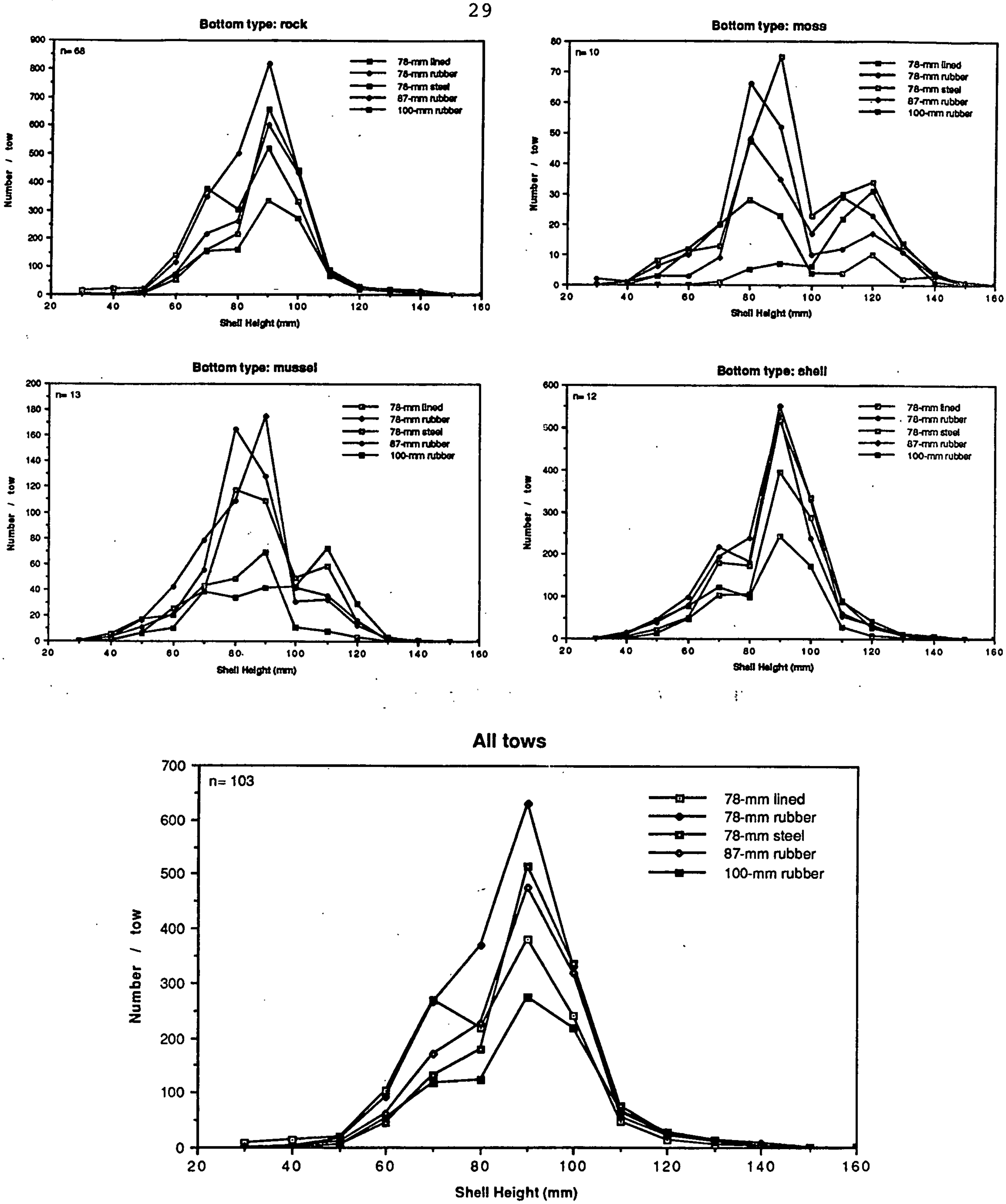
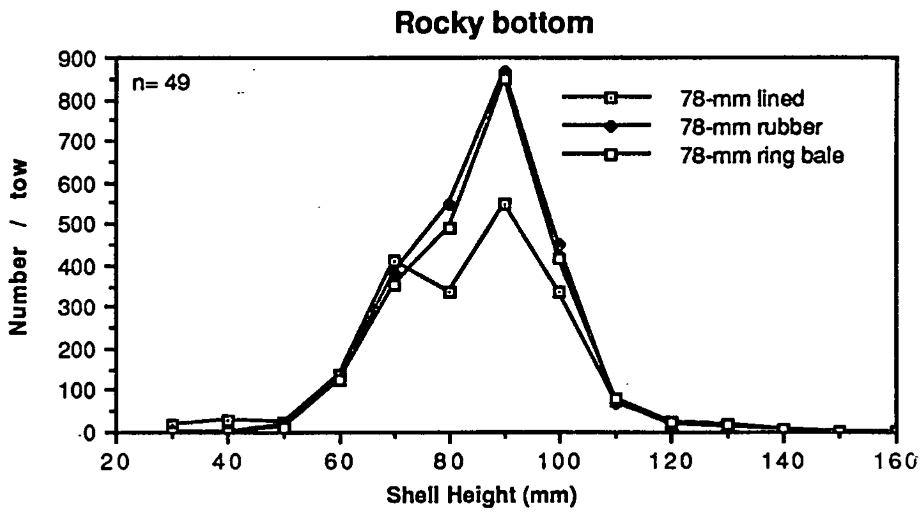


Figure 3.- Frequency distribution of the mean number of scallops per standard tow by 10-mm shell height intervals for buckets linked with rings of 78 to 100 mm inside diameter. Four bottom types are represented individually in the upper graph. All available data is used in the lower graph regardless of bottom types.



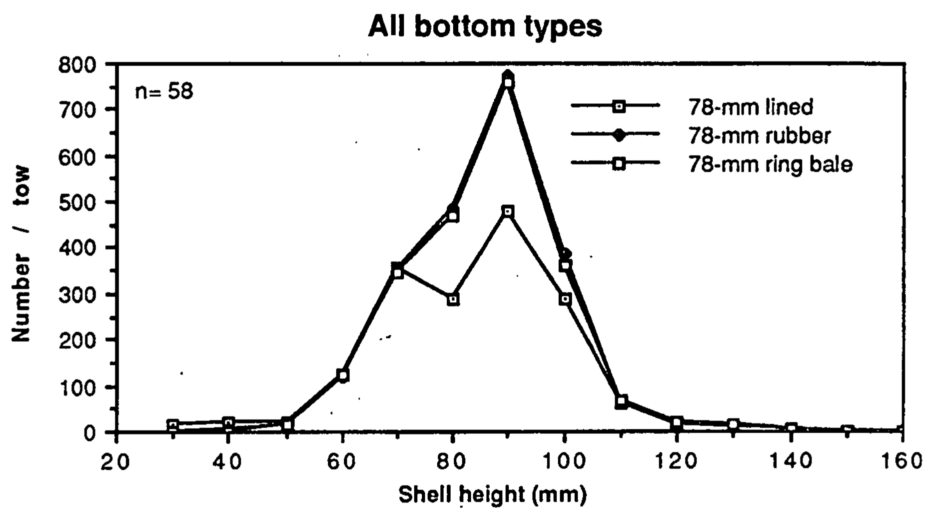
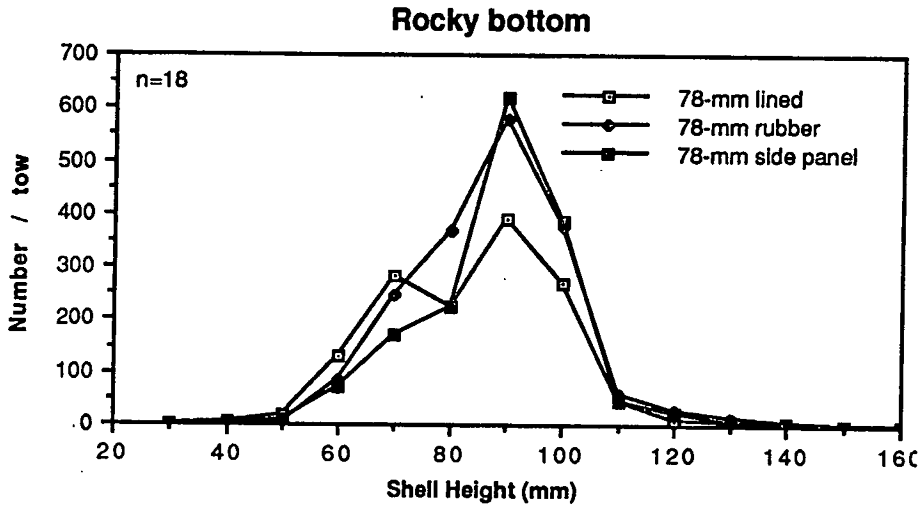


Figure 4.- Frequency distribution of the mean number of scallops per standard tow by 10-mm shell height intervals for a conventional 78-mm rubber bucket and another bucket that has a ring bale bottom. All available data is pooled together in the lower graph.



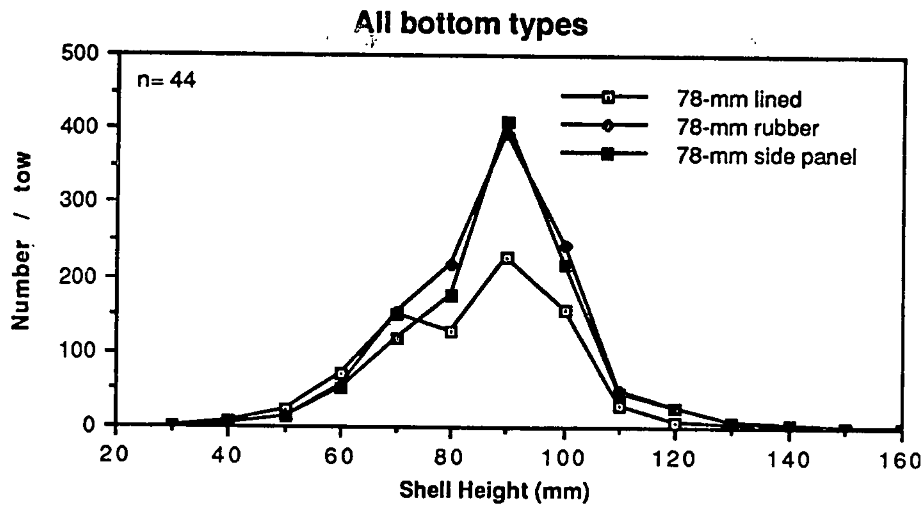


Figure 5.- Frequency distribution of the mean number of scallops per standard tow by 10-mm shell height intervals for a conventional 78-mm rubber bucket and another bucket with a side panel of offshore rings. All available data is pooled together

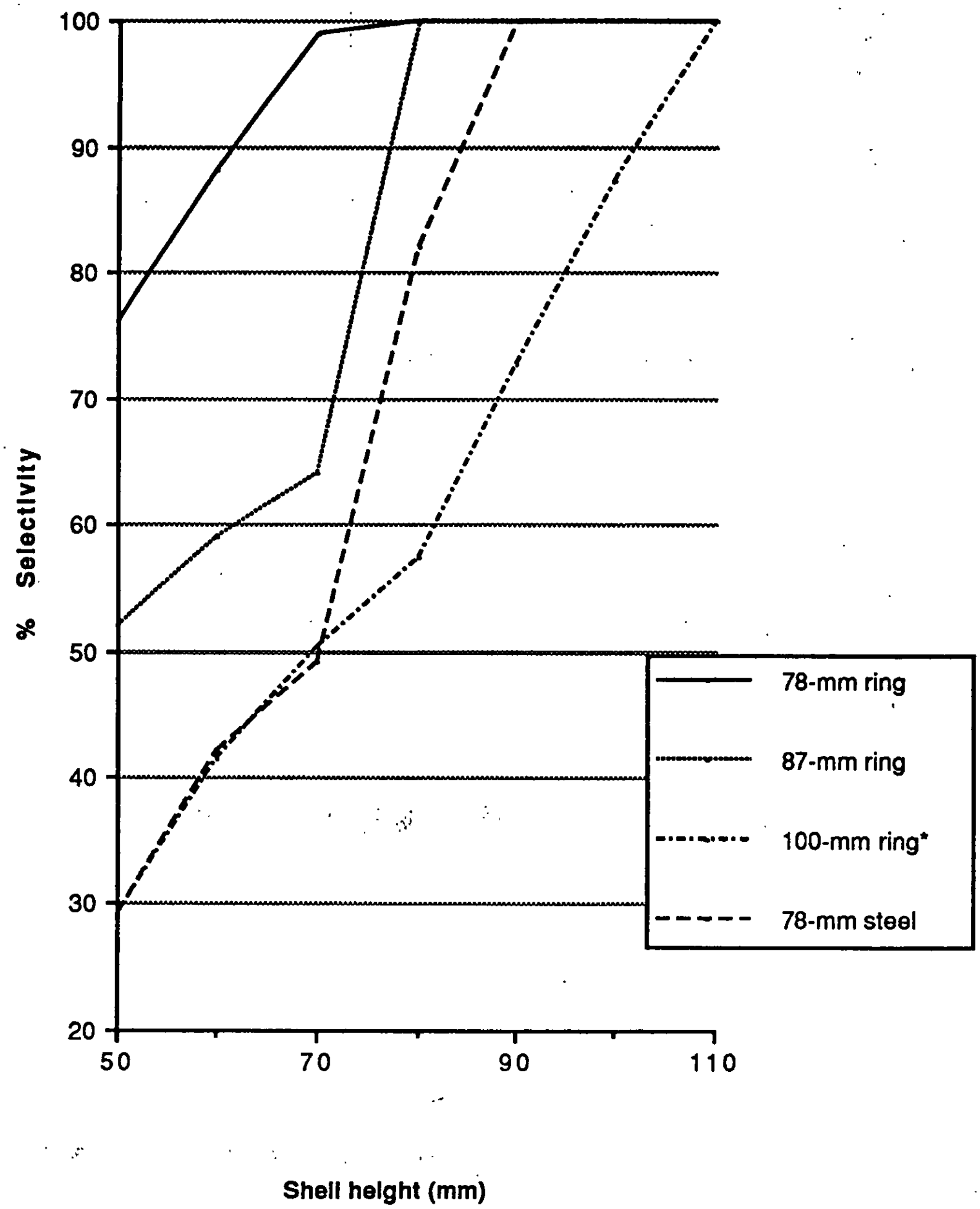


Figure 6.- Selectivity curves (data from all tows combined) of 3 ring sizes linked with rubber washers and of 78-mm rings with steel washers. * The curve for the 100-mm ring was smoothed for the three middle values (Table 10). Shell height values on the x-axis correspond to shell height intervals 41-50, 51-60, etc. The 78-mm rubber bucket retains over 75 % of juvenile scallops at 50-mm SH while a 78-mm ring with steel washers and a 100-mm ring with rubber washers keep about 30 %. Both the 78-mm steel and 100-mm rubber keep 50 % of relatively small scallops at 70-mm SH. They respectively reach 100 % retention for 90 and 110-mm SH scallops.