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Gear performance in the Bay of Fundy scallop fishery.
I.- Preliminaries

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ABSTRACT

Following concerns expressed by a component of the Bay of Fundy fleet that some gear designs were catching scallops at too small a size, available stock survey data of the traditional Digby beds for 1987 were re-examined for this purpose. The Digby gear used during the survey had lined buckets to estimate size distribution and abundance of prerecruits and commercial type buckets linked with either rubber or steel washers to estimate recruits, all assembled on the same tow bar. 119 tows were carried out on 4 different bottom types (rock, shell debris, mussel bed, and moss). 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 at over 100 mm size scallops. 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.

RESUME

Des membres de la flottille de la Baie de Fundy s'inquiètent du fait que certaines configurations d'engin de pêche capturent des pétoncles de taille beaucoup trop petite. A cette fin, on a ré-examiné les données disponibles de l'inventaire de recherche pour 1987 des stocks traditionellement exploités à Digby. L'engin de pêche de Digby utilisé durant l'inventaire avait des paniers doublés pour évaluer la distribution des tailles et l'abondance des prérecrues et des paniers de type commercial tricotés avec des rondelles de caoutchouc ou d'acier pour estimer les recrues, le tout assemblé sur la même barre de trait. On a effectué 119 coups de drague sur 4 types de fond différents (roche, débris coquilliers, moulière, et mousse). Pour la même taille d'anneau, un panier à rondelles de caoutchouc retenait à 100 % des pétoncles beaucoup plus petits (71-90 mm hauteur de coquille) qu'un panier à rondelles d'acier avec des pétoncles de plus de 100 mm. En favorisant davantage des pétoncles plus petits les paniers à rondelles de caoutchouc n'étaient seulement que 33 % efficace pour le rendement en viande écaillée comparé aux paniers avec rondelles d'acier.

INTRODUCTION

Faced with the perspective of declining stocks in the early 1980's, the Bay of Fundy fleet sought alternate measures to sustain the landings expected by its huge fishing power. One of the ways adopted was to modify the gear so that scallops would be caught at an earlier age, by reducing escapement space through the use of rubber washers instead of the conventional steel washers. When at the opening of the "inside" fishing season (October) for 1987-88, large numbers of relatively small scallops, under 90 mm shell height, showed up in the gear some concerns were expressed as an important year class was to pass in the fishery and with considerable loss of yield.

Prior to the improvement of the stock status of the commercial Digby beds, fishermen had recommended that gear fishing behaviour be examined as part of the Bay of Fundy Management Plan resulting from the Inshore / Offshore Agreement. If the gear could not be rendered more efficient, at least that the management plan dictate that the gear selects against small scallops.

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 an offshore rake with its large capacity bag (for one thing) with a Digby bucket which dimensions, mouth design, knitting materials, etc. all differ, hence the need for an appropriate investigation targeting the Digby type of drag itself.

During the 1987 annual stock survey of the traditional beds off Digby on the chartered vessel "Bonnie & Brent" we had the opportunity to combine in the same gang , buckets with rubber washers and steel washers in addition to the lined buckets. This data may be used, to give some indications at least, of the retention rate of small scallops on different bottom types for different bucket configurations and approach the subject of efficiency. All of the buckets we used had the same ring size but different washer types.

METHODS

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). Because of the rather poor fishery performance of late, the fleet has been covering fishing grounds extensively, 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

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. On average, tows covered a tract of 624 m during the 1987 survey. In any event 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 as observed from 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. It is a good observation to record physical dimensions of a scallop shell with respect to degrees of selectivity offered by different sizes of rings used to knit a bucket. 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). Although live and cluckers ('recently dead') shells were collected, only live scallops are considered here.

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 1 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. Mechanically speaking, the physical dimensions of shell height transfer well to the sizes of bucket rings or inter-ring spaces. 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 1987 stock survey (Figure 1) had 81 stations on 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 1987 stock survey (Figure 1) had 81 stations on rocky bottom, 17 over mussel beds, 11 on bryozoans, and 10 over shell debris. This ratio is not necessarily representative of the areas covered by the 4 bottom types where commercial scallop beds occur. A map of substrates (Figure 2) observed during the 1985 to 1987 surveys 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 distribution

Needless to say that to study which bucket design catches which sizes of scallops, which configuration is best at retaining or excluding a particular size class, it is of utmost importance that the stock under study carries 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. A fair mixture of representatives of all possible size classes would lead to better sampling. However, it is difficult to find great quantities of old, large scallops in a stock under (heavy) commercial exploitation. The present structure of this stock is given in Table 2. A strong recruitment pulse has brought in great numbers of relatively small scallops (under 90mm SH). Abundance of prerecruits makes for ideal conditions to study the exclusion characteristics of different gear designs.

Gear configuration

Gear design has changed very little since the 1940s. MacPhail (1954) gives excellent descriptions of individual drags or buckets, gang of drags, and of fishing operations. Individual buckets (76 cm, 30-in inside width usually) are made of 7 rows of wire rings, 9 across, 3 on the side fastened to an angle iron frame at the mouth and a piece of wood (2"X4") at the tail end (Figure 3). Wire rings of 4 mm (11/64 inches) steel wire have an inside diameter of 76 mm (3 in.); they are linked together with 2-25 mm (1 in.) steel washers or 2-46 mm (1 13/16 in.) rubber washers. In the commercial fishery there are numerous variants as to the width of a bucket, from 46 to 76 cm (18-30 in), 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 frame. Figure 3 illustrates the types of buckets and configuration used during the survey.

In Bay of Fundy waters the overall width of scallop fishing gear is limited at 5.49 m (18 feet) which means that 7 conventional 76 cm buckets is the maximum 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. Figure 4 outlines the general set-up of a 7-bucket gang.

For the survey the 3 middle buckets are lined with 38-mm polypropylene stretch mesh to improve the evaluation of the abundance of juvenile scallops that would not be retained otherwise. Lined buckets would effectively retain scallops with SH over 40 mm. Some other buckets had rubber washers throughout or a complement of steel and rubber washers. Steel washers linked the greatest surfaces i.e. back and belly while rubber washers linked the sides which corresponds to about 33% of the total mesh surface (Figure 4).

Gear evaluation

To evaluate gear performance from a conservation point of view involves addressing 2 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. 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 2 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:

$$\sum_{i=40\text{ mm}}^{i=140\text{ mm}} SH_i \quad \frac{n\text{ caught}}{n\text{ entered}} \times 100 \quad = \quad \%\, S_{Gith} \quad = \quad \sum_{i=2\text{ years}}^{i=11+\text{years}} Age_i \quad \frac{n\text{ caught}}{n\text{ entered}} \times 100$$

Efficiency of the gear (E_G), also expressed as a percentage, corresponds to:

number of scallops caught / number of scallops present in the path of the drag.

From these measures, one may also derive a level of efficiency of capture (E) introduced by Caddy (1971) for the offshore scallop dredge where E is a percentage ratio of:

number of scallops entering the drag / number of scallops present in the path.

A lesser 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.

RESULTS

Gear configuration

Different bucket types were used within the same gang of 7 buckets. This way, the probability that all 7 buckets covered the same scallop aggregation was enhanced compared to attempts at tow replication by navigational maneuvering using a single bucket type for each tow. 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 domain. We verified that our results identified similar performance in our gear design. Analysis was performed for tows on a rocky bottom due to their large number (81) and for all tows combined (119). Table 3 presents in summary form that: the catch of lined buckets is significantly different from the catch of unlined buckets; lined buckets catch significantly more prerecruits under age 5 than unlined

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. The gang configuration of lined and unlined buckets on the same tow bar is equivalent to the alternate tow method mentionned in Clarke (1963).

Frequency distribution

Survey data have been analysed according to bucket types used in the gear and bottom types where tows were performed. Tables 4 and 5 represent mean number of scallops per tow according to 10-mm SH increments and according to age. Tables 6 and 7 are similar except that all tow data are combined. Lined buckets are not considered reliable for animals under 40 mm although a fair number was 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. Recruited sizes are less abundant and decrease gradually with increasing size. Graphs 5, 6, and 7 illustrate the frequency distributions of different bucket types according to 4 bottom types by SH and by age and for all tows combined. Lined buckets excel at catching juveniles, up to 5 times or more the level of buckets with rubber or steel washers. Over rocks and shells, buckets furnished with rubber washers catch nearly as many or as many prerecruits in the 60-80 mm range than the lined ones. It is only for much older animals that the steel washer bucket catches the most (ages 6-7). If one ignores the bottom types as in Figure 7 where all tows have been combined, results are similar with rubber washers catching almost as many age 4 scallops as a lined bucket, and the same number of age 5; steel washers getting the highest catch only for scallops over 100 mm. Emphasis will be given to results from rocky areas and from all tows combined because the 3 other bottom types are occurring less frequently over the fishing grounds and much fewer stations represent them.

Gear retention

Percentage retention is expressed as a percentage in the number of scallops per standard tow in each 10-mm SH class retained in the drag from the total number in that class caught in the lined bucket. These scallops 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. The size at which unlined buckets catch equal or greater numbers of scallops than lined buckets vary with bottom types.

Bottom types	SH interval (mm)	
	Steel washers	Rubber washers
Rock	91-100	81-90
Shell	71-80	61-70
Moss	81-90	81-90
Mussel	71-80	71-80

Although not lined, buckets with rubber washers retain, in relatively large quantities, scallops that are quite small, always under 90 mm while the lowest retention level for steel washers is similar or slightly greater (rock at 91-100 mm SH).

Whether one examines data from rocky bottoms or from combined tows, percentages of retention are very similar (Table 8). 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. Figure 8 illustrates these observations for rocky bottoms. The 50 % selection level (Clarke 1963) occurs with very small animals, 66 mm, (2 5/8 in.) for rubber and still small scallops for steel washers at 76 mm (3 in.). On an age basis, scallops below the age of 5 get retained 50 % of the time.

Gear efficiency

Gear efficiency is a measure of the number of scallops caught with respect to the number of scallops that were in the path of the gear. It is difficult to ascertain with precision quantities of scallops in the path of the drag. One may suppose that the number of scallops that entered the lined bucket corresponded to the number in the path. The lined bucket should have had the greatest number of scallops for each and every SH class. This is not so; therefore the lined bucket did not fish effectively for the whole duration of the tow. Previous studies (Jamieson et al 1979; Worms and Lanteigne 1986) have recognised the fact that since lined buckets catch small materials in greater amounts than unlined buckets they may fill up earlier than unlined ones. An independent density estimate via a photographic inventory, for example, would be more appropriate to derive the number of scallops encountered in the path of the drag. However, a direct density estimate was beyond the scope of the stock survey. As such, a measure of gear efficiency may only be derived indirectly and should be interpreted as preliminary. If one was to assume that the results obtained are accurate, efficiency rates would be high (in the order of 30 %) compared to what has previously been established for the Digby gear (Dickie 1955 at 5% and 12 %) or for the New Bedford offshore dredge (Caddy 1971 as high as 20 %).

Gear efficiency could also be defined not as the caught ratio of all scallops in the path but more importantly, as a measure of selecting 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. Of the bucket types studied, a bucket with steel washers was retaining the highest number of scallops in SH classes over 100 mm (Table 6) compared to the two other types. With respect to yield, steel washers are more efficient than rubber ones for the same ring size.

DISCUSSION

Bottom types

Our preliminary 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. A more thorough investigation should attempt to elucidate this point. It is of secondary importance however, because the extent of the commercial beds which may be identified as rocky bottom far surpasses the areas covered by the other three types. Rock bottom is a descriptor for a large range of sizes of rocky material, from small gravel 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 factor

In theory, retention should be complete for SH classes greater than the maximum diameter of the ring used (76 mm). Figure 8 shows that this may take place at a much larger size. Large scallops could not have escaped through inflexible metal rings of smaller diameter than themselves. It is important to note the selective action of the spaces between the rings, especially when using steel washers. The free inter-ring space is greater in the case of steel washers (80 mm approximately) used on 76-mm rings than with rubber washers (50 mm approximately) (Figure 3). Selection factor for steel washers computed for internal ring size 76/76 equals 1.00 while for inter-ring space 76/80 equals 0.95. It would appear that rubber washers take much room in the inter-ring space as the selection factor is 66/76 equals 0.87 for the space inside the ring but 66/50 equals 1.32 for the inter-ring space. Under the latter conditions escapement is better achieved through the ring. 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 "legal-sized" scallops but it has not been emphasised as much in the offshore drag studies.

Efficiency of capture

Assuming that a lined bucket has a high degree of efficiency has its drawbacks since the bucket may fill up before an unlined bucket does and not fish effectively for the whole duration of a tow. Nature and quantity of fill material are both important points. Rocks from gravel to fist size occupy a large volume while the fine thread like nature of bryozoans (moss) may filter very little out. If the material collected is predominantly scallops, their size distribution comes into play. On a unit basis, a bucket could easily contain a greater number of small scallops than a lot of large ones regardless of the availability of both sizes. In this study, where the objective is to examine the fishing performance of the gear with respect to smalls, the current stock distribution with preponderance of prerecruits fulfills the study requirements.

It may be possible to improve the estimates of the lined bucket. Buckets with steel washers caught more scallops than lined ones or buckets with rubber washers for SH over 100 mm but the actual number of scallops per tow was relatively low. There would have been only about 12 scallops in one bucket. A dozen 100-mm scallops hardly fills a bucket. For SH between 71 and 100 mm, a lined bucket fished 91 (all tows) to 94 % (rock) as effectively as a bucket with rubber washers; so that the effective tow duration difference is relatively small and this aspect will not be pursued. It could have been more significant if large quantities of scallops over 100 mm would have been present.

Gear efficiency

Although gear efficiency may not be established with absolute certainty because we have no independent density estimate, it is still possible to evaluate the gear performance. The lowest possible density estimate may be related to the minimum number of scallops in the drag path which is defined as the highest number of scallops in each class regardless of bucket type. With respect to SH between 31 and 140 mm for rocky areas n equals 1,559; for ages 3 to 11+ n equals 1,316 over the area dragged during a tow. The assumption that all the scallops in the path of the drag are caught leads to a maximum gear efficiency and a high level of efficency of capture (up to 95 %). Table 9 has some values for selected classes by size and by age. Maximum values for gear efficiency are usually higher for rubber versus steel washers (almost double) and for recruited sizes compared to prerecruits. These values are considerably higher than the ones estimated by Dickie (1955) at 5 and 12 % for 'inshore' and 'offshore' areas respectively. He used smaller rings (67 mm diameter) and a different methodology. Furthermore, these figures only deal with abundance of scallops in terms of numbers and do not concern themselves with yield in terms of meat weight caught.

Density estimates

The minimum number of scallops (1,559) in the tow area corresponds to 0.365 scallop / m^2. Dickie's estimate (1955) on the Buoy Ground for 1950 for SH over 70 mm is 1.193 scallops / m^2 and 3.099 for 1951. Generally speaking, the performance of a fishery reflects the status of the stock it relies upon. During the 1950-51 inside fishing season, catches were only about 150 t of meats (Robert et al 1987). Densities of 1.2 to 3.1 scallops / m^2 are not excessive given the size class distribution determined on the Buoy Ground and the level of catches.

Given the present stock frequency distribution characterised by a sizable recruitment pulse (Robert et al 1987), it is not unreasonable to inflate our minimum density estimate by 3 to 1.096 scallops / m^2, even by 6 times to 2.192 scallops / m^2. Such density estimates decrease the values previously assigned to gear efficiency. Using the estimated density of 1 scallop / m^2, gear efficiency becomes 32 % for lined buckets, 20 % with rubber washers, and 12 % with steel washers with a capture efficiency of about 32 %. Furthermore, these density estimates bring them in line with the values that Dickie (1955) had established when he used the Digby gear which at that time had 67-mm rings and steel washers.

Yield efficiency

For the same ring size, SH classes most abundant in buckets with rubber washers are small size scallops ranging from 71 to 90 mm while buckets with steel washers target scallops of a much larger size at over 100 mm (Table 6). Buckets with steel washers are superior to buckets linked with rubber washers in the escapement of small size animals. Directing fishing effort toward large scallops is most efficient from a yield point of view. Given that 80 mm scallops have 3 times less meat (in terms of weight) than 110 mm scallops, means that to get the meat yield shucked from one bucket with steel washers (containing over 110 mm size scallops) is equivalent to shucking all scallops 70 - 90 mm size fished by 3 buckets with rubber washers. Given the opportunity to grow, these 3 buckets worth of small scallops would, in time, increase to 9 buckets worth of large scallops. An extensive discussion of meat yield with respect to size of scallops is an integral part of the Bay of Fundy stock assessment for 1987 (Robert et al 1988). An additional point that we did not look at, is the amount of trash dragged up, rocks, debris, other epifauna of no commercial value, clumps of sponges and bryozoans. When the trash material has no possibility of filtering through the bucket, it takes up space that is no longer available to retain a more valuable item such as scallops. Once on board, sorting operations are rendered more tedious, the greater amount of trash there is to sort through.

CONCLUSIONS

1.- This investigation is only the second study of gear performance of different commercial type bucket configurations on the scallop beds traditionally fished in the Bay of Fundy.

2.- In addition to the types of bucket used in the commercial fishery, some buckets were lined to appreciate small size scallops from 40 mm shell height and up.

3.- 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 linked with different washer types.

4.- 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.

5.- Because of the inflexibility of the metal rings by opposition to fish net mesh material, inside ring diameter and inter-ring space contribute to escapement through the bucket.

6.- For the same ring diameter, buckets linked with rubber washers reduce the inter-ring space compared to buckets with steel washers and select toward scallops of a relatively small size at 70-80 mm SH. Steel washers buckets retain scallops of a larger size at 100 mm SH.

7.- According to the best relative density estimates which may be derived, gear efficiency would be of the same order of magnitude than what Dickie (1955) calculated over 20 years ago at 12 % for steel washers. Rubber washers catching a greater number of scallops had a higher efficiency at 20 %.

8.- However, because of the smaller size scallop which rubber washers target, meat yield is considerably lower. It would be necessary to shuck scallops from 3 buckets with rubber washers to get the same meat yield than from the content of one bucket with steel washers.

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Table 1.- 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 2.- 1987 stock survey. Average number of scallops at age caught in a seven-gang Digby drag projected from an end, unlined bucket for recruits (age >4 years) and from a centre, lined bucket for prerecruits (age <4 years).

	Age (years)								
	2	3	4	5	6	7	8	9	10+
Catch stratum:									
low	167	445	469	71	25	23	17	10	22
medium	217	328	617	124	24	15	8	9	19
high	480	464	490	333	45	20	10	2	7
exploratory	29	209	184	26	23	21	20	16	31
Area stratum:									
Centreville	14	76	53	31	66	52	56	38	92
Gulliver's Head	220	195	208	83	28	22	21	15	24
Digby Gut	276	554	775	182	25	19	14	11	34
Delaps Cove	208	641	824	101	20	18	22	8	19
Parker's Cove	19	154	48	18	32	21	11	3	3
Young Cove	39	82	13	37	42	24	7	6	13
Hampton	55	189	20	13	23	26	11	3	1
Zone stratum:									
inside 6-mile	457	373	727	253	18	10	8	7	22
outside 6-mile	51	355	296	31	31	26	18	11	22

Table 3.- Statistical characteristics of gear configuration of the 7-drag Digby gang.

		F_{ratio}	$F_{prob.}$
I. Catch of lined VS unlined bucket			
	rock bottom	7.856	0.000
	all tows	7.600	0.000
II. Lined bucket catches more prerecruits			
	rock bottom	9.599	0.000
	all tows	10.134	0.000
III. Location of buckets in a gang			
unlined	rock bottom	0.029	n.s.
	all tows	0.024	n.s.
lined	rock bottom	0.220	n.s.
	all tows	0.194	n.s.

Note Jamieson et al (1979) have already demonstrated that bucket location may be interchanged regardless of whether they are lined or not.

Table 4.- 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 steel	2	13	28	24	105	203	53	26	36	31	15	4	2	0
rubber	5	31	51	82	256	329	99	28	31	25	14	4	1	0
lined	21	149	205	229	434	310	98	21	26	22	11	3	1	1
MOSS steel	1	1	3	2	5	1	2	5	6	14	10	2	0	0
rubber	1	0	8	15	15	6	3	2	3	9	4	2	0	0
lined	4	4	5	33	75	9	1	5	1	4	6	3	0	0
MUSSEL steel	2	2	15	6	4	5	24	51	57	9	1	0	0	0
rubber	0	3	24	12	9	8	24	38	40	6	0	0	0	0
lined	16	11	98	57	14	5	6	16	15	2	0	0	0	0
SHELL steel	0	11	14	94	152	67	41	42	42	16	13	1	0	0
rubber	1	33	34	158	285	54	44	52	25	20	8	1	0	0
lined	3	33	60	186	249	47	16	16	12	10	3	1	1	0

N.B. 81 tows for rock bottom type; 11 for moss (bryozoans); 17 for mussel shells, and 10 for shell debris.

Table 5.- 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 steel	26	57	271	74	23	22	22	15	10	24
rubber	55	161	497	138	25	21	17	12	8	22
lined	247	458	597	143	19	17	14	10	8	18
MOSS steel	3	6	5	1	5	5	5	6	5	11
rubber	2	27	20	3	3	2	4	4	3	6
lined	10	52	72	3	4	2	2	1	1	10
MUSSEL steel	8	19	7	28	50	45	12	4	3	1
rubber	10	32	12	28	37	29	12	3	1	0
lined	51	136	15	9	15	10	4	1	0	0
SHELL steel	19	149	168	46	42	36	12	11	7	5
rubber	44	297	219	52	47	25	15	8	5	4
lined	53	307	213	22	15	11	9	3	2	2

N.B. 81 tows for rock bottom type; 11 for moss (bryozoans); 17 for mussel shells, and 10 for shell debris.

Table 6.- SHELL HEIGHT Mean number of scallops per standard tow (800 m) projected for a full Digby gang according to 3 bucket types (L: mesh lined; R: rubber washers; S: steel washers). Data from all tows were used; average was weighted by number of stations for each bottom type. Shell height (SH) are grouped in 10-mm class.

S H	L	R	S
21-30	17	4	2
31-40	106	24	10
41-50	159	42	23
51-60	183	72	25
61-70	325	201	85
71-80	217	230	145
81-90	69	75	43
91-100	18	29	29
101-110	21	29	37
111-120	16	20	25
121-130	8	11	12
131-140	2	3	3

Table 7.- AGE Mean number of scallops per standard tow (800 m) projected for a full Digby gang according to 3 bucket types (L: lined mesh; R: rubber washers; S: steel washers). Data from all tows were used; average was weighted by number of stations in zone (inside, outside) strata. Age is in years.

Age	L	R	S
2	181	42	21
3	361	141	54
4	434	360	200
5	101	102	59
6	17	27	27
7	14	21	25
8	10	15	18
9	7	10	12
10	5	6	8
11+	14	16	19

Table 8.- Percentage retention in bucket types (R: rubber washers; S: steel washers) of scallops caught according to 10-mm shell height classes and age groups on rocky bottoms and all tows combined. It is assumed that a lined bucket catches all scallops in its path with a shell height over 40 mm until filled.

SHELL HEIGHT					
Rock bottom			All tows		
SH	% R	% S	SH	% R	% S
31-40	21	9	31-40	23	9
41-50	25	14	41-50	26	14
51-60	36	10	51-60	39	14
61-70	59	24	61-70	62	26
71-80	100	65	71-80	100	67
81-90	100	54	81-90	100	62
91-100	100	100	91-100	100	100
101-110	100	100	101-110	100	100

AGE					
Rock bottom			All tows		
AGE	% R	% S	AGE	% R	% S
3	35	12	3	39	15
4	83	45	4	83	46
5	97	52	5	100	58
6	100	100	6	100	100
7	100	100	7	100	100
8	100	100	8	100	100
9	100	100	9	100	100
10	100	100	10	100	100

Table 9.- Percentages of retention (S_G) and gear efficiency (E_G) assuming a minimum density estimate for selected size classes and age groups.

	% S_G		% E_G	
	Rubber	Steel	Rubber	Steel
All SH classes (31-140 mm)	63	36	61	35
Prerecruits (31-80 mm)	56	28	56	28
Recruits (over 80 mm)	100	91	94	77
Recruits (over 100 mm)	100	100	83	100
All age groups (3-11+ years)	70	40	68	39
Prerecruits (3-4 years)	62	31	62	31
Recruits (5+ years)	100	83	93	73

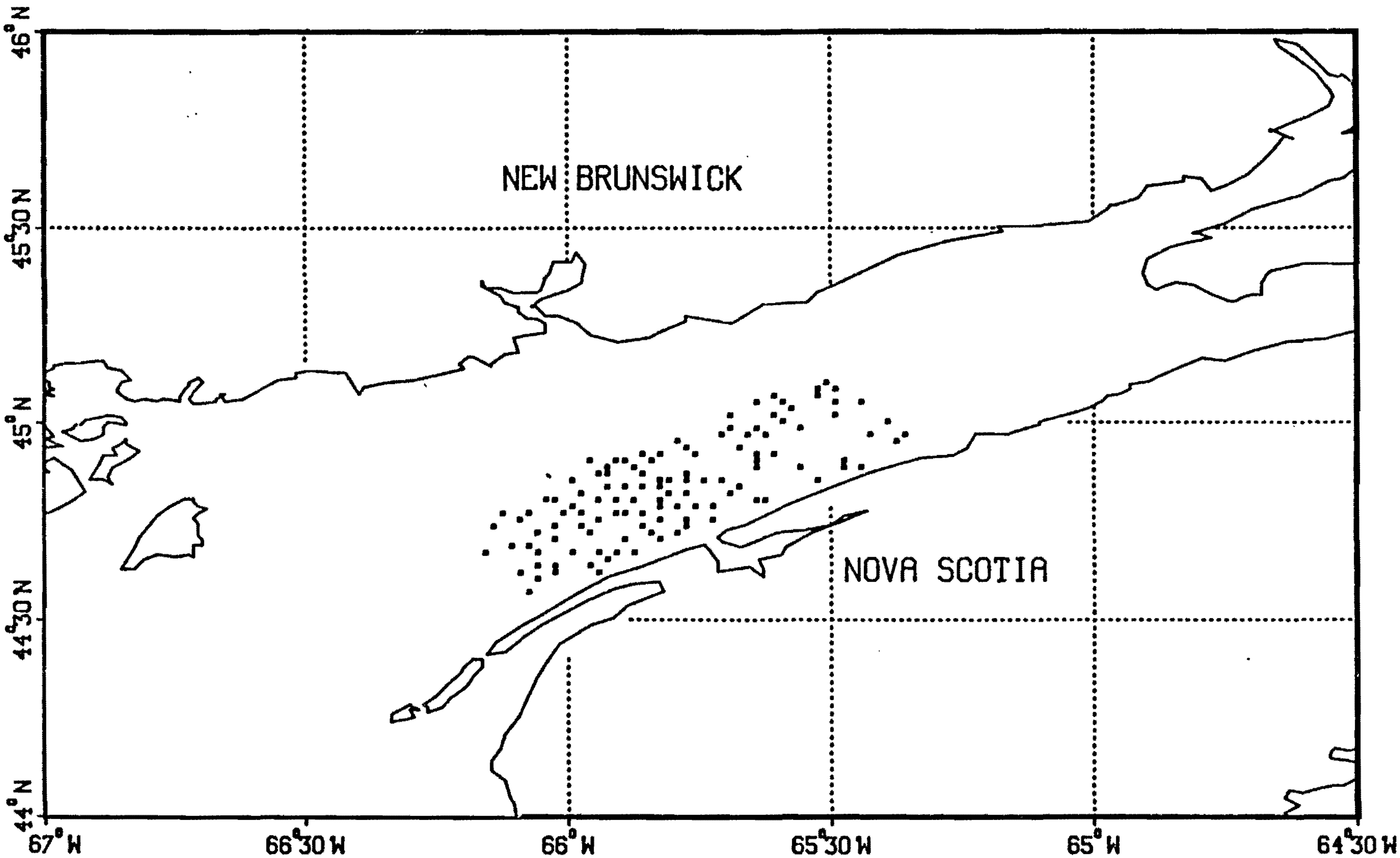


Figure 1.- Location of survey stations of the 1987 inventory of the traditional scallop beds near Digby, Nova Scotia.

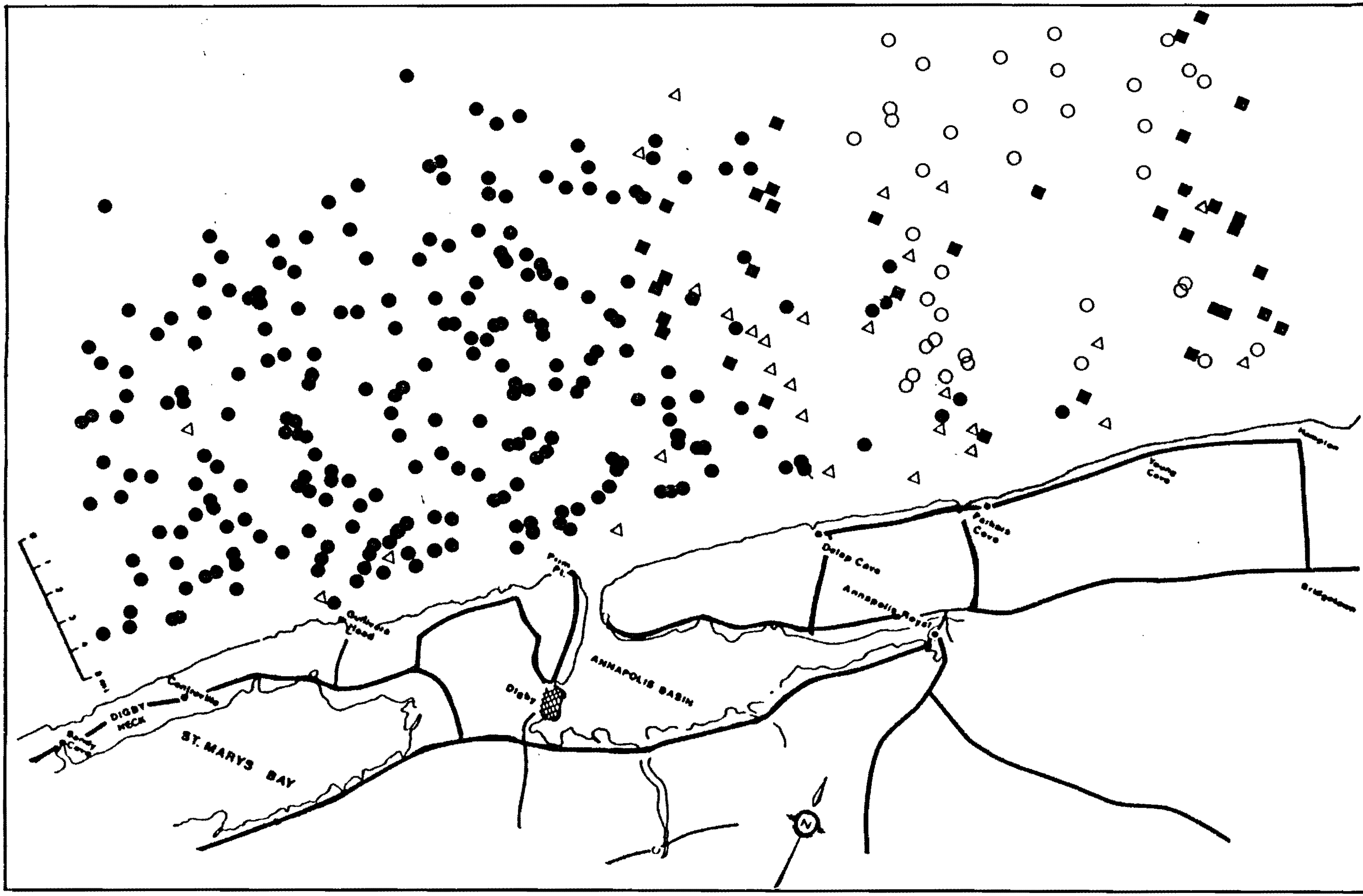


Figure 2.- Predominant bottom types on the commercial scallop grounds off Digby, N.S. according to the 1985-87 stock survey data.
● : rock, Δ : shell debris, O : mussel beds, ■ : moss.

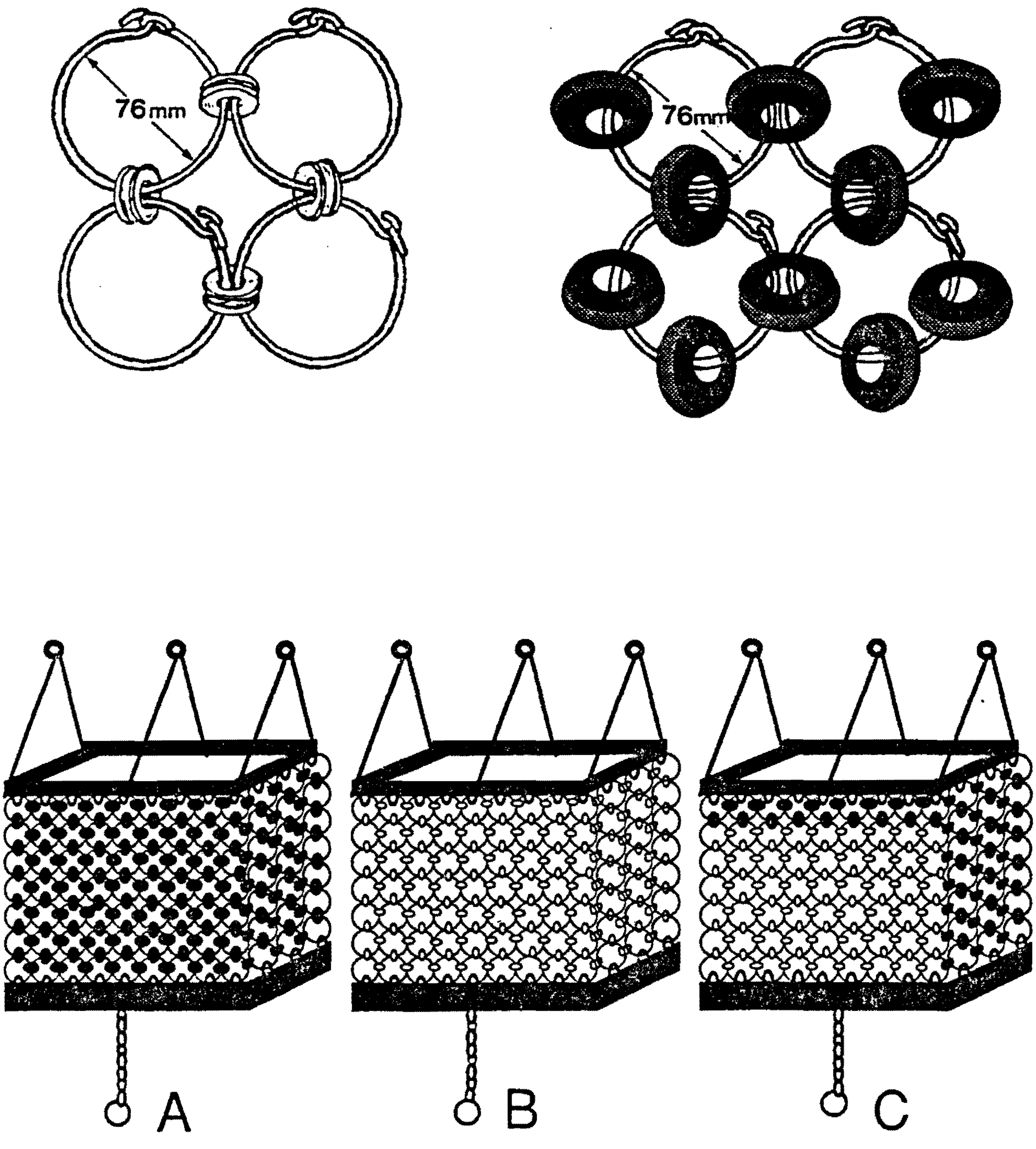


Figure 3.- Digby scallop fishing gear. Schematic details of bucket structure. A: Rubber washers linking, B: Steel washers linking, C: Steel washers linking actually used during the survey. Details of wire rings linkage with steel (above, left) and rubber (above, right) washers showing available escapement space through rings and inter-ring spaces.

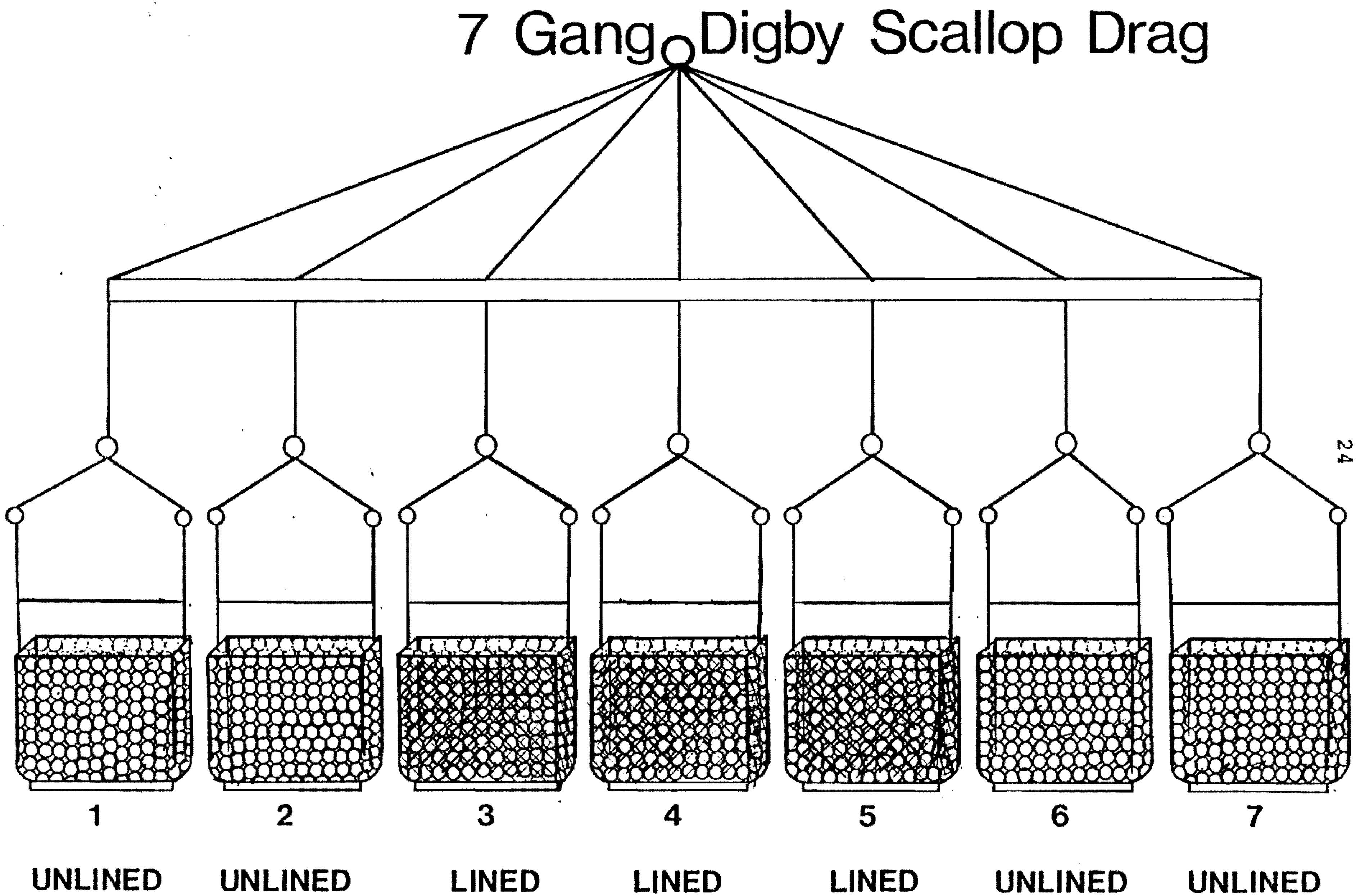


Figure 4.- General outline of the Digby scallop fishing gear with some buckets lined for the survey; bucket no. 6 was the one used with steel washers.

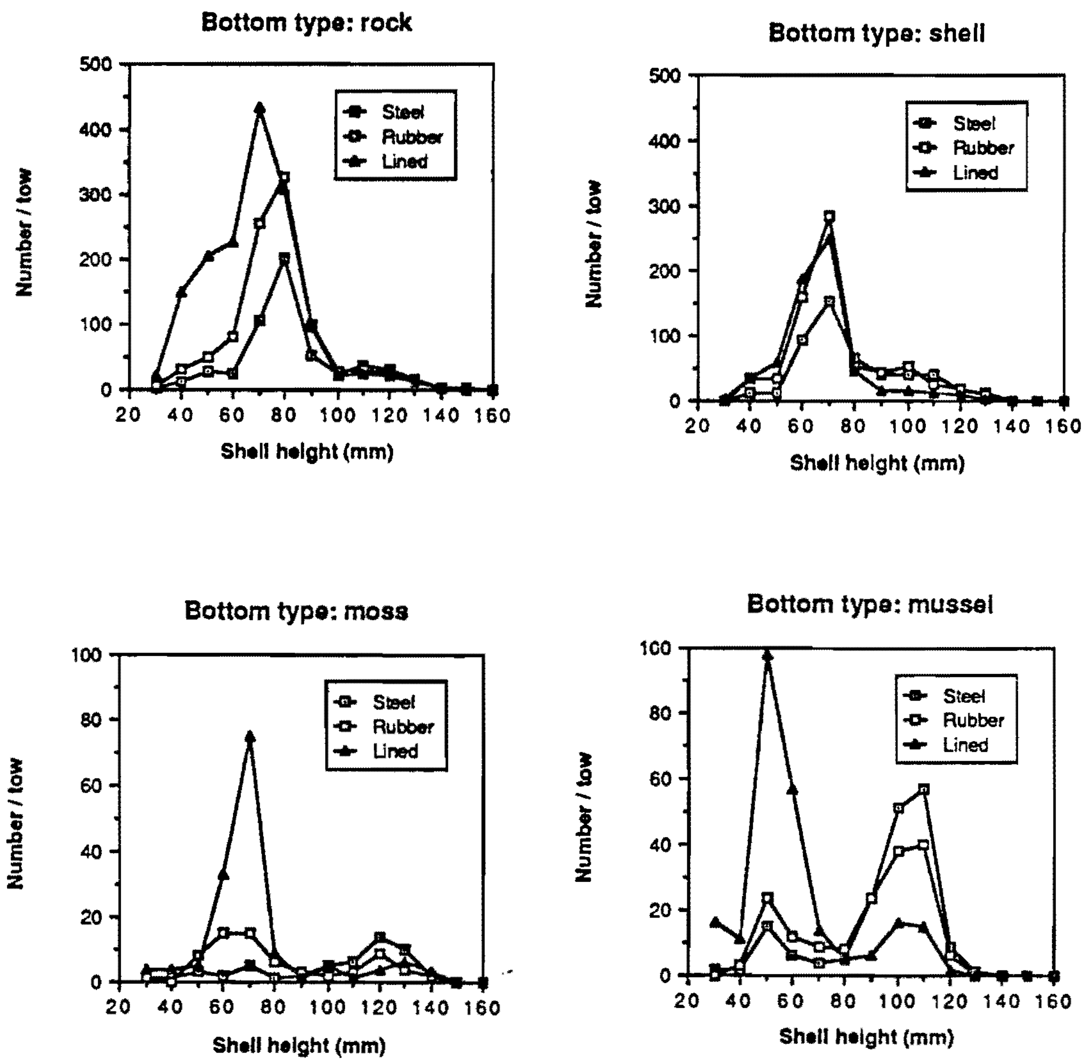


Figure 5.- Frequency distribution of the mean number of scallops per standard tow by 10-mm shell height intervals from 3 different bucket configurations; lined, rubber washers and steel washers. (SH intervals on the x-axis are referred to by the maximum height in the interval; 80 means scallops between 71 and 80 mm SH). Four bottom types are represented individually.

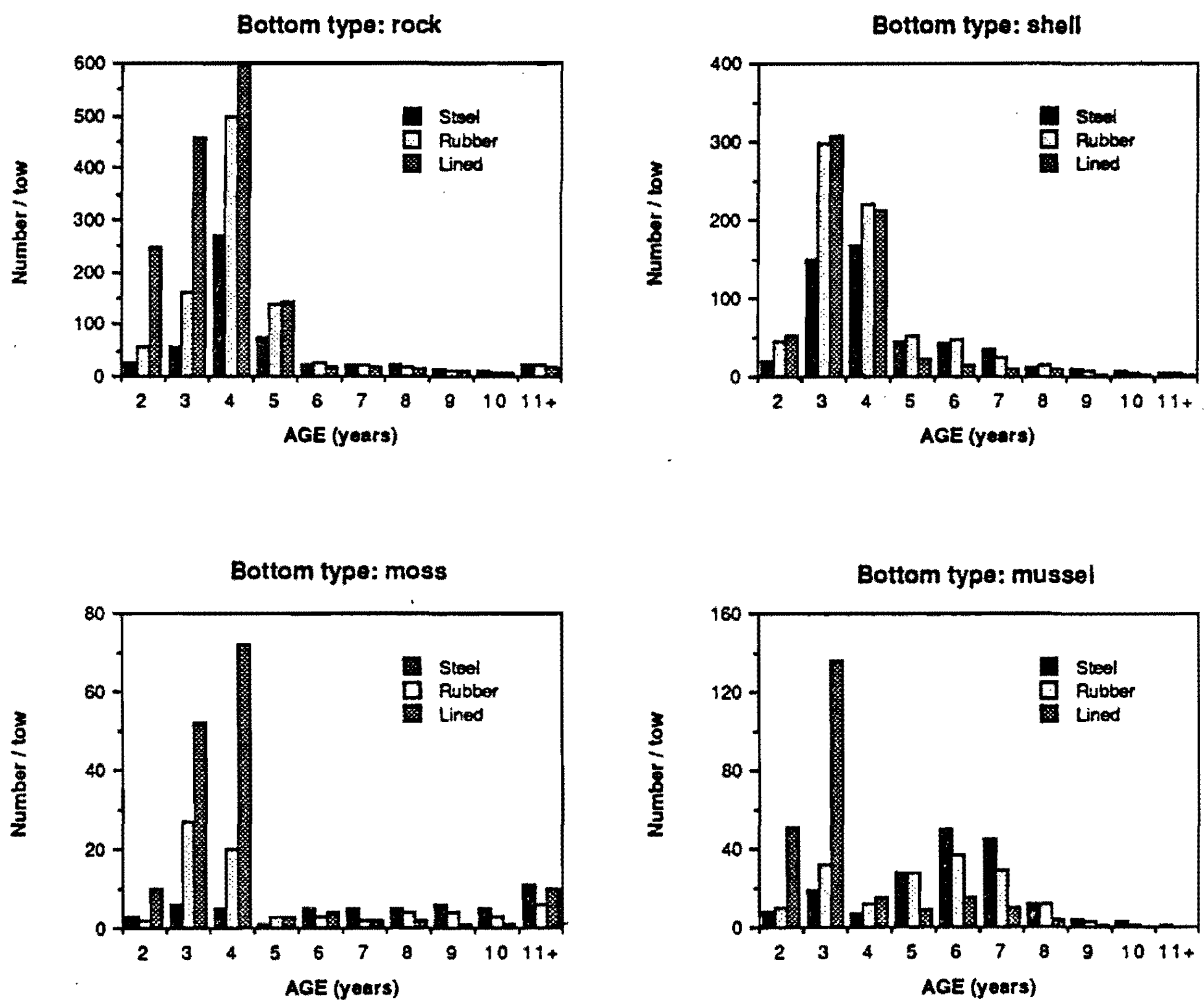
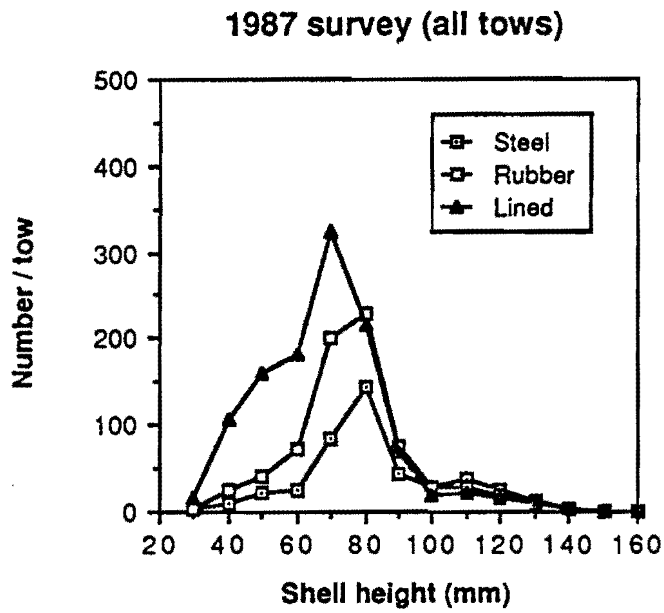


Figure 6.- Frequency distribution of the mean number of scallops per standard tow by age groups from 3 different bucket configurations: lined, rubber washers and steel washers. Four bottom types are represented individually.



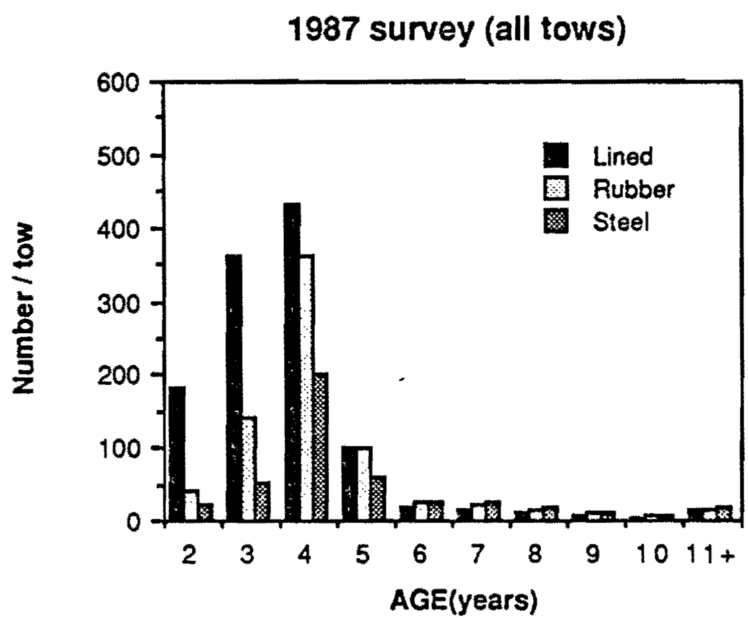


Figure 7.- Frequency distribution of the mean number of scallops per standard tow by 10-mm shell height intervals and by age groups when all tow data are combined.

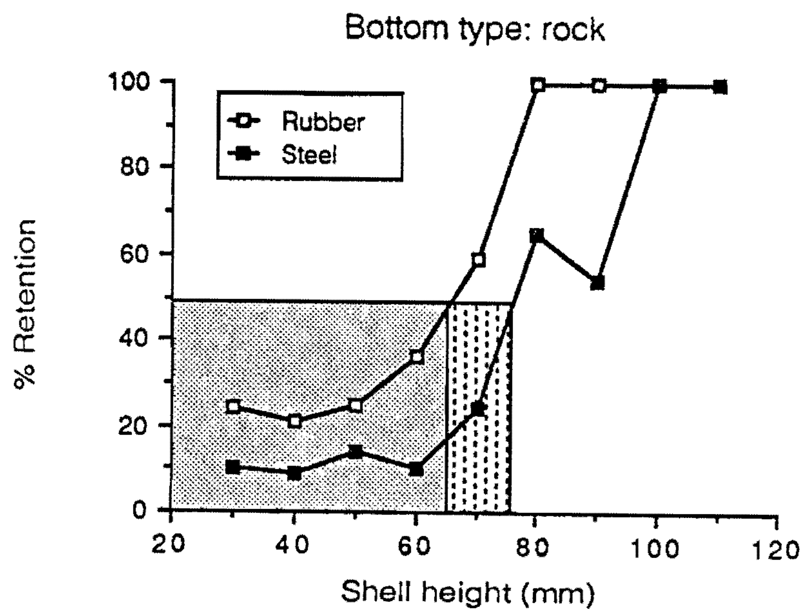


Figure 8.- Retention of scallops in buckets with rubber washers and with steel washers according to shell height on rocky bottom. The shaded area represents the area of 50 % or lower selection level for rubber washers; the dashed area, for steel washers.