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CAFSAC Research Document 79/43

BAY OF FUNDY SCALLOP STOCK ASSESSMENT - 1978

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Jamieson, G.S. and M.J. Lundy. 1979. Bay of Fundy scallop stock assessment - 1978. Fish. Mar. Serv. Tech. Rep.

The 1978 Bay of Fundy scallop stock assessment is presented. Bucket location and the presence or absence of a mesh liner affected gear performance in a 7-gang drag; and except for prerecruits, unlined drags consistently fished a greater number and yield of scallops than did lined drags, regardless of location.

The modal age of scallops caught was seven years. Recent recruitment has been relatively poor and shows regional variation. The total scallop biomass was estimated at 4744 mt, but scallop contagion was evident and only a fraction of this scallop biomass is sufficiently concentrated to allow profitable commercial fishing. A continuing cyclical fluctuation in scallop abundance is indicated and recently, above-average catches from the Bay of Fundy can be expected to decline as the more abundant older age-classes are depleted in number.

RESUME

Jamieson, G.S. and M.J. Lundy. 1979. Bay of Fundy scallop stock assessment - 1978. Fish. Mar. Serv. Tech. Rep.

On présente l'évaluation de 1978 des stocks de pétoncles dans la baie de Fundy. L'emplacement des gobelets et la présence ou l'absence d'une doublure ont inflé sur le rendement d'une drague munie de sept gobelets et, exclusion faite des jeunes pétoncles, les prises de pétoncles obtenues pendant une période de trait de dix minutes avec des dragues sans doublure ont été sensiblement supérieures à celles obtenues avec des dragues munies d'une doublure et ce, quel que soit le lieu de pêche.

L'âge modal des pétoncles pêchés était de sept ans. Le recrutement a été relativement faible récemment et il varie d'une région à l'autre. On a évalué la biomasse totale de pétoncles à 4744 tm, mais on constate que les pétoncles sont regroupés par secteurs et qu'il n'y a qu'une fraction de cette biomasse de pétoncles qui soit suffisamment concentrée pour pouvoir sountenir une pêche commerciale profitable. On

indique au'il y a une variation cyclique continue de la population de pétoncles et on peut s'attendre à ce que les prises obtenues dans la baie de Fundy, qui ont été supérieures à la moyenne récemment, fléchissent au fur et à mesure que le nombre de pétoncles appartenant aux classes d'âge plus avancées, actuellement plus nombreuses, diminuera.

INTRODUCTION

Annual scallop stock assessments have not been routinely implemented in the past in any Maritime scallop fishery, with the exception of the Georges Bank scallop fishery which has been surveyed for the past two years. As a result, there is no data base with which to compare present survey results. A stock assessment of the Bay of Fundy scallop fishery off Digby, Nova Scotia, is presented, based on the relative age-composition of the stock and recent fishery performance.

The most intensive scallop stock assessment undertaken in any Maritime scallop fishery was that by Dickie (1955) for the years 1942 to 1952 in the Digby area of the Bay of Fundy. He noted that variable recruitment was primarily responsible for fluctuations in the fishery, and that individual year-class strength was correlated with water temperatures which prevailed at the time the scallops were present as pelagic larvae. The study reported here does not discuss factors affecting recruitment magnitude (see Caddy, 1976), but does extend fishery data summaries to the present. Management options are discussed in the context of both short- and long-term benefits to the fishery.

MATERIALS AND METHODS

A. Sampling Procedures

In late September, 1978, a survey was conducted off the coast of Digby, Nova Scotia (Figure 1) to measure the relative abundance of the sea scallop, *Placopecten magellanicus*, and to determine the distribution of the stocks. The 63 ft. (19.2 m) commercial Digby scallop dragger, M.V. Barbara T., skippered by Reg Hazelton, was chartered from September 28 to October 2 for this survey.

During the year, each vessel of the Digby scallop fleet submitted fishing logs which included effort data. The information received was very general regarding the areas fished; for example, areas fished would be recorded as 3 miles off Digby Gut, 2.5 miles off Gullivers Head, 5.5 miles off Broad Cove, and so on. To eliminate straight-line peaks of number of days fished in 1978 off each main point on the coastline as recorded in the fishermen's logs and to allow for a randomized sampling technique, 3-mile (4.8 km) bands were drawn perpendicular to the coast, each having the main coastal point as the centre point (Figure 1). The number of stations assigned per area was proportional to the relative number of days fished there from January to July, 1978, inclusive (Tables 1 and 2), which meant areas with greater fishing activity were more intensively surveyed. Once the number of stations (72) inside and outside the closure line (6-mile line) were established, random number tables were used to assign the distance of each station off the coast. The point parallel to the shore within the 3-mile band for each of the randomized distances was also assigned randomly; this distance was measured from the northeastern edge of the 3-mile band. Due to there being a risk of damage to gear from the rocky bottom within 2 miles (3.2 km) of the coast, any stations randomly located within this area were excluded from the survey track. The direction of each tow was left up to the skipper's discretion in order to optimize the time available for the survey. The order of which stations were sampled was done in such a manner as to optimize available time yet allow some stations in each of the four areas to be sampled each day.

Bad weather necessitated the dropping of 27 of the originally-planned 72 stations, and so following the third day of fishing, all remaining unfished stations were dropped from the survey plan.

The gear (Figure 2) was a 7-gang Digby drag with 3-inch (76 mm) rings. Numbers 1 and 5 buckets contained a cover of 1-1/2 inch (38 mm) mesh on the outside of the upper side of the bucket to allow measurement of scallops that actually passed through the rings during the dragging operation. Numbers 4 and 5 buckets were equipped with a hood on the upper side. This gave a representative sample of the size and number of scallops that actually eluded the drags by swimming over them.

At many of the stations (Table 3), Number 4 bucket flipped over during the dragging procedure causing the cover to be torn. In these cases the cover's catch was not sampled. On Stations 5, 16, 34, 35, and 36, the cover and bucket were filled with hydroids which probably prevented scallops from entering the cover. From Station 29 to Station 36 the cover was continuously torn and repaired, and this continual tearing resulted in an irrepairable cover at Station 37. Due to the time needed to replace the cover and the limited sampling time still available, the cover was not used for the remainder of the survey. During the tenth tow, the drags with the hood flipped over, resulting in irrepairable damage to the hood. All liners were repaired when necessary.

Individual height frequencies were performed on scallops in buckets 1, 4, 5, and 7, the cover, and the hood, although for the first ten tows all scallops fished were measured. In subsequent tows, a subsample was taken, if necessary, and values prorated. Clucker (paired dead shells) frequency was also recorded in each height frequency measurement. A depth sounder operated continously and the approximate depth of each tow was recorded.

B. Growth Parameters

Von Bertalanffy growth parameters for Bay of Fundy scallops off Digby, N.S. were calculated from scallop size at age data obtained in May, 1966 (Caddy et. al., 1970; Table 5). Depth had a profound effect on both growth and asymptotic size, and so separate growth parameters were determined for scallops at depths less than or greater than 60 fathoms (109.9 m):

	$\leq$ 60 fathoms	$\geq$ 60 fathoms
L_∞	145.5	114.9
K	0.24	0.29
t_0	0.8	1.7
n	2082.0	1973.0

All scallops in the present resource survey were obtained from depths less than 60 fathoms. The above growth parameters were used to determine average scallops size at age (Table 4, Figure 3).

It should be noted that the scallop measuring procedures used by Caddy et. al. (1970) differ from those presently in use. Caddy et. al. felt that the first ring laid down occurred when the scallops were only a few months old and about 2-5 mm in height. This ring can seldom be observed in scallops which exceed 20 mm in height. This ring was called ring 1, and the ring laid down in the scallops' second winter, when they were about 10-15 mm in height, was called ring 2. This latter ring is now called ring 1, and the scallop is considered to be one year old at the time it is laid down. The data in Caddy et. al. (1970) has thus been adjusted accordingly.

Brannen (1949) measured the average growth for each year of life for Digby scallops collected in 1940, and noted some variation between sampled transects. However, no depth information was provided; and since this factor appears to significantly affect growth, Brannen's data have not been included in subsequent analyses.

C. Height-Weight Relationships

Available data on height-weight relationships for Bay of Fundy scallops is primarily from three sources: three plots of regressions (est. 314 measurements) for three separate regions off Digby, N.S. (Dickie, 1955), a long-time series of unpublished data (3,600 measurements) for scallops in Passamaquoddy Bay, and data (269 measurements) obtained in the present survey. Owing to relatively small sample sizes and a limited scallop size range, the height-weight regressions derived from the samples collected during this survey and from Dickie (1955) were not utilized, and so a regression derived from 1960-62 Passamaquoddy Bay data has been used in subsequent analyses. This latter regression,

$$\log_e(\text{weight}) = -12.24 + 3.24 \log_e(\text{height})$$

was based on data obtained through an entire year; and although perhaps less indicative of the situation off Digby, N.S., it is felt to be most suitable until sufficient recent Digby data can be collected.

RESULTS

A. Gear Performance

To evaluate the relative gear efficiencies of the seven, separate Digby tumble buckets in the overall drag gang, lined and unlined bucket catches from both the centre and the end of the gang are compared (Figure 4). The meat yield and number of commercial-size scallops fished by unlined drags were both significantly (Tukey's HSD test) greater than that fished by comparably located, lined buckets. End buckets on the average (not significant) fished higher catches of commercial-size scallops than did comparable-mesh size, centre buckets.

The number of prerecruits fished by the lined, end bucket was significantly (Tukey's HSD test) greater than that fished by the unlined buckets, regardless of location. The lined, centre bucket's catch was significantly greater only from the unlined, end bucket's catch. No significant difference existed between the numbers of prerecruits fished by the lined centre and end buckets.

Possible explanations for why end buckets tended to catch more commercial-size scallops than centre buckets are in the design of the gear, its behaviour on the bottom, and the age-specific swimming ability of scallops. The seven buckets are individually chained to a common towing bar, which precedes the buckets by approximately 60 cm. Four chains connect the ends and two mid-points of the towing bar to a shackle at the end of the towing cable, which in turn precedes the towing bar. In operation, scallops in the centre of the drag path thus encounter the drag before scallops located near the ends of the drag. Scallops are capable of swimming, and it may be that scallops in the centre of the overall drag path are stimulated to swim early enough so that by the time the drag arrives, they are either above the drag or have again settled to the bottom thereby possibly passing under the drag. In contrast, scallops at the edge of the drag path may receive relatively little prior warning of the drag's arrival, and hence are still located in the portion of the water column swept by the drag.

There also appears to have been a tendency for the lined buckets to fish differently from the unlined buckets. The lined buckets may have filled up more rapidly with trash, and either because of this or the liner itself, created a "pressure zone" earlier, which preceded the bucket and caused the water and scallops to be swept aside rather than enter the bucket. The lined and unlined buckets were normally completely filled with scallops and trash, except for five tows when hydroids were very abundant and clogged the drag, and so the drags cannot be assumed to have fished equally throughout the ten-minute tow.

The hood catch (Figure 4) consisted predominantly of three-year old scallops, with about equal numbers of four- to nine-year old scallops. Since younger scallops tend to be more active swimmers than older scallops, it was anticipated that the younger age-classes would be more abundant in the hood. In this respect, the relatively few four- and five-year old scallops contained in the catch (Figure 4E) suggest a decreased abundance of these age-classes relative to three-, six-, and seven-year old scallops. This observation is supported by the propotionately lower numbers of four- and five-year old scallops in the lined buckets (Figure 4C).

As expected, the scallop catch in the cover on the top, or back, of the bucket was most age-specific (Figure 4): no scallops greater than age four were collected.

B. Year-Class Abundance

In terms of both number and age specific yield, the modal age of recruited scallops caught in both unlined and lined buckets was seven years (Figure 4). This may partially be explained by the high retention of this age class (Dickie, 1955) in unlined buckets (Figure 5A), but since this age class was most abundant in the lined buckets as well, it is felt to be a real phenomenon. The 38 mm mesh liner should have retained most scallops age three (60 mm) or older.

Recognizing that some scallops might swim over the drag, the catches from both the hood and centre, lined bucket were summed (Table 5) to give an estimate of relative age class abundance. Since a centre bucket was used, escapement to the side cancels out, leaving only scallops which swam over the hood or passed beneath the bucket excluded. It is felt unlikely that any scallops would elude the hood (81 cm high) by swimming above it, and it is assumed that there were not age-specific differences in scallops passing under the drag. However, two-year old scallops may still be underestimated since according to the growth parameters their mean size is 36 mm, about the same size as the linear mesh.

The low relative abundance of five- and six-year old scallops indicate that recent recruitment is well below the level which is sustaining the present fishery. Future catches can therefore be expected to decline as the 1971 scallop year-class is depleted.

C. Regional Variation in Population Age Structure

To evaluate the extent recruitment varied regionally within the relatively small area (116 km^2) surveyed, relative age class abundance in the four surveyed regions was compared. Catches per tow for each region were projected as if all the buckets in a drag had catches equivalent to either that of an unlined, end bucket (Figures 6A and B) or lined, end bucket (Figures 6C and D). Catch per drag rather than catch per bucket was compared to allow more accurate representation of scallop numbers actually caught by fishermen. With both unlined and lined buckets, commercial-size scallop number and yield showed little regional differences (Table 6) although catches averaged greater off Centreville and Gullivers Head than off Broad Cove and Digby Gut. Catches off Broad Cove contained a significantly (Tukey's HSD test) greater abundance of prerecruits over catches of Digby Gut.

Age-specific numbers and yields of scallops (Figure 7) fished in waters outside the 6-mile closure line were not significantly different to those observed inside the line, although yields averaged 7% and 26% greater for unlined and lined drags, respectively, outside the closure line. Prerecruits were not as abundant outside the line as inside the line.

DISCUSSION

A. Biomass Estimation

The main difficulty in estimating scallop biomass is determining accurate estimates of drag efficiency and selectivity. Dickie (1955) attempted this in a detailed study in the Bay of Fundy by releasing tagged scallops in a predetermined, marked plot and then by comparing their age-specific recapture rates with subsequent fishing. However, his observations appear to be underestimates of actual efficiencies for the following reasons:

1) Difficulty was encountered in controlling the size of the marked plot because of the strong tidal currents present.

2) Tagged scallops may have drifted outside of the plot during their release.

3) A "large proportion" (quantity unspecified) of marked scallops apparently died as a result of marking, and it was assumed that living scallops, cluckers, and single shells were equally recoverable.

4) Tow duration was 15 minutes. The drags may have quickly filled up with scallops, debris or rocks and thus would not continue to accurately sample scallops in the tow path.

5) The experiment was extended over a period of time (at least one month): additional scallop dispersement could have occurred as a result of scallop swimming behavior arising from drag activity or normal behavior.

In comparing the catches of the lined versus unlined drags in this study, two features are evident: lined drags are more efficient than unliñed drags in capturing two- to three-year old scallops (prerecruits); but the overall percent retention of scallops from the drag path of a ten-minute tow is lowest for lined drags, presumably because they fill up more rapidly with trash and hence stop effective fishing earlier. For scallops aged five or older, unlined drags retained almost double the number of scallops as did lined drags (Figure 4), even though 100% retention should hav been achieved by both drag types (the sizes of these age classes exceeds the inter-ring or mesh sizes). It is thus assumed that with ten-minute tows, lined drags fished effectively for only about half the distance that unlined drags did.

Scallop selectivity by unlined drags can be directly estimated for scallops over two years in age by comparing the lined catch data (number actually entering gear) with the unlined catch data (Figure 5B) and weighting for effective fishing duration. Even with a larger ring size, present selectivity results are greater than Dickie's (1955) (Figure 5A) for ages three to four, supporting the above suggestion that his values were underestimates. Both studies indicated that scallops older than four years had 100% retention. Since two-year old scallops were not fully retained by the lined gear, no accurate estimation can be made of the selectivity of this age class by unlined gear.

Dickie (1955) estimated that the maximum efficiency of commercial drags in inshore and offshore waters off Digby, N.S., was 5% and 12%, respectively. Previous studies indicated an overall gear efficiency of 15-20% for the Canadian offshore scallop dredge over gravel on Georges Bank (Caddy, 1971), and 1-8% for a light offshore drag over sand in the Gulf of St. Lawrence (Caddy, 1968), with dredge efficiency varying as to scallop size. Baird (1959) estimated the efficiency of the toothed European scallop dredge as 8.5% for all sizes of scallops.

Dickie (1955) thus provides data comparable to other studies; but since his selectivity data appear to have been underestimated for three- to five-year old scallops, it seems likely that his overall gear efficiency data were underestimated as well. However, since these age classes are poorly represented in the present stock, Dickie's (1955) estimate of gear efficiency for inshore areas has been used in this study.

Dickie (1955) observed from a series of timed runs over a marked-off course that a 15-minute tow covers, on average, a distance of 900 yards; in his survey, as in the present one, tows were made in the direction of the tide. Since the tows in this study were of ten minutes duration, it is assumed that the average tow distance was 600 yards (549 m). With an average bucket width of 0.76 m, the average area covered by an unlined, single bucket is 417 m^2, or 2919 m^2 for an unlined 7-gang drag. These values would be halved for lined gear since those drags effectively fished only half the distance fished by unlined gear.

Weighing for gear selectivity and efficiency, overall scallop biomass estimates per drag path (Table 6) for the four inshore study areas indicate average densities of about 2-3 scallops/m^2, all age classes combined. These estimates are in the range of that reported by Dickie (1955) from a strip-census fishing of inshore waters between 1950-1953: 0.78-9.12 scallops/m^2. Caddy (1968) recorded scallop densities from corral catches off Richibucto, N.B., of 4.18/m^2 on sand and 1.43/m^2 on mud.

Through areal expansion, overall population biomasses were estimated for each study area (Table 7): in general, scallop abundance was greatest with increasing distance from Digby. The total scallop biomass for all inshore study areas combined was estimated at 4744 mt. The accuracy of this estimate is difficult to assess, since our stations were randomly located over areas known to have a contagious distribution of scallops. In contrast, Dickie (1955) surveyed only what he felt were the major scallop beds in inshore waters and from strip-census fishing, derived much reduced total population biomasses. The total area of productive inshore scallop ground was estimated by Dickie (1955) to comprise only 7.4 km^2, whereas in this study, results are expanded over an area of 116.6 km^2.

This significant difference raises a number of questions as to what is the optimal sampling design for a contagiously distributed species. In theory, all regions with commercial scallop densities should be sampled, but since a number of factors effect whether or not a specific area is fished (scallop price, distance from port, relative scallop density, etc.), and since fishing location data have inherent precision errors, it is difficult to identify all potential fishing locations.

Present catches are the largest since the early 1960's and have only been exceeded by catches in the 1930's, when the stock first began to be exploited on a major scale. It is thus not surprising that the present estimated biomass is large. However, it should be noted that a majority of scallops appears to be presently distributed at low to average densities and as such, cannot be profitably fished. These scallops cannot be considered in any harvestable yield calculations, thus stressing the need for density isopleths to complement overall biomass estimates. Only in this way can the exploitable biomass; i.e. that above the density threshold for profitable fishing, be determined.

B. Fishery Performance

Annual landings (Figure 8) from 1922-1978 indicate that 1978 landings fished in the Bay of Fundy (485 mt) are above the average for the last 27 years (325 mt). This time period was selected since it is only for these years that seasonal catch breakdowns are available. Except for 1975, inshore, or winter, landings (October to May) have exceeded offshore, or summer, landings (May to October). It should be noted, though, that in 1977 and 1978, the relatively high offshore landings (Table 8) are in part the result of fishing activity inside the 6-mile, inshore summer closure area. Area fished is obtained from log data; and to avoid possible prosecution, scallops fished illegally in closed waters may have been reported as being fished outside the closure zone or simply in the "Bay of Fundy".

The occurance of above-average landings appears cyclical, as noted by Caddy's (1976) suggestion of a periodicity of 8-9 years. Caddy also confirmed a lagged correlation of production with temperature, but his use of a periodic function with decreasing amplitude to describe landings over the long term is not supported by the greater magnitude of recent landings. This is not surprising since if recruitment is primarily influenced by environmental parameters, it would be expected to fluctuate about a mean, and not continuously decrease until stock extinction resulted. Although only exploited for about 50 years, this resource has likely existed for centuries since it is not in a fringe area of the species' distribution.

Fleet size has fluctuated between 20 to 50 ships over the past 20 years, and it is interesting to note that like many predator-prey systems, predator, or ship, abundance fluctuations lag behind prey abundance, or landing, fluctuations. It is only after prolonged periods of low landings (about 6 mt meat/boat/year) that fleet size is reduced noticeably.

MANAGEMENT OPTIONS

The continuing cyclical fluctuation in scallop abundance is indicated by the relative low abundance of four- to five-year old scallops, and catches from the Bay of Fundy can be expected to decline as the more abundant older age-classes are depleted. Precise estimates of future landings cannot be predicted. However, on the basis of past cycle duration, a decline in landings can be expected in either 1979 or 1980. Declines have characteristically been very sharp, with catches in a decline often as little as half that of the previous year's landings.

Anticipating a decline in landings, two immediate management options are available: a quota may be placed on the 1979 landings in an effort to spread the yield from the remaining scallops over the next few years so as to dampen the magnitude of landing fluctuations, or landings can be allowed to decline sharply as in the past and management effort directed towards optimizing yield when recruitment improves.

A seasonal closure of the highly productive inshore fishing grounds (within six miles offshore) is in effect, but recent wide-spread abuse of this regulation negates much of its value. With effort restriction difficult to effect, a Bay of Fundy quota and meat count regulation appear the most viable management alternatives.

A number of biological factors influence those management alternatives which might be adopted. Among factors to be considered are:

1) Availability of other exploitable scallop stocks.

Bay of Fundy scallop fishing vessels are restricted in length to less than 19.8 m (65 ft.); and it is their relatively small size that limits the ability of vessels from this fleet to exploit the more distant, offshore scallop fishing grounds. Historically, these vessels have seldom ventured further than Browns Bank. The only consistently productive scallop ground within the normal fishing range of this fleet is that off Digby and Digby Neck. The scallop grounds off Grand Manan Island and on Lurcher Shoals are still unrecovered after being heavily exploited in the 1950's and 1960's.

The offshore banks, along with any area outside the Bay of Fundy, can be exploited by vessels of the offshore scallop fleet as well, permitting only a fraction of that area's total production to be harvestable by the Bay of Fundy fleet.

In 1977, the Bay of Fundy fleet was permitted to fish Georges Bank, which at that time was producing yields well above average. Although initially specified to be only for that year, economic hardship was claimed by the fleet in 1978, and although Bay of Fundy production was well above average (Figure 8), an annual Georges Bank allocation of 2.9% of the previous year's Canadian scallop landing from Georges Bank was given to the Bay of Fundy fleet. Although a small overall percentage, Georges Bank landings by the Bay of Fundy fleet were 367 and 264 mt for 1977 and 1978, respectively. In comparison, Bay of Fundy landings were 450 and 485 mt, respectively. Georges Bank production is now declining, but with an average annual combined Canadian and American landing of 10,000 mt, the Canadian share might be expected to average 7360 mt annually in the future, thereby providing an average annual landing of 213 mt to the Bay of Fundy fleet (66% of the average annual Bay of Fundy landing).

2) Yield per recruit (Y/R)

Although not determined specifically for Digby scallops, growth rate estimations suggest that Y/R for Bay of Fundy scallops from less than 60 fathoms is maximized at age of first harvest of about seven to ten years. Since the present modal scallop age is seven years, maximal yield from this year-class would be achieved if it is fully exploited over the next three years.

When relative year-class abundance cycles over a time period which approximates the optimal age of first harvest, there is a tendency to overexploit the next year-class of above-average recruitment at ages below that of maximal Y/R. Potential yield over the long term may be thus decreased; and as the only Maritime scallop fishery without a maximum meat count per pound regulation, this fishery is particularly susceptable to overfishing of young scallops. Depletion of older scallops increases the likelihood of subsequent overexploitation of young scallops, as short-term rationalization may override potential long-term benefits.

3) Fleet size

It has been recognized for a number of years that the scallop resource available to the Bay of Fundy fleet was finite, with fleet size theoretically frozen in 1973 to 54 vessels. In the interim, fleet size has continued to increase, so that by April 21, 1978, this fleet comprised 70 vessels in Nova Scotia and, unconsidered in 1973, 16 unrestricted Bay of Fundy scallop licenses in New Brunswick.

In recent years, potential effort directed in the Bay of Fundy alone has been estimated (Caddy, pers. comm.) at about double that required to provide MSY with long-term recruitment levels. It is thus evident that with increased fleet size and a predicted decline in Bay of Fundy landings, this resource is not capable of supporting present levels of expended effort. Because of the close proximity of this resource to the fleet's home port of Digby, N.S., this resource provides the main source of scallops for most of the vessels in the fleet and hence will be particularly susceptable to future overfishing of new recruits.

CONCLUSIONS

1. Depth has a profound effect on Digby scallop growth rates with scallop growth at depths of < 60 fathoms significantly greater than growth in deeper water.

2. Lined, end scallop buckets (38 mm mesh) retain significantly more prerecruits than do unlined scallop buckets, regardless of location. With a ten-minute tow, lined buckets fished significantly fewer commercial-size scallops than did unlined buckets. End buckets in a 7-gang drag, whether lined or unlined, tended to fish more commercial-size scallops (insignificant) than did comparable centre buckets.

3. A greater proportion of prerecruits than recruits avoid capture by swimming over the drag, indicating that hooded gear has a role in assessing prerecruit abundance.

4. The modal age of scallops fished in 1978 was seven years, and little regional variation in inshore waters was evident for recruits with unlined gear. However, some significant regional variation was evident for prerecruits with lined gear.

5. The modal age and abundance of scallops in the limited offshore area sampled were similar to those observed in inshore waters, although abundance of prerecruits was less.

6. Unlined gear retention of Digby scallops at ages three, four, and five years or older is estimated at 25, 95, and 100%, respectively.

7. Weighing for gear efficiency, the total scallop meat biomass in the study area is estimated at 4744 mt, averaging 2-3 scallops/m^2. However, significant contagion was evident and only an unknown fraction of this biomass is at a density sufficient for profitable commercial exploitation.

8. A continuing cyclical fluctuation in scallop abundance is indicated and catches can be expected to decline as the more abundant older age-classes are depleted.

9. A seasonal quota on landings and the introduction of a meat count regulation appear the most attractive long-term management options as effort control is difficult to effect.

ACKNOWLEDGEMENTS

We are grateful to Ross Chandler, Nancy Witherspoon, Ian Marshall, and John Priest for their participation in data collection and analysis for this report.

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TABLE 1. Expended effort (days) distribution in 1978 inside the 6-mile, summer closure zone off Digby, N.S. (Total = 276 days, January-August inclusive)

Distance off shore (miles)	Centreville		Gullivers Head		Broad Cove		Digby Gut		Delaps Cove	
	Effort	%	Effort	%	Effort	%	Effort	%	Effort	%
1	2	0.7	0	0	0	0	0	0	0	0
1.5	10	3.6	7	2.5	0	0	1	0.3	0	0
2	1	0.3	4	1.4	10	3.6	2	0.7	1	0.3
2.5	7	2.5	13	4.7	6	2.1	9	3.2	1	0.3
3	3	1.0	3	1.0	23	8.3	5	1.8	3	1.0
3.5	0	0	3	1.0	2	0.7	0	0	0	0
4	0	0	17	6.1	7	2.5	24	8.7	0	0
4.5	0	0	0	0	6	2.1	5	1.8	0	0
5	0	0	7	2.5	2	0.7	13	4.7	0	0
5.6	0	0	5	1.8	0	0	0	0	0	0
6	0	0	28	10.1	23	8.3	23	8.3	0	0
TOTAL		8.1		31.1		28.3		29.5		1.6

TABLE 2. Expended effort (days) distribution in 1978 immediately outside the 6-mile summer closure zone off Digby, N.S. (Total = 159 days, January-August inclusive)

Distance off shore (miles)	Gullivers Head		Broad Cove		Digby Gut		Delaps Cove	
	Effort	%	Effort	%	Effort	%	Effort	%
6	0	0	0	0	0	0		
6.5	7	4.4	6	3.7	11	6.9		
7	0	0	2	1.2	4	2.5		
7.5	0	0	0	0	2	1.2		
8	0	0	4	2.5	6	3.7	2	1.2
8.5	0	0	0	0	5	3.1	0	0
9	0	0	3	1.8	52	32.7	1	0.6
9.5	2	1.2	0	0	5	3.1	1	0.6
10	4	2.5	6	3.7	25	15.7		
10.5	0	0	3	1.8	5	3.1		
11	0	0	0	0	3	1.8		
TOTAL		8.1		14.7		74.8		2.4

TABLE 3. Catch data and comments for each sample station. Height frequencies were only obtained for the measured amounts. Region 1 = Centreville; 2 = Gullivers Head; 3 = Broad Cove; 4 = Digby Gut. Sample 1 = Bucket 7 (B7); 2 = B1; 3 = B5; 4 = B4; 5 = Back cover; 6 = Hood.

Station	Region	Samples measured	Amount measured (lb)	Amount not measured	
1	3	1,2,3,4,5,6	2.0*	-	
2	2	1,2,3,4,5,6	3.5*	-	
3	2	1,2,3,4,5,6	2.5*	-	
4	1	1,2,3,4	4.5*	-	Hood and cover flipped.
5	1	1,2,3,4,5,6	2.0*	-	Lot of moss, 5 gal. tub trash in cover
6	1	1,2	3.0*	-	Centre, hood and cover flipped.
7	1	1,2,3,4,5,6	2.5*	-	
8	1	1,2	2.3*	-	Centre, hood and cover flipped.
9	1	1,2,3,4,5,6	2.5*	-	
10	2	1,2,	2.0*	-	Hood removed. Centre, hood, cover flipped.
11	2	1,2,3,4,5	0.3*	0.3*	
12	2	1,2,3,4,5	1.5*	1.0*	
13	2	1,2,3,4,5	0.5*	0.7*	
14	3	1,2,3,4,5	28	46	
15	3	1,2,3,4	7	67	Cover torn.
16	3	1,2,3,4,5	32	48	Lot of moss, cover full.
17	3	1,2,3,4	23	42	Centre flipped.
18	3	1,2,3,4,5	43	43	
19	3	1,2,3,4,5	53	59	
20	3	1,2,3,4,5	53	44	
21	3	1,2,3,4,5	42	39.5	
22	3	1,2,3,4,5	50	44	
23	2	1,2,3,4	42	79	Cover torn.
24	1	1,2,3,4,5	34	55	
25	4	1,2,3,4,5	43	56	
26	4	1,3,3,4,5	5	4	
27	4	1,2,3,4,5	0	-	All large rock.
28	4	1,2,3,4,5	53*	60	
29	4	1,2,3	32	33	Cover torn. Regular centre caught up.
30	2	1,2,3,4	33	36	Cover torn
31	2	1,2,3,4	44	50	Cover torn.
32	2	1,2,3,4	24	50	Cover torn.
33	2	1,2,3,4	40	23	
34	2	1,2,3,4	74	59	Lot of sponge, cover torn.
35	2	1,2,3,4	62	66	Lot of sponge, cover torn.
36	2	1,2,3,4	46	41	Lot of sponge, cover torn.
37	2	1,2,3,4	76	72	Cover irrepairable.
38	2	1,2,3,4	22	33	Cover irrepairable.
39	2	1,2,3,4	58	53	Cover irrepairable.
40	4	1,2,3,4	39	25	Cover irrepairable.
41	4	1,2,3,4	73	86	Cover irrepairable.
42	4	1,2,3,4	82	67	Cover irrepairable.
43	4	1,2,3,4	53	45	Cover irrepairable.

*Bushel

TABLE 4. Average scallop height at age for Digby scallops from < 60 fathoms as determined from the regression $L = 145.5\ (1-e^{(-0.24[t-0.8])})$.

Age (yr)	Height (mm)
1	6.8
2	36.4
3	59.7
4	78.0
5	92.4
6	103.7
7	112.6
8	119.7
9	125.2
10	129.5
11	132.9
12	135.6
13	137.7
14	139.4
15	140.7

TABLE 5. Relative year- and age-class abundance and yield per tow path of a 7-gang Digby drag, projected from both the centre, lined bucket (CL) (n = 7) and hood (H) (n = 5) fishing in inshore waters.

Year Class	Age (yr)	Number				Yield (kg)			
		CL	H	CL+H	%	CL	H	CL+H	%
1976	2	2	5	7	3	.0	.0	.0	0
1975	3	23	32	55	22	1.4	.0	1.4	1
1974	4	9	4	13	5	1.5	.0	1.5	1
1973	5	14	3	17	7	5.0	.0	5.0	5
1972	6	35	6	41	17	18.8	.1	18.9	17
1971	7	64	6	72	29	44.9	.1	45.0	42
1970	8	22	3	25	10	19.5	.1	19.6	18
1969	9	7	2	9	4	7.5	.0	7.5	7
1968	10	3	1	4	2	4.1	.0	4.1	4
1967	11	4	1	5	2	5.2	.0	5.2	5
TOTAL		185	63	248		107.9	.3	108.2	

TABLE 6. Age-specific drag selectivity and relative age class numbers and yields (kg) per tow path of a 7-gang Digby drag, projected from an end, unlined bucket catch. Estimated area per tow is 2919 m^2

Age	% efficiency	% retention	% fished	Estimated Number				Estimated Yield (kg)			
				Centreville	Gullivers Head	Broad Cove	Digby Gut	Centreville	Gullivers Head	Broad Cove	Digby Gut
3	1.25	25	0.3	334	412	4200	260	0.6	0.8	7.8	0.4
4	4.75	95	4.5	310	36	170	18	1.4	0.2	0.8	0.0
5	5.0	100	5.0	1060	536	334	426	10.4	5.0	2.8	3.8
6	5.0	100	5.0	2180	2088	946	1312	28.4	27.8	12.6	17.6
7	5.0	100	5.0	2468	2850	2016	2150	43.4	49.0	36.0	37.0
8	5.0	100	5.0	1372	852	918	668	30.8	19.0	20.2	15.0
9	5.0	100	5.0	400	296	294	528	10.8	8.0	7.8	14.2
10	5.0	100	5.0	200	214	168	264	6.2	6.6	5.2	8.0
11+	5.0	100	5.0	184	274	184	286	6.6	10.2	6.2	10.0
				7	17	10	9				
			Total $\pm$ SE	8608$\pm$1240	7746$\pm$848	9246$\pm$2156	5914$\pm$1308	138.8$\pm$18.2	126.4$\pm$13.4	99.6$\pm$12.2	160.0$\pm$22.4
			Avg. density per m^2	2.94$\pm$0.42	2.60$\pm$0.30	3.16$\pm$0.74	2.02$\pm$0.44				

TABLE 7. Scallop meat biomass estimates ($\pm$ 1SE), weighed for gear performance, for selected areas off Digby, N.S.

	Centreville	Gullivers Head	Broad Cove	Digby Gut
1) Mean yield scallops per drag (kg) (end unlined)	13.80 $\pm$ 1.84	12.56 $\pm$ 1.34	9.22 $\pm$ 1.12	10.58 $\pm$ 2.24
2) Estimated yield scallops in drag path (kg)	138.8 $\pm$ 18.2	423.4 $\pm$ 13.4	99.6 $\pm$ 12.2	106.0 $\pm$ 22.4
3) Estimated area fished per tow (m^2)	2919	2919	2919	2919
4) Total area (km^2)	31.08	31.08	31.08	31.08
5) Projected total scallop biomass (mt)	1566.8 $\pm$ 193.8	1346.0 $\pm$ 142.8	795.4 $\pm$ 97.4	1128.6 $\pm$ 238.6

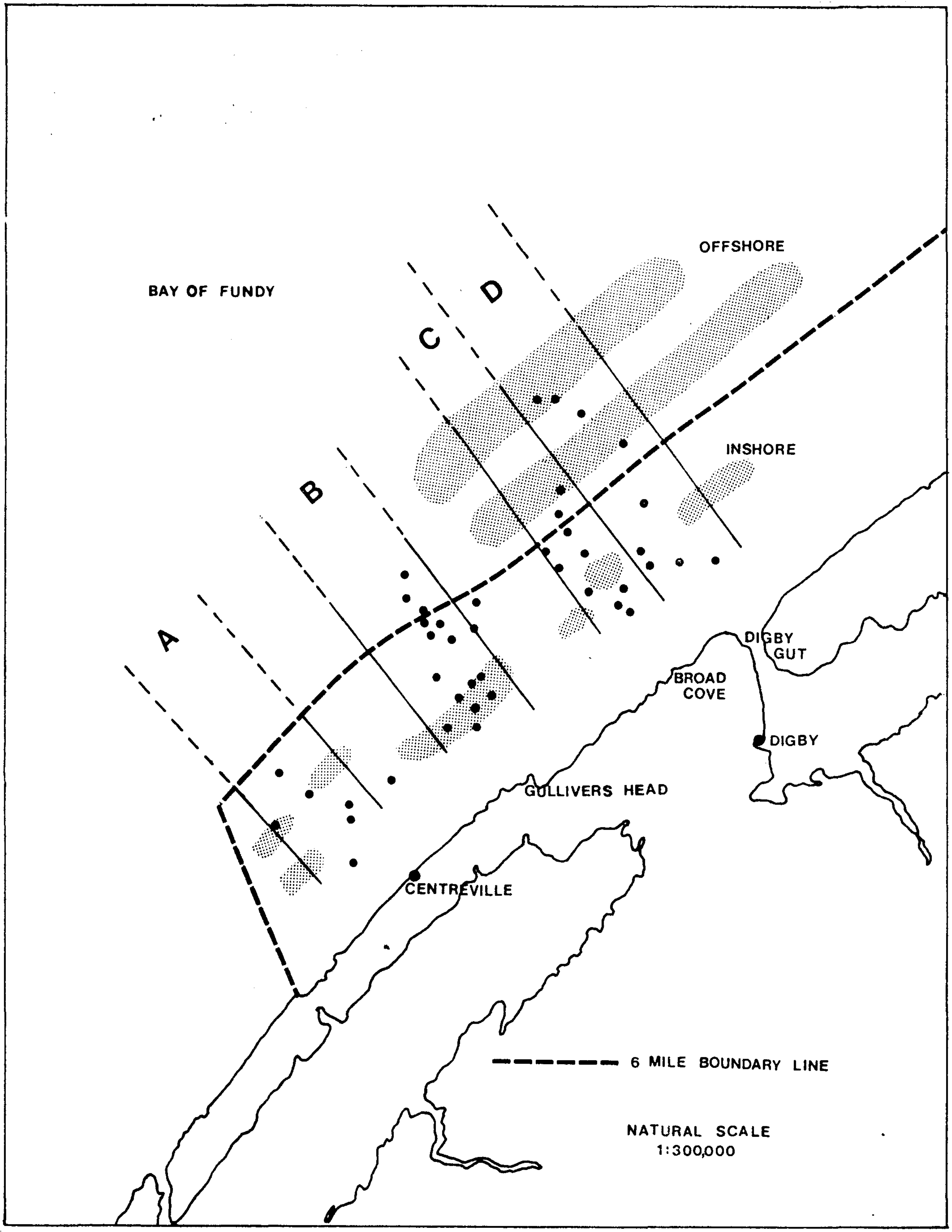


Figure 1. The fishing ground sampled off Digby, N.S. A = Centreville; B = Gullivers Head; C = Broad Cove; shaded areas = commercial beds as outlined by Dickie (1955).

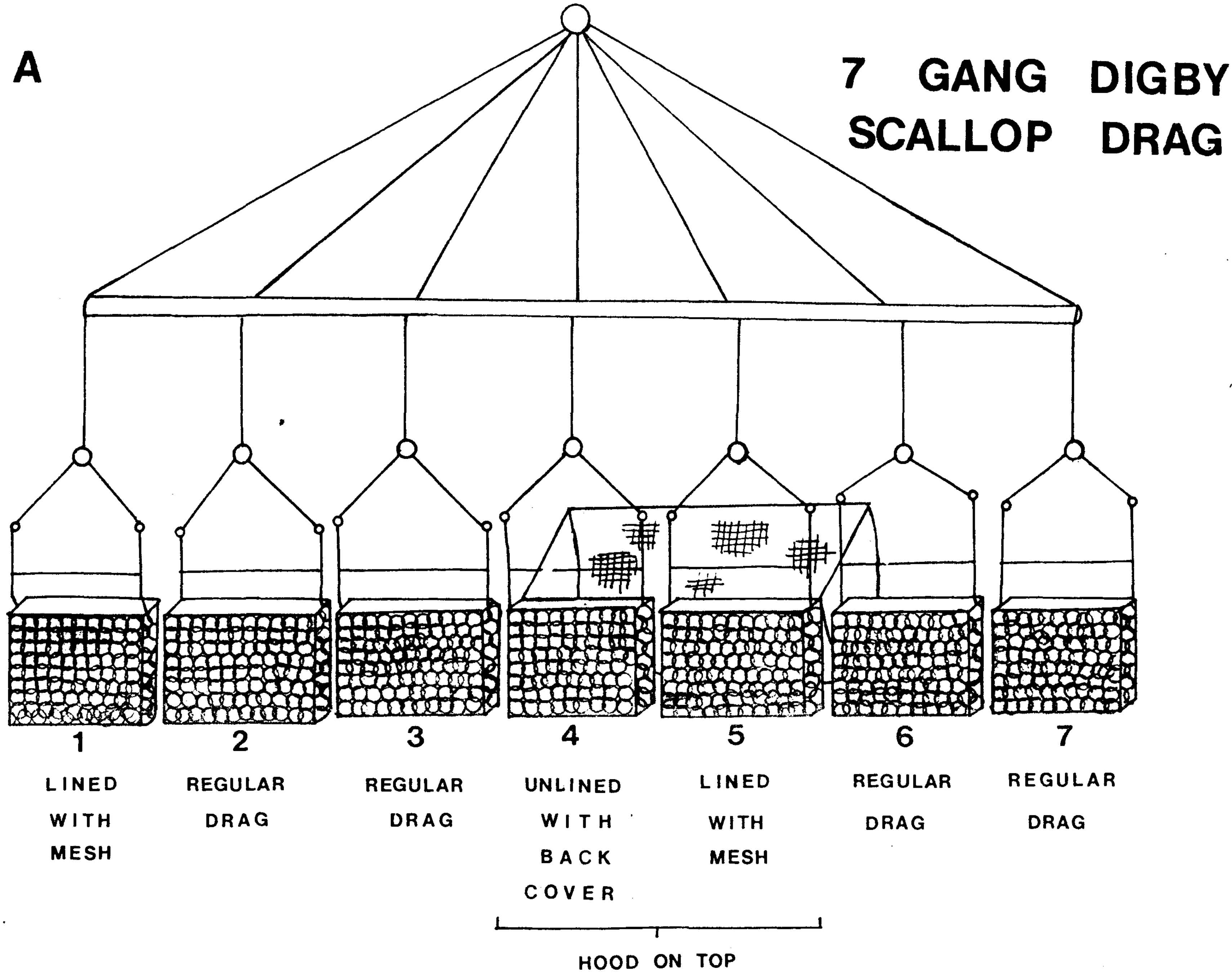
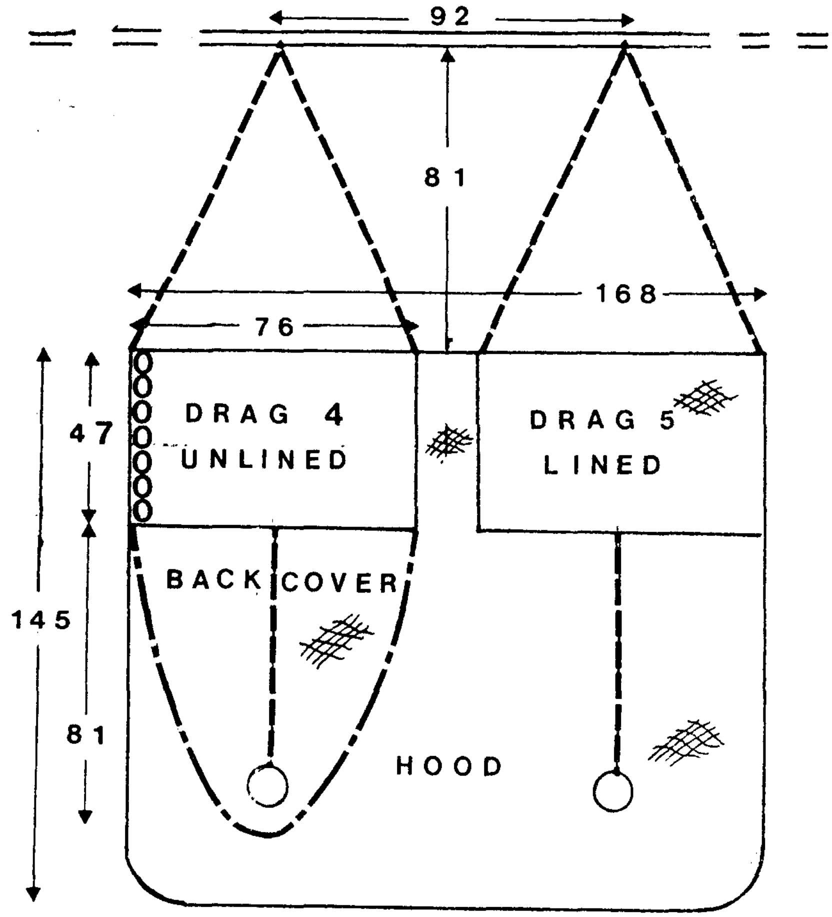


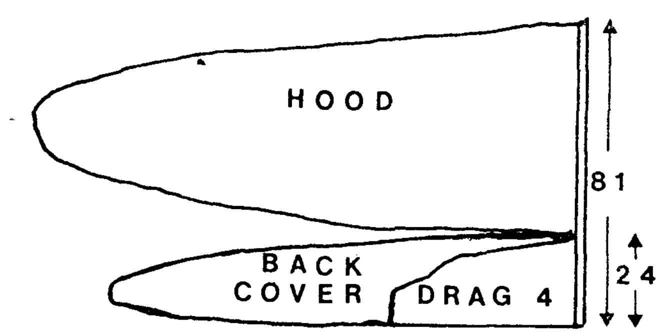
Figure 2A. A commercial, 7-gang Digby drag used in the 1978 Bay of Fundy resource survey and its modifications for research purposes.

B1.



TOP VIEW

2.



SIDE VIEW

Figure 2B. Relative dimensions (cm) of the individual buckets in the above 7-gang drag. B1 = top view; B2 = side view.

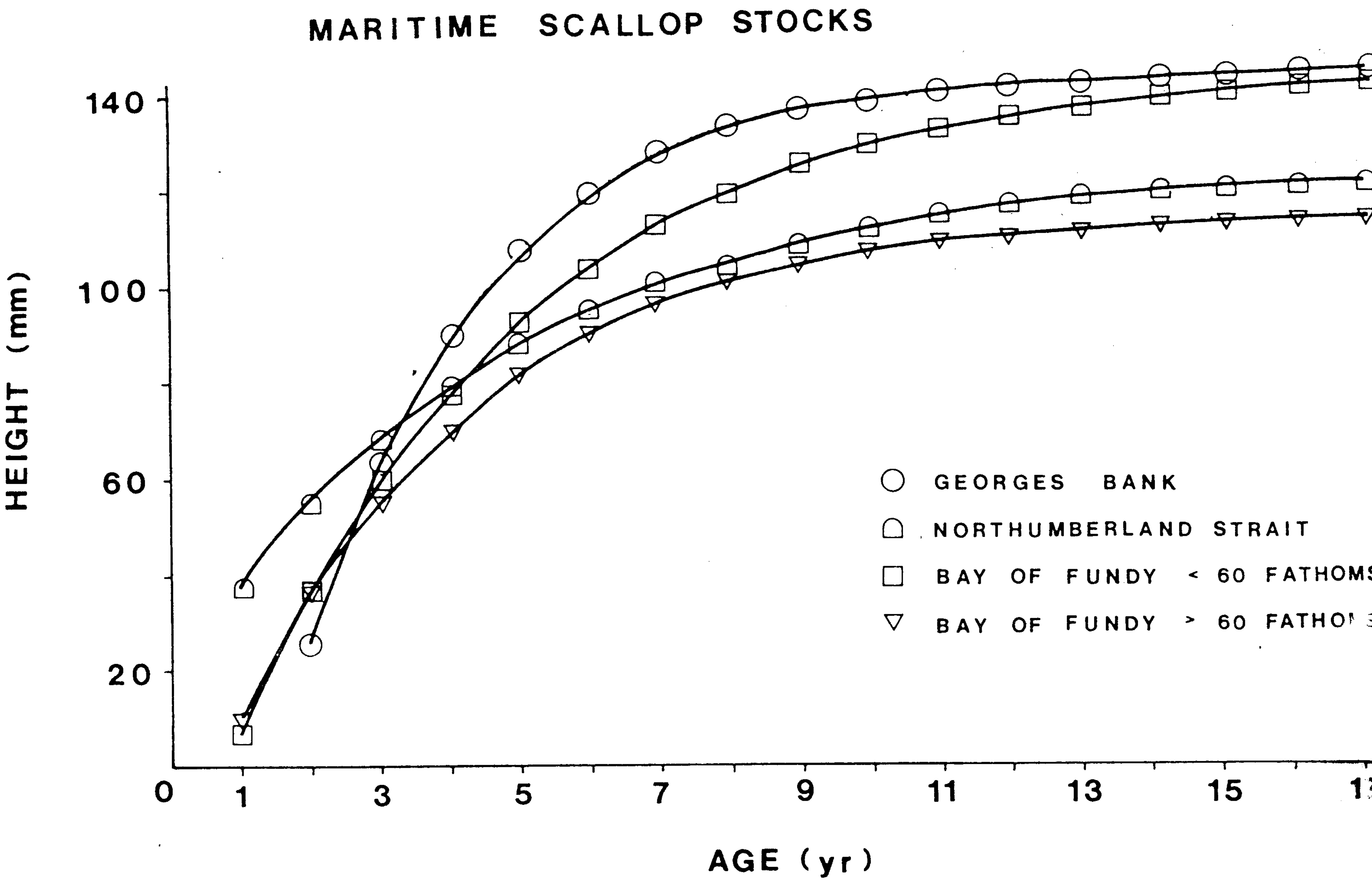


Figure 3. Von Bertalanffy scallop growth curves for Georges Bank, Northumberland Strait, and Bay of Fundy waters, < 60 and > 60 fathoms.

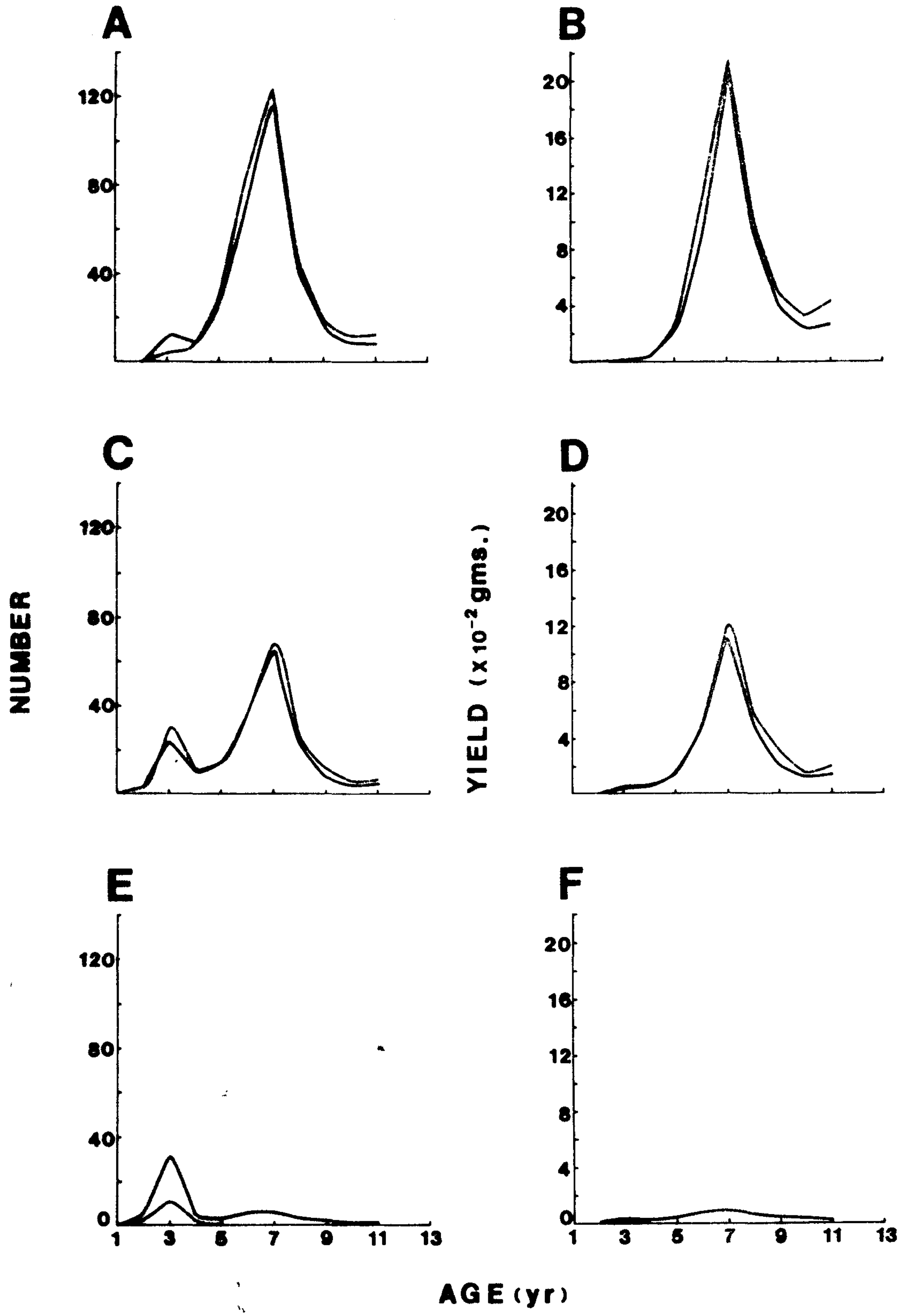


Figure 4. Age-specific numbers and yields of scallops fished by the different, individual "drags" in inshore waters off Digby, N.S. A, B: unlined drags; C, D: lined drags; E, F: hood and cover. A-D: dotted line = end drag; solid line = centre drag. E-F: dotted line = cover; solid line = hood.

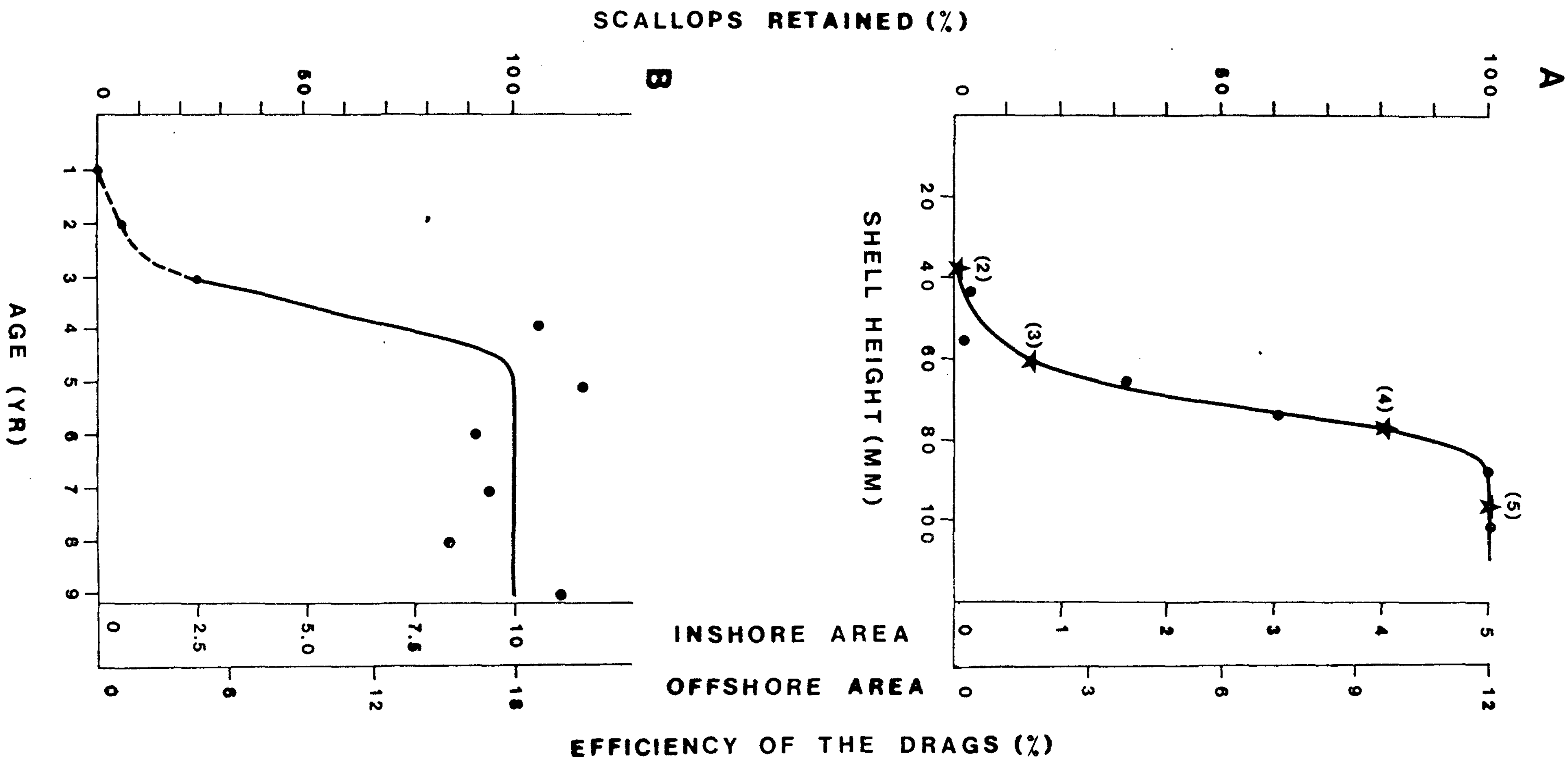


Figure 5. Relationship between size and age of scallops, the proportion of those enterring the drag which are retained by A. 2-5/8 inch (67 mm) and B. 3 inch (76 mm) rings, and the efficiency of the drags for capturing scallops on the rocky inshore and smoother offshore areas. () = age (yr.). (A. modified from Dickie, 1955).

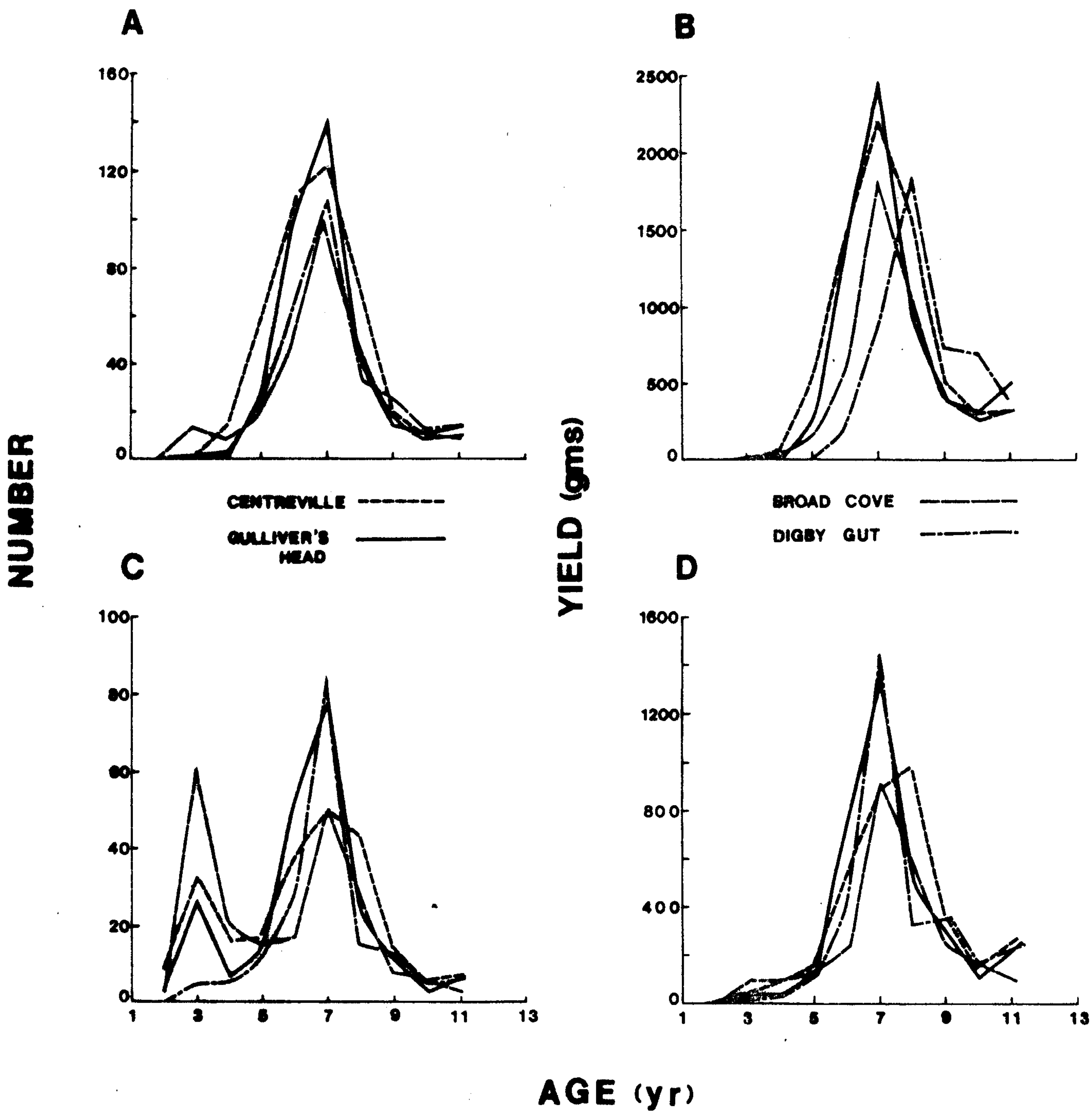


Figure 6. Age-specific numbers and yields of scallops fished in the different inshore areas off Digby, N.S. A, B: unlined drags; C, D: lined drags.

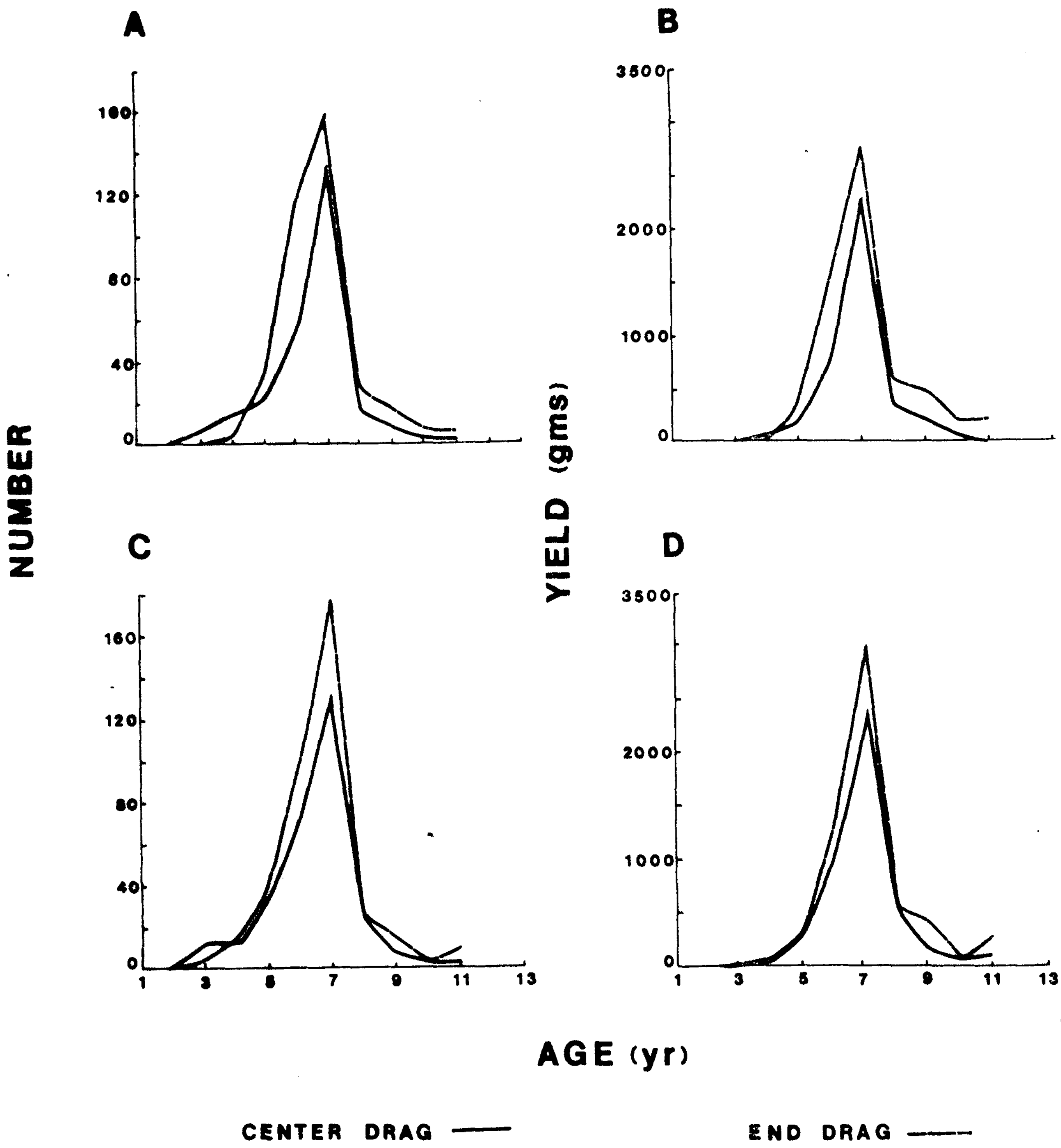


Figure 7. Age-specific numbers and yields of scallops fished in offshore waters off Digby, N.S. A, B = unlined drags; C, D = lined drags.

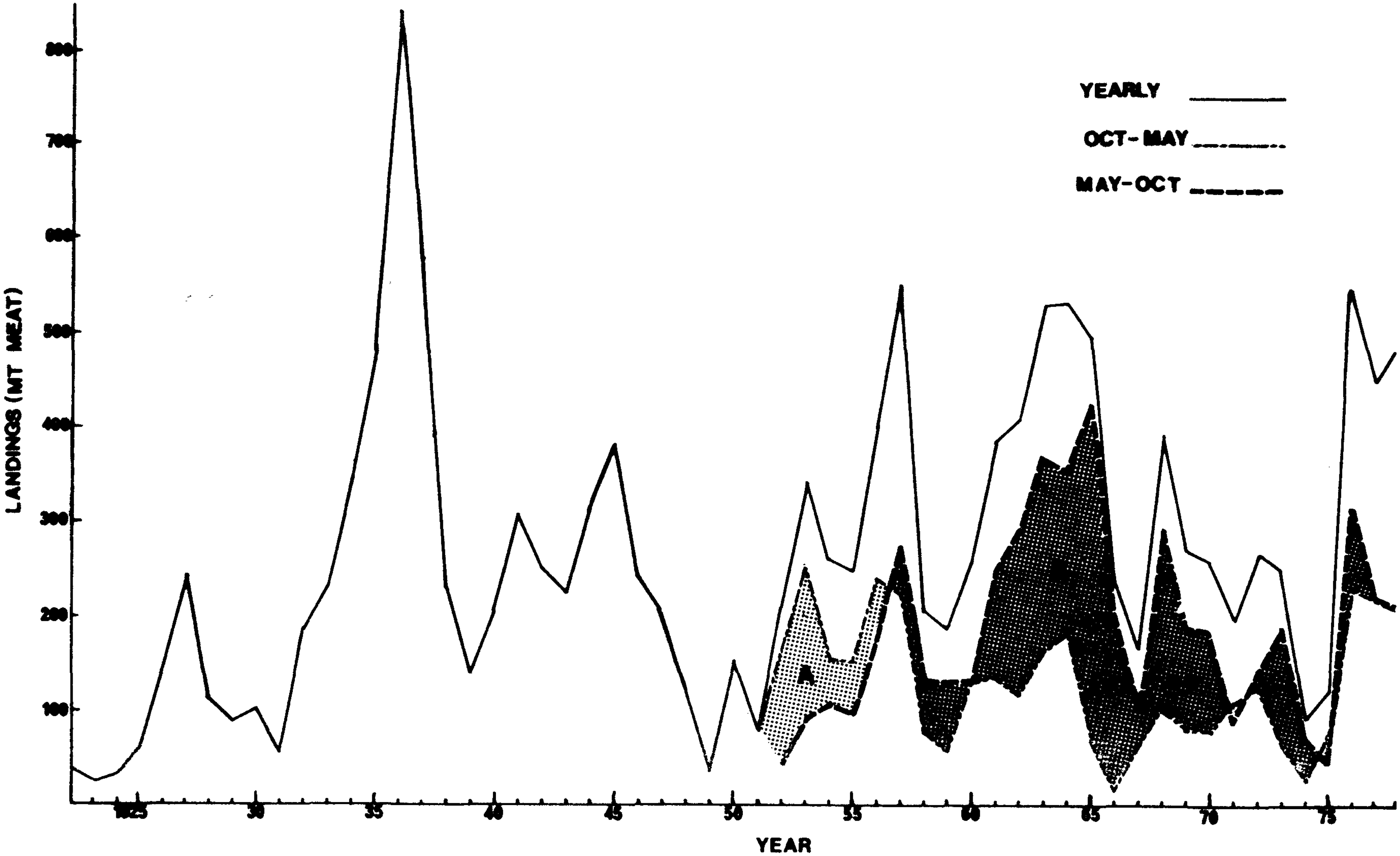


Figure 8. Landings (mt meat) of scallops fished by the Digby scallop fleet from 1922 to 1978.
A: winter landings greater than summer landings. B: vice versa.

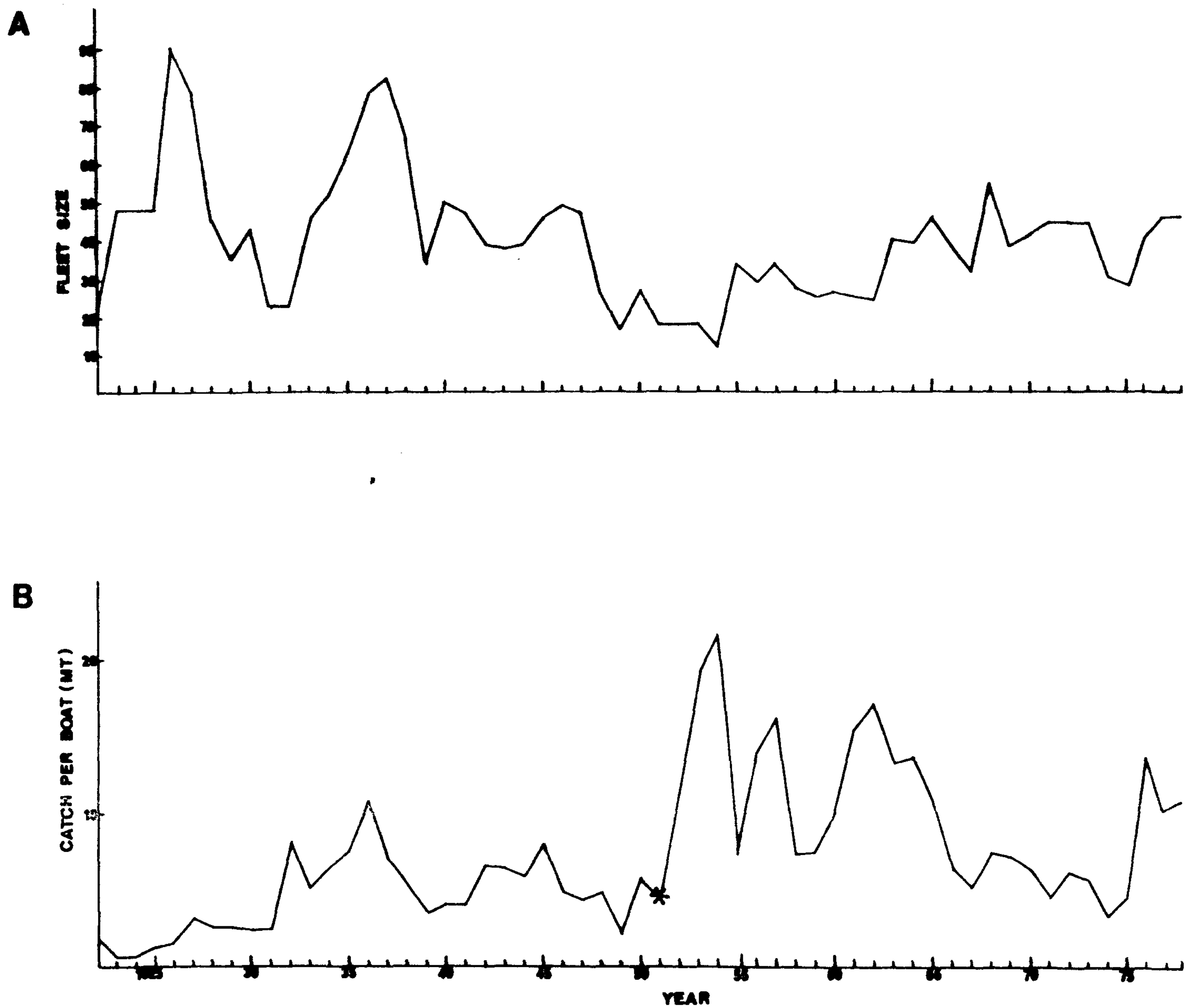


Figure 9. Annual fleet size and average catch per vessel off the Bay of Fundy scallop fleet from 1922 to 1978.