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The Iceland scallop (*Chlamys islandica*) size selectivity of an offshore scallop survey dredge

by

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Abstract

Estimation of the biomass of commercial-sized Iceland scallops (*Chlamys islandica*) on the St Pierre Bank requires knowledge of the size selectivity of the New Bedford offshore dredge used in the reseach surveys. To estimate the size-selectivity of this dredge, and to compare its catching efficiency with that of a nonselective dredge, paired tows with a standard (uncovered) and a covered dredge were performed on the St Pierre Bank in August 1991. Despite 100% retention, the covered gear was less efficient and caught a lower weight of both scallops and trash than the standard dredge.

The catch data from the covered gear was unsuitable for selectivity analysis by parametric statisitical techniques. Using the nonparametric technique of isotonic regression, it was seen that on a tow to tow basis, the shell height of 50% retention (h_{50}) varied considerably, and was dependent on the quantity of matter in the dredge. For the catch data combined over all tows, h_{50} was estimated to be 69.4 mm with 95% confidence interval of 67.4 - 72.7 mm. If knife-edge selection at h_{50} is assumed then this corresponds to retention of 83% (95% CI = 71 - 89 %) by meat weight of all commercial-sized Iceland scallops.

Résumé

Pour estimer la biomasse de pétoncles d'Islande (*Chlamys islandica*) de taille commerciale du banc de St. Pierre, il faut connaître la sélectivité selon la taille de la drague de pêche hauturière New Bedford utilisée dans les campagnes d'évaluation des stocks. Dans le but de déterminer la sélectivité de cette drague et de comparer son efficacité de capture à celle d'une drague non sélective, on a procédé à des traits jumelés d'une drague conventionnelle (non couverte) et d'une drague couverte sur le banc de St. Pierre en août 1991. En dépit d'une rétention de 100 %, l'engin couvert s'est avéré moins efficace et a capturé un poids inférieur, tant de pétoncles que de débris, à celui des captures de la drague conventionnelle.

Les données sur les captures de l'engin couvert n'ont pu servir à l'analyse de sélectivité au moyen de méthodes statistiques paramétriques. En recourant à une technique non paramétrique, soit la régression isotone, on a constaté que, trait par trait, la hauteur de coquille à 50 % de rétention (h_{50}) variait considérablement et dépendait de la quantité de matière dans la drague. Pour ce qui est des données de prises combinées de tous les traits, on a estimé que h_{50} était de 69,4 mm à un intervalle de confiance de 95 % se situant à 67,4 - 72,7 mm. Si l'on assume qu'à h_{50} la sélection est bien tranchée, on aboutit à une rétention de 83 % (IC de 95 % = 71 - 80 %), selon le poids de chair, de tous les pétoncles d'Islande de taille commerciale.

Introduction

Due to the highly variable but typically rough and rocky bottom over large areas of the St Pierre Bank (NAFO Div. 3Ps), the biomass of commercial-sized ($\geq$ 60 mm) Iceland scallops (*Chlamys islandica*) on the Bank is estimated by research cruises (Naidu 1991) deploying a "standard" commercial New Bedford offshore scallop dredge (Fig. 1). A lined or covered dredge is not routinely used because it would frequently be torn, thereby incurring inordinate downtime and necessitating the repeating of tows. Also, it is suspected that linings or covers could considerably reduce the dredge's catching efficiency.

The primary objective of this study was to quantify escapement of commercial-sized scallops from the standard dredge so that it can be taken into consideration in biomass calculations. It was also desired to assess the relative performance of a covered dredge and to investigate the effect on selectivity of the volume of matter (scallops and trash) in the dredge.

There is limited literature on the selectivity of Iceland scallops in offshore dredges. Naidu and Cahill (1989) give selectivity results from paired tows with standard and lined dredges. However, the study was not performed under scientifically regulated conditions, and the statistical analysis used unreliable techniques (see, for example, Cadigan and Millar 1991). The selectivity work on sea scallops (*Placopecten magellanicus*) is also limited (Bourne 1965, 1966; Caddy 1971; Serchuk and Smolowitz 1980). Bourne (1965, 1966) only looked at comparative catches, and did not attempt estimation of selection curves. Serchuk and Smolowitz (1980) estimated a selection curve for a 2 inch ring survey dredge using the method of alternate tows with standard and lined dredges. Caddy (1971) used a 3.8 cm cover over the top (ring back and rope back) of a 3 inch ring dredge (double linked belly and single linked ring back), but no cover was fitted under the dredge belly.

Material and methods

Selectivity trials were performed onboard the 82 m stern trawler, GADUS ATLANTICA, during the last week of August 1991 as part of the regular scallop biomass survey. The offshore dredge used in these surveys is 3.66 m (12 ft) wide with 3 inch inside-diameter rings interconnected by quadruple belly links and triple links in the ring back. The average inside mesh opening of the rope back was 126 mm. For this study, two such dredges were simultaneously deployed, one with 35 mm (inside mesh opening) shrimp netting covers separately attached over the dredge's belly and top (ring back and rope back). Chafing gear, constructed from the same mesh as the rope back, was used under the belly cover. Henceforth, the term "covered gear" is taken to be the union of three gear compartments, the (covered) dredge, belly cover, and top cover.

The pair of dredges was towed over the distance (1.0 nautical mile) and at the speed (2.5 kt) used in regular biomass survey tows. Ten replicate paired tows were performed, with the dredges being interchanged from port to starboard and vice-versa. Of these, the first four (tows A-D) were over a relatively smooth bottom consisting mainly of small stones and pebbles. The remaining six tows (E-J) were over a rougher bottom consisting of larger stones, rocks and boulders. Haul E was discarded due to a torn belly cover.

The entire contents of the standard dredge and each compartment of the covered gear (dredge, belly cover, top cover) were separately dumped, carefully picked over, and all Iceland scallops were removed. For each compartment, the total scallop catch was weighed and a representative sample of between 20 and 40 kg (200-400 scallops), or the entire scallop catch if less than 20 kg, was taken for measurement. Each scallop in the sample was measured to the nearest millimetre in shell height. The weight of trash (all remaining matter) in each gear compartment was measured, or estimated when the volume was excessive.

Results

Figures 2a, 2b and 2c show the total (estimated) number of scallops, shell weight of scallops, and weight of trash respectively in the nine tows. Escapement of scallops from the covered dredge was primarily through the top (ring back and rope back) and only 14% by shell weight of escapement was through the dredge belly. Figure 2c shows that the dredges collected larger amounts of trash over the rough bottom (tows F-J) than the smooth bottom (tows A-D).

Figure 3 shows the size frequency distribution of Iceland scallops in the standard dredge and three gear compartments of the covered dredge for each set and for the data combined over all sets. In sets B, C and F the covered gear (covered dredge + top cover + belly cover) caught a greater weight of scallops than the standard dredge (Figure 2b). These are sets with relatively high frequencies of small scallops (Figure 3). The greatest difference was in set C where 101 kg were taken in the covered gear and only 33 kg in the standard dredge. In the other sets the standard dredge sometimes caught considerably more scallops than the covered gear. For example, in set G the catches in the covered gear and standard dredge were 109 and 395 kg respectively. Combined over the nine sets, the covered gear's catch of scallops (989 kg) was 57% that of the standard dredge (1727 kg). The dredge catch of the covered gear was 41% (709 kg) that of the standard dredge.

A paired t-test did not reject (p-value = 0.15) the hypothesis of equal catching efficiency (by scallop shell weight) of the standard dredge and covered gear. (The hypothesis test used the square root of the catch weights since this serves as a variance stabilizing transformation for data obtained from a process of encounter, i.e. a Poisson process). The inability to reject this hypothesis is partly because the relative catching efficiency of the covered gear and standard dredge depends on scallop size. Figure 4a plots the proportion of the total (standard dredge plus covered gear) catch taken by the standard dredge, as a function of shell height. It shows that only scallops above about 65 mm shell height are caught more efficiently in the standard dredge.

The same hypothesis comparing the scallop catch in just the dredge of the covered gear to the catch in the standard dredge was rejected (p-value = 0.016) at the 5% level. This implies that the covers resulted in a statistically significant reduction in the catching efficiency of the dredge. The question therefore arises whether the covers might have also affected the size-selectivity of the dredge. If the two dredges have the same size-selectivity then the relative frequency distribution of scallop sizes should be the same in both. Plotting the proportions of the total dredge (standard dredge plus covered dredge) catch taken by the standard dredge against shell height would then be approximately a straight horizontal line. Figure 4b shows that this is at least the case for commercial-sized scallops. For pre-recruit scallops the covered dredge retains proportionally more as scallop size decreases.

The above hyptothesis tests were also performed to compare the catch of trash in the two gears. The conclusions were the same. That is, the trash catch of the standard dredge and covered gear were not significantly different (p-value=0.35), but significance was obtained when comparing the standard dredge catch to that of just the dredge of the covered gear (p-value=0.02).

Selectivity analysis

Figure 5 shows, for each tow and combined over all tows, the proportion of the covered gear's catch of scallops that were taken in the dredge (dashed line). These retention proportions can be extremely variable, particularly for pre-recruit (< 60 mm) scallops, due to the small numbers encountered.

Selection curves are sometimes fitted to covered trawl data by eye, or using parametric methods such as probit or logit analysis. The curves fitted by probit and logit analysis (Normal ogive and logistic curve respectively) are symmetric about the size of 50% retention, h_{50}. Millar (1991) has shown that these symmetric curves are too restrictive as general models of selectivity and uses a more flexible family of asymmetric curves when the logistic curve exhibits lack of fit (see also Suuronen et al. 1991).

Logistic curves fitted to the retention proportions for both the individual and combined data indicated severe lack of fit through both the goodness of fit statistic and the residual plots. The more flexible asymmetric curves indicated considerable lack of fit to the individual haul data, and a marginal fit to the combined data.

Parametric methods do not appear to be well suited to these data.

The selection curves could be fitted by eye. However, no two people would give the same fits. Moreover, those size classes with many scallops give more reliable estimates of the retention probability than those with few scallops, and therefore should be given more weight in the fit. The plots of the proportions retained in Figure 5 give no indication of the appropriate weight to be given each data point.

It may not be possible to specify a suitable parametric form for the selection curves, but it is at least reasonable to insist that they be nondecreasing. That is, the larger a scallop, the greater its chances of being retained in the dredge. The statistical technique of isotonic regression uses maximum likelihood to fit the most likely curve to data subject to the constraint that the curve be nondecreasing (Barlow et al. 1972). Fitting of the isotonic regression curve is done in an intuitive way - whenever observed proportions in adjacent size classes do not satisfy the nondecreasing constraint, those size classes are pooled. The isotonic regression views violation of the nondecreasing constraint as an artifact due to insufficient numbers in the "offending" size classes. Pooling the size classes results in a combined size class with more data. In this study isotonic regression was performed using the PAV (pool adjacent violators) algorithm (Barlow et al. 1972), written in FORTRAN and interfaced to the *Splus* statistical package.

The isotonic selection curves are overlaid on the proportion retained plots in Figure 5. The "curves" are in fact piecewise linear, and the flat portions of the curve correspond to size classes that were pooled. The estimated sizes of 25%, 50% and 75% retention are given in Table 1. There is considerable variability in the h_{50}'s estimated from the individual sets, with the smallest being 45.3 cm and the largest 80.1 cm. The smaller estimated h_{50}'s are not well determined because there were relatively few scallops less than 60 mm in shell height (Figure 3). A plot of the individual tow h_{50}'s against the total weight of matter in the covered dredge (Figure 6) suggests that part of the tow to tow variability in h_{50} is due to an effect of blockage. If one separates the tows in Figure 6 by bottom type (tows A-D over smooth bottom and F-J over rough bottom) then the effect of catch quantity becomes more apparent.

Isotonic regression by itself does not provide any estimate of the standard errors of the estimated h_{50}'s. These were obtained by bootstrapping the data (Efron 1982). This requires repeating the analysis on data sets that are obtained by resampling (with replacement) from the actual data. The essence of bootstrapping is to ensure that the procedure for resampling from the actual data emulates the experimental procedure. The selectivity trials consisted of randomly choosing tow locations representative of those used in St Pierre Bank research surveys (the first source of variability), and performing a selectivity tow at each location (the second source of variability).

For the purposes of the bootstrap, the nine individual sets were used to define a "population" of tows. To include the first source of variability, the bootstrap chose nine tows (with replacement) from this population. Within each chosen set the retention proportions were also bootstrapped to include the second source of variability. The estimated h_{50}'s from 200 such bootstrap resamplings are shown in Figure 7. The 95% confidence interval for h_{50} is 67.4 to 72.7 mm.

Discussion

Size-selectivity is only one component of the catching efficiency of the standard dredge since it quantifies the probability that a scallop of a particular size will be caught by the dredge upon assuming that it entered the dredge. The other component of catching efficiency is determined by the probability that a scallop in the path of the dredge will enter it. Iceland scallops on the St Pierre Bank are generally bysally attached to the bottom substrate (Naidu 1991) and are therefore largely unable to avoid the dredge. However, Serchuk and Smolowitz (1980) describe underwater observations made on a lined dredge where it was seen that a mound of trash and scallops was pushed ahead of the sweep chain at the front of the belly. This resulted in matter being swept to the side of the dredge and under the dredge belly. It was rarely observed for the standard dredge and so it may be reasonable to assume that most Iceland scallops in the path of the standard dredge will enter it until the flow of water through the dredge becomes blocked by caught matter.

Use of a covered dredge would avoid the issue of size-selectivity. However, the covered gear is less efficient than the standard dredge, particularly when catch volumes are high. This is evidenced by the drop in relative efficiency of the covered gear when the weight of matter caught is high (Figures 2b and 2c) which resulted in a lower (57%) overall scallop catch weight in the covered gear. Note that this percentage is calculated over all sizes of scallops. Due to the higher relative abundance of small scallops in the covered gear it would be smaller if calculated over only commercial sized scallops. Since the covered gear appears to become less efficient as catch volume increases it would be very difficult to obtain biomass estimates using this gear.

Using the estimated selection parameters of the covered dredge to correct biomass estimates requires assuming that its selectivity was similar to that of the standard dredge, despite the different catching efficiencies. As with most applications of covered gear, this is a difficult assumption to verify, though at least Figure 4b is consistent with this for commercial-sized scallops.

The issue of common size-selectivity of the two dredges could be avoided by analysing the data as a twin dredge experiment, analogous to trouser trawl or alternate haul experiments. The covered gear acts as the "control" gear and provides a representative sample of the population length distribution, just as the small mesh codend in a trouser trawl experiment would. We considered this analytical approach but did not find it applicable due to the nature of the data. Parametric methods were not suitable and isotonic regression could not be used since it doesn't provide the estimate of relative catching efficiency required by the model (see Cadigan and Millar 1991).

Caddy (1971) estimated an h_{50} of 73.5 mm from his covered dredge study of sea scallop selectivity in a 3 inch ring dredge and noted that this size might be underestimated due to unmeasured escapement through the dredge belly. The effect of this escapement is probably slight since we saw here that if is minor compared to that through the top of the dredge. Our estimated h_{50} of 69.4 mm is smaller than Caddy's, which was expected because the inter-ring distance in Caddy's dredge was greater since it was constructed with double and single links, compared to the quadruple and triple links used here. Also, in Caddy's experiment, blockage of the rake would not have had as strong an effect since the tows were over a sandy bottom and catches of sea scallops were not large, averaging 129 per kilometre towed.

Under the simplification of knife-edge selectivity at $h_{50} = 69.4$ mm, all scallops less than or equal to 69 mm escape and all equal too or above 70 mm are retained. The distribution of the meat weights of Iceland scallops on the St Pierre Bank was estimated using the size distribution of scallops from the (nonselective) covered gear, and the shell height to meat weight relation from Naidu (1991). The above knife-edge selectivity corresponds to 83% retention by meat weight of all commercial sized (≥ 60 mm) scallops. The end values of the 95% confidence interval for h_{50} (67.4 and 72.7) correspond to 71% and 89% retention respectively.

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Table 1. The estimated sizes of 25%, 50% and 75% retention for sets A-D, F-J and the combined data. These estimates were obtained by isotonic regression.

Set	h_{25}	h_{50}	h_{75}
A	54.0	69.8	77.1
B	52.0	70.0	75.1
C	53.5	80.1	84.3
D	29.8	56.5	71.2
F	67.9	76.7	83.9
G	20.5	45.3	74.4
H	36.9	47.8	63.1
I	58.3	72.4	79.1
J	62.4	69.7	82.1
A-J	50.5	69.4	77.3

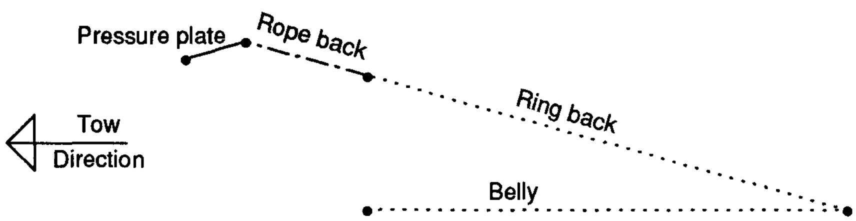
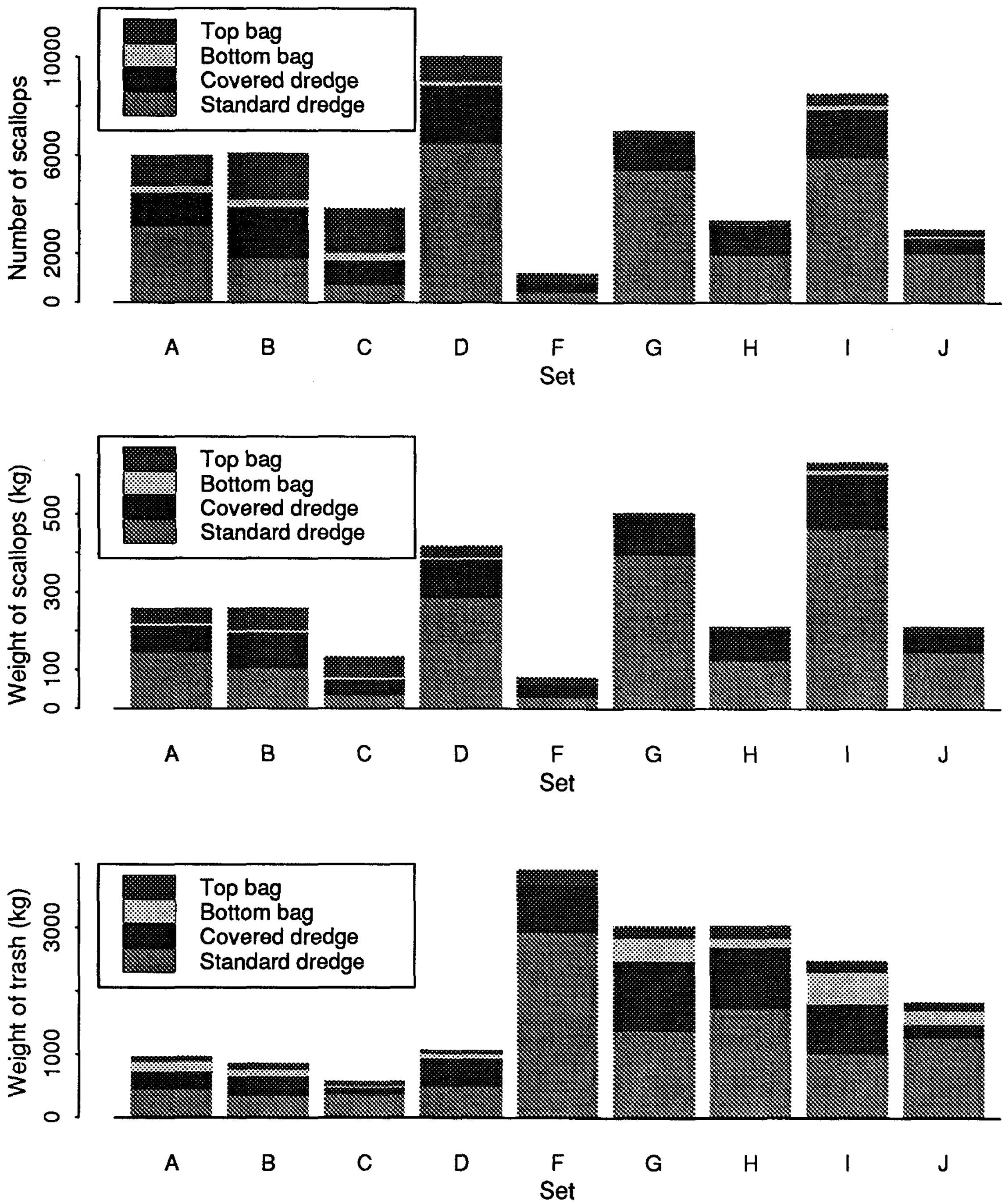


Figure 1. A simplified side view of a New Bedford offshore dredge. The belly and ring back of the dredge are constructed from heavy metal rings interconnected by links. The upper-forward part of the dredge is constructed from mesh and is called the rope back.



Figures 2a-2c. Barplots giving the number of scallops (Fig. 2a), the weight of scallops (Fig. 2b), and the weight of trash (non-scallop matter, Fig. 2c) caught in the standard dredge and the three compartments of the covered gear for each set.

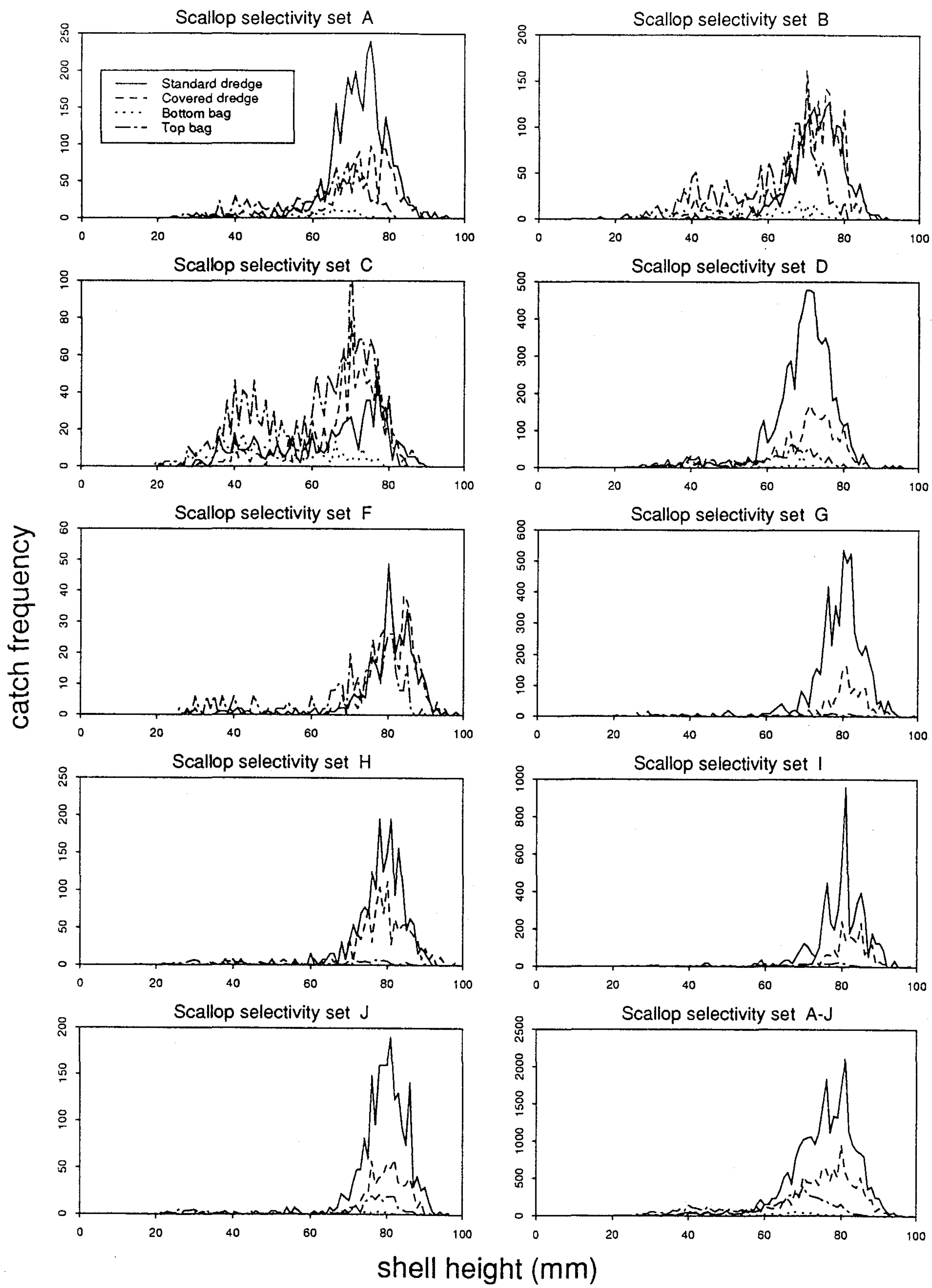


Figure 3. Shell size frequency distribution in the standard dredge and covered gear for each set and combined over all sets.

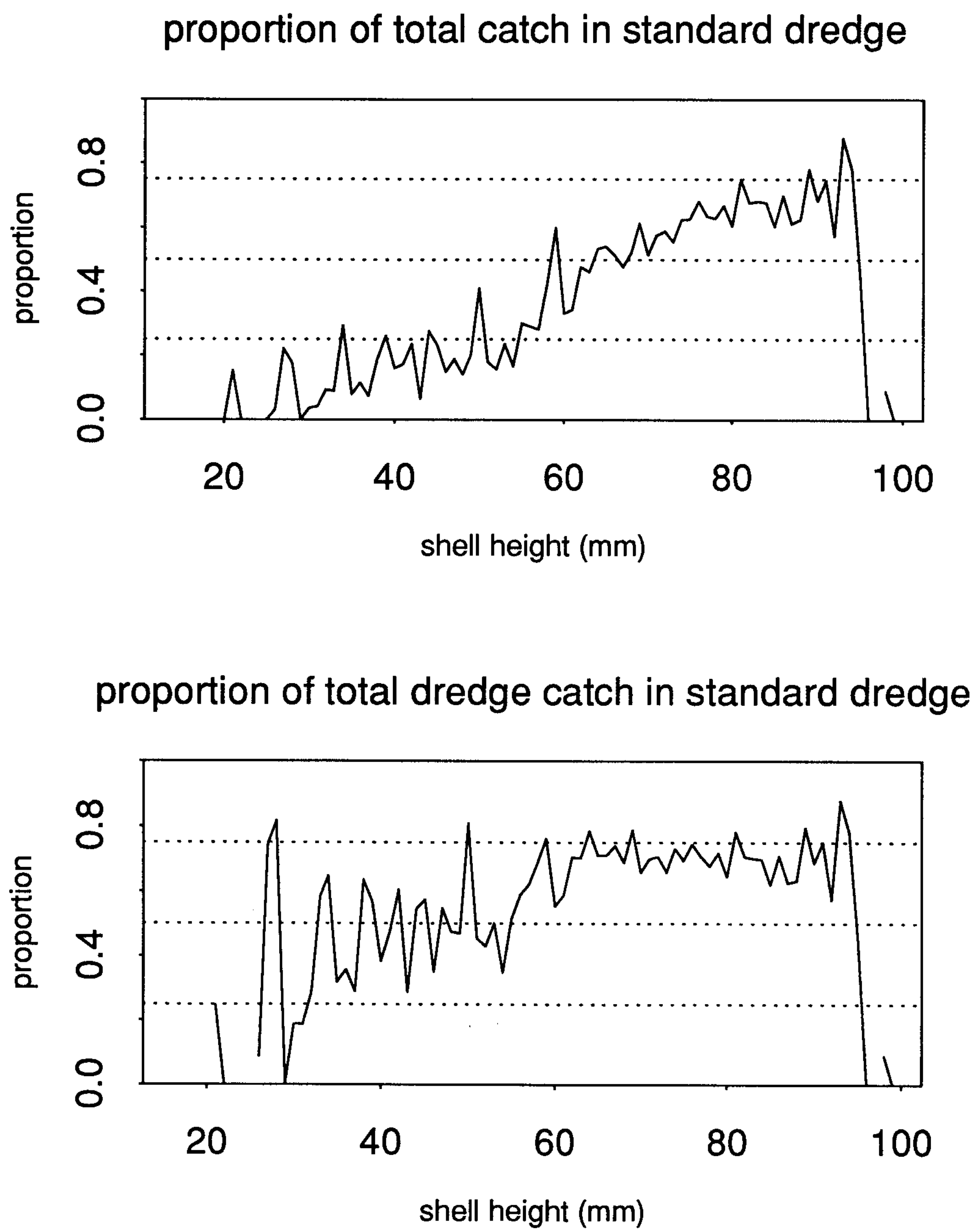
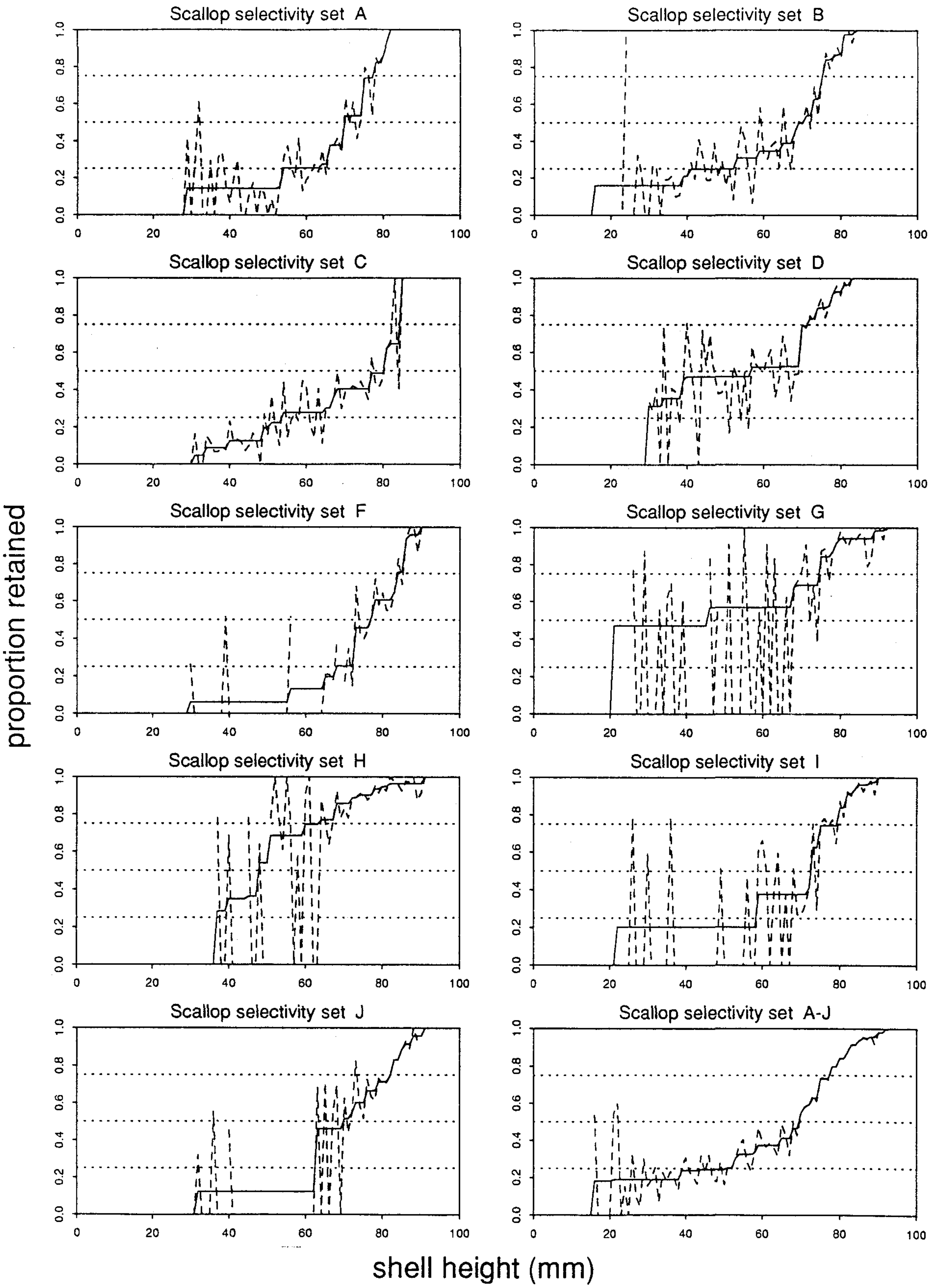


Figure 4a. Proportion of total scallop catch (standard dredge + covered gear) that is from the standard dredge (Fig. 4a). Proportion of total catch taken in the dredges (standard dredge + covered dredge) that is from the standard dredge (Fig. 4b).



Figures 5. Isotonic selection curves (solid line) fitted to the retention data from the individual and combined sets data (dashed line).

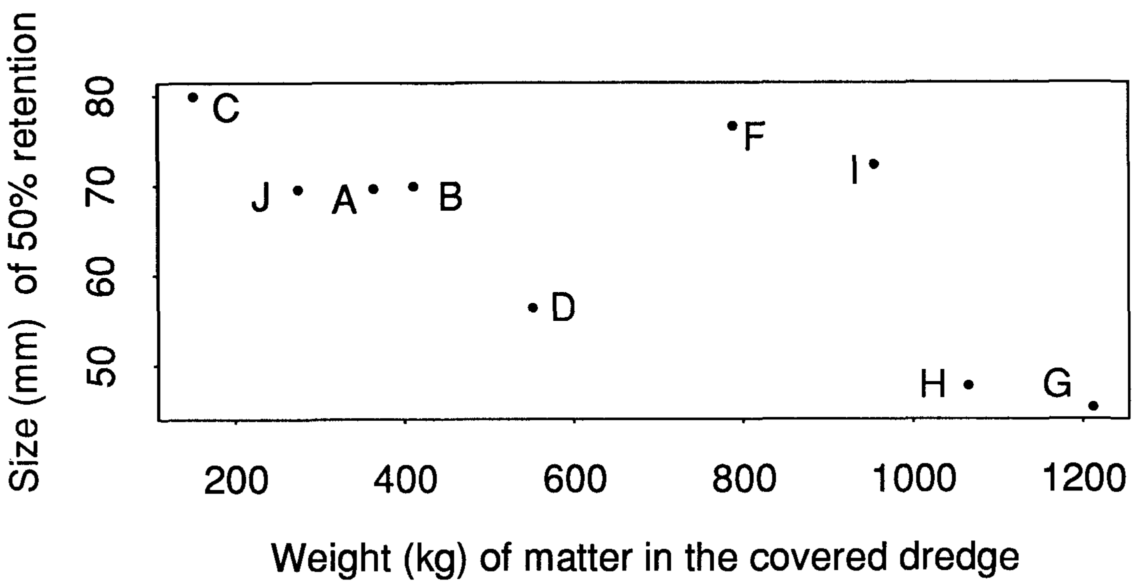


Figure 6. Scatter plot of the total weight (kg) of matter in the covered dredge versus the estimated size of 50% retention.

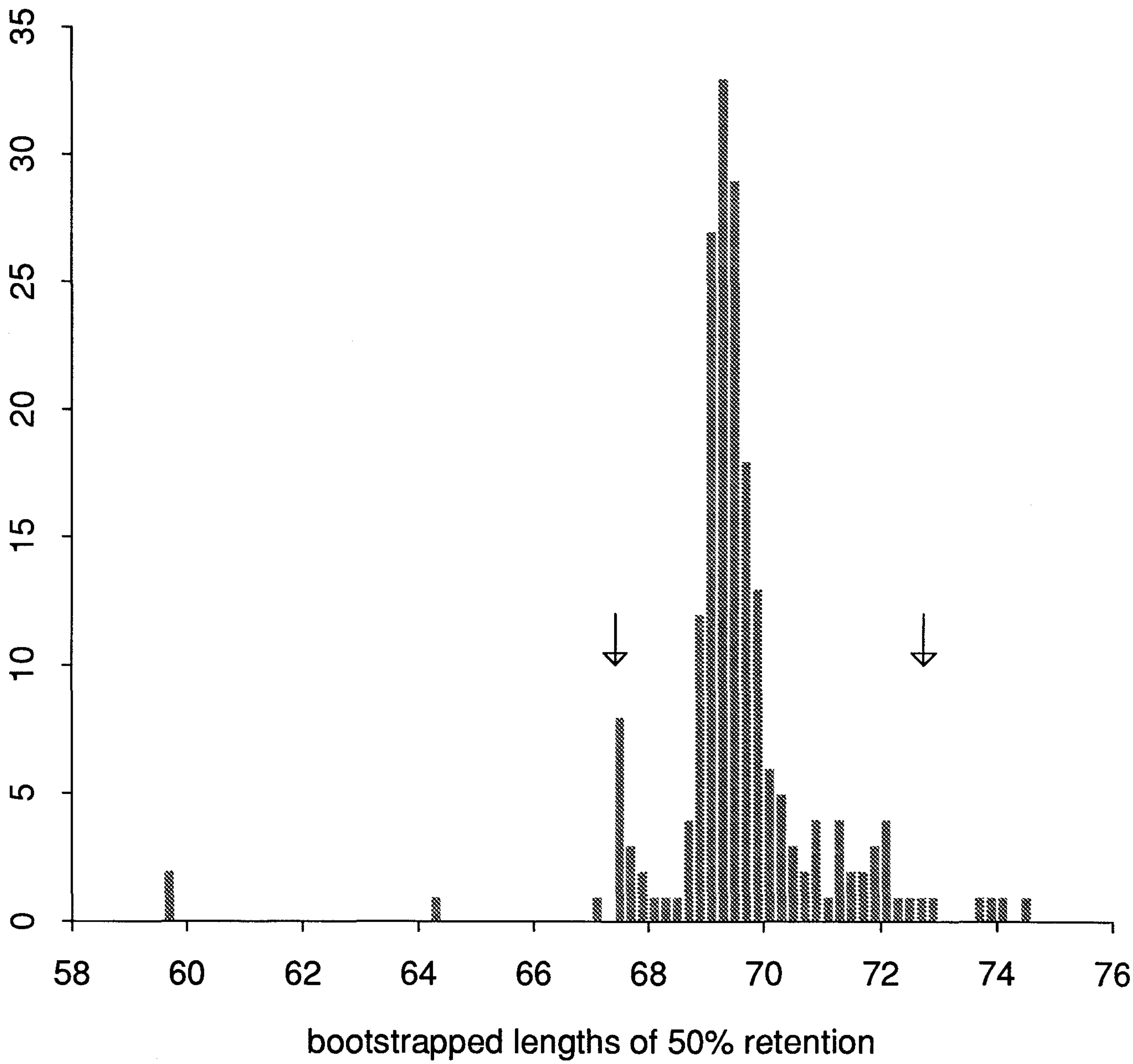


Figure 7. Histogram of 200 bootstrapped estimates of the size of 50% retention. The arrows indicate the 95% bootstrap confidence interval, corresponding to limits containing 95% of the boostrapped estimates.