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Georges Bank Scallop Stock Assessment - 1996

By

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ABSTRACT

The 1996 TAC was set at 3,000 t. This is a 50% increase over the 1995 level. The rise in catch-rates was sharp, 77% from 1995 to 1996. The TAC had been set upward with the advent of a stronger year class (1992 year class) in the fishery.

The total biomass has increased from 1995. It is concentrated mainly in young recruits, ages 3 and 4. The biomass for the directed age group, 4 - 7, has also increased in 1996 due to the 1992 year class. Recruitment has improved with the 1992 year class strength close to long term average.

The 1997 fishery will rely on the 1992 year class at age 5 as its main constituent. But the 1992 year class had already brought an important contribution to the 1996 fishery at age 4. Young recruits almost double the meat yield from age 4 to age 5. Fishing scenarios for 1997 should be conservative to harvest older scallops and to avoid dependence on the incoming year class.

RESUME

On avait établi un TAC de 3,000 t pour 1996. C'est une augmentation de 50 % par rapport à 1995. L'augmentation des taux de capture fut aussi prononçée, 77 % de 1995 à 1996. Le TAC avait été mis plus haut avec l'arrivée d'une classe d'âge (la classe d'âge de 1992) plus forte dans la pêche.

La biomasse totale a augmenté depuis 1995. Elle est concentrée principalement dans les jeunes recrues, âges 3 et 4. La biomasse pour le groupe d'âge dirigé, 4 - 7, a aussi augmenté en 1996 grâce à la classe d'âge de 1992. Le recrutement s'est amélioré; la classe d'âge de 1992 se compare à la moyenne à long terme.

En 1997, la pêche dépendra largement sur la classe d'âge de 1992, âgée de 5 ans. Mais la classe d'âge de 1992 avait déjà apporté une contribution importante à la pêche de 1996 à l'âge de 4 ans. Les jeunes recrues presque double le rendement en viande de l'âge de 4 ans à 5 ans. Les scénarios de pêche pour 1997 doivent être conservateurs pour récolter des pétoncles plus âgés et pour éviter la dépendence sur la classe d'âge nouvellement recrutée.

INTRODUCTION

After the jurisdiction for fisheries on Georges Bank had been settled by the World Court (October 1984), the Canadian scallop industry focused on stock rehabilitation through better harvesting of the resource. An Enterprise Allocation (EA) regime was implemented in 1986 partly to reduce fishing effort. There were 77 active license holders in 1984. Today, less than half the initial number of license holders are actively involved in the Georges Bank fishery. But the fishing power has not necessarily been reduced by the same ratio. The meat count (size limit) was lowered to 33 meats per 500 g in January 1986 to direct exploitation toward slightly larger scallops. In 1995 the offshore scallop industry, in collaboration with Science, instituted a program to monitor the presence of small meats in the catch (50-count). A tolerance level of 10% by number of meats 10 g or less (or 5% by weight) was established. It was based on the size composition of the catch made up of good year classes that have reached most of their yield potential. The low tolerance on 50+ count meats adds more restriction to the regulatory meat count in place.

The 1996 TAC was set at 3,000 t; 2,996 t were caught (Table 1). This is a 50% increase over the 1995 TAC levels. A TAC level of only 2,000 t had been advocated for 1995 given the weakness of the 1990 and 1991 year classes which, at ages 4 and 5 were 2 of the main age groups directed for by the fleet. TAC levels have been set upward (for 1996) with the advent of a stronger year class, the 1992 year class at age 4, in the fishery. The 1996 fishery was highly dependent on this incoming year class though. The 1996 levels are relatively modest. Prior to 1995, catches had been in the narrow range of 5-6,000 tons over the previous 5 years. Catches from the first quarter of the year had reached up to 30% of the total for the year during the 1989 - 1994 period. This was in sharp contrast with traditional levels of 10%. For the first time since 1988, winter 1995 catches at 13% were more in line with traditional levels; they rose slightly to 15% in 1996 (Fig. 1).

Effort has dropped about 20% from 1995 to 1996 (Table 2). On a quarterly basis the bulk of the effort took place in the second quarter. However, effort was highly concentrated in one particular area of Georges Bank at that time (Fig. 2). Overall, most of the effort was expanded on the Northern Edge. A minimum of fishing activities took place on the southeast side.

Annual catch-rates since 1990 are in the medium to high range, peaking in 1993 (Table 2) to decrease in 1995 before rising again in 1996. The rise was sharp, 77% from 1995 to 1996. On a month to month basis medium values at the start of 1993 went steadily downward during 1993 and 1994 to level off, uniformly, during 1995. Catch-rates picked up in 1996 with a seasonal peak in June (Fig.1). (The December 1996 point is an artefact with very few observations). Catch-rates usually experience a small decline due to spawning in the fall (Fig. 1). The available incoming biomass (equivalent to adductor muscle or meat weight not round weight) usually dampens this seasonal effect and allows catch-rates to rebound in good years. A declining biomass in 1994 could not follow this pattern. A detailed geographical distribution of CPUE isopleths for 1995 (Fig. 3) and 1996 (Fig. 4) shows a fragmented distribution of areas with high CPUE's. Areas with CPUE's over 1 kg/crhm covered 4,050 km^2 in 1994 or 85% of the total area; such areas were reduced to 1,100 km^2 in 1995 and 855 km^2 in 1996. The southern half of the Bank had CPUE under 0.5 kg/crhm with only a very small area higher than that in 1995. The situation has worsened in 1996.

The average monthly meat weight in the catch had been increasing from 1993 to 1995 reflecting the weakness of the 1990 and 1991 year classes recruiting to the fishery. Data for 1995 and 1996 are presented in table 3. The average monthly meat weight has decreased from 1995 to 1996. The 1991 year class should have been a main component of the 1996 catch and contribute to maintain the average meat weight in the high range. The weakness of the 1991 year class has resulted in the fishery directing for the 1992 year class earlier. This is a very different catch composition from 1981 when the fishery was competitive and temporarily deregulated. The quarterly distribution of meat weights in table 4 shows the progressive shift toward large scallops (30+ g) in the catch up to 1995. The 1995 catch had an impressive component of large meats especially during the second and third quarters. Large meats have gradually disappeared from the 1996 catch, starting with much fewer in the first quarter. The presence of ≤10 g meats in the catch was severely curtailed once the monitoring program for small meats was in place from the second quarter of 1995 onward. Its effects were stronger in 1996, second quarter catches had under 1% of ≤10 g meats.

METHODS

Fishery data

Offshore scallop landings are monitored at dockside by an independent agency beginning in 1994. The monitoring replaces sale slips issued by fish buyers. Catch information is then transferred to the Statistics Division of Fisheries and Oceans.

Catch and effort data were compiled from commercial logbooks. Logs with complete effort data are called Class 1 and were used to estimate catch-rates. The Class 1 data represent more than 90% of the total logs available (Table 2). Effort is measured in towed hours (h) and towed hours times the width of the 2 drags used times the number of crew (crhm). Catch-rate is presented as catch (kg) per hour and per crew-hour-meter. Catch per h considers only the period that gear was actively fishing. It does not consider how wide the gear is to estimate how much ground is covered by the tow. Gear width may vary from 8.5 to 15.5 m. Scallop meats caught have to be shucked at sea; the smaller the meats, the more crew needed to shuck. Common fishing practices will first change the number of crew if effort has to be modified. CPUE in kg / h is used in the cohort tuning analysis. High catch-rates encountered recently are not necessarily suitable for comparison with high values of the late 1970's. Technological changes in the localisation of scallop beds and operational procedures at sea coupled with quite different management regimes, especially meat count and limit on removals, influence the conduct of the fishery compared to 15 years ago.

Catch sampling

Size distributions of meats from the commercial fleet were derived from port samples. Only one or two company fleet(s) have regularly contributed the information. In 1991 steps were taken to expand the catch sampling database to all fleets. Data representing harvesting strategies of the different company fleets involved have been included in the catch data matrix for the period 1991-1996. Generally speaking, the 1991-1996 data set representing all companies profiles scallops caught at a larger size than the corresponding data set from the 2 'index' companies. (For a comparison, see table 5 this document and the same table in Robert and Butler, MS 1995). Canadian port sampling data were applied to the Canadian and U.S. total catch east of the ICJ line prior to 1985. This assumes similar fishing practices for both fleets. Table 5 lists the frequency distribution of meats on an annual basis. There has been a gradual shift toward larger meats in the catch over the last 10 years, reflecting the implementation of a lower meat count in 1986. Significant differences may be contrasted between the catch distribution in 1995 and 1996 (Table 5). The 1995 catch was made up of age 7 scallops (29+ g) for 20% of the animals caught, this is the once plentiful 1988 year class. In 1996, depleted old year classes made up only 5% of meats 29+ g. The low abundance of the 1990 and 1991 year classes (ages 6 and 5) did not allow for a noticeable contribution. But younger recruits, age 4, contributed over 50% of the catch in a narrow range of weight intervals (11 - 15 g). Catches of the past 2 years also lack ≤10 g scallops, only 7% by numbers for 1995 and 2% for 1996. Table 4 offers a detailed picture broken down by quarters. The monitoring programme for small meats was fully operational during the second quarter of 1995. The presence of ≤10 g meats dropped from 13 % in the first quarter to 6% for the rest of 1995. In 1996, values ranging from ≤1 to 4% were encountered. The last quarter would be expected to have a greater presence of small meats in the catch since new recruits enter the fishery at that time of the year.

Catch in numbers-at-age (Table 6) for the cohort analysis are derived from the port sampling data and the sum of U.S. and Canadian catches in NAFO SA 5Zc. Slicing underestimates large year classes and overestimates weak year classes. The total catch (U.S. prior to 1985 and Canadian) from the Canadian zone is decomposed into 2 - g weight frequencies. The weights were converted to shell heights using the allometric relationship derived from 1982 -1985 research and commercial data (Robert and Lundy MS 1987). The values expressing meat weight as a function of shell height use the parameters 9.102^{-6} for the regression coefficient and 3.097 for the exponent of height. These values agree closely with those of Serchuck et al. (1982) for the same stock. Shell heights were clustered into age groups according to a Von Bertalanffy growth equation (Brown et al. 1972, cf. Table 7).

Traditionally, catch statistics are compiled on an annual basis and recruitment to a fishery is discussed in terms of year class strength. It is generally accepted that, in any given year the majority of Georges Bank scallops are born in October and the first annual ring is laid down the following spring. This is typically less than 10 mm and becomes difficult to discern as the animal grows. For this reason the ring, which is approximately 25 mm from the umbo is often referred to as the first annulus (Naidu 1970). The convention which we shall adopt is that animals born in the fall of a year will be of that year class and it will be further assumed that they were born on January 1 of that year (cohort ages). The deposition of the ring less than 10 mm will take place during the first year of life. The date of the deposition will be assumed to take place on April 1. A back calculation is then made to estimate the shell height for January 1 (eg. cohort age 3 has a shell height of 61 mm on January 1st, while its biological age is 2.25 years). The annual growth rates for weights, given in Table 7, are converted into rates for heights and this results in a 16% reduction of the ring size being used for the January 1 size. For example, an animal born in the fall of 1988 is of the 1988 year class and will be approximately 25 mm on its second birthday (January 1, 1990) although the ring would not be deposited for a few months. Table 7, as well as all other age data, uses this convention, with correction of ring sizes back to January 1. The actual weights used are mid-quarter values in age - weight analyses and projections.

Research survey data

The annual research survey was carried out on Georges Bank during August 1996. A new survey series started in 1994. The design of the survey was based on a stratification by commercial effort (Robert and Jamieson 1986). The logbooks of the commercial fleet in the preceding 9 months were analyzed to determine areas of very high, high, medium, low, and very low catch-rates. A very high stratum was added in 1991 to reduce the variability of the high stratum. The range of catch-rate values encountered had increased markedly until 1995. In 1995, only 14% of the catch-rate points were over 1 kg/crhm, the minimum benchmark of the high stratum. Improved CPUE's with the 1996 fishery contributed 33% of points to belong to the high and very high strata of the 1996 survey. The average number of scallops at age per tow is given in Table 8. The details of the survey results on a per stratum basis are given in Table 9.

In addition to establishing a stratified mean number per tow, the data are contoured to represent the spatial distribution of the scallop aggregations according to a procedure, ACON, by Black (MS 1993) (Fig. 5). Data points describe a three dimensional surface with latitude, longitude, and density to be plotted. A surface is formed by defining Delaunay triangles where the data points form the vertices of triangles connecting neighbouring points. The algorithm used to define the triangles is found in Watson (1982). Collectively, the triangles form a surface. The surface between adjacent contour levels (density of scallops) is illustrated by varying shades of grey. Smoothing of the contours may be performed by interpolating over the surface using inverse weighting of gradients (perpendicular to the planes of the triangles). The interpolation points are found by dividing the sides of the triangle into equal segments. Dividing the sides into 4 segments produces 16 subtriangles. Interpolation is performed on all the new vertices. This method assumes that the data points near the point in question contribute more than distant points (Watson and Philip 1985). The summation of the volumes of all triangles (integration) under the contoured surface approximates the total volume, here the relative abundance estimate for the area covered by the survey. These estimates are presented in table 10a for ages 3 to 6. The degree of interpolation will affect the volume estimates. For the Georges Bank survey data, the estimates stabilize using 16 or more subtriangles when they vary less than 5%.

Biomass indices (Table 10b) from areal expansion of numbers of scallops per standard tow have been computed using weights at age for the middle of the third quarter (August) found in table 7. These estimates correspond to a minimum dredgeable biomass as they are not adjusted for the survey gear efficiency. Data prior to the establishment of the ICJ line, from 1981 to 1985 inclusive, have been recomputed (Tables 8 and 10) to provide density and biomass estimates for the Canadian side of Georges Bank only.

Stock analysis

In the first year of recruitment the animals experience approximately a 300% increase in weight. To reduce the magnitude of the errors caused by ignoring growth effects, the cohort analysis was carried out on a quarterly basis. This required that catch-at-age, effort distribution, and partial recruitment be determined on a quarterly basis. This was done by adjusting recent year's selectivity pattern to reflect the port sampling data for the last quarter of 1996. This pattern, multiplied by the F determined from tuning for the last quarter year (F_{Q4} 1996), was used as a starting vector for the quarterly cohort analysis.

A natural mortality rate of 0.025 per quarter or 0.1 per year is used in the analytical assessment. No variation is provided for seasonal, age, or time dependent effects. Estimates of natural mortality rate for Georges Bank scallops were reviewed in Robert et al (MS 1994). Basically, it would appear that M levels off at 0.1 for recruited age groups of the deep sea scallop and rises slowly beyond age 10. Considering that very few scallops of the Georges Bank stock reach old age, it is not felt necessary to vary M for recruited ages.

The SPA is tuned against a number of independent, and sometimes contradictory, sets of observations. The most important are the commercial CPUE and research survey estimates. F versus effort is sometimes used in the tuning process but of lesser importance.Tuning selectivity is more difficult in scallop data than for most fisheries. This is because the SPA is done on a quarterly basis and the F's on the most recent year affect only the last quarter. Thus one cannot 'dial up' in an iterative fashion the exact numbers of F's one might want for the most recent year as can be done with annually collated data. F on the oldest animals was found by multiplying the effort pattern by the mean terminal F from the older ages. Because the selectivity is highly domed toward ages 4 and 5, these values are not critical and the normal iterative determination was not undertaken. (At the 1989 CAFSAC retrospective analysis workshop it was shown that iteratively estimating the terminal F from younger ages diverged rather than converged.) Peculiarities of some technical aspects such as the dome-shaped selectivity vector, using disaggregated ages versus aggregates, and a non-zero intercept in tuning plots were examined at the RAP session, spring 1996 (Robert and Butler MS 1996). In addition to tuning for cohort biomass over the complete range of ages 3 to 8, iterations were carried out on cohort biomass for certain age groups. Nowadays, indices of abundance in the research surveys best represent ages 3 to 7; indices for ages 3 - 7 were used to calibrate a cohort biomass for these ages. Over the last few years the contribution of age 3 scallops toward achieving good catch-rates has been small. It was found that relating CPUE to a cohort biomass ages 4+ had higher multiple correlation coefficient than relating CPUE to a cohort biomass including all ages (Table 11 and Fig. 6). Fishable biomass was also tuned against CPUE. A better fit is usually achieved when tuning fishable biomass for ages 4+.

Best performers for tuning gave high multiple correlation coefficients and residual values for 1995 and 1996 closest to the regression line (Table 11). Tuning iterations estimated a quarterly rate for terminal F in a narrow range (0.03-0.06). A few more F values and estimated variables are presented in table 11 to give a better perspective. The positive residual values in table 11 denote that the residual points are below the regression line and the negative ones, above. It should be noted that the annual CPUE values are compared to the second quarter biomasses. Q2 corresponds to the quarter where the largest catches are encountered, from 40 to 50% of the total annual catch. The research survey biomass estimates are derived from the average weights at the third quarter. These are compared to third quarter biomasses from the cohort analysis.

Regression of cohort biomass ages 4+ on CPUE: CPUE is expressed under kg/h, CPUEH and kg/crhm, CPUEC. CPUEH: the maximum multiple correlation coefficient, 0.838, for the regression of cohort biomass ages 4+ on CPUE corresponded to an F_{Q4} of 0.05. That terminal F provides for the 1996 residual point to be very close to the regression line. However, an F_{Q4} of 0.06 puts the 1995 residual closer to the regression line with little change in the correlation coefficient (0.810). CPUEC: Although the maximum multiple correlation coefficient at an F_{Q4} of 0.06 is lower, 0.743 versus 0.838, both the 1995 and 1996 residual points are very close to the regression line.

Cohort ages 3 - 7 on research biomass ages 3 - 7: A maximum multiple correlation coefficient of 0.724 occurs at F_{Q4} equal to 0.06. Residual points for 1995 and 1996 are almost on the regression line with the terminal F equal to 0.06 (Fig. 6). Ages 3 to 7 have been consistently represented in the survey data for the last decade. The selected ages offer a better match to corresponding ages in the stock biomass compared to matching the stock biomass for all ages to the ages observed in the research data.

Fishing effort on F: The relationship is not as cohesive as the previous 3 based on CPUE and/or research data. The maximum correlation of 0.841 occurs at a terminal F equal to 0.02. However, the residual points do not cross the regression line. Trials have been carried out for F values beyond the range of F's found in table 11. The lowest values for the last 2 years' residual points correspond to a terminal F of 0.03.

Strong correlations of cohort biomass on CPUE derived 2 ways and cohort biomass on research survey biomass estimates for specific age groups occurred at an F_{Q4} of 0.06. Between 70 and 80% of the variability could be explained when the cohort biomass was tuned against CPUE and 72% for the cohort biomass against survey estimates. In the first case the 1996 residual point is closer to the line at a slightly lower terminal F of 0.05. But differences in coefficient values and distance from the line to the last 2 years residual points are small between terminal F's of 0.05 and 0.06 (Fig. 6). In the second and third case, a terminal F at 0.06 gets the last 2 years residual points closest to the line. The regression of fishing effort versus F differs from the previous 3. Nearly 85% of the variability could be related at a very low F but residual points vary little. Fishing effort has never been a consistently reliable tuning indicator using offshore scallop data.

A sequential population analysis using Non Linear Least Square Regression (NLLS) (ADAPT, Gavaris 1988) was also carried out. Data used are identical to data used in the linear regressions. Residuals were log transformed. The independent estimates selected to carry out NLLS were annual and quarterly values of CPUE and research surveys indices. At times NLLS would not find a solution to minimise residual(s), especially when estimating multiples parameters (F for different ages for example). A Partitioned Search was then used. NLLS would be computed for value(s) incremented over small intervals within a preset narrow range of values for the parameters to be estimated. A presentation of NLLS on offshore scallop data may be found in Robert et al (MS 1994). Retrospective analysis of the recent years' estimation of F and biomass was also carried out.

The ADAPT model estimated F at age 4 for the last quarter of 1996 calibrating with CPUE data as in the first tuning procedure. Ages included in the tuning are from 4 to 7. All other variables are identical to the first tuning. The statistical diagnostics are as follows:

relative change in phi parameter = < 0.01
mean square of the residual = 0.0274
F_4 = 0.060 s.e. = 0.009 CV = 0.157

A partitioned search established the minimum residual equal to 0.419 (Fig. 7). The residuals for age 4 follow:

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994.	1995	1996
age 4	0.1	0.1	-0.0	-0.2	-0.3	0.3	0.2	-0.2	-0.1	0.0	0.1	-0.0	0.0	0.1	-0.2	0.1

A Thompson-Bell type yield per recruit analysis with quarterly time steps is used to take into account the dynamic growth of the younger age groups of scallops. However, this method does not include the effects of blending. A change in fishing strategy to adapt to the 33 meat count regulation required a re-calculation of the yield per recruit in the 1988 stock evaluation (Mohn et al MS 1989) and redefinition of the partial recruitment pattern. Subsequently, the yield per recruit was examined for change in partial recruitment. A difference of 10% (or less) between old and new yield per recruit determination did not warrant any changes being made to the model for a few years. Improvements in the fishery in 1991 - 1992 required a re-evaluation as older age groups (>age 7) became more represented in the catch (Table 4). The implementation of the monitoring of meats under 10 g in the catch resulted in the near-absence of age 3 scallops in the catch starting during the 1995 fishery. The impact of the monitoring program was stronger on the 1996 fishery. It affected the partial recruitment vector to an extent larger than 10%. Hence, the yield per recruit was re-evaluated.

The regulations in effect on the offshore fleet are that the catch should average no more than 33 meats per 500 g which corresponds to an average weight of 15 g per meat. Placing a limitation on the average instead of stipulating a minimum means that the fishermen may take small animals and then balance them with larger ones. Such a practice, called blending, renders the use of most yield models and stock projections inappropriate. If there are not enough larger animals to blend in, then the mortality on the small ones will have to be reduced. Thus, the partial recruitment is a function of abundance-at-age. In order to take this practice into account, a stock projection program was written (Mohn et al. MS 1984) in which the mortality on the animals beneath the stipulated average meat weight is adjusted until the mean weight of the catch is within 1% of the required average. The only other way in which this programme differs from the normal stock projection is that the variables are updated quarterly. The annual growth is divided into quarterly components of 10, 35, 35, and 20% and annual effort is partitioned into quarters by the rates of 15, 50, 23, and 12%, which reflects the 1996 and the 1997 winter fishery. Although the first half of the year has traditionally experienced 50% or more of the annual effort, the effort in the first quarter used to be in the order of 10%. In recent years the effort figure for the first quarter had been twice to three times the historical value. 1995 is the first year to return to historical levels. With the implementation of EA's in 1986, the annual distribution of effort has shifted markedly not only toward the beginning of the year but also in-between quarters. Companies are aligning fishing plans more closely to particular market demands. Lately, the important changes in recruiting year classes modified the partitioning of fishing activities within the year. Selectivity for the stock projections follows the pattern of the fishery as revealed from the cohort analysis rather than that of the gear (Caddy 1972). Starting numbers-at-age for the projections are derived by projecting ahead the fourth quarter cohort estimates of the present year to January of the next year. Recruitment is estimated according to the relative densities of prerecruits observed in the stock survey.

Catch projections and fishing scenarios under the current meat count were carried out for different rates of F including $F_{0.1}$ and F_{max}, to present TAC options and their respective implications on the stock biomass.

RESULTS

Research surveys

Sampling locations of the 1996 research survey are plotted in Figure 5. Station locations are indicated in the plot for age 6. Table 8 presents survey results in terms of the abundance of scallops on an age basis per standard tow. Densities of the older age group, ages 6+ (1988 and older year classes), remain relatively stable. The very low and low strata had over 2 scallops per tow age 8+ (Table 9). There was one main aggregation of age 7 scallops with densities of 5+ animals per tow on the southeast side of the Bank. Abundance of age 5 scallops, the 1991 year class which has been established previously as a weak class, is likely overestimated in table 8. Smearing of year classes with the fastest growers of the 1992 year class could be taking place. The abundance of age 4 scallops is over 150 animals per tow except for the very low stratum. Average density estimates for the whole area surveyed are not as substantial. However, there is an area of 800 km^2 on the Northern Edge with more than 100 scallops per tow (Fig. 5). Abundance of recruited age groups on the South side of the Bank is still at very low levels.

Abundance of prerecruits continues to show some improvement in 1996. The abundance of the 1993 year class (age 3) is underestimated in table 8. The year class settled in good densities but mainly on the northeast Peak at depths greater than 90 m (Fig. 5). Investigations on juvenile scallop growth (Thouzeau and Robert unpubl.) determined that differences existed in growth patterns according to depth in this area. Shell height distribution for the 1995 and 1996 surveys have been plotted as composite pictures in figure 8a. The mode of the 1993 year class in 1995 peaks around 35 mm. This mode cannot be followed in the histogram for 1996. Survey estimates were stratified a posteriori according to depth where 124 stations were shallower than 90 m and 26 stations deeper than 90 m. While the density of age 3's was 49 scallops per tow in shallow waters, it was 82 scallops in deep waters. The mode of the 1993 year class is easily picked out from the histogram for depths below 90 m (Fig. 8b). Age 2 prerecruits (1994 year class) have also been observed during the last survey (Fig. 8a). Even if the gear is lined, age 2 scallops are not reliably caught by the survey gear. Therefore, these results only show trends and rough estimates of abundance. The medium, high, and very high strata have excellent densities of age 2's (Table 9). The 1994 year class settled on the northern Edge near the ICJ line but also on the south side of the Bank. This region is slowly being resettled by the 1994 and 1993 year classes according to survey observations.

The relative indices of biomass for the main age groups (Tables 10) are showing a reversal of the delining trend experienced after 1993. The biomass index for ages 3 - 6 derived by area expansion increased 60% from 1995 to 1996. The age 4 young recruits are mainly responsible for the biomass increase.

Survey results for the U.S. side of Georges Bank indicate that the 1996 indices of relative abundance and biomass increased substantially from the 1995 values. The increase resulted primarily from the 1992 year class which, according to size frequency distribution, would be above average. The index for prerecruits (<70mm shell height) in 1996 decreased 18% from 1995. However, large scallops (33 count or 15 g meats) continue to be well represented in the recruited biomass (Lai and Hendrickson, MS 1996).

Cohort analysis

The virtual population results are given in terms of numbers-at-age, biomass-at-age, and F-at-age (Tables 12 to 14); they have been combined into annual values from quarterly analysis for the terminal F_{Q4} level of 0.06. Numbers-at-age for the early 1990's have seen the passage of 2 good year classes in the stock with over 500 million scallops at age 3 each (Table 12 and Fig. 9) to be followed by the2 poorest year classes since 1981. Recruitment has improved since then with age 3's in 1995 very close to the median value for the the population. Numbers at age 3 in the research surveys coincide well with the strength of these same year classes in the population estimates. Total numbers for the population estimate are also up after the 1994 and 1995 estimates which had been among the lowest recorded since 1981 (Table 12). At present, abundance is concentrated (60%) in young recruits (ages 3 and 4). Total biomass estimates (Table 13, Fig. 10) have been increasing after hitting bottom in 1995. Biomass for the age group 4 to 7 has also improved significantly due to the over 30% contribution of age 4's. Annual fishing mortality rates are presented in table 14. Mean F on all ages has varied little since 1988 and is much lower than before the implementation of EA's (pre-1986) (Fig. 10 bottom). Both overall F and F on the age group 4 -7 had experienced an important reduction from 1994 to 1995. There has been a slight increase from 1995 to 1996. The fishing mortality at age 3 (F3) had peaked in 1981 when the meat count regulation had been relaxed and the strong 1978 year class was recruiting to the fishery. It has become minimal with the meat count reduction to 33 per 500 g in 1986. It dropped from 0.06 in 1994 to 0.01 in 1995 and 1996. Fishing mortality at age 3 has been reduced to almost nil with the monitoring of small meats in the catch.

Retrospective analysis

A retrospective analysis of the biomass and average fishing mortality rate for the directed age group 4 to 7 was carried out on the last 5 year's data. Table 15 details the biomass and fishing mortality rate estimates adding one set of data per year for the last 5 years. Looking down each column shows the generally small fluctuations but no apparent trends of persistent under or over estimation of the 2 variables. No constraint was put on the terminal population to initiate the stock projection given the lack of pattern shown in the retrospective analysis.

Stock projections

The quarterly based yield per recruit analysis uses mid-quarter meat weights and the quarterly expanded selectivity derived from the cohort analysis (See Mohn et al. MS 1987). The

1992 stock assessment led to estimates of 1.10 for F_{max} and 0.70 for $F_{0.1}$. The yield per recruit model is re-evaluated with each new year of data. A change of 10% or less in the values for F_{max} and $F_{0.1}$ is the criteria used to justify modification of the estimates for F_{max} and $F_{0.1}$. It was updated with the 1996 assessment. F_{max} was estimated at 0.89 and $F_{0.1}$ at 0. 54. The same selectivity was used in the cohort analysis, yield per recruit, and the catch projections. The projections are carried out at $F_{0.1}$, F_{max} and other selected F values using the numbers-at-age of the last quarter from the 1996 cohort analysis aged forward to the first quarter of 1997. The projections for a one year period assume a recruitment level of 400 million scallops to reflect the improvement in recruitment with the 1992-1994 year classes. It is conservative, being below the long term median of about 420 million (Fig. 9). The partial recruitment vector used : 0.05, 0.62, 1.00, 0.39, 0.24, 0.18 for ages 3-8. Age 5 selectivity acts as the inflexion point for the selectivity curve; the slope changes on each side of age 5.

Given the rising profile of CPUE's in 1996 compared to 1995, light fishing activities in the last quarter (1996) and the abundance patterns for the main age group found in survey results, catch projections were carried out for 1997 with a terminal F_{Q4} at 0.06. The quarterly catch pattern for 1997 was set with a decreased level of activity during the winter fishery to reflect the shift of the effort toward historical levels during the first quarter. Biomass projections are generally improving from last year given the presence of the seemingly important 1992 year class. Detailed scenarios for $F_{0.1}$ and F_{max} are found in table 16 with additional scenarios in table 17. A fishing scenario with a 1997 catch equal to the TAC for 1996 (3,000 t) gives a directed biomass estimate (ages 4-7) of 11,850 t at the end of 1997. Fishing at $F_{0.1}$, (3,700 t) in 1997 produces a directed biomass highly similar to the first scenario. A F of 0.8 for the year produces a catch figure of 5,000 t while the directed biomass falls under 10,000 t at the end of 1997. A scenario keeping the effort at the 1996 level (5,350 t) provides a slightly lower directed biomass estimate. The last 2 options, F_{max} and $F_{replacement\ yield}$ correspond to F values similar to the last option except that the directed biomass decreases again. The biomass figure for ages 4 to 7 is more important since these particular ages are directed for by the fishery. The directed biomass is a sizable component, 65 to 68%, of the total biomass.The total biomass ranges from 17,425 to 14,614 t. Under the present stock conditions, exploitation rates on the directed age group is above 30% in 4 out of the 6 fishing scenarios presented. The long term average, over the last 10 years, was 39%.

CONCLUSIONS

Poor fishery performance on Georges Bank in the early 1980's resulted from very high fishing mortality rates on weak year classes at a size yielding small meats. The 1978 year class was exploited intensively at age 3 in a competitive fishery with no size limit in 1981. Despite its above average strength it disappeared rapidly from the population. Very low recruitment in 1982 and 1983 made for a slow recovery for the stock and ultimately the fishery. It took until 1986 for the biomass to rebuild to levels high enough to provide the fishery with moderate (0.5 kg/crhm) catch-rates again.

The fishery bottomed out in 1995 with less than 2,000 t landed. Very low recruitment from 2 successive year classes (1990 and 1991 year classes) contributed largely to the downside. However, management of the fishery has changed drastically from the early 1980's (limited catch, meat count and minimum size). With improving recruitment and a limited harvest, the 1996 catches would indicate that improvements will be earlier this time.

Catch levels in 1996 were up 50% from 1995. The fishery was highly dependent on the incoming 1992 year class though. Most of the effort was expanded on the Northern Edge; it was minimal on the Southeast side. Catch-rates rose sharply in 1996; however, areas with high catch-rates have been reduced to less than 100 km^2. The average meat weight in the catch has decreased from 1995 to 1996. The weakness of the 1991 year class has resulted in the fishery directing for the 1992 year class earlier. The monitoring program for small meats in the catch showed only 2% by number were meats under 10 g for the year. Research survey work has established that the strength of year classes replacing the 1990 and 1991 year classes is improving, especially on the Northern Edge. Abundance of recruited age groups is still at very low levels on the Southeast side of the Bank. Stock biomass has also increased 25% over 1995.

The stock indicators would suggest to proceed with caution. The fishery usually directs for age 5 scallops. The 1991 year class should have been the mainstay of the fishery in 1996. This weak year class and the 1992 year class, at age 4 brought important contributions to the 1996 fishery. Their input as percentages by numbers in the catch were 25 and 60 respectively. The 1992 year class has been established so far as average or slightly better than average. The 1997 fishery will rely on the 1992 year class at age 5 as its main constituent. Age 4 young recruits from the 1993 year class would provide more yield if fished mainly in 1998.

To avoid a reversal to a fishery highly dependent on the incoming recruiting year class, fishing scenarios considered for 1997 should be conservative.

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Table 1.- Estimated (pre-1985) catches (t of meats) from Georges Bank, NAFO subarea 5Zc. Since October 1984 the ICJ line separates fishing areas for both countries. TAC's are for the Canadian side only.

Year	U.S.A.	Canada	Total
1981	2000	7612	9612
1982	1054	3918	4972
1983	714	2418	3132
1984	889	1945	2834
1985	0	3812	3812
1986	0	4900	4900
1987	0	6793	6793
1988	0	4336	4336
1989	0	4676	4676
1990	0	5218	5218
1991	0	5805	5805
1992	0	6151	6151
1993	0	6183	6183
1994	0	5003	5003
1995	0	1984	1984
1996	0	2996	2996

Year	Recommended TAC	Set TAC	Catch
1986	---	4300	4900
1987	6500	6850	6793
1988	4800	5400	4336
1989	4700	4700	4676
1990	4800	5200	5218
1991	5200	5800	5805
1992	5800	6200	6151
1993	6200	6200	6183
1994	5000	5000	5003
1995	2000	2000	1984
1996	3000	3000	2996

Table 2.- Catch and effort data. Canadian catches (tons of meats) in NAFO subarea 5Zc. Canadian total effort is derived from effort from Class 1 data.

Year	Catch	Effort		CPUE	
	tons	hours 10^3	crhm* 10^3	kg/h*	kg/crhm
1981	7612	100	14484	76.12	0.526
1982	3918	73	9977	53.67	0.393
1983	2418	67	8690	36.09	0.278
1984	1945	70	8598	27.79	0.226
1985	3812	105	12644	36.31	0.301
1986	4900	52	6957	94.23	0.704
1987	6793	78	10808	87.09	0.629
1988	4336	85	11283	51.01	0.385
1989	4676	78	10774	59.96	0.434
1990	5218	72	10570	72.09	0.494
1991	5805	66	9687	88.40	0.599
1992	6151	73	10957	84.10	0.561
1993	6183	64	9874	96.76	0.627
1994	5003	64	9566	78.12	0.523
1995	1984	39	5687	50.94	0.349
1996	2996	31	4855	95.37	0.617

* crew-hour-meter; hour

Table 3.- Port sampling data. Monthly profile of the catch from NAFO Subarea 5Zc from the frequency distribution of scallop meat weights for selected years from port sampling data.

	% catch examined / catch landed	meat weight (g)				n meats
		mean	min	max	s.e.	
1981	0.013					
January		—	—	—	—	0
February		8.96	3.26	53.21	0.06	1386
March		11.00	2.58	65.10	0.05	3673
April		10.19	4.70	54.38	0.08	402
May		11.56	3.37	76.60	0.02	19036
June		12.15	2.26	79.87	0.02	24514
July		11.44	2.55	73.25	0.02	16301
August		10.50	2.37	74.49	0.02	15204
September		9.90	2.23	59.09	0.03	4321
October		7.28	2.37	56.52	0.03	3165
November		8.13	2.10	54.47	0.03	4146
December		8.56	2.30	53.68	0.04	3004
1995	0.057					
January		17.90	5.87	56.44	0.13	568
February		19.67	5.31	55.26	0.13	771
March		19.10	4.62	51.96	0.05	4520
April		20.45	4.85	62.67	0.06	3998
May		21.80	3.78	75.02	0.04	8839
June		23.10	5.59	77.86	0.05	7078
July		21.66	3.81	70.47	0.04	7920
August		21.43	6.57	72.68	0.06	4470
September		18.01	5.53	65.20	0.05	3895
October		18.02	2.59	61.42	0.03	8403
November		16.83	5.14	52.49	0.04	4504
December		18.02	7.58	50.35	0.11	563
1996	0.041					
January		14.90	7.92	39.00	0.08	339
February		16.56	5.63	57.47	0.04	3962
March		16.30	5.74	58.81	0.03	8384
April		16.11	6.29	59.75	0.02	10976
May		17.65	5.52	65.27	0.02	9147
June		17.59	4.46	68.36	0.02	7579
July		16.90	6.54	68.40	0.02	8359
August		16.49	6.82	55.45	0.03	5818
September		16.79	6.46	66.24	0.02	7362
October		16.81	6.30	53.13	0.03	6010
November		16.49	7.18	55.76	0.03	4307
December		16.11	8.82	61.54	0.06	630

Table 4.- Port sampling data. Frequencies of numbers of meats at weight in 2-g intervals (normalized to 1000) by quarter for recent years from port sampling data.

Grams	1993	Q1	Q2	Q3	Q4	1994	Q1	Q2	Q3	Q4
1		0	0	0	0		0	0	0	0
3		0	0	0	0		0	0	0	0
5		0	0	0	0		1	5	4	5
7		3	4	6	13		9	29	32	30
9		26	29	37	61		52	71	69	79
11		104	110	108	137		123	104	98	102
13		215	206	166	170		156	131	102	98
15		231	217	167	159		143	124	101	94
17		174	146	150	130		124	112	95	85
19		100	89	119	104		97	90	89	100
21		54	62	80	76		74	79	85	87
23		30	42	56	52		57	61	70	73
25		21	32	39	36		43	49	57	62
27		13	22	26	23		35	34	45	50
29		8	13	16	14		25	29	40	37
31		9	11	11	9		21	22	30	26
33		4	6	7	6		15	16	21	23
35		3	4	5	3		9	13	18	15
37		1	3	3	3		7	10	13	11
39		1	2	2	1		4	8	9	7
41		1	1	1	1		3	5	7	5
43		1	1	0	0		1	4	7	3
45		1	0	0	0		1	2	3	3
47		0	0	0	0		1	2	2	1
49		0	0	0	0		1	1	2	1

Grams	1995	Q1	Q2	Q3	Q4	1996	Q1	Q2	Q3	Q4
1		0	0	0	0		0	0	0	0
3		0	0	0	0		0	0	0	0
5		4	1	0	0		0	0	0	0
7		37	10	5	8		3	0	1	3
9		92	50	46	56		29	7	19	36
11		107	116	117	159		143	54	92	134
13		111	126	158	185		270	183	215	224
15		104	96	122	143		228	273	232	197
17		77	74	88	101		120	217	165	123
19		69	62	67	72		54	115	94	83
21		64	55	62	53		26	50	54	54
23		62	52	46	44		17	26	39	39
25		58	48	39	37		15	17	25	27
27		47	43	33	30		16	12	19	19
29		43	38	32	28		14	9	12	14
31		38	37	30	23		15	7	9	9
33		30	33	28	16		11	7	7	9
35		20	28	23	13		10	5	5	8
37		14	26	20	11		10	4	3	5
39		9	24	18	6		7	4	3	4
41		7	18	14	5		5	3	2	3
43		4	18	13	3		3	2	2	2
45		4	13	10	4		2	2	1	1
47		1	9	8	2		1	1	0	1
49		1	7	6	1		0	1	1	1

Table 5.- Port sampling data. Frequencies of numbers of meats at weight in 2-g intervals (normalized to 1000) by year from port sampling data.

	Year									
Grams	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
5	2	3	1	2	1	0	0	3	1	0
7	17	28	14	24	12	7	6	23	11	2
9	79	98	83	96	64	47	36	65	55	19
11	150	163	179	164	141	135	113	109	126	93
13	175	179	219	177	174	196	190	126	148	214
15	168	152	182	146	162	184	196	119	116	242
17	129	104	117	113	126	135	150	107	85	171
19	89	75	72	80	93	89	102	94	67	93
21	59	54	43	62	65	56	68	81	58	47
23	44	36	30	43	44	41	45	64	49	30
25	29	27	18	30	30	28	32	51	44	21
27	18	22	14	19	21	22	22	40	37	16
29	12	16	7	13	18	17	13	32	34	12
31	9	11	6	9	11	12	10	24	32	10
33	6	9	4	6	9	8	6	18	27	8
35	4	6	4	5	6	6	4	13	22	6
37	3	5	2	3	6	4	2	10	19	5
39	2	4	2	2	4	4	2	7	16	4
41	1	3	1	2	4	2	1	5	13	3
43	1	2	1	1	2	2	1	4	12	2
45	0	1	1	1	3	1	0	2	9	1
47	0	1	0	0	1	1	0	1	6	1
49	1	1	0	0	1	1	0	1	5	1
51	0	1	0	0	1	0	0	1	3	0
53	0	0	0	0	1	0	0	0	2	0
55	0	0	0	0	1	1	0	0	1	0
57	0	0	0	0	0	0	0	0	1	0
59	0	0	0	0	0	0	0	0	1	0
61	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0

Table 6.- Catch-at-age in numbers (10^6) east of the ICJ line.

Ages	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	289	45	33	65	65	2	21	21	16
4	492	170	90	68	144	185	186	119	159
5	75	93	65	33	37	108	188	96	103
6	16	13	14	20	11	10	16	22	19
7	8	6	3	8	10	3	3	5	9
8+	13	10	9	6	7	3	6	5	3
Total	894	338	215	202	275	311	420	268	308

Ages	1990	1991	1992	1993	1994	1995	1996
3	11	13	15	5	8	5	3
4	173	150	175	176	64	33	106
5	124	140	131	158	158	23	44
6	13	20	27	19	20	20	8
7	8	6	8	8	8	5	11
8+	6	16	11	8	15	10	6
Total	335	345	367	374	273	96	178

Table 7.- Shell height (mm), meat weight (g) and meat count per 500 grams at age, biological and cohort. Height and weight as of first day of quarter.

Biological age	Cohort age	Shell height	Meat weight	Count /500g
2.25	3.00	61.23	3.11	161
2.50	3.25	63.22	3.44	145
2.75	3.50	74.57	5.73	87
3.00	3.75	83.13	8.03	62
3.25	4.00	87.30	9.34	54
3.50	4.25	89.23	10.00	50
3.75	4.50	96.26	12.64	40
4.00	4.75	102.35	15.29	33
4.25	5.00	105.51	16.80	30
4.50	5.25	107.02	17.55	28
4.75	5.50	111.60	19.99	25
5.00	5.75	115.81	22.42	22
5.25	6.00	118.08	23.81	21
5.50	6.25	119.18	24.50	20
5.75	6.50	122.23	26.49	19
6.00	6.75	125.13	28.49	18
6.25	7.00	126.72	29.63	17
6.50	7.25	127.50	30.20	17
6.75	7.50	129.55	31.73	16
7.00	7.75	131.54	33.26	15
7.25	8.00	132.65	34.13	15
7.50	8.25	133.19	34.57	14
7.75	8.50	134.58	35.69	14
8.00	8.75	135.94	36.82	14
8.25	9.00	136.70	37.47	13
8.50	9.25	137.08	37.79	13
8.75	9.50	138.03	38.60	13
9.00	9.75	138.96	39.41	13
9.25	10.00	139.48	39.88	13
9.50	10.25	139.74	40.11	12
9.75	10.50	140.39	40.68	12
10.00	10.75	141.02	41.26	12
10.25	11.00	141.38	41.58	12
10.50	11.25	141.56	41.75	12
10.75	11.50	142.00	42.15	12
11.00	11.75	142.44	42.55	12

Table 8.- Total weighted average (by stratum) number of scallops at age per tow.

Sampling dates	Age (years)						
	2	3	4	5	6	7	8+
1981	177	191	24	5	2	1	0
1982	26	49	23	6	1	0	0
1983	44	31	18	5	1	1	0
1984	271	35	14	3	1	0	0
1985	104	206	18	2	0	0	0
1986	198	136	145	12	1	0	0
1987	94	98	63	17	5	2	0
1988	98	110	52	10	2	1	0
1989	117	131	71	13	2	1	0
1990	105	89	39	15	4	1	0
1991	359	103	49	13	3	1	0
1992	83	195	108	23	6	2	0
1993	10	42	46	24	7	2	0
1994*	90	24	24	14	5	2	1
1995	159	97	27	10	6	2	1
1996	95	60	93	22	5	3	2

* new survey series

Table 9.- Stratified average number of scallops at age per tow and stratified total number of scallops per tow, N. A new survey series starts in 1994.

Stratum	Sampling dates	Age (years)							N	s.e.
		2	3	4	5	6	7	8+		
Very low	1993	4	197	90	18	8	2	0	321	174
	1994*	49	6	21	23	7	3	1	114	53
	1995	93	15	14	11	5	2	1	141	37
	1996	30.6	21.9	28.2	12.8	5.2	3.3	2.7	104.6	23.9
Low	1993	3	26	30	14	6	2	1	83	22
	1994*	111	5	5	11	7	2	1	143	111
	1995	155	48	17	9	7	3	1	240	111
	1996	28.9	81.9	153.6	41.6	6.4	2.5	2.4	317.4	112.9
Medium	1993	7	59	38	21	1	4	1	144	40
	1994*	25	6	10	14	6	2	1	65	15
	1995	287	179	40	9	5	2	1	522	196
	1996	291.3	141.2	189.1	31.7	4.5	1.7	0.9	660.4	343.0
High	1993	11	23	36	20	7	2	1	101	14
	1994*	82	19	24	13	5	2	1	148	33
	1995	404	384	80	7	5	2	1	883	255
	1996	154.9	88.8	159.9	18.9	4.2	1.9	1.3	429.9	284.2
Very high	1993	11	29	48	28	6	1	0	124	8
	1994*	132	43	35	16	5	1	0	234	40
	1995	66	408	80	5	3	1	0	564	165
	1996	351.4	143.1	209.4	30.8	2.1	0.8	0.5	737.9	326.8

* new survey series

Table 10a.- Indices of abundance of scallop age-classes by volume estimates: numbers-at-age (10^6), minimum dredgeable biomass at survey time (t of meats).

Sampling dates	Age (years)				
	3	4	5	6	Biomass
1981	279.47	53.60	9.34	3.48	2965
1982	121.76	56.95	15.47	3.43	2056
1983	99.32	50.76	14.31	5.28	1841
1984	85.74	30.32	8.08	2.21	1245
1985	557.64	45.29	5.88	1.26	4628
1986	309.16	225.53	26.46	3.81	5942
1987	214.58	145.50	41.78	11.27	4704
1988	238.53	105.06	23.45	5.05	3744
1989	266.38	161.01	31.79	5.24	4899
1990	188.70	72.16	31.18	8.72	3207
1991	158.67	89.56	29.10	7.79	3174
1992	347.56	188.88	40.19	11.89	6209
1993	94.79	72.29	37.79	12.77	2814
1994*	32.87	34.86	23.69	10.80	1512
1995	250.86	63.09	21.21	13.03	3415
1996	112.87	158.56	40.71	9.71	4122

* new survey series

Table 10b.- Minimum dredgeable biomass at age (t of meats) using aerial expansion as per number of scallops per standard tow. Weights at age for the middle of the third quarter (August) are used.

Sampling dates	Age (years)				
	3	4	5	6	Total biomass
1981	3,435.56	876.56	277.26	143.74	4,733.12
1982	881.37	840.04	332.71	71.87	2,126.00
1983	557.60	657.42	277.26	71.87	1,564.15
1984	629.55	511.33	166.36	71.87	1,379.11
1985	3,705.36	657.42	110.90	35.94	4,509.63
1986	2,446.25	5,295.89	665.36	71.75	8,479.25
1987	1,762.72	2,301.00	942.78	359.29	5,365.79
1988	1,978.62	1,899.22	554.43	143.77	4,576.04
1989	2,356.33	2,593.11	720.93	143.77	5,814.14
1990	1,600.84	1,424.38	831.86	287.55	4,144.63
1991	1,852.68	1,789.70	720.93	215.52	4,578.83
1992	3,507.50	3,944.53	1,275.39	431.22	9,158.65
1993	755.46	1,680.08	1,330.84	503.09	4,269.47
1994*	431.69	876.56	776.33	359.35	2,443.93
1995	1,744.76	986.13	554.52	431.22	3,716.63
1996	1,079.23	3,396.68	1,219.94	359.35	6,055.20

* new survey series

Table 11. - Tuning criteria for the regressions of cohort biomass ages 4+ on CPUE in kg/hour (CPUEH), cohort biomass ages 3-7 on research survey biomass estimates ages 3-7, of fishing effort on F, and cohort biomass ages 4+ on CPUE in kg/crhm (CPUEC) for selected F_{Q4}.

	Coh Biom ages 4+ vs CPUEH			Coh Biom ages 3-7 vs Res Biom ages 3-7		
F_{Q4}	R^2	1995*	1996*	R^2	1995*	1996*
0.02	0.381	-9399	-11987	0.168	-10084	-15633
0.03	0.576	-4554	-5464	0.331	-5137	-7742
0.04	0.756	-2132	-2203	0.531	-2663	-3797
0.05	0.838	-679	-246	0.680	-1179	-1429
0.06	0.810	290	1058	0.724	-190	149
0.07	0.726	982	1990	0.693	517	1276

	Fishing effort vs F			Coh Biom ages 4+ vs CPUEC		
F_{Q4}	R^2	1995*	1996*	R^2	1995*	1996*
0.02	0.841	-0.018	-0.011	0.264	-9406	-13448
0.03	0.836	-0.017	-0.011	0.439	-4666	-6434
0.04	0.815	-0.019	-0.016	0.621	-2296	-2926
0.05	0.780	-0.021	-0.022	0.731	-874	-822
0.06	0.734	-0.024	-0.030	0.743	74	581
0.07	0.680	-0.027	-0.039	0.694	752	1583

* Residual value with respect to regression line

Table 12.- Population numbers (at beginning of the first quarter) (10^6) east of the ICJ line from cohort analysis using a terminal F_{Q4} of 0.06.

Ages	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	652	232	209	447	623	449	341	439	487
4	672	309	167	158	342	501	404	288	377
5	112	145	118	66	78	172	278	187	146
6	33	30	43	46	28	35	54	75	79
7	25	15	15	26	22	15	22	34	47
8	68	63	53	45	32	29	33	36	49
Total	1563	794	605	787	1125	1201	1131	1059	1184

Ages	1990	1991	1992	1993	1994	1995	1996
3	425	504	597	163	142	425	344
4	425	374	444	525	142	121	379
5	190	221	196	234	308	68	78
6	36	55	69	54	64	131	40
7	54	20	32	37	30	39	99
8	74	86	77	68	72	54	66
Total	1204	1272	1413	1081	759	838	1007

Table 13.- Biomass Q2 (t of meats) east of the ICJ line from cohort analysis using a terminal F_{Q4} of 0.06.

Ages	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	2891	1038	900	1997	2787	2010	1527	1963	2176
4	6637	3224	1534	1697	3745	5494	4277	3099	3928
5	1854	2345	1852	1125	1401	3056	4094	3202	2145
6	768	707	1048	1068	689	853	1198	1775	1827
7	723	422	450	737	660	433	635	989	1337
8	2347	2311	2040	1696	1144	1027	1148	1281	1714
Biom 3+	15220	10048	7824	8321	10426	12874	12878	12310	13127
Biom 4+	12330	9010	6924	6324	7639	10864	11351	10347	10951

Ages	1990	1991	1992	1993	1994	1995	1996
3	1901	2255	2671	728	636	1898	1537
4	3988	3904	4643	5446	1437	1298	4042
5	2466	3240	2676	3069	4574	1154	1242
6	807	1263	1540	1205	1444	3176	959
7	1576	555	908	1054	848	1138	2945
8	2643	3453	2820	2489	2533	1961	2410
Biom 3+	13381	14670	15258	13991	11472	10626	13135
Biom 4+	11480	12415	12587	13263	10836	8727	11598

Table 14.- Annual fishing mortality east of the ICJ line from cohort analysis using a terminal F_{Q4} of 0.06.

Ages	1981	1982	1983	1984	1985	1986	1987	1988	1989
3	0.65	0.23	0.18	0.17	0.12	0.01	0.07	0.05	0.04
4	1.44	0.86	0.83	0.60	0.59	0.49	0.67	0.58	0.59
5	1.21	1.11	0.85	0.75	0.70	1.07	1.21	0.77	1.31
6	0.72	0.60	0.42	0.62	0.56	0.37	0.36	0.36	0.28
7	0.39	0.57	0.27	0.40	0.63	0.22	0.15	0.17	0.21
8	0.44	0.33	0.28	0.23	0.30	0.09	0.23	0.24	0.11
F ages 3+	0.81	0.62	0.47	0.46	0.48	0.37	0.45	0.36	0.42
F ages 4-7	0.94	0.79	0.59	0.60	0.62	0.54	0.60	0.47	0.60

Ages	1990	1991	1992	1993	1994	1995	1996
3	0.03	0.03	0.03	0.04	0.06	0.01	0.01
4	0.55	0.55	0.54	0.43	0.63	0.34	0.35
5	1.13	1.07	1.19	1.20	0.76	0.44	0.88
6	0.50	0.46	0.52	0.47	0.41	0.18	0.25
7	0.17	0.35	0.29	0.24	0.33	0.16	0.13
8	0.09	0.17	0.19	0.12	0.26	0.27	0.09
F ages 3+	0.41	0.44	0.46	0.42	0.41	0.23	0.28
F ages 4-7	0.59	0.61	0.64	0.59	0.53	0.28	0.40

Table 15.- Retrospective analysis of biomass (10^2 tons) for the first quarter of the year, ages 4 to 7 and annual fishing mortality rates for ages 4 to 7. The analysis was carried out for the last 5 years as per row label.

Biomass

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1992	9.5	6.2	4.6	3.8	5.2	8.2	9.5	7.9	8.8	9.0	9.2	10.2				
1993	9.5	6.2	4.6	3.8	5.1	7.9	9.0	7.3	8.0	8.3	8.2	8.7	7.9			
1994	9.5	6.2	4.6	3.8	5.2	7.9	9.2	7.7	8.9	9.9	9.8	10.8	11.9	9.3		
1995	9.5	6.2	4.6	3.8	5.2	7.9	9.0	7.3	8.3	9.1	9.4	10.1	11.1	8.5	6.0	
1996	9.5	6.2	4.6	3.8	5.2	7.9	9.0	7.2	8.2	8.9	9.2	10.2	11.5	9.1	6.6	8.8

Fishing mortality rate

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1992	1.07	0.95	0.73	0.75	0.84	0.79	0.78	0.55	0.64	0.65	0.64	0.64				
1993	1.07	0.95	0.73	0.75	0.85	0.83	0.86	0.65	0.73	0.77	0.81	0.90	0.97			
1994	1.07	0.95	0.73	0.75	0.84	0.83	0.86	0.59	0.61	0.56	0.56	0.59	0.55	0.50		
1995	1.07	0.95	0.73	0.75	0.84	0.83	0.87	0.65	0.67	0.63	0.60	0.65	0.61	0.58	0.30	
1996	1.07	0.95	0.73	0.75	0.84	0.83	0.87	0.65	0.71	0.67	0.64	0.64	0.59	0.54	0.28	0.41

Table 16 .-Stock projections at $F_{0.1}$ (0.54) and at F_{max} (0.89) using starting numbers from cohort analysis with a terminal F_{Q4} of 0.06.

F = 0.54	1997_{Q1}	1997_{Q2}	1997_{Q3}	1997_{Q4}
Mean Wgt. Catch	18.98	18.34	20.67	26.56
Catch (Mill.)	27.09	100.76	38.56	21.33
Catch (t)	514	1,847	797	567
Cum. Catch (t)	514	2,361	3,158	3,725
Biomass	15,233	15,163	15,567	16,588

F = 0.89	1997_{Q1}	1997_{Q2}	1997_{Q3}	1997_{Q4}
Mean Wgt. Catch	19.00	18.31	20.62	25.75
Catch (Mill.)	43.78	151.82	53.41	27.31
Catch (t)	832	2,780	1,101	703
Cum. Catch (t)	832	3,612	4,713	5,416
Biomass	14,895	13,762	13,757	14,663

Table 17.- Fishing scenarios established for 1997 given different options of fishing mortality rate. Biomass figures are for the end of 1997. Under the biomass for ages 4 to 7, the percentage that the target biomass represents from the total biomass is in parenthesis. Exploitation rate is for the directed age group. Catch figures are rounded off to the nearest 50 t.

No.	Options	Fvalues	Biomass (t)	Biomass 4 - 7	Exploitation rate	Catch (t)
1	$F_{1996\ TAC}$	0.41	17,425	11,849 (68%)	19%	3,000
2	$F_{0.1}$	0.54	16,588	11,280 (68%)	24%	3,700
3	F_{int}	0.80	15,117	9,977 (66%)	33%	5,000
4	$F_{1996\ effort}$	0.88	14,712	9,563 (65%)	36%	5,350
5	F_{max}	0.89	14,663	9,678 (66%)	36%	5,400
6	$F_{replacement\ yield}$	0.90	14,614	9,645 (66%)	36%	5,450

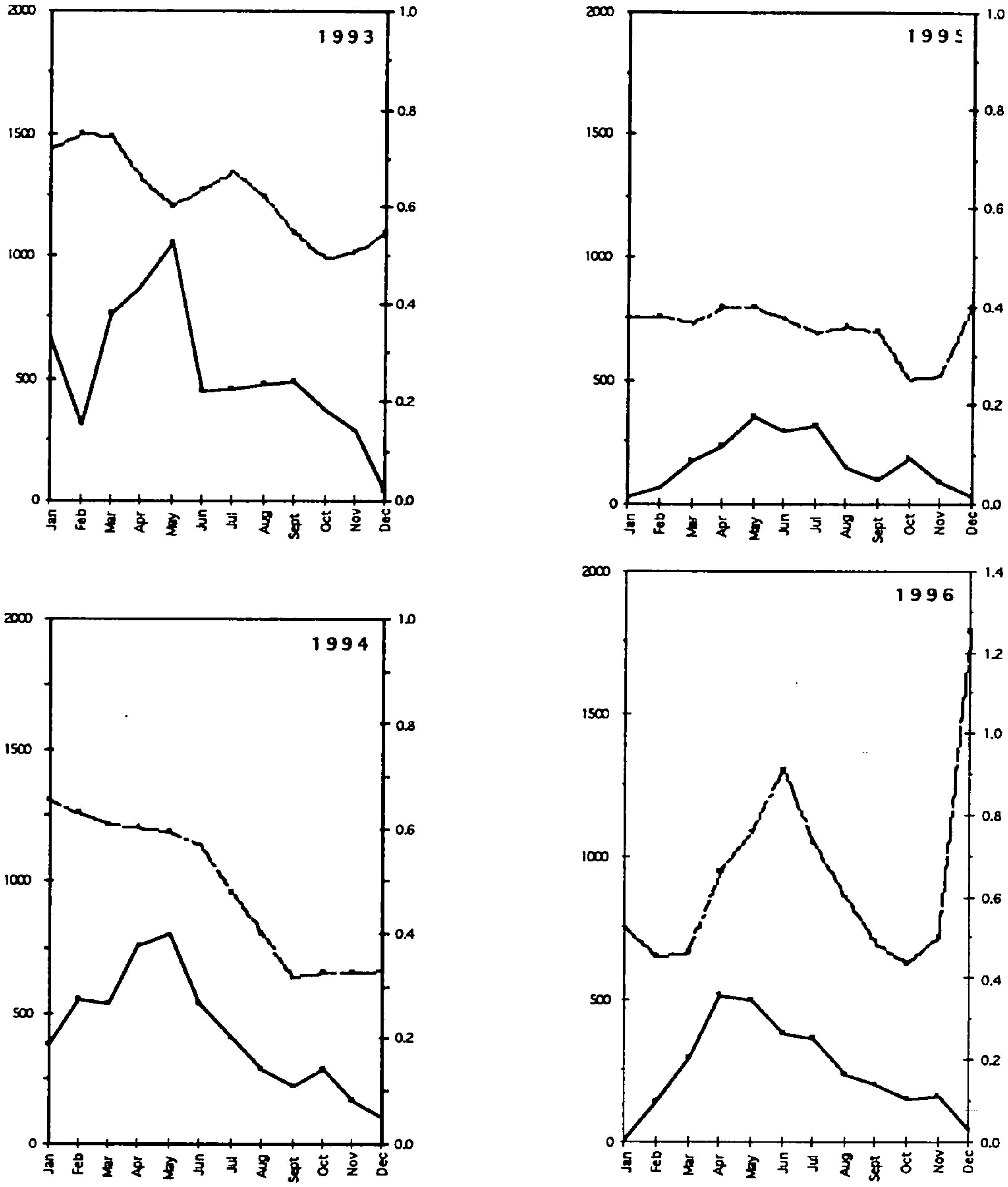


Figure 1.- Monthly CPUE in kg/crhm (dashed line, scale on the right) and catch in tons of meats (solid line, scale on the left) from Georges Bank over the last 4 years.

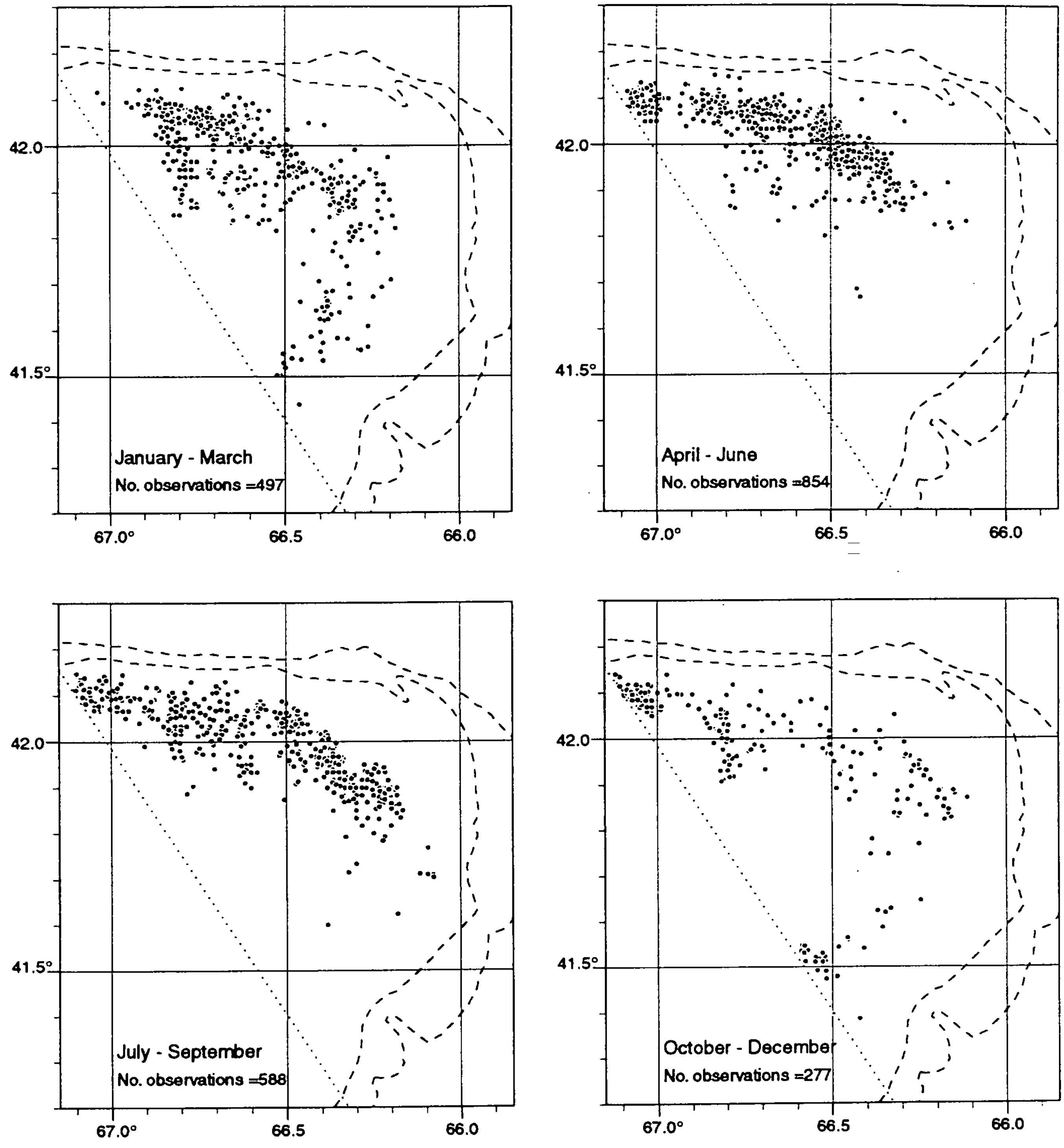


Figure 2.- Fishing locations on Georges Bank in 1996 by quarter of the year. Dots represent fishing locations visited at least once. Total number of days fished per quarter is shown on each map.

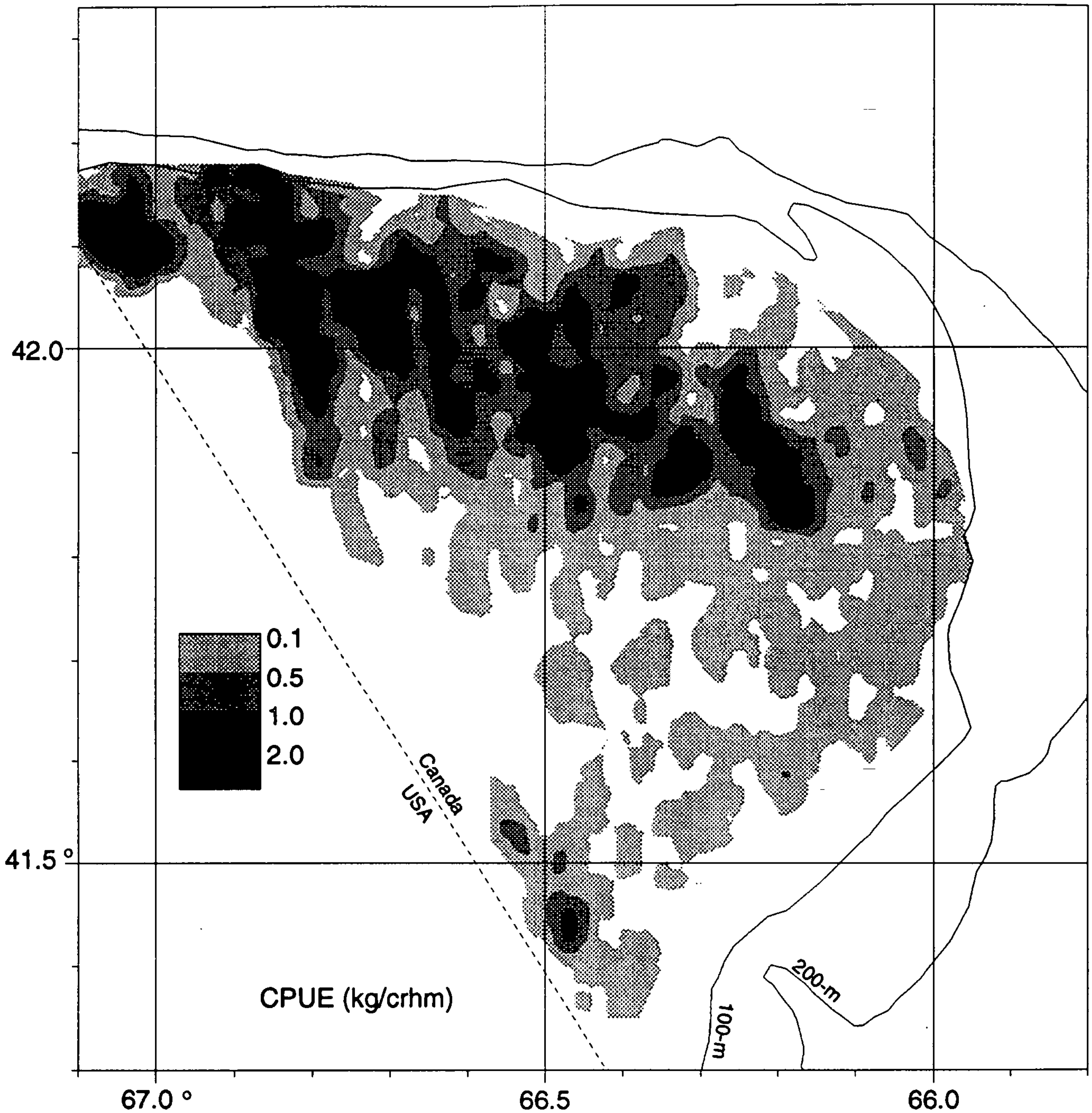


Figure 3.- Catch-rates encountered on Georges Bank in 1995. The scale of grey shades represents an ascending catch-rate up to 2+ kg / crhm.

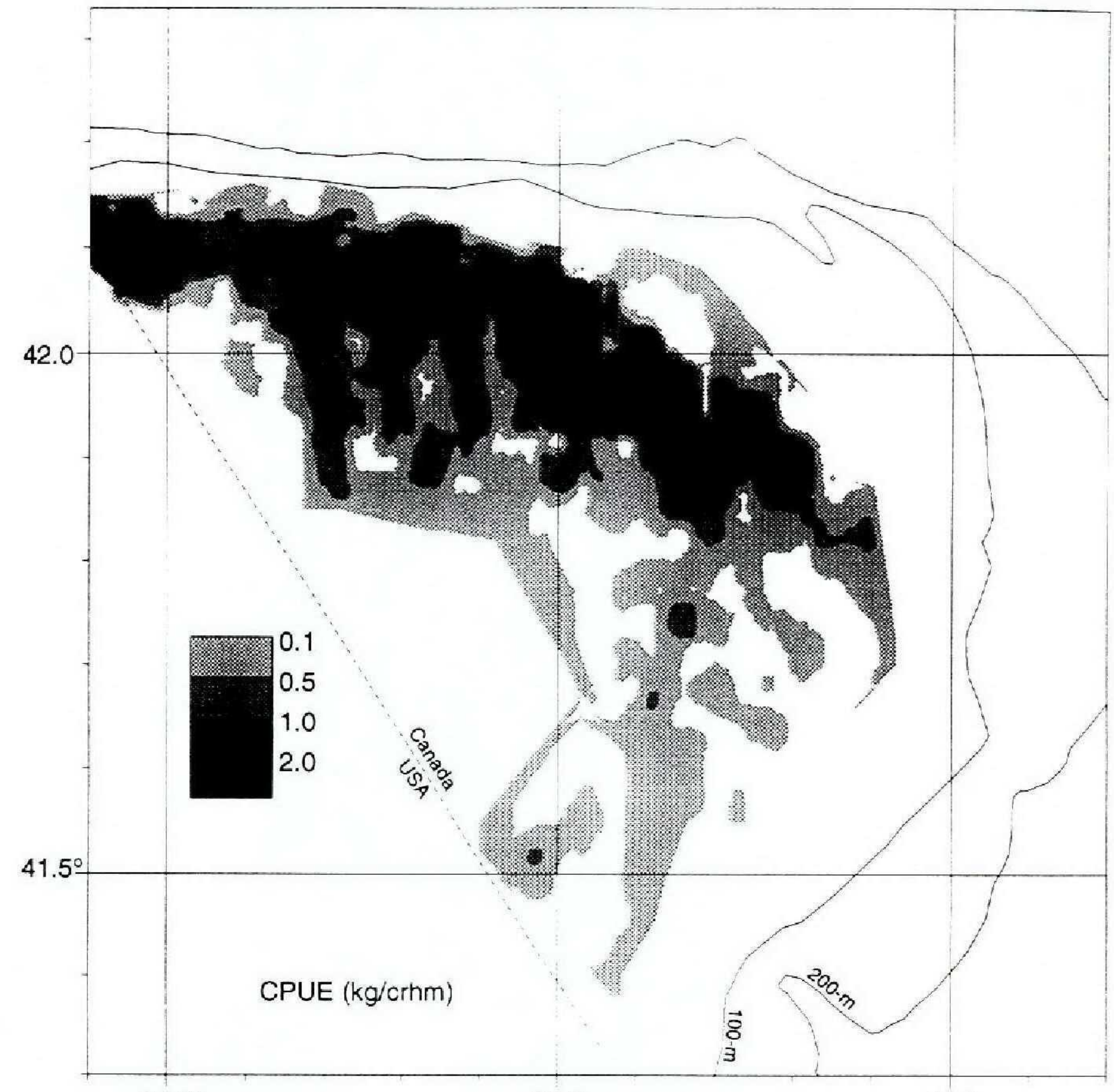


Figure 4.- Catch-rates encountered on Georges Bank in 1996. The scale of grey shades represents an ascending catch-rate up to 2+ kg/crhm.

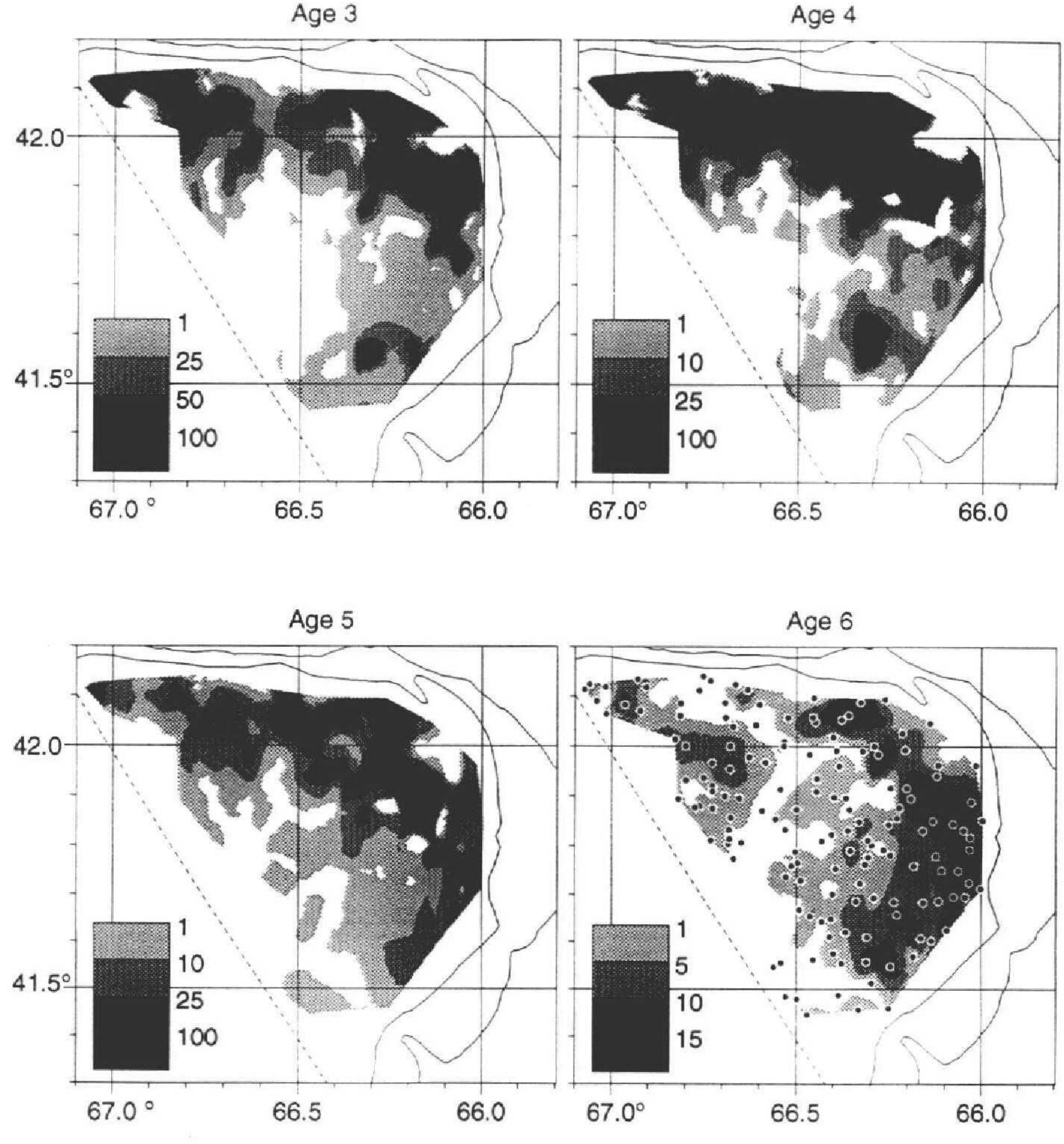


Figure 5. Scallop distribution at age from the research survey of August 1996. Location of sampling stations is indicated on the graph for age 6 scallops. The shading scale represents number of scallops per standard tow.

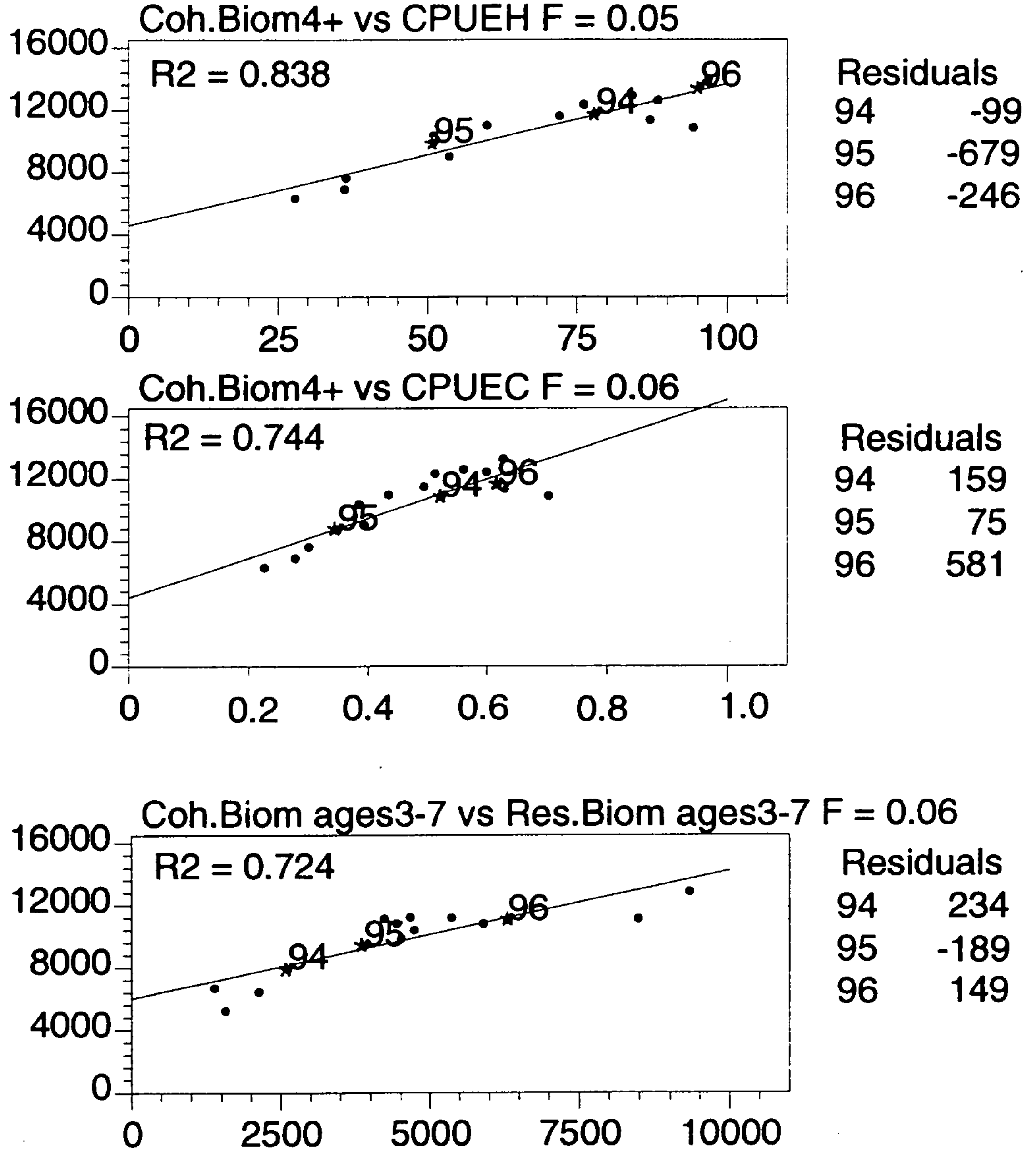


Figure 6.- Cohort biomass for ages 4+ (tons) versus CPUE (kg/h), cohort biomass for ages 4+ (tons) versus CPUE (kg/crhm), and cohort biomass for ages 3-7 versus research survey biomass for ages 3-7 (tons) using a terminal F_{Q4} as shown. Asterisks mark the position of the last 3 years points from the regression line. Corresponding residual values are to the right of each graph.

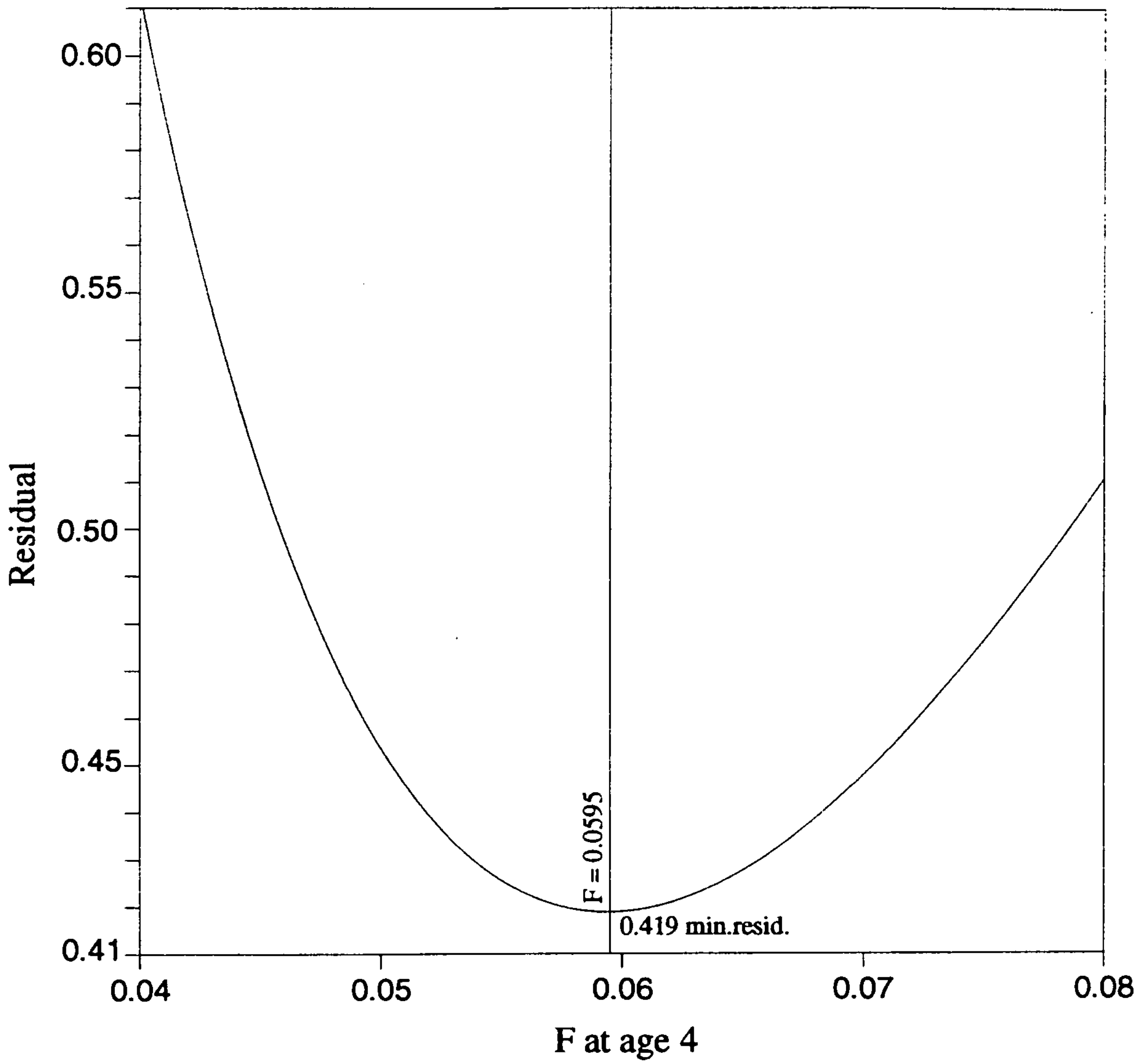
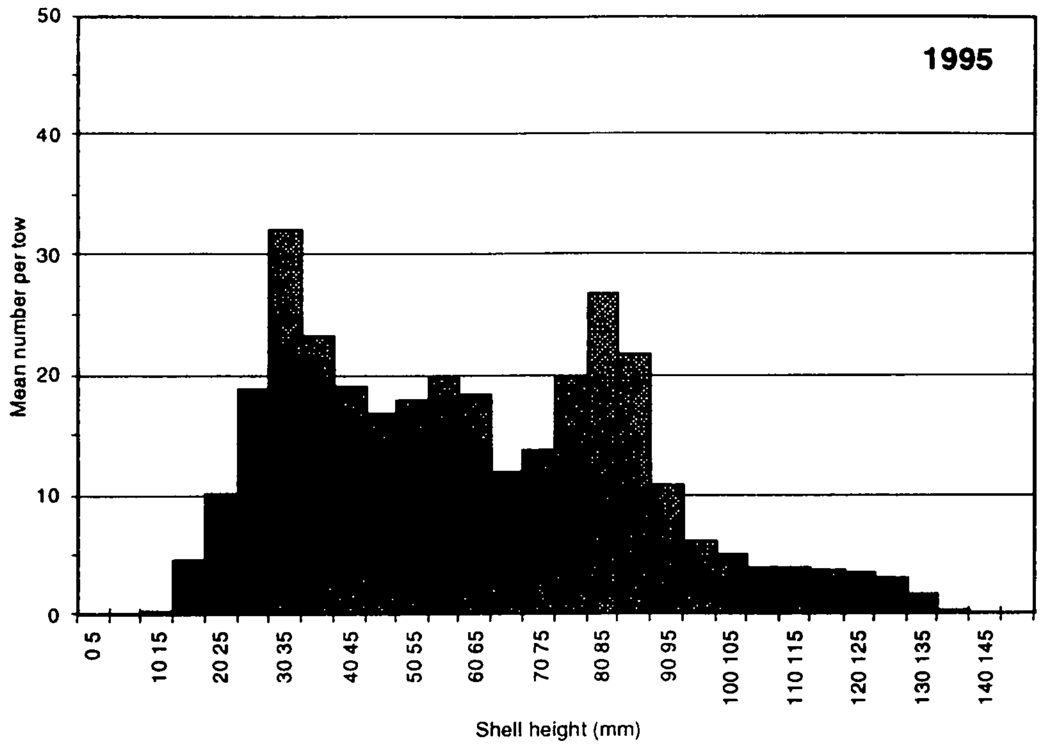


Figure 7.- Terminal F at age 4 from a partitioned search with annual CPUE as independent estimate. The vertical line shows the F value (0.0595) with the minimum residual.



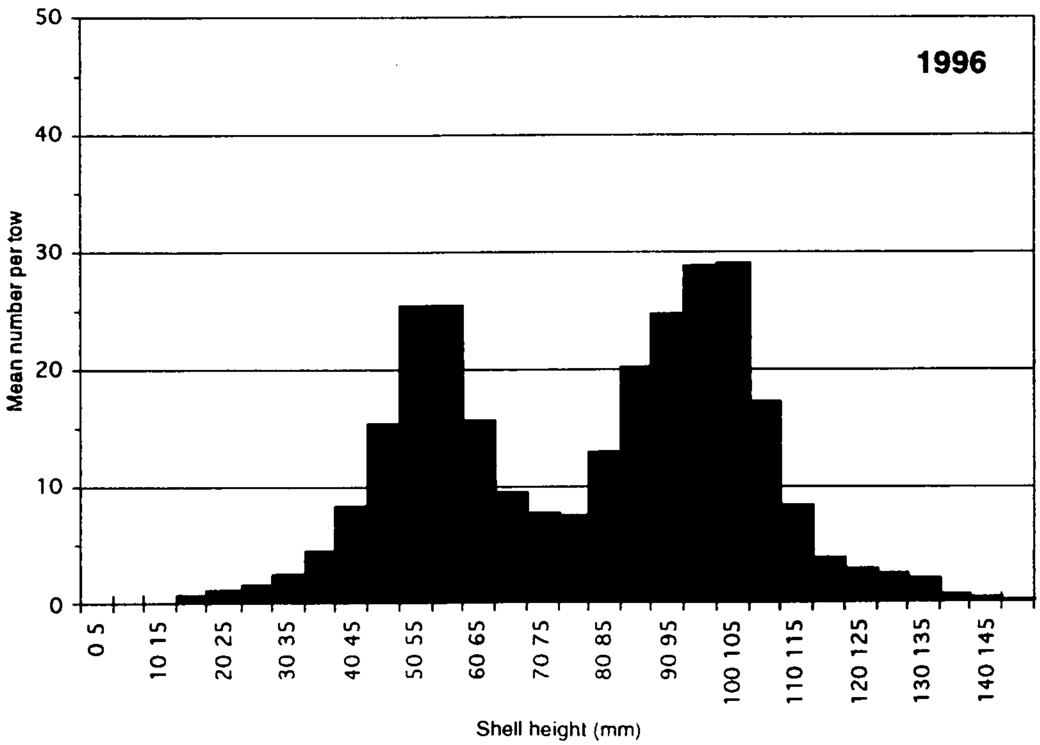


Figure 8a.- Shell height distribution for Georges Bank research surveys, 1995 and 1996 as composite pictures.

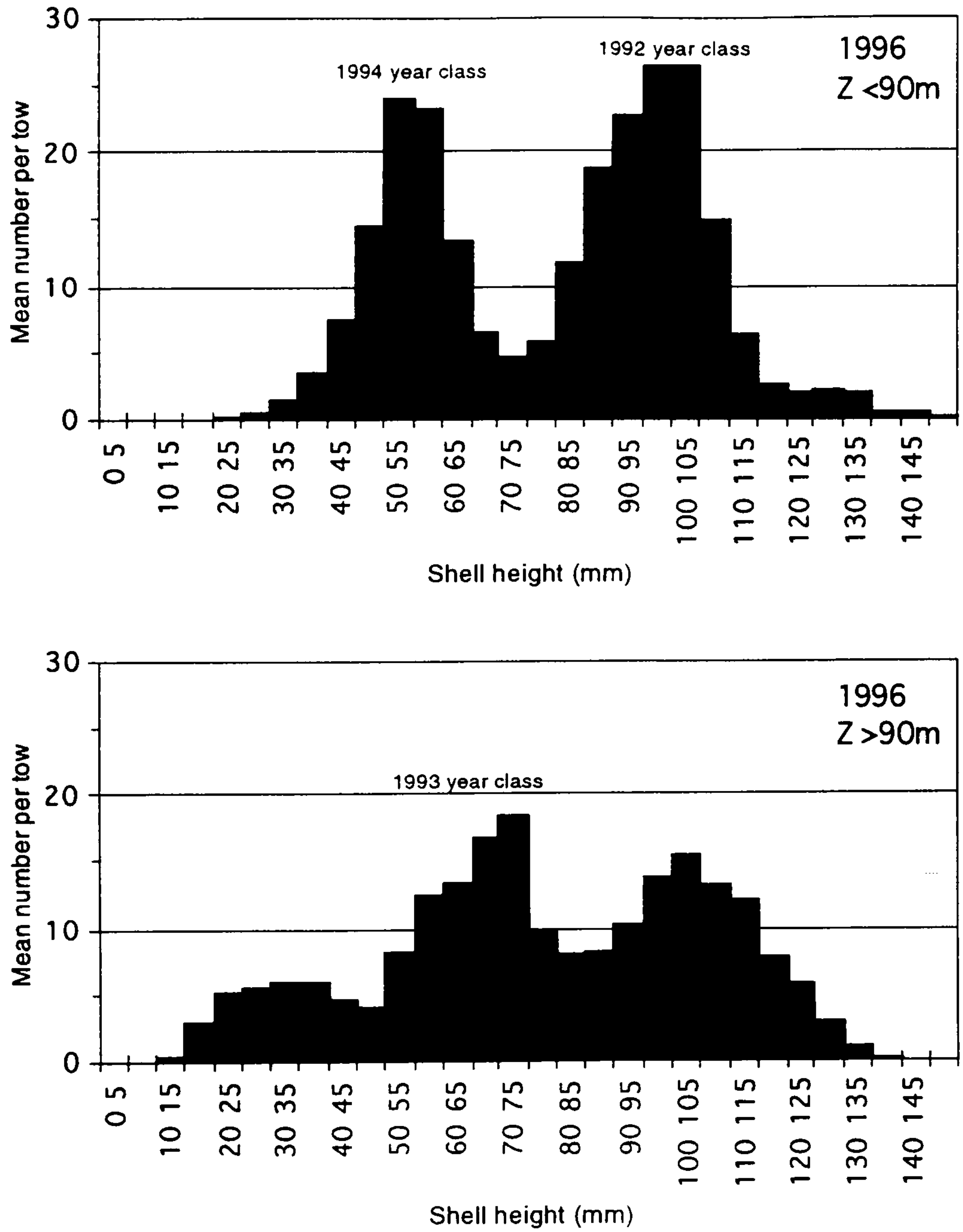


Figure 8b.- Shell height distribution in the 1996 Georges Bank research survey according to depth (Z). 124 stations were shallower than 90m; 26 stations were deeper than 90 m.

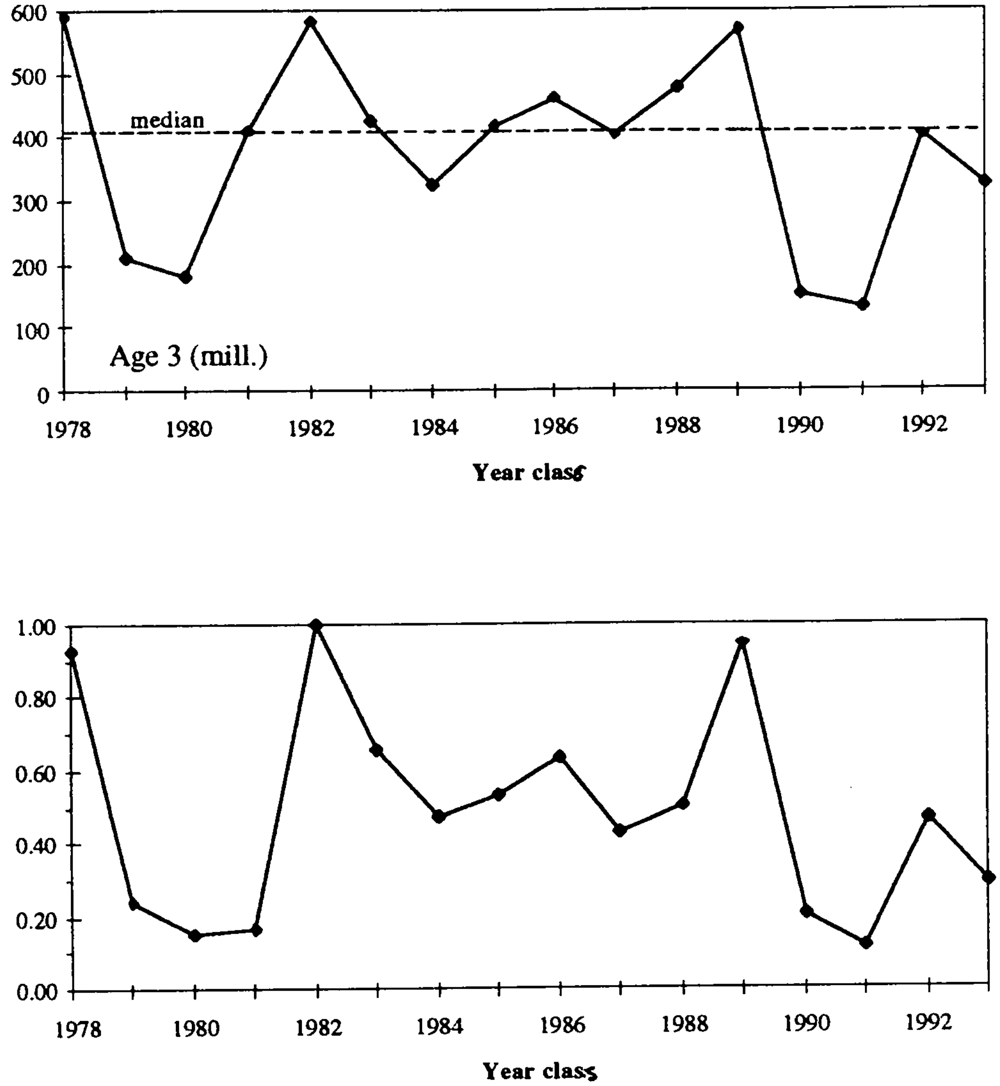


Figure 9.- Time series of estimates population numbers at age 3 in million (top graph) and normalised abundance index from research surveys for age 3 (bottom graph). The dashed line shows the geometric mean for recruitment. Year classes are labeled on the X-axis.

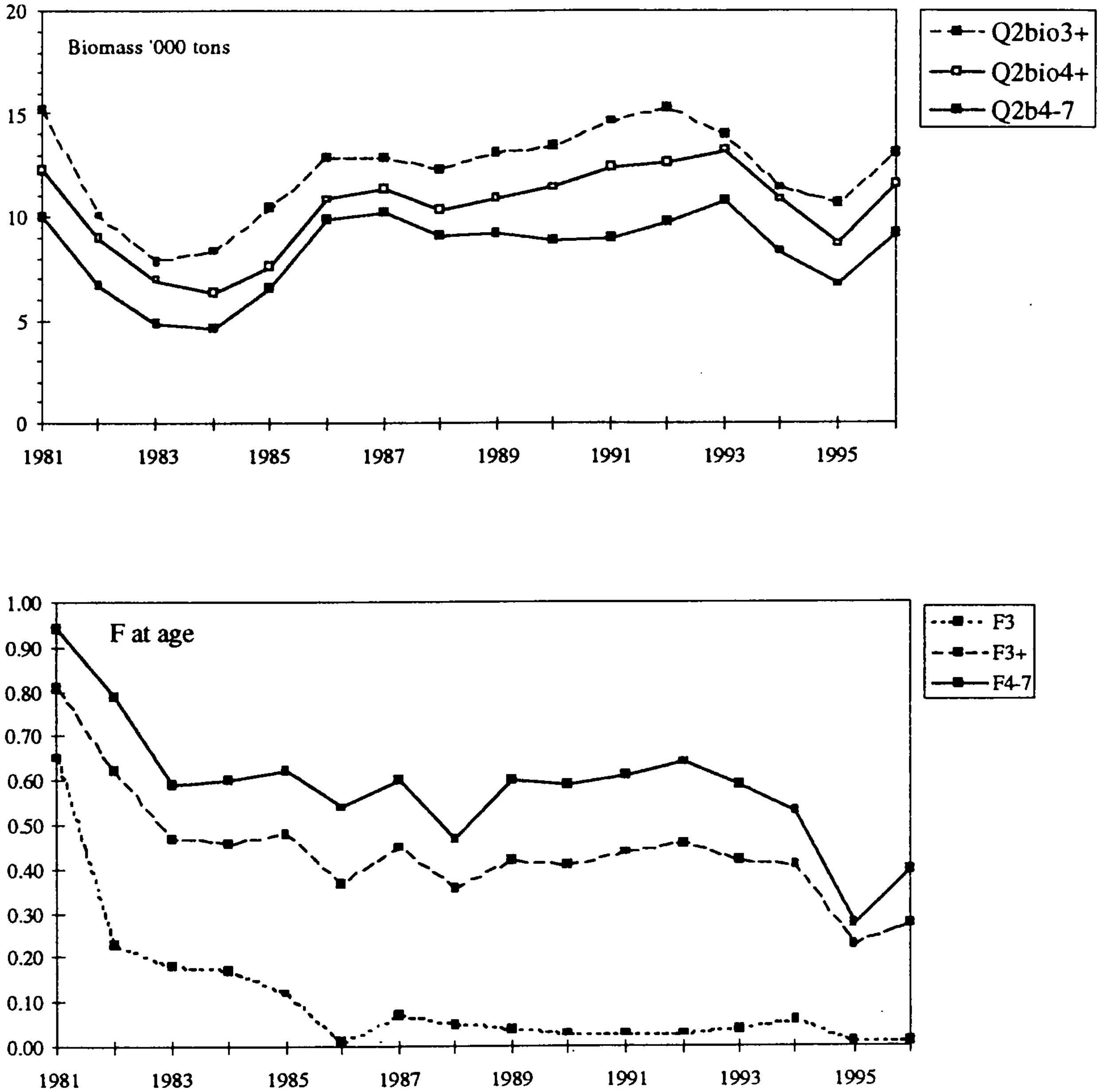


Figure 10.- Trends in population biomass and fishing mortality rates. Fishing mortality rates are the mean for the ages indicated in the F label.

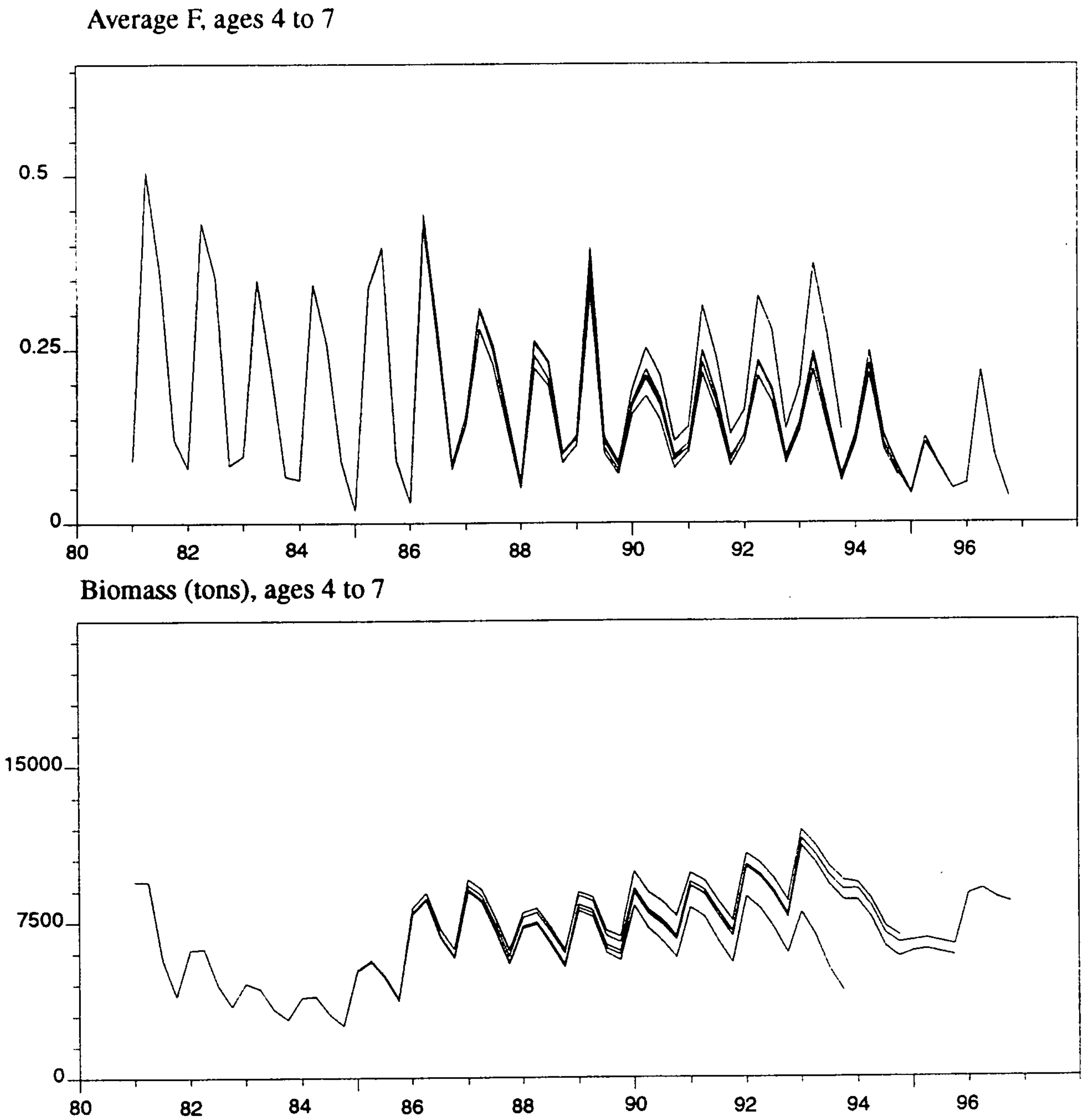


Figure 11.- Retrospective analysis patterns for fishing mortality rates and biomass estimates, ages 4 to 7, peeling by sequences of 4 quarters over the last 5 years.