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Bay of Fundy scallop stock assessment - 1989

By

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ABSTRACT

A strong recruitment pulse localised over the scallop beds of the inside fishing zone has contributed to outstanding catches for the last two fishing seasons, about 10 times the historical average level of 350 t. However, a significant drop in the pre-recruit index of the most recent research stock survey and a reduction of the latest catch-rates (from 16 to 6 kg / hm) indicate an imminent decline in the fishery performance. A sizable scallop bed off Cape Spencer doubled the landings of the outside fishing zone compared to the 1988 levels. Both the Bay of Fundy and Mid-Bay fleets expended considerable effort over this bed.

RESUME

Une forte classe d'âge localisée sur les bancs de pétoncles de la zone de pêche intérieure a contribué aux prises exceptionnelles des deux dernières saisons, environ 10 fois la moyenne historique de 350 t. Cependant, une baisse significative de l'indice des pré-recrues de l'inventaire du stock le plus récent et une réduction des taux de capture de 16 à 6 kg / hm indiquent un déclin imminent dans la performance de cette pêcherie. Un banc de pétoncle important près du Cap Spencer a permis de doubler les débarquements de la zone de pêche extérieure comparé à 1988. Tant la flotte de la Baie de Fundy que la flottille de Mid-Bay ont exercé un effort considérable sur ce banc.

INTRODUCTION

A strong recruitment pulse first observed in the 1986 research stock survey localised mainly over the scallop beds of the inside fishing zone has contributed to two outstanding fishing seasons in this zone. The last completed season (1988-89) had 3 times (Fig. 1) the catch levels of the previous season; catch-rates also improved markedly. But after reports of a summer die-off, the latest figures for the first half of the 1989-90 season indicate that the peak catches are declining.

The 1989 outside fishing season fared very well with landings at twice the 1988 level. A sizable scallop bed off Cape Spencer is responsible for this improvement. Starting in late summer both the Bay of Fundy and the Mid-Bay fleets expended considerable effort in the area. With poor log compliance and the intense participation of vessels under 25.5 G.T. that do not have to complete logbooks it is extremely difficult to establish a fair estimate of that scallop bed production.

METHODS

Fishing Information

All vessels over 25.5 G.T. are required to maintain logbooks where daily fishing activities are recorded. Catch-rates are computed from Class 1 data when information is provided on the catch and its location, and effort in terms of hours fished and width of the gear (m). It is not possible to get effort data and areas fished from vessels less than 25.5 G.T. and / or under 14 m L.O.A.. However, their participation in the fishery and landings on a vessel basis may be estimated through sales slip records. Assuming that these vessels fish in the vicinity of home ports, a crude estimate of their activity may be derived from the sales slip records.

Survey Procedures

Survey stations are randomly stratified according to the catch distribution to reflect commercial levels of abundance. Stations are distributed in 3 to 4-mile bands running perpendicular to the shore. A description of the survey procedures may be found in Robert et al (1984). The logged data from May 1988 to May 1989 was used to establish the randomly catch-stratified stations. There were 100 sampling locations in 1989; time allowed an additional 10 exploratory tows. Once again the stock survey extended upstream, beyond the conventional scallop beds with stations off Hampton and off Young's Cove to cover these extra grounds visited by the fleet. The Centreville area was also sampled (9 tows); no fishing activity was reported but exploratory work was conducted. At the analysis stage, survey data are also post-stratified according to fishing areas, usually referred to by a prominent location or a headland, and according to fishing zones.

The research vessel "J.L. Hart" was used to replace a chartered vessel from the commercial fleet. The deck layout only allows a 4-gang Digby gear (unlined buckets at the ends and lined buckets in the centre of the gang) instead of the conventional 7 buckets. The data are still prorated to a conventional gear.

In addition to establishing a stratified mean number per tow, the data were contoured to represent the spatial distribution of the scallop aggregations. Abundance estimates are also derived. Data points describe a three dimensional surface with latitude, longitude, and value to be plotted. A surface is formed by defining Delaunay triangles; the data points become the vertices of

triangles connecting neighbouring points. The algorithm used to shape the triangles is found in Watson (1982). The surface between adjacent contour levels in this case, the abundance of scallops, is represented as darkening shades of grey. Contours may be smoothed by interpolating the surface by inverse weighing of gradients (slopes of triangles). The sides of the Delaunay triangles are divided into equal segments (chords) to establish the interpolation points. For example, dividing the sides into 4 segments gives 16 subtriangles. The interpolation points become new vertices. This method assumes that data points near the point in question contribute more than distant points (see also Watson and Philip 1985). Each triangle is assumed to have a flat surface. The summation of the volumes of all triangles under the contoured surface is equal to the total volume, here the abundance estimate for the survey area. The degree of interpolation will affect the volume estimates. Work is still in progress to refine the procedure. A complete description may be found in Black (MS 1988).

The extent of the surveyed area varies from year to year, depending on the level of fishing activity, since the survey design is catch-stratified. The traditional area will always cover a 'core' area. However, before the early 1980s the area above Digby (Delaps Cove to be precise) had not generated much fishing effort compared to today when the fleet extends its activity up to Isle Haute in the Upper Parts of the Bay. The Centreville area downstream from Digby is another area not exploited intensively by the fleet every year. To recognise the changing patterns in the fleet's activity, the volume estimates for survey abundance indices have been calculated for the total survey area but also for the area divided into sectors (Fig. 2). Thus, it becomes easier to compare abundance estimates for the core area which survey coverage should vary less than the other sectors.

Biological Data

Data have been collected since 1982 to study ageing, somatic and gonadal growth cycles in the Bay of Fundy. As for previous investigations we observed (Robert et al 1985) that growth (age) measured by shell ring-reading was a function of depth. Three depth-intervals, under 85 m, 86-105 m, and over 105 m, have shown the most significant (P 0.05 level) difference. This is an on-going study. At this point, 7,051 scallops have been examined from samples taken between 1982 and 1985. Three von Bertalanffy growth curves have been established with the following parameters:

Depth(m)	Height $_\infty$ (mm)	t_0	k
00-85	143.210	1.3800	0.2221
86-105	133.763	1.4011	0.2414
> 105	125.989	1.4469	0.2610

The meat weight on shell height allometric relationship was fitted by a least square regression. Allometric values derived from samples collected throughout the year, from 1982 to 1986 were selected to represent year round conditions. Equations generated by grouping data on an annual basis and a general one combining data from all years to reduce inter-annual variability were derived.See Robert et al (1988) for a summary of data specifications. Briefly, it may be said that the variability in the yield of scallop meats may amount to 25 % between different years. An equation combining values from 1982 to 1986 has reduced to 8 % the difference between its parameters and the maximum values given by any equation representing a single year of data.

RESULTS

The spatial distribution of scallop beds and their exploitation by scallop fishing fleets in Bay of Fundy waters is complex. For 1988, this report covers two main areas of scallop-producing grounds in the Bay of Fundy: 1) the traditional beds in the vicinity of Digby, N.S.; and 2) the Upper Parts of the Bay of Fundy.

The Traditional Beds in the Vicinity of Digby, N.S.

Since 1981 the total number of vessels with a Bay of Fundy scallop license and involved in the fishery has remained virtually constant both in Nova Scotia and in New Brunswick with the majority of vessels being in the largest category of vessels allowed (Table 1). The high performance achieved in 1987 has attracted all banked licenses back into the fishery for 1988. Furthermore, 3 additional licenses were granted. In all, 98 licenses were renewed or applied for. This interest was sustained in 1989. After a gradual decline in participation rate from 1984 to 1986, activity rose up to 20 % in 1987 but more significantly in 1988 and 1989 when all but one licensed vessel over 25.5 G.T. actually fished (Table 2). Unfortunately, only 15 % of vessels complied with the logbook requirement. This trend has worsened over the past few years.

Most Bay of Fundy scallop license holders carry additional license(s) (Table 3), up to 4 - 5 in a few cases. Only 20 % of the license holders rely entirely on scallop fishing for their livelihood. Two-thirds of the vessels carry a 'groundfish' license and / or swordfish; other species fished include herring, mainly in New Brunswick, lobster, squid, and shrimp. Fishery performance for scallop and groundfish justify to a great extent the involvement from one fishery to the other and vice versa. Besides the attraction caused by high scallop catch-rates, many vessels switched trawl gear for scallop drags in 1989 when groundfish quotas available for that sector of the fleet ran out early in the year. In other years they may have stopped fishing entirely, while in the last two years dragging for scallops extended their fishing season. However, at the same time this re-directed effort pushed scallop fishing exploitation levels to new heights (Robert et al 1989).

Annual landings on the Nova Scotia side of the Bay of Fundy may indicate general trends in this fishery. Table 4 lists an historical profile of landings for statistical district 37 (Digby Neck), 38 (Digby), and 39 (Annapolis). After record highs in 1981 and 1982, landings decreased steadily and markedly, until 1987. These figures may be misleading. When the traditional Digby stocks were not as abundant, the Bay of Fundy fleet ventured opportunistically on the western Scotian Shelf and sometimes, for a considerable fraction of the fleet's landings, to Georges Bank. During the 1980's this has taken place on a regular basis. Landing figures do not make the distinction as to location of the catch. In 1986 and 1987, Georges Bank contributed appreciably to the landings of the Bay of Fundy fleet (in the order of 500 t +). In 1988, almost 2,800 t were landed in Digby alone. However, with good catch-rates at home, the fleet did not venture far and only 15 t may be attributed to Georges Bank. In 1989 landings reached 3,650 t; once again, it is unlikely that an important fraction of these landings came from outside the Bay.

It is very difficult to get a reliable estimate of the total catches of the inner Bay of Fundy because of the delineation of the statistical areas 4Xr and 4Xs and the involvement of more than one fleet in the pursuit of the Bay of Fundy scallop fishery. Statistical catches from NAFO sub-subarea 4Xs include catches from the Upper Bay of Fundy fleet near the upper end of the Bay, some of the catches from the distant side of the traditional grounds and all the catches from the Grand Manan area and the nearshore beds along the New Brunswick coast fished mainly by the Mid-Bay license holders of New Brunswick. Since1986 a sizable and increasing fraction of catches are statistically recorded under the generalistic sub-area 4X. Without log information, catches cannot be statistically appropriated.

Adequate estimates for catches on the traditional grounds are difficult to obtain because of the poor logbooks compliance. Non-compliance with logbook completion has developed into a serious problem over the last few years. Since this fishery operates on the equivalent of seasonal

closures i.e. inside and outside fishing zones, catches may be partitioned according to the zones and we may assume that catches from October to April, coming from the inside zone and statistical catches for sub-subarea 4Xr covering that time period should match relatively well (assuming no activity in the area when the season is closed). We further assume that effort and catch-rates associated with Class 1 catch data for that area during that time period are representative of the overall fishing performance. Statistical catches from the outside fishing zone (4Xr + 4Xs) i.e. May-September fit more loosely with Class 1 logged catches (Table 5). With very high levels of catches being statistically recorded under the generalistic sub-area 4X, especially in the last three years, we had to devise our own catch tabulation system to derive a better estimate of the productivity of the grounds than the estimates offered by the statistical catches. These catch estimates appear in table 5. They correspond better to the landings profile than the statistical catches. With enhanced productivity in the Bay it is also safe to postulate that the fleet landings have, in all probabilities, not originated outside the Bay during that time period.

If we relate the inside statistical catches and catch-rates on a per season basis (Table 5), catch-rates around 7 kg/hm and about 250 t per season were maintained prior to 1980-81. Then catches increased sharply, up to 565 t in 1982-83, while CPUE went down to 5 kg/hm. This was followed by a dramatic decline both in terms of quantities caught and catch-rates with a very poor performance for 1985-86. Catch-rates continued to drop when the 1986-87 season opened and catches were very low. Only small scallops were caught in any amounts and the area was closed prematurely at the request of the fishermen. Fishing performance changed drastically with the 1987-88 season when catches jumped to 1,100 t; mean catch-rates for the season rose significantly to 13 kg/hm. A very small fraction of the estimated catches refer to class 1 logged data. The fleet has not got access to any other grounds but the traditional beds off Digby to account for such high figures. Selected fishermen interviews and surveillance reports also support these estimates. The resurgence of the fishery has not carried over to the outside fishing zone. There is only a slight improvement in the outside zone catch-rates (3.52 kg/hm for the 1987 summer and 6.06 kg/hm for the 1988 summer). Catches for the 1988 summer are questionably high at 930 t but this value is suspected to contain an unknown, large, quantity caught inside the 8-mile line. The outside zone fished during the summer of 1989 improved greatly from the previous year with a 100 % increase. Small size, high density scallops off Cape Spencer on the New Brunswick side of the Bay provided the high catches, but at a moderate (4.98 kg/hm) catch-rate only.

The outstanding fishing performance of the inside zone appears to wind down since the catch for the first half of the 1989-90 season is only 60 % of the same figure for the previous year with a 75 % decline in CPUE.

A catch history series (over 65 years) for the inside zone (or time period October-May when a restricted fishing zone was not in effect) illustrates (Fig. 1) that sharp rises and downfalls have often taken place over the existence of this fishery. Present catches surpass any other height experienced by the fishery.

Monthly catch-rates (kg/hm) during the inside fishing season (Fig. 3) typically show a slight decrease from the beginning to the end within each fishing season. Since the 1983-84 season CPUE had remained in the range of 2-4 kg/hm with relatively little variation within a month and between months until the fishery closed prematurely in December 1986. At that time considerable amounts of small scallops (75 mm shell height) were being caught but the meat size was too small to improve CPUE. When the fishery resumed a year later (1987-88 season) performance had improved considerably although with huge variation. October had a mean catch-rate of 25 kg/hm (s.d. 17.68). Although CPUE stayed high throughout the season compared to previously, there was a downward progression from October (25 kg/hm) to April (7 kg/hm). The within season CPUE decrease was not caused by the lack of scallops but rather by their small size. The 1988-89 season repeats the pattern of the previous season, from 27.7 to 13.4 kg/hm except that, by then, meats easily met the 55-count (55 meats per 500 g).

There is relatively little information available on meat weight distribution of catch from the inside zone. Port sampling activities outside of the summer season have always been minimal and the fragmentary data may not be representative. It seems that, until the 1987-88 season, meat

weights were of good size giving meat counts in the 20 - 30 (meats per 500 g) range (Table 6). Meats fished in October 1987 weighted 10 g on average and belonged to the abundant pulse coming into the fishery. This is an important reduction in size compared to the traditional meat size associated with the Digby fishery. A meat count of 55 meats per 500 g became regulation for the inside zone in December 1987 so that this meat size is the smallest that may be legally caught. The fact that the actual meat count experienced in October 1987, 50.3 meats per 500 g was close to the regulated 55 meats and that growth processes slow down from October onward may be one factor responsible for the declining performance during the 1987-88 season. The 1988 summer growth season made a difference as, while exploiting the same scallop beds, the average meat weight increased to 13.5 g (October) and 15.1 g (November) when the 1988-89 season opened. High effort in addition to slow winter growth contributed to the reduction in meat size to 10.7 g in April. With summer growth the average meat weight for October rose to 18.9 g.

In summary, although the 1988-89 inside fishing season continued the trends initiated the previous season for catch-rates and augmented catches by 300 %, results for the first half of the 1989-90 season announce a downturn to the spectacular performance. The outside fishing zone has also done quite well in 1989, doubling the 1988 catch levels.

Annual stock surveys have been carried out for a number of years (Table 7) with slight changes in the number of stations per stratum according to the fishery performance from a catch or an area perspective. The strong recruitment pulse that hit the Digby Gut area more than others resulted in concentrated fiishing activity, especially between 3-6 miles from shore at the Gut. Hence more survey stations targeted the Digby area in the 1989 survey. Tables 8-11 present a detailed history of survey catch-rates by catch, area, and zone stratum for the last 4 years. Average number per tow started to improve with age 2 in 1986 although the gear, even lined, is not catching this age class reliably. An important recruitment pulse manifested itself more clearly in the 1987 survey with sizable numbers of prerecruits (ages 2-4) per standard tow, especially in the Digby Gut area. This pulse is followed through in the next two years. Although the number of young recruits (ages 5-7) is still high in the 1989 survey, it is reduced by 50 to 33 %. From Parker's Cove to Hampton which seem to have caught the tail-end of the strong pulse, young recruits are more abundant (about 50 %) in 1989 than in 1988. However, the abundance of the prerecruits (ages 2-3) is declining, except for a small patch in the Gulliver's Head and Centreville areas.

Table 12 gives a time series profile for prerecruits and recruits since 1981. Prior to 1986, the recruitment outlook was rather bleak but it improved considerably afterward. Increased abundance of prerecruits was most noticeable in the core area from Gulliver's Head to Delaps Cove; adjacent areas do not appear to have received as many prerecruits. The 1989 results clearly illustrate that the pulse is over. The pattern of young recruits (ages 5-7) also initiated an upward trend in 1986 when the fleet intensified its exploitation of scallop beds upstream from Parker's Cove. This rise was continued in 1987 and 1988 with the first segments of the strong pulse coming of recruiting age. Simultaneously older recruits (age 8+) have gradually decreased; 1989 shows one of the lowest values for the decade (except for Centreville). The recruitment pulse is graphically followed through since first observed in 1986 (Fig. 4), also note the scale used to plot the number per tow.

Abundance at age per standard tow may also be plotted in an isopleth fashion, linking points of similar value along a 'contour' line, then graphically filling the surface between two isopleths with shades of grey, the darker the grey, the higher the abundance. Scallop distribution for the last survey was plotted for ages 2-9 (Fig. 5) following the contour plots for the distribution of the last 3 surveys (Robert et al 1989). As with survey catch-rates given in number per tow, young recruits are still aggregated in patches of fairly high concentrations but the level of prerecruits is low. The age 2 contour plot has only one patch off Centreville with a maximum isopleth of 25 scallops per tow.

Abundance estimates may also be derived from the survey data by calculating volumes under the contoured surface (Table 13). Subtriangulation of the surface may be used as an interpolation technique to smooth the contours, hence adding refinement to the volume estimates. In the 1989 Bay of Fundy Research Document (Robert et al 1989) we established the small

variation (5 %) in volume estimates from the degree of subtriangulation used and that the estimates stabilise after 4 chords or 16 subtriangles. Table 13 estimates were derived with 16 subtriangles. The survey area got smaller from 1988 onward reflecting the reduction in fishing area coverage by the fleet. Whether one looks at the volume estimates for the core area or the total area, they reflect the trends observed in the survey abundance on a tow basis.

The compilations for shell height frequencies of empty scallop shells (clucker or clapper) were higher than usual (over 10 %) in the last June survey. It appears that ages 5 - 7 were implicated in the die-off. These size-classes correspond to the strong recruitment pulse that had significantly increased scallop density over particular areas. At the prerecruit's level, densities over 2 scallops per m^2 had been calculated. Mapping of the clapper's distribution revealed that the die-off was well delineated between Gulliver's Head and Delaps Cove with the highest values 5 - 6 miles from shore. Examination of clapper shells for ligament disarticulation, epifaunal colonisation of the inside of the shell, and lack of growth increment after the annual spring check mark indicates that the process started within 3 months prior to the census. Excessive die-off had taken place on Georges Bank the year before. A more thorough investigation had eliminated indirect fishing mortality, predator pressure, warm temperatures, or an epizooty as the primary cause of the die-off. Observations led to the carrying capacity of the habitat in terms of food production to sustain such a large (high density) and fast growing scallop population as a potential cause of mass mortality. In the case of the Digby grounds, the phenomenon could have continued during the summer according to fishermen.

The Upper Parts of the Bay of Fundy

The Upper Parts of the Bay of Fundy designation applies to the waters of the Bay included in the Upper Bay Management Zone. This zone includes the area east of a line drawn between Annapolis and Kings County on the Nova Scotia side of the Bay and between Saint John and Albert Co. on the New Brunswick side. Historically speaking, Minas Basin and Chignecto Bay at the upper end of the Bay of Fundy are not scallop-producing areas. Until recently, landings of less thant 10 t of meats per year had been recorded. Local fishermen became interested in the scallop fishery in the 1980's. To participate in the fishery, vessels, all under 14 m L.O.A., are issued a Upper Bay (3-mile) scallop license. Up to 1986 there had been 14 licenses issued annually with only one vessel over 25.5 G.T. (Table 14); licenses have increased by 2-3 since then. Most of these licenses used the privilege. A few of these licenses are issued in New Brunswick (Albert Co. where there are also about 10 Mid-Bay scallop license holders) with the remainder in Colchester and Cumberland, Kings Counties, Nova Scotia. In all likelihood these small vessels land their catches at home ports in Cumberland Co. (statistical districts 24, 40, 43, and 44) and Albert Co. (79). Landings from these districts reflect the productivity of the Upper Parts of the Bay of Fundy (Isle Haute, Quaco Ledge, areas northeast of the Ledge). Since 1983, landings were gradually increasing with fishing taking place between April and October; 1986 shows a temporary decline before rebounding in 1987. Landings continued to surge in 1988 and 1989, more than doubling the 1987 value. Advocate Harbour (district 44) and Alma (district 79) witnessed this increased activity, mainly in May and August. Landings for district 79 include catches from both Mid-Bay and Upper Bay license holders (Table 16). Landings by statistical district compare well with the summation of landings of all vessels located in the area. Concurrently to a sizable improvement in total landings, average annual landing per vessel tripled (Table 15) from 1,000 kg per vessel in 1986 to almost 3,000 kg in 1988, to increase again to nearly 4,000 kg in 1989 with marked participation (13) of the mid-Bay fleet component. Some vessel landed considerably more than average while others landed as little as 100 kg. Scallop fishing may only be considered as an accessory activity in a multi-fishery system. Since these vessels are under 25.5 G.T. they are not required to provide effort data by logbooks; hence there is little fishery information available. According to recent surveys, scallop abundance is fairly limited in the immediate area (Chandler et al 1989). The recent catch improvement is more likely the result of increased effort as reported by local fishermen rather than a rise in available stocks.

DISCUSSION

Survey catch-rates

Relative survey catch-rates established as number of scallops per standard tow are compared to absolute survey catch-rates derived from volume estimates of a smoothing interpolation technique by subtriangulation. In both cases, the estimates have been normalised by the maximum annual value for each index. To optimise the comparison between the estimates, the n / tow for the inside zone stratum and the volume estimate for the core area only were used. Estimates for 2 pre-recruit age classes (3 and 4) and 4 recruited classes (ages 5-8) are graphically represented in fig. 6.

There are differences between abundance as n / tow and abundance as volume estimates. Although both indices follow parallel trends with only slight differences for pre-recruits and young recruits (age 5), slopes are different in the case of older recruits (ages 7 and 8). These age classes have a lower density, either low n / tow value or small volume estimate compared to pre-recruits. In scallop beds of recruiting size, individuals are constantly removed by fishing but also, the cohesiveness of the patch itself is disrupted as the fishing activity redistributes a certain quantity of scallops. After sorting of the catch on board, debris and discarded scallops are thrown overboard while the vessel is underway for the next tow. The distinction between the 2 sets of results is to be taken into consideration if one relates the survey catch-rates with variables from the commercial catch.

Survey index and catch projections

There are enough comparable survey points and variation in the amplitude of both survey results and catches of the inside fishing zone to examine the relationship between these elements. Results (n / tow or biomass / tow) for the inside zone stratum of the summer survey preceding the opening of the fishing season in the inside zone are plotted against the catch for that season. Excluding the elevated values of the 1988-89 season (top section of fig. 7) considerably limits the scope of the relationship with lower regression coefficients, especially with biomass on the y-axis. Its usefulness is also curtailed given the maximum values for both x and y axes.

The regression coefficient of catch vs biomass / tow is lower than vs n / tow but still important (0.93 and 0.97 respectively) in the relationship including the 1988-89 season. Because of the large scope of values involved in the latter regression, one can examine possible catch levels for the next season (1989-90) given the 1989 survey results.

Using biomass as a predictor would estimate catches over 2,000 t for the season (asterisk on graph). This value may be high since only 650 t were caught in the first half (43 % to be exact) of the season i.e. Oct.-Dec. 1989. Growth increments of the recruiting age classes (classes mainly fished) are very important (over 50 % per annum) so that survey biomass may be too rough an estimate to represent the available biomass when the fishing season opens.

The relationship using n / tow projects the 1989-90 catch at about 1,700 t which is more in line with the 650 t caught until December. And that, despite the poor weather that afflicted the area from mid-November onward. Only more sets of data will test the strength of the relationship between survey data and catch levels for that zone.

Volume estimates so far have only been calculated for the 1986 - 89 survey results. Because a longer time series of such estimates is lacking, we did not attempt to model absolute catch-rates with catch levels of the inside fishing zone.

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Table 1.- Number of vessels carrying a Bay of Fundy scallop license during the last ten years. Eligible and banked licenses are not included here. Source: Licensing Unit, Fisheries and Oceans, Halifax. Number of vessels based in Nova Scotia + number of vessels based in New Brunswick.

Year	under 25.5 G.T.		over 25.5 G.T.		Total
	under 14m	14-19.8m	under 14m	14-19.8 m	
1980	5 + 13	1 + 0	2 + 0	52 + 7	80
1981	8 + 14	1 + 0	3 + 0	64 + 6	96
1982	8 + 8	1 + 0	4 + 4	65 + 4	94
1983	3 + 7	1 + 0	7 + 5	67 + 5	95
1984	2 + 7	0 + 0	7 + 5	70 + 5	96
1985	2 + 7	0 + 0	7 + 4	71 + 3	94
1986	1 + 7	0 + 0	7 + 5	70 + 3	93
1987	0 + 6	0 + 0	8 + 4	68 + 5	91
1988	1 + 5	0 + 0	9 + 4	72 + 7	98
1989	0 + 1	0 + 0	8 + 5	76 + 9	99

Table 2.- Number of (1) Bay of Fundy licensed vessels (Source: Licensing Unit, Fisheries and Oceans, Halifax), (2) active fishing licenses for vessels over 25.5 G.T. supposed to follow log procedures, and (3) vessels complying with log procedures.

Year	(1)	(2)	(3)
1981	96	68	65
1982	94	66	63
1983	95	77	74
1984	96	82	76
1985	94	70	67
1986	93	67	57
1987	91	80	44
1988	98	91	16
1989	99	96	14

Table 3.- Additional licenses carried by Bay of Fundy scallop license-holders for the year 1989. This table considers 100 Bay of Fundy scallop licenses. Source: Licensing Unit, Department of Fisheries and Oceans, Halifax.

Types and number of other licenses	
Groundfish (otter trawl, long lining, etc.)	64
Swordfish	45
Herring	11
Lobster	4
Squid	11
Shrimp	2
total	137

Number of Bay of Fundy scallop license-holders with ' n' additional licenses.

21	license-holders	do not carry	additional license(s).		
34	"	carry	1	additional license.	
35	"	"	2	additional licenses.	
8	"	"	3	"	"
1	"	"	4	"	"
1	"	"	5	"	"
total 100					

Table 4.- Annual landings (t of scallop meats) by statistical district (Digby Neck, Digby, and Annapolis); by vessel tonnage, (1): ≤ 25.5 G.T., (2): > 25.5 G.T. Prior to 1967, landings were not segregated by vessel tonnage. Source: Statistics Division., Fisheries and Oceans, Halifax.

District	37		38		39	
Tonnage	(1)	(2)	(1)	(2)	(1)	(2)
1960		102.17		157.23		0.84
1961		80.60		303.49		1.93
1962		-		355.42		8.43
1963		17.47		512.29		0.48
1964		90.48		530.48		2.89
1965		-		476.99		19.16
1966		-		234.94		7.23
1967	0.96	5.42	39.04	115.66	-	4.94
1968	-	5.42	53.49	329.28	-	5.42
1969	4.10	56.27	33.13	176.87	-	6.75
1970	2.29	74.82	18.55	161.93	0.48	1.81
1971	4.94	69.88	10.00	104.34	3.61	3.61
1972	17.23	24.94	16.75	222.77	-	4.10
1973	0.96	10.00	16.39	130.24	-	7.23
1974	-	0.60	11.69	54.22	-	3.13
1975	-	-	22.29	96.99	-	6.27
1976	-	21.81	24.46	479.76	-	21.33
1977	10.00	96.75	35.66	766.99	1.08	24.22
1978	-	120.00	33.49	570.24	1.45	20.96
1979	2.29	54.94	22.53	685.42	6.27	15.90
1980	10.60	49.40	18.31	696.02	4.34	5.90
1981	28.55	147.35	3.98	1080.24	0.48	1.69
1982	28.31	106.51	21.20	915.42	-	7.95
1983	12.05	43.61	19.28	722.53	0.72	26.99
1984	5.90	53.98	7.59	564.22	0.24	29.88
1985	-	28.67	8.18	554.34	0.48	18.31
1986	-	45.05	2.52	398.43	1.68	10.34
1987	-	56.75	21.55	844.23	-	26.99
1988	-	59.40	27.71	2735.66	-	75.54
1989	-	58.19	54.94	3412.90	16.39	105.18

Table 5.- Fishery characteristics for Bay of Fundy licensed vessels (14-19m) on a fishing zone basis. Statistical catches (Stats) for the inside zone corresponds to NAFO sub-subarea 4Xr; statistical catches for the outside zone are for NAFO sub-subareas 4Xr plus 4Xs. Class 1 logged catches were used to estimate CPUE.

Year	Inside zone (Oct-Apr)			Outside zone (May-Sep)		
	Catches (t meats)		CPUE	Catches (t meats)		CPUE
	Stats	Class 1	kg/hm	Stats	Class 1	kg/hm
1976-77	251.71	99.83	7.99	122.80	24.33	3.38
1977-78	238.27	180.18	7.29	188.02	141.84	4.88
1978-79	247.70	220.01	6.85	214.02	167.89	4.54
1979-80	280.22	245.44	6.95	161.33	131.80	3.88
1980-81	413.60	290.15	6.87	390.07	173.04	4.78
1981-82	417.80	304.40	6.86	429.65	160.74	4.65
1982-83	565.16	372.57	5.03	479.49	205.00	4.71
1983-84	319.15	267.66	3.59	397.35	267.22	3.06
1984-85	270.26	277.85	3.15	322.77	262.13	2.56
1985-86	121.33	142.37	2.36	282.51	274.86	2.25
1986-87	39.24	**21.21	1.81	90.54	56.62	1.92
1987-88	*1096.28	103.78	12.73	***129.97	26.39	3.52
1988-89	*3034.52	263.26	15.09	*929.41	86.13	6.06
1989-90	****625.47	63.44	6.96	*1827.06	113.92	5.05

*our estimate.
**The inside zone was closed from Jan. 1 to April 30, 1987 (end of season). During that time period, CPUE was 2.09 kg / hm in the remainder of the Bay (NAFO 4Xr plus 4Xs).
***we estimate over 100 t. to have been caught in the inside zone during Aug - Sept.
****our estimate for October to December only.

Table 6.- Characteristics of the meat size distribution in the commercial fishery while fishing the inside zone.

Season	Month	Meat weight				Sample size	Meat count
		Mean	Min	Max	S.E.	(n meats)	per 500 g
1978-79	Apr	17.9	5.6	33.7	0.4	78	27.9
1979-80	Oct	20.6	6.5	86.4	0.4	229	24.3
	Nov	21.8	5.3	44.4	0.3	374	23.0
1980-81	Oct	26.0	5.6	60.2	0.5	329	19.2
	Dec	24.5	5.1	59.5	0.8	137	20.5
	Feb	22.0	5.2	50.5	0.3	681	22.8
	Mar	22.0	6.3	50.0	0.3	572	22.8
1981-82	Oct	27.2	5.7	54.2	0.6	177	18.4
	Nov	24.1	3.7	77.9	0.3	849	20.8
1982-83	Oct	24.9	5.0	69.4	0.4	632	20.1
	Nov	27.4	5.9	62.6	0.6	231	18.3
1983-84	Apr	18.8	2.3	55.5	0.1	1807	26.6
1984-85	Oct	25.1	4.2	63.6	0.1	2250	19.9
	Apr	19.6	3.7	57.5	0.3	503	25.5
1985-86	Oct	28.5	5.9	56.2	0.2	809	17.6
1986-87	Oct	17.7	2.3	57.5	0.2	1743	28.2
1987-88	Oct	10.0	2.5	55.1	0.1	3215	50.3
1988-89	Oct	13.5	3.3	48.0	0.1	3770	37.1
	Nov	15.1	5.5	51.2	0.1	1100	33.0
	Apr	10.7	5.4	23.7	0.3	103	46.7
1989-90	Oct	18.9	2.3	58.9	0.2	1802	26.4

Table 7.- Number of survey stations in the Digby area by year and by stratum types. In 1988, there were also 4 stations located in the Annapolis Basin; this is not indicated on a per area stratum.

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989
Catch stratum:									
low (0 - 1%)	15	29	40	40	48	49	48	19	20
medium (1 - 3%)*	17	20	20	20	28	27	27	26	8
high (> 3%)*	38	22	15	15	14	14	14	30	40
exploratory	--	30	25	25	30	30	30	29	42
total	70	101	100	100	120	120	119	104	110
Area stratum:									
Centreville	3	19	20	20	21	16	4	0	9
Gulliver's Head	22	20	28	23	29	21	23	15	15
Digby Gut	41	49	35	40	30	42	45	34	52
Delaps Cove	4	9	14	12	18	14	13	18	15
Parker's Cove	--	4	3	5	14	12	13	12	6
Young Cove	--	--	--	--	--	3	10	10	7
Hampton	--	--	--	--	8	9	11	11	6
Zone stratum:									
inside 6-mile	27	50	40	49	58	48	38**	45	59
outside 6-mile	43	51	60	51	62	72	81**	59	51

* 2% in 1981.
** ratio is 53, 66 stations for inside / outside 8-mile.

Table 8.- 1986 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	146	19	12	33	41	38	25	15	18
medium	556	157	16	18	20	21	17	16	23
high	482	110	25	19	19	18	18	13	20
exploratory	534	136	23	16	24	29	26	20	42
Area stratum:									
Centreville	77	24	22	13	29	37	33	22	35
Gulliver's Head	201	72	20	22	29	33	30	19	27
Digby Gut	671	176	22	20	21	24	25	22	34
Delaps Cove	744	97	19	24	20	21	19	13	24
Parker's Cove	15	5	3	34	44	25	10	2	4
Young Cove	40	4	0	27	51	69	6	4	6
Hampton	48	7	7	45	51	39	8	7	7
Zone stratum:									
inside 6-mile	591	186	18	10	16	17	10	9	17
outside 6-mile	230	26	17	33	38	38	31	21	30

Table 9.- 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 10.- 1988 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	19	94	141	390	95	26	17	7	7
medium	6	97	180	887	114	38	23	12	17
high	4	241	572	885	540	47	9	5	20
exploratory	82	255	545	712	271	46	17	11	20
Area stratum:									
Annapolis Basin	25	69	372	146	115	22	4	4	28
Gulliver's Head	153	446	930	848	368	69	22	13	22
Digby Gut	4	235	552	1239	514	48	11	7	23
Delaps Cove	2	103	217	1010	226	24	15	9	20
Parker's Cove	12	60	85	173	36	22	21	12	7
Young Cove	5	43	68	98	32	31	16	6	8
Hampton	29	106	149	91	50	41	22	7	2
Zone stratum:									
inside 6-mile	52	298	662	788	527	55	12	7	19
outside 6-mile	11	94	178	715	87	30	19	10	15

Table 11.- 1989 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	6	86	115	258	166	97	23	9	9
medium	2	8	21	249	275	135	17	6	9
high	2	9	35	234	259	141	36	10	6
exploratory	9	111	79	244	245	133	42	16	18
Area stratum:									
Centreville	23	329	167	229	261	221	81	22	31
Gulliver's Head	12	185	157	319	350	183	45	21	27
Digby Gut	1	8	33	218	253	137	35	11	8
Delaps Cove	2	4	26	245	228	114	21	5	2
Parker's Cove	1	8	84	326	41	16	6	4	2
Young Cove	3	5	11	119	140	48	12	4	2
Hampton	4	21	92	348	103	30	16	8	4
Zone stratum:									
inside 6-mile	7	98	86	292	288	159	49	16	13
outside 6-mile	2	12	39	187	177	94	17	5	8

Table 12.- Summary of average number of scallops at age caught for prerecruits and recruits by area stratum.

	Age (years)		
	2-4	5-7	8 +
1981			
Centreville	31	222	174
Gulliver's Head	475	208	85
Digby Gut	47	167	94
Delaps Cove	13	35	172
1982			
Centreville	35	237	129
Gulliver's Head	41	175	123
Digby Gut	23	130	74
Delaps Cove	10	93	90
Parker's Cove	0	1	29
1983			
Centreville	24	113	73
Gulliver's Head	38	166	75
Digby Gut	32	122	81
Delaps Cove	22	139	96
Parker's Cove	0	3	0
1984			
Centreville	31	71	44
Gulliver's Head	33	147	71
Digby Gut	17	75	49
Delaps Cove	12	57	50
Parker's Cove	0	30	4
1985			
Centreville	26	82	77
Gulliver's Head	13	79	59
Digby Gut	14	53	64
Delaps Cove	9	55	71
Parker's Cove	3	45	33
Hampton	0	39	67
1986			
Centreville	123	79	90
Gulliver's Head	293	84	76
Digby Gut	869	65	81
Delaps Cove	860	65	56
Parker's Cove	23	103	16
Young Cove	46	147	16
Hampton	62	135	22

continued

Table 12.- Continued. Summary of average number of scallops at age caught for prerecruits and recruits by area stratum.

	Age (years)		
	2-4	5-7	8 +
1987			
Centreville	143	149	186
Gulliver's Head	623	133	60
Digby Gut	1605	226	59
Delaps Cove	1673	139	49
Parker's Cove	221	71	17
Young Cove	134	103	26
Hampton	264	62	15
1988			
Annapolis Basin	116	283	36
Gulliver's Head	1529	1285	57
Digby Gut	791	1801	41
Delaps Cove	322	1260	44
Parker's Cove	1897	231	40
Young Cove	116	161	30
Hampton	284	182	31
1989			
Centreville	519	711	134
Gulliver's Head	354	852	93
Digby Gut	42	608	54
Delaps Cove	32	587	28
Parker's Cove	93	383	12
Young Cove	19	307	18
Hampton	117	481	28

Table 13.- Surveyed areas of the traditional Digby grounds. The area has been subdivided: below Digby; core area; above Digby as, except for the core area, the other ones are not always represented at the same level (see text). Survey catch-rates (Numbers are in 10^6) on an age basis have been derived by volume calculations (smoothing interpolation technique with 16 subtriangles).

Area (km^2)

Year	Below	Core	Above	Total
1986	113.89	1036.95	568.43	1719.27
1987	77.52	959.38	612.91	1649.80
1988	0.00	683.22	539.32	1222.55
1989	51.47	735.06	475.80	1262.34

	Age (years)							
	2	3	4	5	6	7	8	9
Core area only (N 10^6)								
1986	117.79	26.94	4.76	5.81	6.44	6.73	6.18	5.00
1987	57.17	98.33	139.20	31.97	5.93	5.09	4.28	2.64
1988	3.10	35.24	75.48	192.70	53.68	7.46	2.75	1.70
1989	0.58	7.13	8.33	34.02	42.30	21.72	5.06	1.78
Total area (N 10^6)								
1986	137.43	30.54	6.93	16.98	16.71	14.36	10.99	7.62
1987	61.70	114.47	143.12	33.86	9.07	7.75	5.86	3.28
1988	4.99	46.67	92.88	209.02	60.61	11.02	5.32	2.83
1989	1.07	10.96	14.71	59.66	55.58	26.97	7.37	2.53

Table 14.- Vessels licensed for scallop fishing in the upper parts of the Bay of Fundy. These licenses used to be called 'Cumberland' or 3-mile licenses.Their present appellation is 'Upper Bay of Fundy'. All vessels are less than 14 m long. Numbers in parenthesis indicate active licenses that submitted at least one sales slip during the year.

Year	under 25.5 G.T.	over 25.5 G.T.	Total
1983	14 (N / A)	0	14
1984	13 (N /A)	1 (1)	14
1985	13 (6)	1 (1)	14 (7)
1986	16 (10)	0	16 (10)
1987	16 (13)	0	16 (13)
1988	17 (16)	0	17 (16)
1989	17 (15)	0	17 (15)

Table 15.- Mean annual landings per active vessel with an Upper Bay of Fundy or a Mid-Bay license landing in the Upper Bay statistical districts.

Year	Active licenses	Mean landing (kg)
	Upper Bay + Mid-Bay	
1985	7 + 11	1,597
1986	10 + 6	1,050
1987	13 + 4	1,903
1988	16 + 9	2,929
1989	15 + 13	3,792

Table 16.- Landings in t of scallop meats by statistical districts in the upper parts of the Bay of Fundy. Districts 24 and 44 are in Cumberland Co., district 40 in Kings Co., district 43 in Colchester Co., Nova Scotia; district 79 is in Albert Co., New Brunswick. Source: Statistics Division, Fisheries and Oceans, Halifax, N.S.

Year	District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	40	--	--	--	--	0.12	--	0.24	0.12	0.24	--	--	--
	44	0.12	0.24	--	0.24	0.72	0.24	0.36	0.24	0.12	0.12	--	0.24
	79	--	--	--	2.65	4.34	2.29	1.93	2.41	1.69	0.24	--	--
		0.12	0.24	--	2.89	5.18	2.53	2.53	2.77	2.05	0.36	--	0.24
	total for year:	18.91											
1987	24	--	--	--	--	--	--	--	--	0.72	2.89	--	--
	40	--	--	--	0.12	0.24	--	--	--	0.24	--	--	--
	44	0.24	0.12	0.24	1.33	1.20	0.96	3.73	4.10	5.42	1.93	0.72	1.08
	79	--	--	--	1.20	0.72	0.12	--	7.71	5.66	0.36	--	--
		0.24	0.12	0.24	2.65	2.16	1.08	3.73	11.81	12.04	5.18	0.72	1.08
	total for year:	41.05											
1988	24	--	--	--	--	0.36	0.60	0.48	0.60	1.69	0.72	0.48	--
	40	--	--	--	0.36	1.33	0.60	0.36	--	0.96	--	--	--
	43	--	--	--	--	--	--	--	0.24	0.24	--	--	--
	44	--	--	1.57	4.22	4.82	2.17	5.42	12.29	6.87	2.41	1.20	1.08
	79	--	--	--	1.57	4.58	3.98	2.77	11.20	3.13	0.96	0.36	0.12
		0.00	0.00	1.57	6.15	11.09	7.35	9.03	24.33	12.89	4.09	2.04	1.20
	total for year:	79.74											

Table 16.- Continued.

Year	District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	24	--	--	--	--	0.12	1.20	1.33	1.45	1.81	1.08	--	--
	40	--	--	--	--	2.77	2.05	3.61	1.69	0.84	--	--	--
	43	--	--	--	--	--	--	--	0.12	0.24	--	--	--
	44	1.20	0.96	0.48	3.01	8.80	6.02	5.06	9.52	11.45	6.02	0.96	--
	79	--	--	--	4.10	9.40	11.57	7.35	7.95	6.51	2.29	0.48	2.53
		1.20	0.96	0.48	7.11	21.09	20.84	17.35	20.73	20.85	9.39	1.44	2.53

total for year: 123.97 (An additional 1.69 t was landed by vessels over 25.5 G.T.)

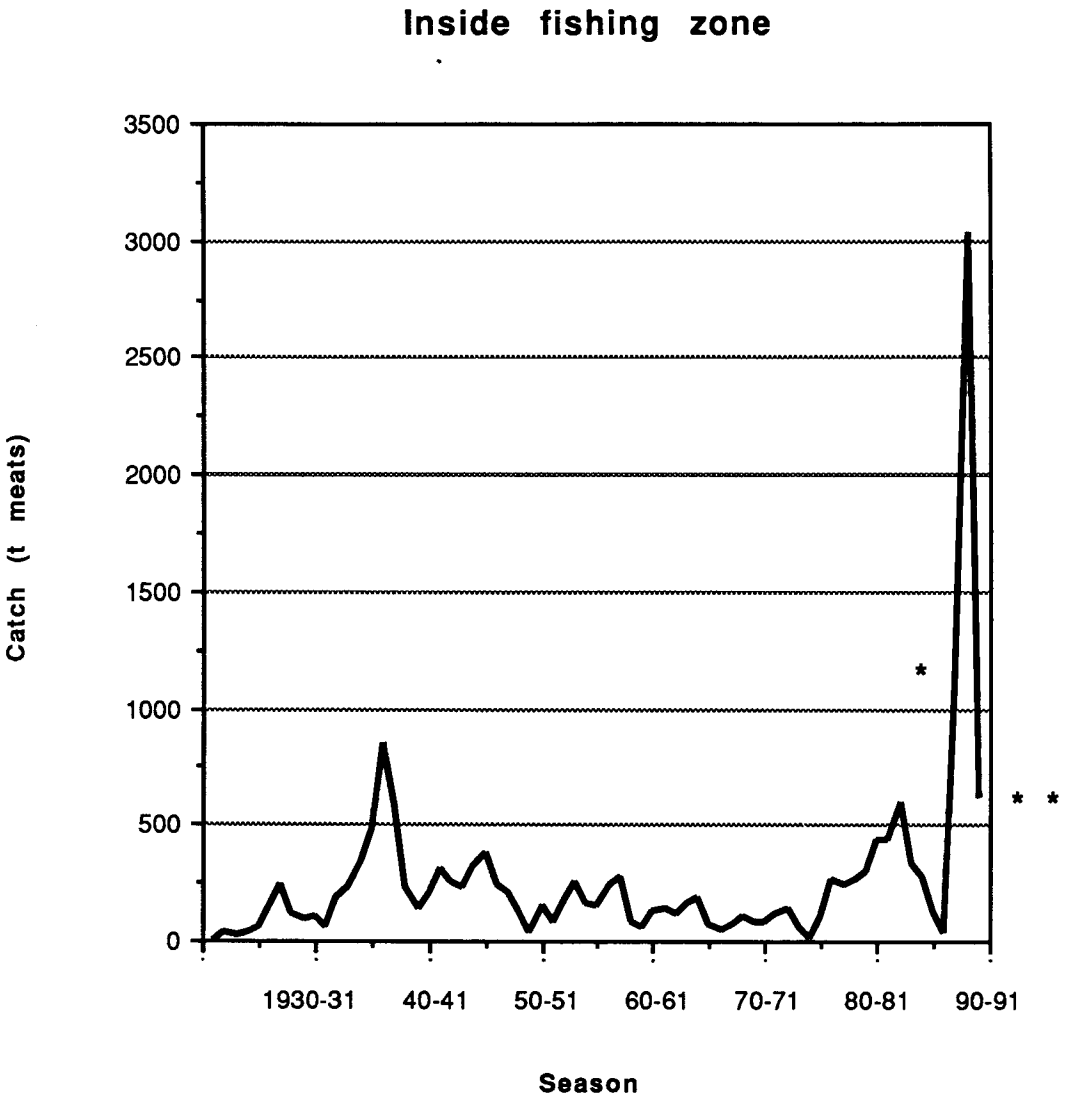


Figure 1.- Catch profile of a 65+ years time series for the traditional grounds off Digby of the inside fishing zone or catches recorded from October to April in NAFO sub-subarea 4Xr when a fishing zone did not exist. Source: Caddy (1979) up to 1972; then catches in NAFO sub-subarea 4Xr from October to April for vessels under 19.8m, Statistics Division, Fisheries and Oceans, Halifax. Catches for 1987 - 90 are from our estimates. The 1987-88 catches (*) rose to 1,100 t to reach a peak at 3,035 in 1988-89. The 1989-90 figure (**) is for the first half of the season only.

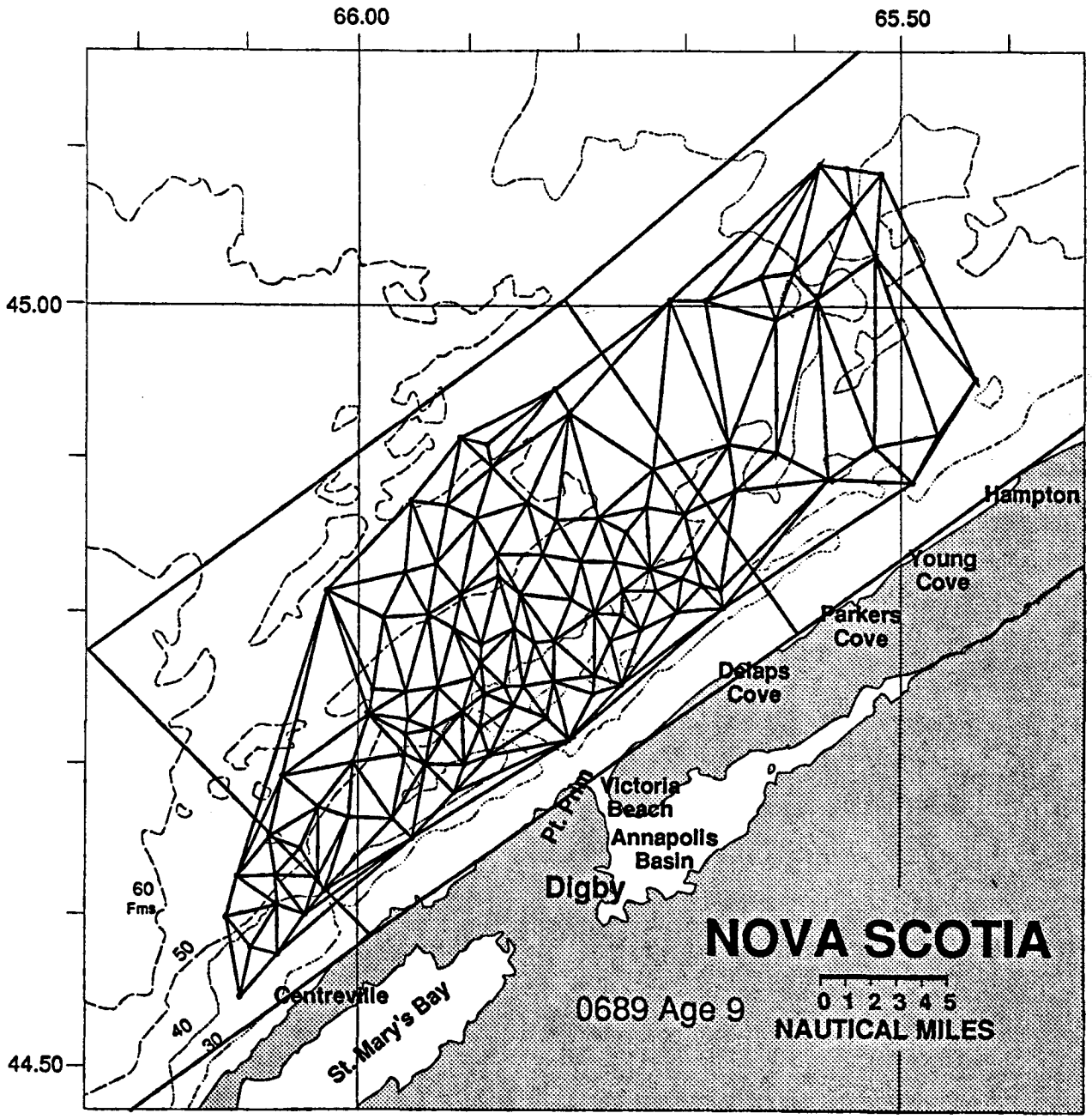


Figure 2.- The traditional Digby grounds. The survey area has been divided into 3 sectors: (from left to right) below Digby, a core area and, above Digby for establishing abundance via volume estimates. The survey stations for 1989 are located at the apices of triangles.

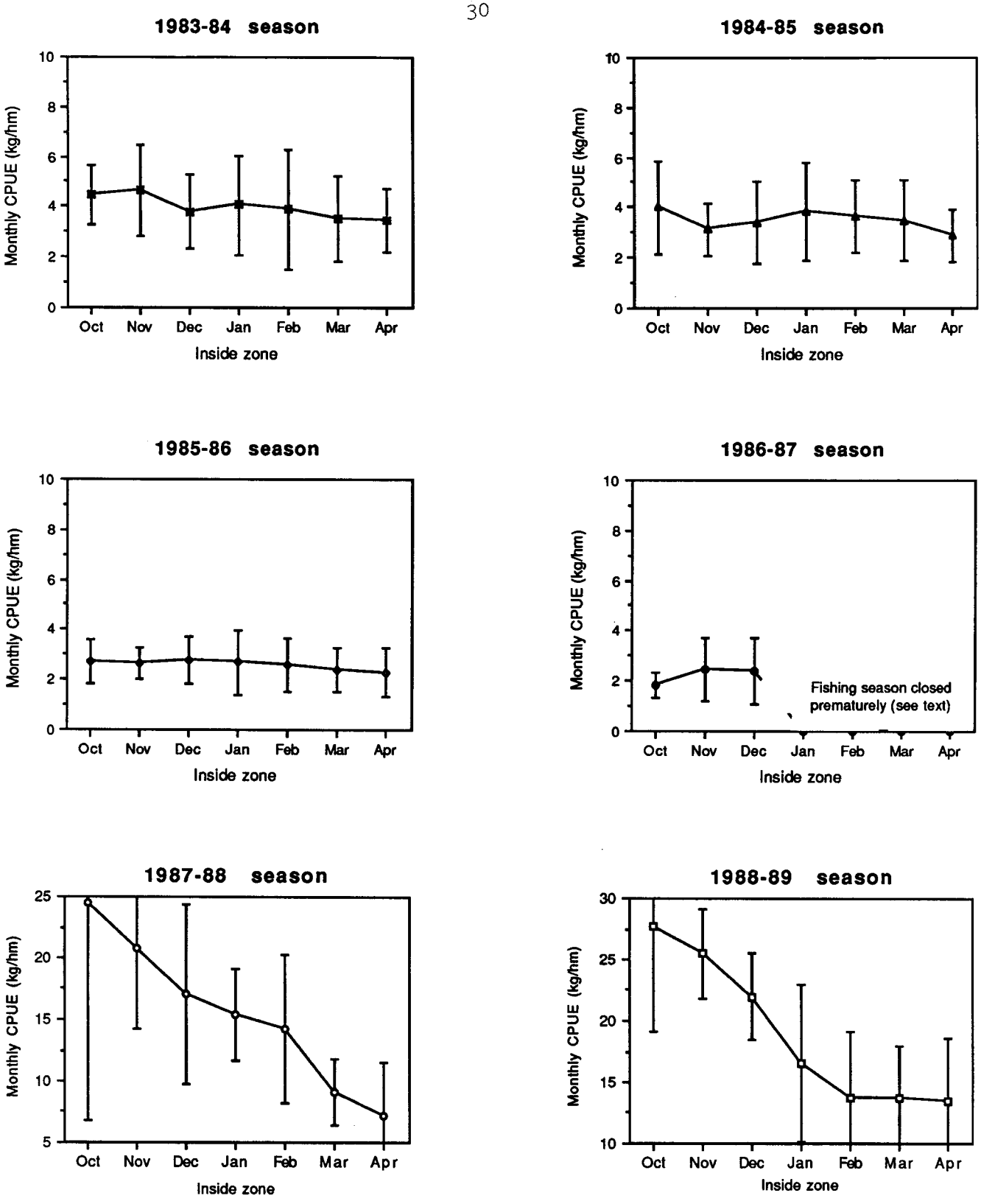


Figure 3.- Bay of Fundy fleet fishery performance. Monthly catch-rates (kilograms per hour-meter) during the inside fishing season in Nova Scotia for the period 1983 to 1989. Means and standard deviation are plotted.

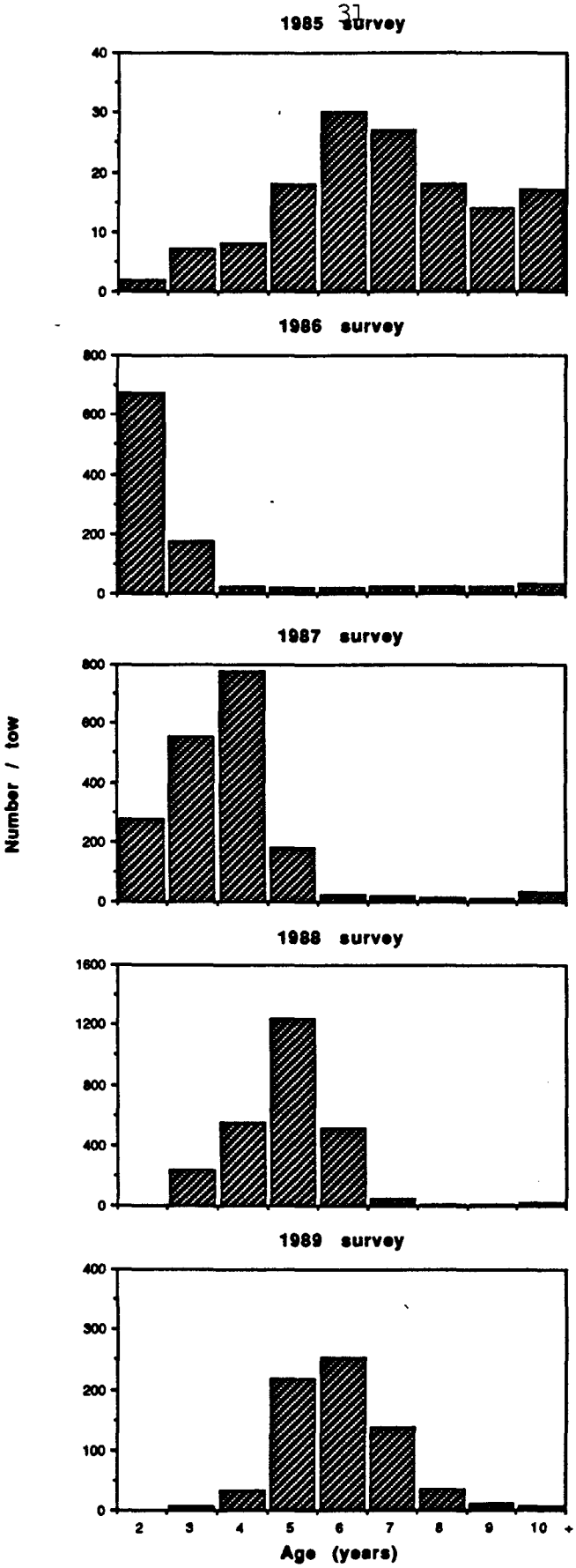


Figure 4.- Profile of the abundance of age classes (no. scallops per standard tow) from the last 5 annual surveys along a cluster of stations from the most productive Digby Gut area.

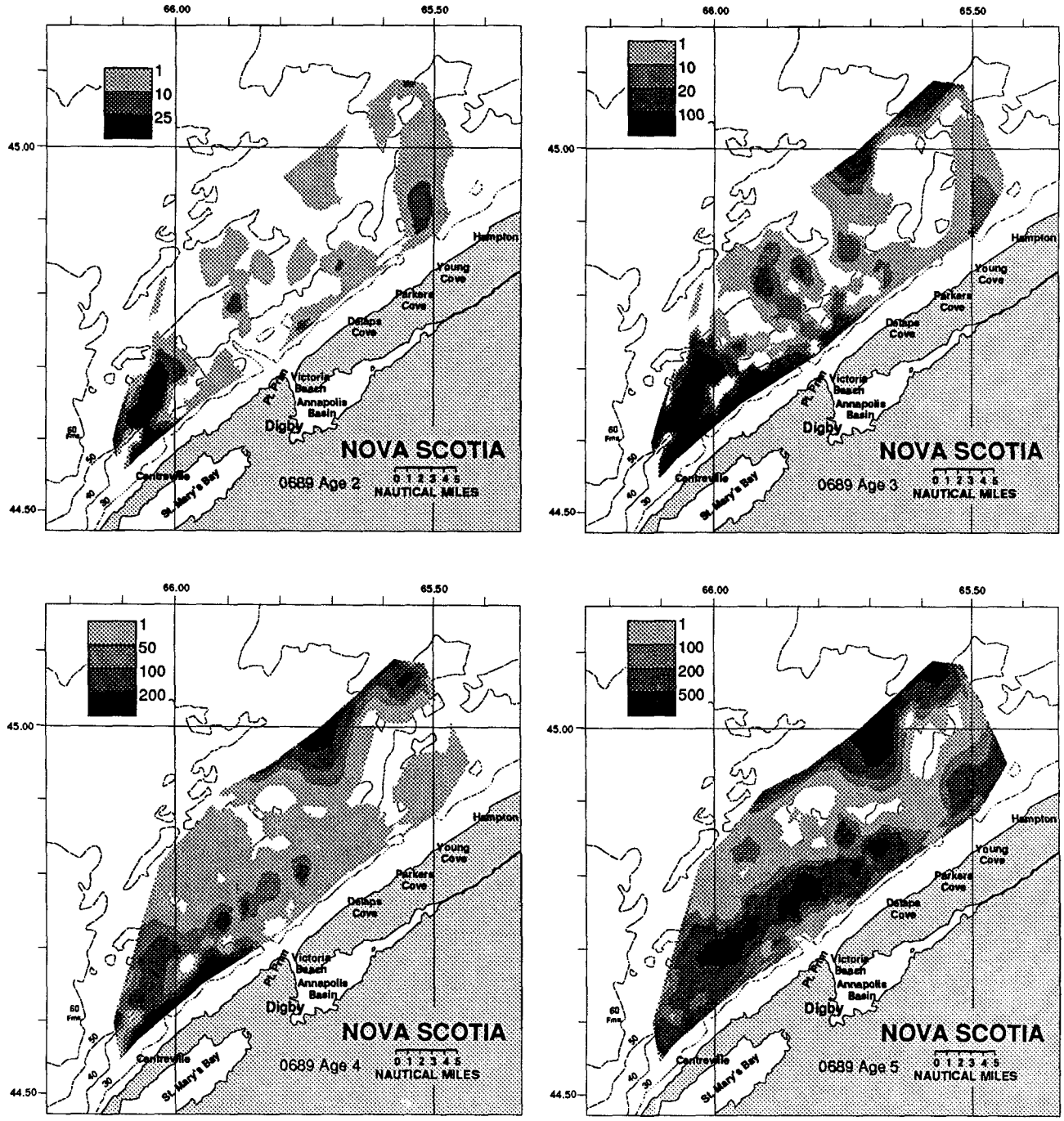


Figure 5.- 1989 survey catch-rates. Scallop distribution on an age basis from abundance isopleths of survey data. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in upper corner of plot).

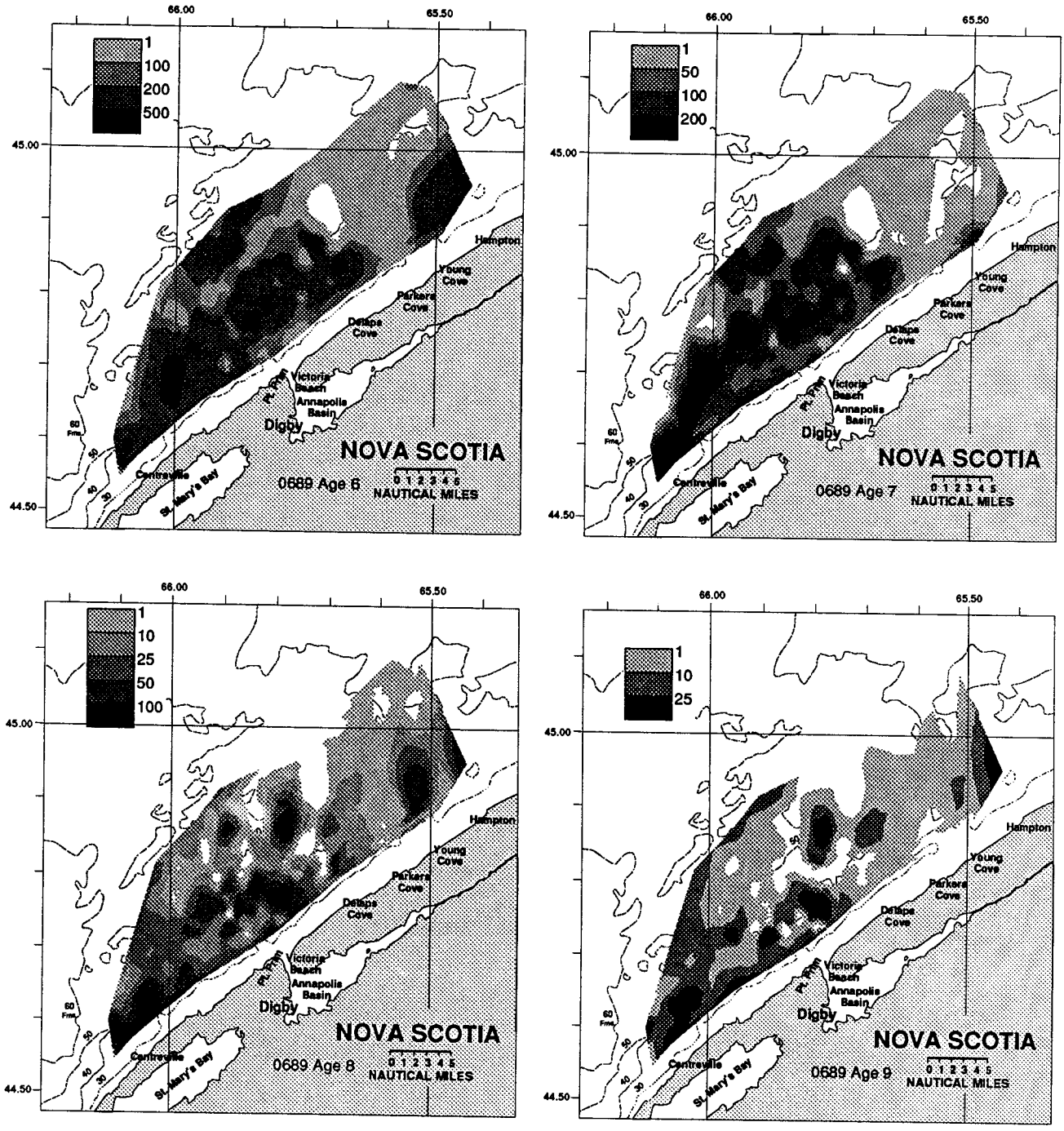


Figure 5.- Continued. 1989 survey catch-rates.

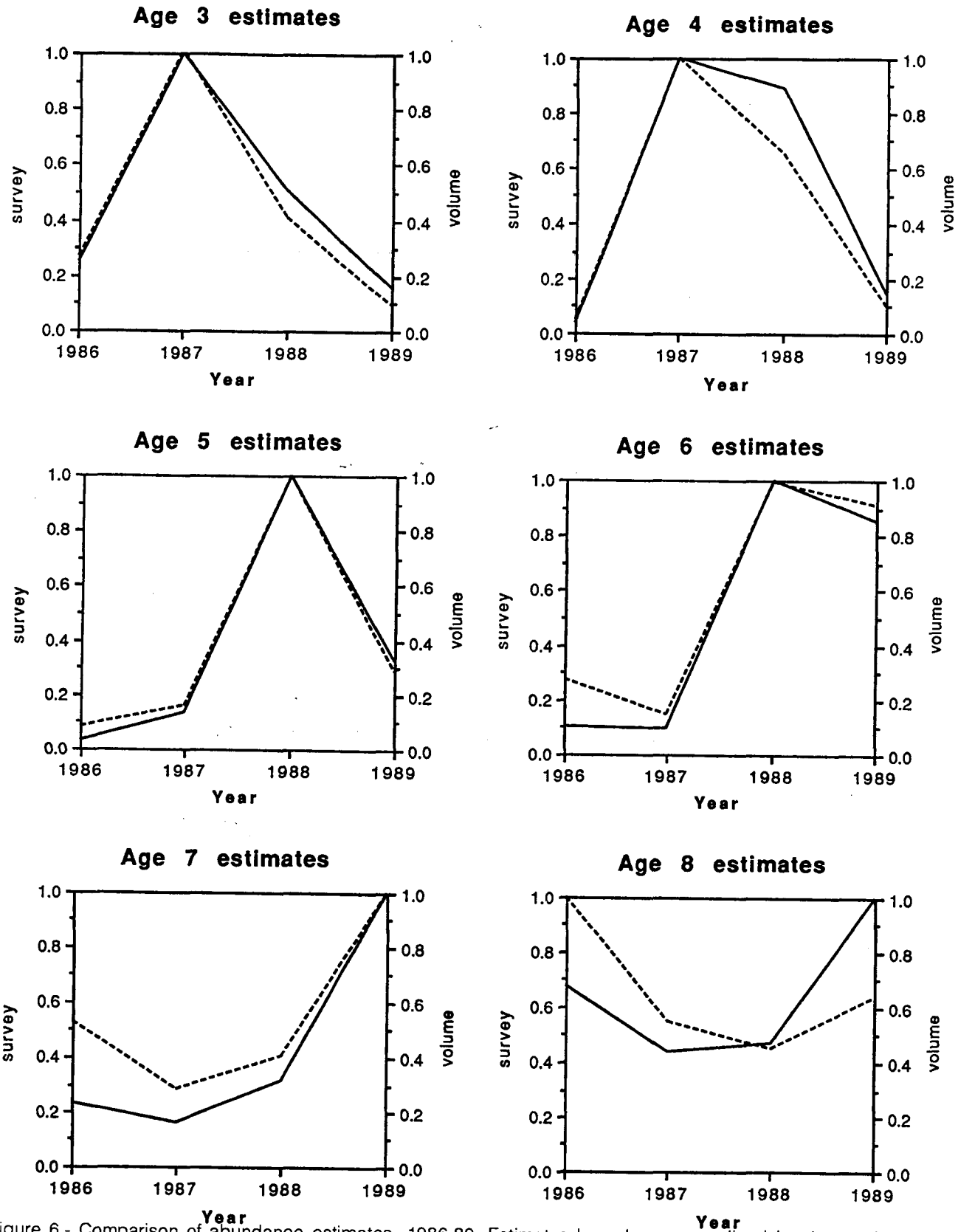
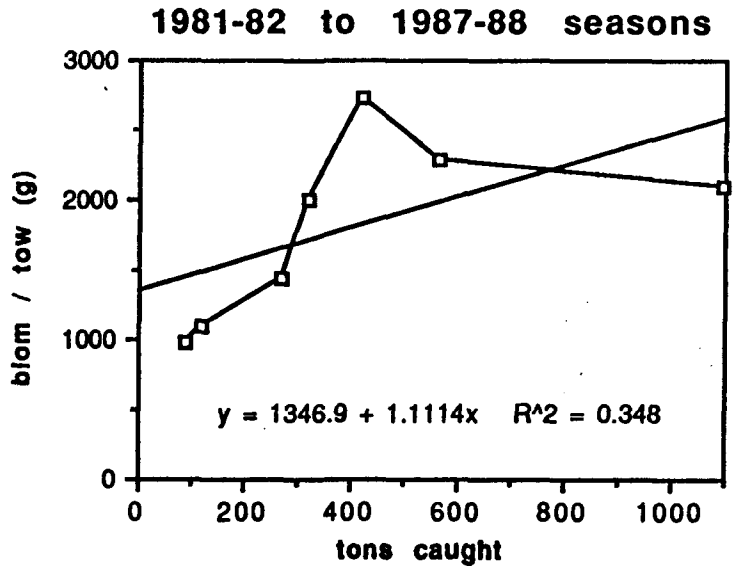
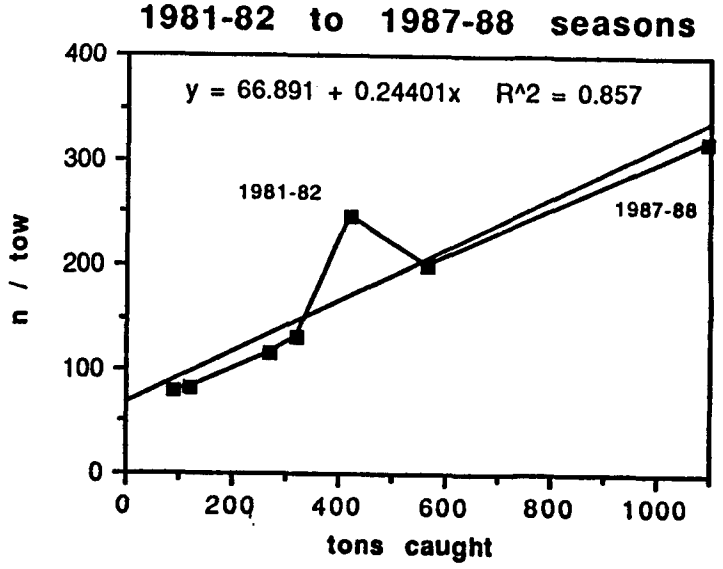
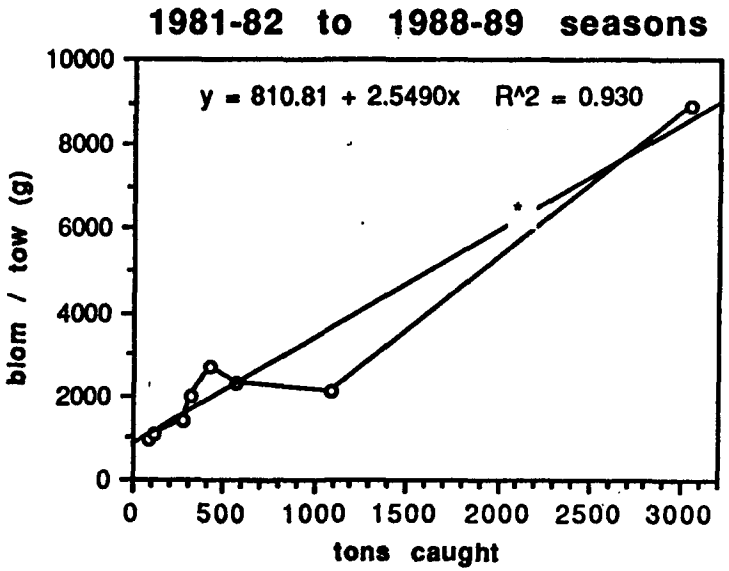


Figure 6.- Comparison of abundance estimates, 1986-89. Estimates have been normalised by the maximum annual value for each index. The survey index, no. per standard tow, is drawn with a smooth line. The volume index, no. in millions, as per Delaunay triangulation is expressed with a dashed line.







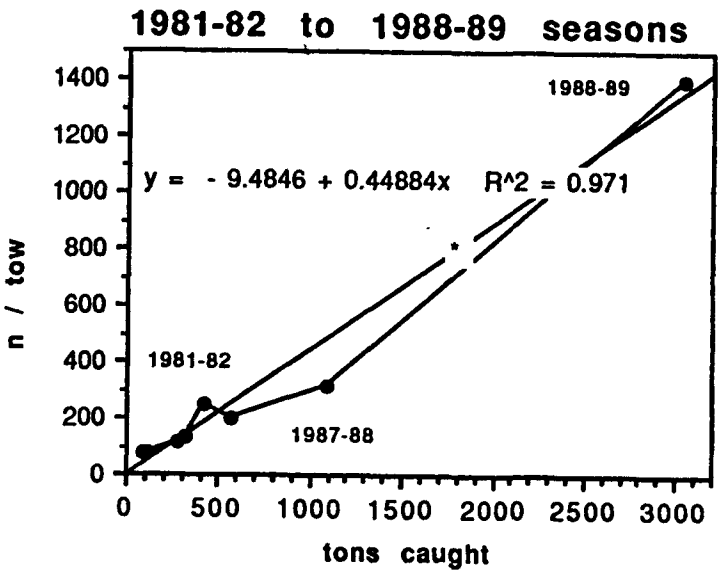


Figure 7.- Catch projections for the inside fishing zone. Plots are made with and without the high 1988-89 season value. Inside zone catches are related to the recruited biomass / tow for the zone from the summer survey preceding the fishing season on the left and to the recruited n / tow from the same survey on the right. Corresponding regressions and coefficients are given on each graph. The asterisks in bottom graphs show the projected level of the 1989-90 catch given the 1989 survey results.