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Assessment of the Southern Gulf of St. Lawrence Cod Stock, March 1995

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Abstract

Directed cod fishing in the southern Gulf of St. Lawrence was closed in September, 1993 because stock size had reached an historic low level because of reduced recruitment, low growth rates and high fishing mortality. A new analysis based on the results of research vessel surveys indicates that overfishing and discarding of undersized fish in the late 1980's and early 1990's depleted above average year-classes that could have supported a commercial fishery in 1993-94. The results of the 1994 research vessel survey and data from other sources indicate that the adult biomass has stabilized since the closure but that the abundance of young fish is well below average. The prospects for improved recruitment are poor. Continued low levels of fishing, similar to that in 1994, and improved recruitment are required for stock recovery.

Résumé

La pêche sélective de la morue dans le sud du golfe du Saint-Laurent a été fermée en septembre 1993, l'effectif du stock ayant atteint un seuil historique à cause d'une baisse du recrutement, de faibles taux de croissance et d'une forte mortalité par pêche. Une nouvelle analyse fondée sur les relevés des navires de recherche révèle que la surpêche et le rejet de poissons de taille inférieure à la taille réglementaire à la fin des années 1980 et au début des années 1990 a décimé des classes d'âge supérieures à la moyenne, qui auraient pu alimenter une pêche commerciale en 1993-1994. Selon les résultats du relevé de recherche de 1994 et des données d'autres sources, la biomasse d'adultes s'est stabilisée depuis la fermeture de la pêche, mais l'abondance du jeune poisson est bien inférieure à la moyenne. Les possibilités d'amélioration du recrutement sont minces. Le maintien de bas niveaux de pêche, comparables à ceux de 1994, et l'accroissement du recrutement sont les conditions nécessaires au rétablissement du stock.

1. Description of 1994 Fishery

Directed cod fishing in the southern Gulf of St. Lawrence has been closed since September 1993 because of extremely low cod abundance. Commercial fisheries for other species such as redfish, American plaice, and white hake continued and cod were taken as by-catch, subject to management measures described in section 1.2. In addition, there was a recreational fishery using hook and line gear. This section provides a summary of landings, management measures and input from the fishing industry about the status of the southern Gulf cod stock in 1994.

1.1 Landings by gear, area, season, fishery type

The total reported landings of southern Gulf cod was 1288 t in 1994 (Table 1). The landings were the lowest on record, second only to the 5239 t reported in 1993 (Figure 1). 89% of the reported landings were from 4T and the remainder was from 4Vn (N-A).

Landings decreased for otter trawls, gillnets, longlines and handlines in 1994 (Table 2). There was a slight increase in landings by seines, with the bulk of the seine landings coming from an experimental fishery testing the impact of lastridge rope adjustments on gear selectivity. Landings by miscellaneous gears (mainly unspecified gear) were the highest since 1986. This component included 120 t from the recreational fishery.

Monthly landings peaked in July and October (Figure 2). This trend is contrary to the traditional pattern with peaks in January (in 4Vn), April and November (in 4T) (Figure 3 in Sinclair et al. 1994). Most landings from the January to April period were from trawlers. During July to September most landings were by fixed gears, and seines dominated the landings in October-November.

The DFO statistical system determines the directed species of a fishing trip by the main species landed. Space is provided in logbooks for fishers to indicate the main species sought, however not all landings are covered by logbooks and the information is not always provided in logbooks. In previous years there has been a close correspondence between the main species landed and sought in fishing trips. A breakdown of the 1994 landings by main species and gear is given in Table 3. The majority of cod landings by all gears except trawls came from trips where cod was the main species landed. For gillnet, handline and longline gears, these landings were made throughout July to September. For seines, most of the main-species-cod landings were made as part of the lastridge rope experiments in October-November.

1.2 Management measures

Directed fishing for cod in the southern Gulf was closed in 1994 and DFO imposed by-catch limits of 10% (by weight) on fisheries directed towards other species. In consultation with the industry, DFO developed and implemented a cod by-catch protocol that if a given fleet sector exceeded the limit of 10% in an area, the groundfish fishery would be closed for 10 consecutive days. The closure would be followed by a test fishery to determine if the cod by-catch level in the area was less than 10%. In 4Vn, redfish fisheries were restricted to using midwater trawls as a way of reducing cod by-catch. A cod by-catch limit of 5% per day and 1% per trip was imposed. In addition, flatfish fisheries were not permitted in 4Vn during the winter months (January-April).

In addition to the by-catch protocol, DFO implemented a small fish protocol where by fisheries were closed if the percentage of fish caught exceeded specific targets. The minimum fish sizes agreed to by the industry were the following:

- 30 cm for American plaice;
- 45 cm for white hake;
- 25 cm for winter flounder;
- 41 cm for cod.

Fisheries in 4T directed at species other than cod were closed on 11 occasions in 1994 due to high by-catches of cod. The closures affected both fixed and mobile gear fleets fishing for flatfish and hake. There was one closure due to high incidence of small American plaice. There were no closures in 4Vn.

1.3 Input from industry

The views from industry on the status of the cod stock were expressed at a number of meetings during 1994. Staff from the Groundfish Section attended meetings of the Fisheries Resource Conservation Council (FRCC) in July (Gaspé, July 5; Caraquet, July 6; Petit-de-Grat and Chéticamp, July 7; Moncton, July 8) and in September (Cap-aux-Meules and Carleton (Québec), September 27; Charlottetown and Moncton, September 28; Port Hawkesbury, September 29). A Forum on the Management of cod in 4T and 4Vn, attended by approximately 40 industry representatives was also held in Moncton, October 25 and 26. A meeting of the Gulf Groundfish Advisory committee was held November 30 , 1994.

In general, the views from fishers from the western southern Gulf differed from the ones from the eastern area. In the western area (Gaspé, northeast N.B. and Magdalen Islands), the almost unanimous view was that cod abundance in 1994 was very low. In the eastern area (P.E.I. and Gulf Nova Scotia), where fishers made good catches of cod while directing for other species (lobster, hake) close to shore, the view was that the abundance of cod was sufficient to allow a fishery. Generally, all agreed however that cod abundance in recent years was lower than in the mid-1980's.

A series of Science Workshops, designed specifically to obtain the views of industry on the status of the stocks, were held throughout the southern Gulf of St. Lawrence in late

November. The meetings were held in Grande Rivière, Québec on November 15, in Shippagan, N.B. on November 16, in Charlottetown, P.E.I. on November 23, in Chéticamp, N.S., on November 24 and in Cap-aux-Meules, Magdalen Islands, on November 28.

The views regarding stock status expressed during the Science Workshops were similar to the comments heard during the other meetings. In the western southern Gulf, abundance of cod was considered to be very low while fishers indicated that they had perceived an increase in the abundance of cod in the eastern area. Fishers who had fished in several areas of the southern Gulf were of the opinion that cod abundance was low. The following is a short summary of comments made at these Science Workshops.

In Grande-Rivière, 61 fishers attended the meeting. The general consensus was that cod abundance was low. Decreases in the abundance of cod were noted around Bonaventure Island and in the St. Lawrence estuary. There were a few dissenting opinions and some indicated that it was difficult for them to determine the level of abundance as they had not fished in 1994. Seals are considered to be one of the factors implicated in the decline in the fishery. Fishers indicated that the recreational fishery had not been sufficiently controlled and that catches from that fishery are likely underestimates. High-grading was also reported to have occurred.

The meeting in Shippagan was attended by 23 fishers. Fishers who had fished over broad areas in 1994 felt that cod were less abundant than in the past. Some pointed to indications of good catches such as in the jigger fishery and a selectivity experiment conducted off Chéticamp as evidence that abundance may not be as low as indicated. Several fishers reported that cod had migrated outside of the Gulf in the fall earlier than in previous years. Some reported that illegal fishing for cod had taken place in 1994 and that real catches may be two to three times the amount reported. Finally, many questions related to the methods used in groundfish surveys were asked and answers were provided by DFO.

In Charlottetown, 27 fishers attended the Science Workshop. In general, fishers considered that cod were far more abundant in shallows near the east end of PEI (Souris) than ever seen before and thought the survey had underestimated cod abundance. They thought that cod were in shallower water (<15 fathoms) in 1994. Occurrence of cod in lobster traps was among the highest ever seen and were present virtually all season. The fishers want a reduction of the seal herds and the abundance be controlled as recommended by the FRCC. Several questions were posed regarding the accuracy of the groundfish survey.

In Chéticamp, 47 fishers attended the November 24 Science Workshop. In terms of abundance, fishers indicated that cod abundance was high in the mid 1980's and low in the early 1970's. They thought that there were far more cod in the Chéticamp area in 1994 than recently (1992 and 1993) and that abundance was lower from 1989 to 1992. Cod jigging was reported to be good in 1994. After the closure of the mobile fishery in the early 1970's, fishers indicated that the cod stock recovered within 5 years. It was reported that the 10 fish/day limit was exceeded in the recreational fishery and that by-catch of cod in redfish fisheries was underestimated. On the latter, it was suggested that catches of cod may be 10 times greater than those reported. Questions regarding the groundfish survey were raised and addressed by DFO.

On November 28, the meeting in Cap-aux-Meules (Magdalen Islands) was attended by about 30 fishers. Participants commented that cod abundance had declined from the mid 1980's, and felt that abundance in 1994 was still very low while some others felt that there had been an increase over 1993. Some participants noted that it was difficult to judge the abundance of cod in 1994 because there was no directed fishing. Several noted more small cod (pre-recruit size) in 1994 than in 1993, particularly east of the Islands. Participants indicated that both harp and grey seal abundance was very high and that seal predation was affecting cod abundance. It was also noted that seals remain near the Magdalen Islands for longer periods.

2. Commercial Fisheries Data

2.1 Data updates

All commercial landings statistics were updated for the recent publication of the final 1991 NAFO statistics as well as for changes to Canadian catch and effort.

2.2 Age Determination

Consistency of age determinations was verified by regular blind readings of a reference otolith collection. Tests were performed after about 1000 otoliths had been read. The two readers were tested on the same test samples on the same date. The otoliths comprising the test samples differed between dates. The level of agreement and direction of bias is summarized below.

	Reader 1		Reader 2	
Date	% agreement	direction of bias	% agreement	direction of bias
940809	88	0	n/a	n/a
941103	88	0	89	0
941114	87	0	85	0
950210	86	0	95	0

Consistency with the reference collection was always at least 85% for both readers. No bias was detected.

2.3 Catch weight and length at age 1994

The calculation of the 1994 commercial catch at age was complicated by the limited fishery. It was not possible to maintain the traditional quarterly stratification by gear due to limited sampling coverage. It was necessary to use ageing material collected during the January 1994 and September 1994 research vessel surveys to augment the commercial samples. We also included all observer length frequencies collected by the Gulf and Quebec region observer programs. Observer samples are collected on a set-by-set basis while commercial port samples are collected on a trip-by-trip basis. The set-by-set observer samples were weighted to the catch in the set, then combined within trips and weighted to the observer estimate of trip catch. At this stage they were treated as commercial port samples and trip-by-trip data were then combined within the regular gear and time period strata. A summary of the sampling data used in constructing the 1994 catch at age is given in Table 4.

The following length (L, in cm)-weight (W in grams) relationship was obtained from the September 1994 research vessel survey and was used to calculate mean weights at age

$$W = 0.007117 * L^{3.0631}$$

Landings numbers, mean weights at age, and mean lengths at age for each age-length key are presented in Tables 5 to 7.

The time series of landings at age and mean weights at age from 1971-94 for the southern Gulf stock (including 4T, 4Vn, Nov.-Apr., and 4Vs Jan.-Apr.) are given in Tables 8 and 9. The total number of fish landed was the lowest on record. The 1994 landings were dominated by ages 6-8 (1986-88 year-classes). Weights at ages 7-12 increased again in 1994 while weights at other ages were comparable with the previous 5 years (Figure 3).

2.4 Nominal fishing effort

Sinclair et al. (1994, section 5.6) noted a strong relationship between the amount of cod directed fishing effort by mobile gear vessels and the fishing mortality by those vessels. The 1994 nominal fishing effort by mobile gear vessels was estimated using the same approach. Days fished was used as the unit of effort and subtrips where cod was the main species landed were extracted. The reporting rate for fishing effort was approximately 90%. The reported catch with effort was used to estimate the amount of unreported effort. The observations were grouped by gear, month, and area.

The total nominal effort was 52 days distributed among otter trawls (8.5 days) midwater trawls (0.5 day), and seines (43 days).This is a substantial decrease from the 600 days reported in 1993 and the 6,000 to 8,000 days reported in 1989-92 (Figure 4).

2.5 Discarding

There was very little discarding of cod observed by DFO fisheries observers in 4Vn and 4T in 1994. This is expected since discarding became illegal in 1993. However, as was reported in Sinclair et al. (1994), length frequency data collected by observers were compared with those collected by port sampling technicians in an attempt to detect discarding on unobserved vessels. Observers measure fish at sea before any are discarded. Port samplers collect samples from the fish being off-loaded at the wharf. If the fish sampled at port are larger than those measured at sea, this could indicate that some smaller fish were being discarded. Individual samples taken by observers were first weighted by the set catch, then by the trip catch, and finally pooled by gear (trawlers and seiners), season, and area. The port samples were weighted by the trip landings and pooled for the same gears, seasons, and areas.

A comparison of the sizes of fish measured by observers at sea with those sampled at port suggest that discarding may have occurred in some fleets and areas in 1994 (Figure 5). The observer and port samples from OTB's fishing in 4Vn during the winter were very similar, suggesting very little if any discarding occurred. However, at-sea samples of seines fishing in 4Tfg in the second quarter indicated more smaller fish were being caught than were being landed by unobserved vessels. The same pattern was noted for 1993 (Sinclair et al. 1994, section 5.3). Sampling in other areas, periods and gears was insufficient to draw any conclusions.

2.6 Index Fishers

In 1994, 36 of the 53 (68%) fishers who volunteered to participate in the Gulf Region's Groundfish Index Fisher Program actually fished and submitted log records.

At the end of the fishing season (Nov. 1994) all of the volunteers were contacted by phone and asked for their responses to a questionnaire concerning the 1994 groundfish fishery. Some of the questions and the responses from respondents that fished in 1994 that traditionally directed for cod in other years follow:

> "On a scale from 1 to 5, how would you describe the abundance of cod this year, where 1 represents the lowest (or minimum), 3 represents the average and 5 represents the highest (or maximum)?"
>
> Responses: 1 - 0% 2 - 0% 3 - 57% 4 - 29% 5 - 14%
>
> "How would you describe the size of cod this year? Small(er), Average, or Large(r)?"
>
> Responses: Small(er) - 0% Average - 86% Large(r) - 14%

The catch rates for three of the index fishers who caught cod in 1994 are shown in Figure 6. The fisher in Chaleur Bay experienced reduced cod catch rates over the past four years. Two fishers in the eastern part of the southern Gulf experienced improved catch rates in 1994.

3. Research Data

3.1 Fall survey

3.1.1 Revisions to Abundance Index

A bottom trawl survey of the southern Gulf of St. Lawrence has been conducted each September since 1971. These surveys have followed a stratified design, with stratification based on depth and geographic region (Figure 7). Fishing was by the *E. E. Prince* from 1971 to 1985, the *Lady Hammond* from 1986 to 1991, and the *Alfred Needler* since 1992.

In 1985, the *Lady Hammond* fished alongside the *E. E. Prince* to compare fishing power between the two vessels. This comparison revealed no overall difference in cod catch rates between the two vessels, so no adjustments were required to account for the change in fishing vessel in 1986. The *E. E. Prince* fished during daylight hours only, while the *Lady Hammond* and *Alfred Needler* fished 24 h per day. However, comparative fishing during the 1988 survey revealed no significant differences between day and night catches of cod, so no adjustments have been made to catches to account for variation in time of day (Nielsen 1989). In 1992, a comparison between the *Lady Hammond* and the *Alfred Needler* was made one month prior to the September groundfish survey. This comparison indicated depth-dependent differences in fishing power between the two vessels, with the *Alfred Needler* catching more cod in shallow water and the *Lady Hammond* catching more cod in deep water (Nielsen 1994). Thus, to account for the change in fishing vessel in 1992, cod catches by the *Alfred Needler* in 1992 and 1993 have been adjusted in recent stock assessments using a depth-dependent correction factor that discounts catches in shallow water and inflates those in deep water (e.g., Sinclair et al. 1994).

A recent re-analysis of the 1985 comparison between the *Lady Hammond* and the *E. E. Prince* revealed that, although the average catch rate of cod did not differ between the two vessels, there was significant depth-dependent variation in relative fishing power between the two vessels, with the *Lady Hammond* catching more cod than the *E. E. Prince* in deep water but not in shallow water (Nielsen 1994). Swain et al. (1995) developed and evaluated a time series of cod catch rates that incorporated corrections for the depth-dependent differences in relative fishing power between the *Lady Hammond* and both the *Alfred Needler* and the *E. E. Prince*. This involved correcting catches by both the *Lady Hammond* and the *E. E. Prince* to be equivalent to those by the *Alfred Needler*. Catches by the *Lady Hammond* were corrected using a depth-dependent adjustment factor that inflated catches in shallow water and discounted those in deep water. Catches by the *E. E. Prince* were corrected by multiplying by a depth-independent factor of 1.3. This approach has been adopted in the analyses presented here.

From 1971 to 1983, 61-70 stations were fished each year in the fall survey. Of these, 10-13 were fixed stations selected in the mid-1950's and the remainder were randomly-selected stations. In past assessments, only the randomly-selected stations have been used to calculate cod abundance indices. From 1984 to 1987 the survey followed a fixed-station design, using stations chosen from the randomly-selected sites fished in the previous three years (Hurlbut and Clay 1990). With the advent of fishing by the *Lady Hammond* on a 24-h basis, the number of stations that could be fished during a survey increased substantially. However, only the 61 stations fished each year from 1984 to 1987 (out of a total of 90-131 stations per year) have been used in past assessments to calculate cod abundance indices. From 1984 to 1987, several stations were fished more than once in a survey - some as many as 8 or more times. These repeat sets have not been used in the calculation of abundance indices. Similarly, catches by the *Lady Hammond* during the 1985 survey, the night catches by the *Lady Hammond* in 1985-87, and the repeat night sets during the 1988 day-night comparison have not been used in calculating the abundance indices.

Nielsen (1995) examined methods of including all available information (i.e., all sets made during the 1984-1987 period, the 13 fixed stations fished from 1971 to 1988, the repeat sets) in the calculation of research survey abundance indices for cod. This analysis was presented to the Atlantic Zone Statistics, Sampling and Surveys Committee in November 1994. The recommendation of the committee was to include all sets in the index, averaging repeat sets before including them in the stratified means and treating fixed stations in the same way as randomly-selected stations (Atlantic Zone SSSC Nov. 22-24, 1994 Final Report). This approach has been adopted in the analyses presented here.

To summarize, the survey abundance index used in this report differs from that used previously in the following respects:

- the 10-13 fixed stations fished from 1971-1988 are included in the index.
- all stations fished in the 1984-1987 period are included, not just the 61 stations fished each year.

- catches by the *Lady Hammond* in 1985 are included (after adjustment to the *Alfred Needler* and, in the case of comparative fishing sets, averaging with the paired *E. E. Prince* sets).
- paired day-night catches in 1988 were averaged and then included in the index (previously, only the day catches were used).
- all other repeat sets at the same location were averaged and included in the index.
- catches by the *E. E. Prince* and the *Lady Hammond* were adjusted to be equivalent to catches by the *Alfred Needler*.

Also, an error in the indices for 1991 was noted and corrected. The values for 1991 reported in the 1993 and 1994 assessments appeared to be those calculated using the 1991 catches per tow and the 1990 age-length key.

3.1.1.1 Comparison of the Revised and Previously-used Indices

Both the revised and the previously-used survey abundance indices indicate the same temporal trends in cod population size (Figure 8, 0+ panel). Mean catch rates in the 1971-1984 period are higher in the revised series than in the old series. This partly reflects the 30% inflation of *E. E. Prince* catches in their conversion to *Alfred Needler* equivalents. The most substantial change is the increased mean catch rate for 1988 in the revised series. In addition, the very high coefficients of variation for 1985 and 1986 in the old series (see Figure 20, Sinclair et al. 1994) are greatly reduced in the revised series (Figure 9).

The revisions to the RV time series had little effect on the perception of stock size and stock history. The most substantial differences between the old and revised abundance indices are for the youngest ages (Figure 8). Catch rates of ages 2 and 3 were considerably greater in the revised series than in the old series for 1977, 1978, 1979, 1982, 1983 and 1988. However, these revised estimates of juvenile abundance are now more consistent with year-class estimates at older ages (see section 4.1.3).

3.1.2 September Survey Results

The 1994 survey was conducted by the *Alfred Needler*, September 10-29. In 1994, survey coverage was extended into NAFO subdivision 4Vn, but only results for NAFO Division 4T (strata 415-439, 156 successful tows (Figure 7)) are reported here.

3.1.2.1 Abundance Indices and Biomass Estimates

The stratified mean number of cod per tow (ages 0+) in the 1994 survey remained at the low level observed since 1992 (Figure 9). The 1994 mean decreased by about 15% from the 1993 mean. This catch rate is at the 1992 level and is the lowest since 1975.

The 1989 and 1990 year classes (ages 6 and 5) were again the most abundant in the survey (Table 10). The proportion of older cod (ages 5+) in the survey catch has been increasing from 1991 and is now at the 1984-1988 average of approximately 60%. The catch rate of age-2 cod continues to be low, suggesting below average year class sizes since 1988. Coefficients of variation for the 1994 survey are low, ranging from 10.1 to 25.1% (Table 11).

The 1994 estimate of total cod biomass in the survey area dropped slightly from the estimate in 1993 (Table 12). Only estimates for 1975 and 1992 are lower in the 24-yr time series. The percent of the biomass in eastern 4T (strata 431-439) was 35% in 1994, the highest value in the time series. This value is similar to those in recent years (25-31% in 1991-1993) but is considerably higher than the average value for the early portion of the time series (16% for 1971-1982).

3.1.2.2 Length Distribution

The length distribution of cod catches in the 1994 survey resembles those since 1992 (Figure 10). As in recent years, few cod were over 50 cm, in contrast to the 1971-1985 period, when cod over 50 cm averaged 22% of the catch. The catch of cod less than commercial size (40 cm) continues to be very low in comparison to catches since 1976, indicating that recruitment will be poor.

3.1.2.3 Weight at Age

For all but the youngest age groups, weights at age from the survey have declined from high values in the 1970s to low values in the mid-1980s (Table 13, Figure 3). Values from the 1994 survey are similar to or only slightly higher than 1993 values. The declines in weight-at-age from the late 1970s to the mid-1980s are consistent with density-dependent growth. However, weight-at-age has not improved as population size decreased in the late 1980s and early 1990s. Other factors such as short feeding seasons, cold water temperatures and size-selective fishing may contribute to the low weights-at-age in recent years.

3.1.2.4 Geographic Distribution

Distributions of cod aged 1 to 8+ were mapped for September 1994 (Figure 11) using the methods outlined in Sinclair et al. (1994). Age-1 cod were rarely caught except for a small concentration near Georges Bay. Age-2 cod were also rare in the 1994 survey. The dense concentrations of age-2 cod southeast of the Magdalen Islands and southeast of Miscou Island in 1993 were not seen in 1994. As in 1993, the highest concentrations of age-3 cod were in the Magdalen Islands and Shediac Valley areas. However, the concentration SE of the Magdalens was not as pronounced as in 1993 and 1992; instead, concentrations of age-3 cod were greatest in the Shediac Valley area in 1994. This is the typical pattern seen in 1971-1990. Age-4 cod were also most strongly concentrated in inshore areas in the Shediac Valley area and around the Magdalen Islands; the concentration of age-4 cod seen at intermediate depths NE of PEI in 1993 was not seen in 1994. Cod aged 5 and 6 were most concentrated in a band extending from the Miramichi-Shediac Valley area along the coast of PEI and north to the Magdalen Islands. The highest concentration was inshore west of the Magdalen Islands. The concentration in the Miramichi-Shediac Valley area was more inshore than in 1993. Cod aged 7 and 8+ were most concentrated in a band extending from Miscou Island, through the Shediac Valley-Miramichi areas, along the coast of PEI and Cape Breton, and NW of the Magdalen Islands. The highest concentrations were inshore off East Point PEI and west of the Magdalen Islands. Densities of older cod throughout eastern areas of the southern Gulf were more pronounced in 1994 than in recent years, although the high concentration of older cod seen off St. Paul's Island in 1993 was not seen in 1994.

The spatial distribution of commercial sized cod (>41 cm) from the last six years was examined with kriging. The catches at length were converted to weights using the annual length-weight relationships. Annual variograms were estimated and used to project the catches onto a 10' by 10' grid of latitude and longitude. These were then plotted using shaded rectangles, the levels of shading corresponded to the 25th, 50th, 75th, and 90th percentiles of the kriged values in the 6-year dataset.

The maps indicated an overall decline in biomass of commercial sized cod from 1989-92 followed by a period of relative stability (Figure 12). In the last three years, there appeared to be a southeasterly shift in distribution. Catches declined in the area between Miscou and Gaspé. There was an increase in catches between the Magdalen Islands and Cape Breton, northwest of the Magdalen Islands, as well as north of Prince Edward Island. However, the density of the shaded rectangles was still far lighter than in 1989-90.

3.1.2.5 Depth Distribution

We described the September depth distribution of cod aged 3-8+ using Poisson regression models as described in Sinclair et al. (1994). Models included both linear and quadratic depth terms. We tested the overall significance of the effect of depth on cod catch rates as well as the individual significance of the linear and quadratic terms by analysis of deviance (McCullagh and Nelder 1989) using the GLIM software package (Payne 1986). We used the percent of the total deviance explained by each depth effect as an indication of the strength of these effects.

The overall effect of depth on cod catch rates was significant for all six age groups (Table 14). The percent of the total deviance in cod catch rates explained by depth decreased as age increased (26% for age 3 to 5% for age 8+). The quadratic term was not significant for ages 3 to 6 and, although significant, explained only 3% of the deviance for ages 7 and 8+. For ages 3 to 6, models with a linear term only were highly significant and had negative slopes, indicating peak densities in shallow water.

There appears to be density-dependent shifts in the depth distribution of southern Gulf cod during the 1971-1994 period. Swain (1993) reported density-dependent shifts in the depth distribution of southern Gulf cod during the 1971-1991 period (see Table 15). When abundance was low in the early to mid-1970s, cod density was either unrelated to depth (older cod) or highest in shallow water (younger cod). When abundance was high in the early to mid-1980s, cod density tended to be highest at intermediate depths. The 1994 results conform to the low abundance pattern of the mid-1970s: cod density tended to be highest in shallow water for ages 3 to 6 and only weakly related to depth for ages 7 and 8+. It is possible that a greater fraction of the population is sampled by the survey when population size is large than when it is small. This issue will be discussed further in the section on assessment parameters.

3.1.2.6 Temperature Distribution

Following Perry and Smith (1994), we examined relationships between cod density (fish per standard tow) and temperature using cumulative distribution functions (cdf) and randomization tests. Temperature distribution in September 1994 is summarized in Figures 13 and 14. Temperature selection was significant for young cod (P=0.0007 for age 3 and 0.012 for age 4) and for old cod (P=0.014 for age 7 and 0.0007 for age 8+) but not for cod of intermediate ages (P=0.14-0.16). In all cases of significant temperature selection, cod selected warm temperatures in relation to those available. All ages of cod tended to avoid areas with temperatures below 1°C (Figure 13).

Bioenergetic considerations suggest that animals should reduce metabolic costs when food resources are low. Swain and Kramer (1995) found a significant negative relationship between cod temperature distribution and abundance in the southern Gulf, and suggested that cod temperature preference shifts toward colder temperatures to reduce metabolic costs when abundance is high. In this case, a shift back to warmer temperatures is predicted for recent years of low abundance. The data for recent years provide some evidence of such a shift (Figure 15). For all ages of cod, the median temperature occupied has been greater than the median temperature available in recent years including 1994.

3.2 Juvenile survey

The fifth annual survey to derive an index of abundance of young cod was conducted in the Miramichi Bay - Shediac Valley area during early July 1994. The survey followed the same stratified random design (four depth based strata) as used in the previous four years and followed standard Gulf Region survey protocols (Hurlbut & Clay 1990). The survey was conducted on the CSS Calanus II. This is the fourth vessel that has been used for this survey and no comparative surveys have been conducted. However, the same doors, bridles, and net have been used all years. Forty-four valid sets were made during the 1994 survey.

3.2.1 Numbers at age

As in previous years, ages were determined from thin sections of otoliths embedded in polyester resin. Age reading consistency was maintained by regular testing against a reference collection of otoliths. Ages were determined for 837 pairs of otoliths. The number at age per standard tow was determined using the RVAN program (Clay 1990) written in SAS/IML (SAS Institute Inc. 1989).

The survey is conducted too early to capture age 0 fish. Two estimates are provided for 1994 because there was one extremely large set (2400 fish), of which most were age 3 (1535 fish) or age 2 (400 fish). Inclusion of this set greatly increased the estimates and the CVs for these two ages. To be conservative, both estimates are presented but the lower estimates were used, at this time, to estimate year class strength. Future surveys will show which perception of the 1994 survey is most correct. All of the year classes occurring after 1987 (age 3 in 1990) have been weaker than the 1987 year class. The estimates for the 1992 year class continued to be very low. Similar to the September survey, there appeared to be many more adult fish (age 5 and older) in the shallow water covered by this survey compared to previous years. This is interpreted as a change in distribution (Table 16).

3.2.2 Lengths at age

In nearly all cases, the September lengths at age were substantially larger than those recorded during the juvenile cod surveys as expected if summer is the primary period of growth for this stock. The exceptions were at the extremes (some cases for age 1, 8 and 9) and likely reflects availability of these fish to the two surveys. When difference in timing of the surveys is considered, there does not appear to be a strong trend in mean size at age over the five years of the juvenile survey (Table 17).

3.2.3 Maturity at age

The juvenile survey is conducted during a period much closer to the peak spawning time of southern Gulf cod, therefore, assigning maturity stages should be more accurate, especially for females. September is a difficult time to try to assess maturity for southern Gulf cod due to it being well after peak spawning and before significant maturation of the ovaries for the following year. Furthermore, the same two samplers have done the staging during the juvenile survey using Powles (1958) and Clay (1989) as a guide with the exception that ovaries were routinely cut and examined internally before assigning maturity stages. In contrast, many samplers having a wide range of experience have been assigning maturity stages during September.

Proportions of females at various maturity stages were calculated and compared (as proportion immature) for the juvenile cod and September surveys for 1990 to 1994. Assignment of maturity stages was much more consistent for the juvenile survey, the length at which 50% were mature varied between 35 and 38 cm and the ogives followed much the same shape between years (Figure 16). The ogives for the September survey were irregular in shape, which most likely indicates inconsistency between samplers in differentiating between immature and resting stages. In addition, the length at 50% maturity varied between 27 and 35 cm in the September surveys. Clearly the September survey does not provide consistent maturity data and the utility of analyses of year to year changes in size and age of maturity based on this survey is questionable.

3.2.4 Recruitment index

Although the time series is very short, the survey appears to be a useful independent index of year class strength for the southern Gulf of St. Lawrence cod stock. The utility of the series as an index of pre-recruit abundance was examined in a separate study (Hanson 1995 in press). A multiplicative model (Table 18) with age, year-class, stratum, and age*stratum effects appears to be the most promising index and is consistent with the results of the September survey (see section 4.1.1). The age*stratum interaction is a necessary part of the model because younger age-groups were consistently found in the shallowest strata and older age-groups in the deeper strata. This is illustrated in the least square means estimates of means for each stratum (Figure 17) where peak catches increased from age 2 in stratum 1 (8 to 16 fathoms deep) to age 5 in stratum 4 (32 to 40 fathoms deep).

In part due to the few years of data available, the estimates of year-class strength have very wide 95% confidence intervals (Figure 18), nevertheless, the means show the same pattern in year-class strength as shown in the index based on 1971 to 1994 data from the September survey. The year-class estimates declined from a maximum in 1987 (age 3 in the first year of the juvenile survey) to a minimum in 1992. The precision of the estimates of the most recent year-classes should improve as additional observations of their abundance are made in future surveys.

3.3 January 1995 survey

A groundfish-herring survey was conducted in Cabot Strait from January 10-29, 1995 on board the research vessel *Alfred Needler*. A similar but smaller survey was conducted in January 1994 (Chouinard 1994). The main objective of this survey was to determine the distribution and relative abundance of groundfish species and herring in the Cabot Strait area during the winter.

The survey design followed a grid pattern and covered waters deeper than 50 m. The survey extended from 45° 15' to 48° 05' North and from about 58° to 61° East. The survey proceeded in a north-south direction to minimize problems with ice. At each location, a standard 30-minute tow, using an Atlantic Western IIA trawl (with 19 mm liner in lengthening piece and codend), was conducted. Depth profiles of conductivity, temperature and oxygen concentrations were also done. A total of 166 sets were attempted, of which 164 were successful. No problems were encountered with ice and weather conditions were generally milder than in 1994.

3.3.1 Spatial Distribution of catches

A contoured map of the cod catches in kg per tow (Figure 19) show that the largest catches were made on the slope of the Laurentian Channel in 4Vn at depths of 200 to 300 m. A large catch of 2738 kg was made south of St. Paul's Island. Concentrations were also detected in 3Pn. There appeared to be a lower concentration of cod in the middle of the Channel than on both sides. This is consistent with previous observations of the occurrence of the two stocks found in the area in winter (Halliday and Pinhorn 1982). The distribution of catches was relatively similar to that observed in 1994 (Chouinard 1994) both in terms of area and depth. Concentrations in the southern section of 4Vn in 1995 were further north than in 1994.

3.3.2 Abundance

Mean numbers per tow and biomass estimates were compared with values for the same area covered in the 1994 survey (Chouinard 1994). These included strata 803 (4S), 407, 438 and 439 (4T), 415, 440, 441, 442 (4Vn) and 444 and 446 (northern 4Vs). The biomass estimate for these areas increased from 34,324 t in 1994 to 41,351 t in 1995. Mean numbers per tow for that area also increased by about 10% from 62.1 fish/tow (s.e. 29.8) to 69 fish/tow (s.e. 21.7).

Because of the potential mixing of several stocks in winter in this area, abundance estimates from this survey should not be considered as an index for the southern Gulf of St. Lawrence cod stock until the extent of the mixing is better understood.

3.3.3 Length frequency distribution

The relative length frequency distribution for cod in area 4T and 4Vn indicates a mode at around 40 cm (Figure 20) and is compared with the length frequency from January and September 1994. A mode was seen at around 31 cm in January 1994 and appears at around 34 cm in September 1994. In January 1995, there is a higher proportion of fish in the 35 to 40 cm range.

3.4 Cod condition

Both seasonal and annual conditon factors were examined. In recent years, there has been a debate in the literature as to which measures of condition are most appropriate. Bolger and Connolly (1989) concluded that various indicators, including the classic Fulton's condition index (K), can be satisfactory but that assumptions need to be checked. Some of the various indicators that he discussed included the Fulton's condition index, predicted weight at a given length and relative weight. Cone (1989) pointed out that Fulton's condition index has often been misused insofar as the assumption of isometric growth is not verified. In many cases, condition indices will be length-dependent. In this case, only populations with similar length distributions can be compared. In response to Cone (1989), others have presented a case for their favorite condition measurement (see Springer et al. 1990). The debate around the predicted weight estimates focuses around the issue of using either least squares regression or the geometric mean regression. Finally, the difficulty in using the relative weight index lies in the determination of the standard fish.

In the present analyses, two measures of condition indices were examined and compared. The first measure examined was Fulton's condition factor:

$$K = \alpha \frac{W}{L^3}$$

where K = Fulton's condition index
W = total weight (g) - (weight of stomach + weight of gonad), (annual indices from surveys used total weight (g))
L = fork length in cm
α = scaling factor to control the number of decimals (here 100)

The condition index was calculated for fish in the 40 to 50 cm range only to minimize problems of correlation between condition index and length. In the case of the seasonal condition indices which were calculated from total weight minus the weight of stomach and gonad, there was no relationship between condition index in all but three cases where the slope was marginally significant. The condition indices from the annual surveys used the total weight.

The second measure was the predicted weight of a 45 cm cod derived from least squares length-weight relationships:

$$W_{45} = aL^b$$

where W = predicted weight for a 45 cm fish
a and b = parameters of the length-weight relationship
L = length of fish (here 45 cm)

The two condtion indices were then compared.

3.4.1 Seasonal patterns in cod condition

Seasonal cod condition has been monitored since September 1991 in the southern Gulf of St. Lawrence. Originally, a monthly sampling regime was followed as closely as possible. With the closure of the directed cod fishery on September 1 1993, it has been difficult to obtain samples at certain times of the year. During 1994, samples were obtained in January, May, June, July, September and October as well as in January 1995. Because of the cod migration, samples originate from 4Vn in January, western Cape Breton in early spring and late fall and the western southern Gulf (4Tk and 4Tl) in summer.

Results of the analyses indicate that both condition indices were highly correlated (R^2=0.98) (Figure 21). The predicted weight for a 45 cm cod (minus stomach and gonad) ranged from a low of 650 g in the spring to 900 g in late fall, a difference of nearly 40% between the low and the high values. The Fulton condition index (Figure 22) shows that condition appears to have been lower in 1992 for the period examined. Condition indices in the fall of 1994 were the highest seen since 1991. There is a regular cycle of cod condition: cod attain their highest condition in the fall, usually in September-November. Condition then declines and reaches a minimum during the spawning season in May-June.

3.4.2 Annual Condition indices

Annual condition indices and weight of a 45 cm cod were calculated from the data collected during the September groundfish surveys. Relationships between condition factors and length were significant as sample sizes were very large. However, trends in condition using the two measures are highly correlated ($R^2 = 0.83$, $p < 0.0001$, Figure 23).

The annual condition indices calculated from the annual survey do not appear to correspond well with the seasonal samples obtained from the same survey. The condition indices from the annual survey probably suffer from several potential deficiencies and biases. First, the condition indices from the annual survey are calculated using total weight which can be affected by the degree of feeding of the animals and gonadal development. Secondly, the samples are collected during the entire survey and could be affected both by temporal and areal differences. This was not investigated in the present study but should be examined.

Another limitation with the annual condition indices is that with the pronounced seasonal variation in condition, samples originating from one period of the year will be sensitive to variations in the annual cycle. From the seasonal samples examined so far, it appears that cod are near their peak condition in September in most years. In 1993, however, condition increased and peaked in November. From this examination, we conclude that seasonal monitoring of condition (somatic weight) is likely to provide a more meaningful index of changes in condition than the annual values. Annual values may be sufficient to detect long-term trends but the problems associated with them should be kept in mind.

3.5 Sentinel fisheries

Multiple indices of stock abundance permit more accurate estimates of the population size of exploited fish species. The goals of sentinel fisheries in the southern Gulf of St. Lawrence are to use commercial vessels to:

(1) develop one or more independent indices of Atlantic cod abundance;

(2) monitor the timing of cod migration during autumn and spring;

(3) collect samples to monitor fish condition, maturity and time of spawning, diet, and interspecific interactions (especially competition); and

(4) enhance information exchange with fishers by having them directly involved in the data gathering process.

One project was funded for 1994, for mobile gear (Danish seines) in conjunction with the Association des Pêcheurs Professionnels Acadiens (APPA).

3.5.1 Survey Protocol for the 1994 Mobile Gear Project

The original plan was to have six sampling areas, three in the east and three in the west, to cover as much of the southern Gulf of St. Lawrence as possible. Due to funding limitations and late start, the project was scaled back to two boats covering the three sampling areas in the western Gulf. Six trips were done, about weekly, between 6 October and 15 November 1994 using two 65 foot Danish seiners (*Mars D* and *Wayne and Randy*). The choice of fishing gear and participating fishing vessels was made by the sponsoring organization (APPA).

Three sampling areas were selected in conjunction with the two boats' captains. Within each sampling zone, twenty 3 X 3 naut. mile fishing stations were identified by unique number. Prior to each of the six trips, each boat was assigned, at random, four stations within each sampling zone. The Danish seines were standardized, as much as possible, between boats and used 145 mm square mesh in the lengthening piece and cod end with 130 mm diamond mesh elsewhere. On trips two, four, and six, a 58 mm diamond mesh liner was used in the cod end. A standard set deployed 2,200 m of cable and covered an area of about 1 square naut. mile. Observer coverage was complete.

Sampling of the catch followed standard Gulf Region groundfish research survey protocols (Hurlbut and Clay 1990), the data were entered onto standard survey cards, and data were keypunched by the fishers into standard data files. Individual fish weights were not recorded at sea nor were otoliths collected. Length distributions were collected for Atlantic cod, American plaice, and white hake.

3.5.2 Results

Because the program was delayed and did not cover the entire southern Gulf, the goal of gathering data to develop an independent index of abundance could not be achieved, however, the study served as a pilot project that solved many of the technical and organizational problems inherent in setting up a new program. This experiecnce will simplify how the program is conducted during future years. The six trips completed showed the timing of the autumn 1994 migration and we obtained samples to monitor cod condition, diets, and maturity. The final goal, enhanced information exchange with fishers by means of their direct participation in the data gathering was accomplished.

Adverse weather prevented complete sampling of Chaleur Bay during trips 3 and 6. Consequently, this area was not included in the analysis of timing of the autumn migration. Nearly all of the cod catch was taken during the first two weeks. The catch at age was determined using an age-length key for the same area but collected during mid-September in the annual groundfish survey. The catches at age were included in the commercial fisheries data.

To examine the timing of the autumn migration, the catches were separated into catches of fish > 41 cm (6 trips) and fish < 41 cm (3 trips) because a liner was used during every second trip. The mean number per tow of cod > 41 cm from areas 1 and 2 increased from about 460 fish tow^{-1} during early October to 2400 fish tow^{-1} the following week and dropped rapidly to < 1 fish tow^{-1} by early November (Figure 24). The pattern for the juveniles (< 41 cm) was similar: the mean number per tow was 2,446 fish tow^{-1} on 13-15 October; dropped to 202 fish tow^{-1} on 23-25 October; and dropped further to 11 fish tow^{-1} on 13-15 November. Thus, the autumn migration from the western Gulf began during mid-October 1994 and was over before the end of October. The smaller fish appeared to leave slightly after the adults. Because there was no eastern component of the program, we do not know how long it took for the cod to travel to the eastern Gulf.

4. Analysis

4.1 Analysis of September Research Vessel Survey Results

4.1.1 Internal Consistency

One of the main objectives of the annual research vessel surveys is to obtain estimates of the abundance of different year-classes at successive ages. When the RV data are used in SPA calibration, each age group is treated as a separate index. Provided there is enough variation in year-class size, it is expected that the RV estimates of the same year-class but at different ages would be correlated. Examination of these correlations could suggest which age groups to use in both SPA calibration and analyses of the RV data on their own.

Correlations among the RV abundance estimates of the same year-classes at ages 0 to 15 were calculated and the significance of the correlations were plotted using shaded rectangles (Figure 25). The correlations were highly significant between adjacent ages from age 2 to 12, and between ages 13 and 14. In addition, the correlations were significant among several ages (i.e. ages 2 to 6, 4 to 12, etc.). This indicates that variations in year-class strength begin to be consistently picked up at age 2 in this survey. In addition, the year-class signals persist throughout most of the adult life of the stock (age 4-12). Sample sizes at younger (ages 0 and 1) and older (13+) ages are probably too small to provide quantitative information on year-class strength.

4.1.2 Total Mortality

The RV mean numbers per tow at age (Table 10) were analyzed using a multiplicative model to obtain information on trends in total mortality (Sinclair et al. 1994, sec. 6.4). The model was

$$\ln A_{ij} = \beta_0 + \beta_1 \mathbf{I} + \beta_2 \mathbf{J} + \varepsilon \qquad 1)$$

where A_{ij} = the RV index at age i and year-class j
$\mathbf{I}$ = a matrix of 0 and 1 indicating age
$\mathbf{J}$ = a matrix of 0 and 1 indicating year-class

Analyses were conducted on data for ages 2-10 and on 5-year moving windows of the dataset. The predicted least square mean catch at age from each analysis was taken to represent a catch curve for that period, with year-class effects removed. The slope of the catch curve from age 6-10 was used as an estimate of the mean total mortality for that time period.

There were 20 separate analyses. In all cases both the age and year-class effects were highly significant ($p < 0.01$) and the R^2 values were in excess of 0.9.

The pattern of total mortality was similar to that estimated in the last assessment (Sinclair et al. Fig. 29). Z varied between 0.8 and 0.45 in the early 1970's to late 1980's (Figure 26). There was a sharp increase in 1990 to levels greater than 1.0. However, the Z estimates declined again in the last 5-year period.

4.1.3 Year-class Strength

Multiplicative analyses were also used to examine trends in relative year-class strength. These analyses were done for two reasons. The first was to obtain an index of incoming recruitment for catch projections. The second was to examine trends in pre-recruit mortality in a manner that is independent of commercial fisheries data. Myers et al. (1995) used such an analysis in an investigation of the causes for the recent decline in the major cod stocks in eastern Canada, including 4TVn cod. They concluded that excessive fishing and the subsequent discarding of pre-recruits was a principal cause of the decline. Their conclusions are re-examined using the revised RV population index.

In previous assessments, 2 different models were used to obtain an index of incoming recruitment for catch projection purposes. One used the results of the analysis described above. In this case, all the predicted age two ln mean catches per tow for each year-class covered by the 5-year analyses were averaged. The back-transformed means were used as a recruitment index. In the second analysis, the input data were the mean catches per tow at age (2-7) and stratum (Sinclair and Chouinard 1992) for the years 1978-94. A multiplicative model with additional terms for strata (K) and age*stratum interactions was used (Sinclair et al. 1994). The interactions term was necessary because the age groups are not proportionally distributed among strata.

$$\ln A_{ijk} = \beta_0 + \beta_1 \mathbf{I} + \beta_2 \mathbf{J} + \beta_3 \mathbf{K} + \beta_4 \mathbf{K} * \mathbf{I} + \varepsilon \qquad 2)$$

The back-transformed least square mean year-class estimates were used as an index of year-class strength.

A potential difficulty with this analysis is that a single age-effect is estimated. Changes in survival at age due to variations in either natural or fishing mortality will be confounded with year-class effects. For example, if two year-classes are of identical abundance but one experiences higher fishing mortality than the other, the mean catch per tow of the heavily fished year-class in the RV survey will be less. Consequently, the year-class estimate from the heavily fished year-class from the multiplicative analysis will be less that that of the lightly fished year-class. The 5-year moving window analysis indicates that there have been important trends in total mortality of cod in the southern Gulf. The potential confounding effect of variations in fishing mortality on year-class estimates may be avoided by restricting the multiplicative analysis to ages not heavily exploited commercially.

A third set of multiplicative analyses was used to test whether there had been differential mortality among year-classes sampled by the RV survey. Two multiplicative analyses with age and year-class effects (equation 1) were conducted on all years in the time series, the first was restricted to pre-recruit ages 2 and 3, and the second used the recruiting ages 4, 5, and 6. The difference in the least square mean estimates of the ln catch per tow of each year-class was taken as an estimate of the relative total mortality (Z') between these two age groups. Consider that the instantaneous total mortality of a year-class from age group 2-3 and 4-6 is

$$Z = \ln(N_{2-3}) - \ln(N_{4-6}) \qquad 3)$$

Let

$$Z^r = J_{2-3} - J_{4-6} \quad 4)$$

where J_{2-3} = the least square mean estimate (ln scale) of the year-class from the multiplicative analysis of ages 2-3

The RV catchability of the two age groups is different; let s be the catchability of ages 2-3 and k be the catchability of ages 4-6. Then equation 3 may be written

$$Z = \ln(s) + J_{2-3} - \ln(k) - J_{4-6} \quad 5)$$

The difference between the absolute and relative Z is a scalar, i.e. the ln ratio of the catchabilities. Changes in Z^r through time would be equivalent to changes in absolute Z.

Both the age and year-class effects were highly significant ($p < 0.01$) in the age 2-3 and 4-6 analyses, the R^2 values were 0.89 and 0.91 respectively, and the residuals were normally distributed.

The four indices of relative year-class strength are shown in Figure 27. The upper two panels correspond to estimates presented by Sinclair et al. (1994, Figure 30). Differences in the trends between the current and previous analyses are mostly due to modifications to the RV time series (section 3.1.1). While the trends are similar, the estimate of the 1975 year-class from the 5-year analysis is quite different. In last year's analysis this year-class was estimated to be about average in abundance and in the current analysis it is one of the largest. The addition of the fixed stations to the RV index resulted in increased estimates of young cod in 1977-78, and this has resulted in increased estimates of the 1975 year-class. Sinclair et al. (1994) noted that both the SPA and the multiplicative analysis of mean catch per tow and stratum estimated the 1975 year-class to be above average in abundance while it was below average in the RV index at age. The revision of the RV index seems to have overcome this difference.

There are large differences in the estimates of the 1985-87 year-classes among the four series. They are above average in abundance in the age 2-3 analysis, about average in the 5-year analysis, and below average in the age-stratum and ages 4-6 analyses. The estimates were higher (relative to the series) when younger ages were used in the analyses. Differences in the ln year-class estimates between the age 2-3 and age 4-6 analyses indicates that the 1985-87 year-classes experienced the highest total mortality of all year-classes considered (Figure 28). The difference in the relative Z indicate that the 1985-87 year-classes experienced, on average, a total mortality 0.75 greater than the three previous and three following year-classes. In the normal scale, this suggests that only half as many of the 1985-87 year-classes survived from age 2-3 to age 4-6 as did the three year-classes before (1982-84) and after (1988-90).

4.2 Sequential Population Analysis (SPA)

4.2.1 Laurec-Shepherd and XSA

In the 1993 and 1994 assessment of this stock, SPA was calibrated with the research vessel and otter trawl CPUE abundance indices using a variety of methods including

ADAPT (Gavaris 1988), Laurec-Shepherd, XSA and the Hybrid method (Darby and Flatman 1994). The calibrations using the Hybrid method were used to derive the final fishing mortality and population numbers because they did not suffer from the retrospective problem (Sinclair et al. 1994). This method allows for a trend in the catchability of the abundance indices. For a unique solution to be possible, at least one abundance index should not present a significant trend in catchability. Swain et al. (1994) examined changes in catchability for the two abundance indices. They found that catchability for the RV index was lower in the early- to mid-1970's but was relatively stable during the 1980's, and that the CPUE catchability increased steadily from the early-1980's to the present. As a result of this work only the research survey results from 1978 to the present were used in calibrations and the Hybrid method was used to estimate a trend in catchability for the otter trawlers' index.

In this year's assessment, no CPUE index could be calculated for the otter trawler or other commercial fleet because of the closure in the directed fishery. The Lowestoft assessment package used in previous years could not be used because it is not designed to handle missing data in Hybrid analyses. Consequently, Laurec-Shepherd and XSA analyses were conducted using only the RV index from 1978-1994 and ages 3 to 12. In both analyses, no special options (i.e. weighting, shrinking) were used. The fishing mortality on the oldest age was set at the arithmetic mean of the 5 previous age groups and full recruitment was assumed for ages 9 and over. For both analyses retrospective calculations were conducted.

The diagnostics for the Laurec-Shepherd are shown in Table 19. They indicate full recruitment to the survey at age 5. The residual pattern is somewhat unbalanced with several negative residuals in the first few years. In most other cod surveys, the population estimates from surveys are lower than the SPA estimates. In this case, however, the catchability coefficients indicate that the survey estimates are greater than the SPA estimates. Similar results were found with the XSA analysis (Table 20) .

Retrospective caluclations did not indicate a strong pattern in the last 5 years (Figure 29), however only the XSA analyses with 1991, 1992, 1993 and 1994 terminal years converged. Estimates of the 7-12 mean F in the Laurec-Shepherd analyses were tightly grouped, except for the 1992 terminal year, with no apparent bias. The age 4+ abundance estimates were relatively stable in all analyses except the 1989 terminal year.

Both analyses suggest fishing mortalities in the range of 0.04 to 0.05 in 1994 (Tables 21 and 23). Population numbers in 1993 and 1994 remained stable but at the lowest level observed. The estimates of the 1990 and 1991 year-classes are poor (about 1/10 of the 1980 year-class) (Table 22 and 24).

4.2.2 ADAPT

The adaptive framework (ADAPT) (Gavaris 1988) was used as the basis for a third SPA of southern Gulf cod. Two stock abundance indices were used, the RV results from 1971-94, and the commercial CPUE at age series for 1982-93 (see Sinclair et al. 1994). The standard SPA calibration models assume proportional relationships between the estimated population abundance and the indices. However, in previous assessments this assumption has been questionned. The Hybrid model allows for a temporal trend in the catchability of one index fleet and this model has been used for southern Gulf cod in the past. The Hybrid model was cast in ADAPT by estimating one parameter of increasing catchability (δ) that was applied to all ages in the following manner:

$$U_{ik} = (q_i + \delta k)N_{ik}$$

where U_{ik} = the CPUE at age i in year k
q_i = the catchabiity at age I
N_{ik} = the SPA estimate of numbers at age i in year k

Secondly, recent research has suggested that the research survey catchability is density dependent and increases as the population increases (Swain et al. 1994, Sinclair et al. 1994, section 7.3). The ADAPT formulation was modified to accomodate this type of relationship by using the following relationship:

$$A_{ik} = a_i N_{ik}^{b_i}$$

where a and b are parameters describing the density dependent relationship. The modified Hybrid and density dependent RV ADAPT formulation is:

Parameters

Terminal N estimates:

N_i,1995, i=4 to 13

Calibration coefficients:

a_i i=3 to 10
b_i i=3 to 10
q_i i=5 to 12
δ

Structure Imposed:

Error in catch at age assumed negligible
PR on ages 14 and 15 in 1994 = 1.0
F on oldest age equal to average at ages 9-10
M=0.2

Input:

C_{ik} i=3 to 15, k=1971-1994
A_{ik} i=3 to 10, k=1971-1994
U_{ik} i=5 to 12, k=1982-93

Objective function:

Minimize sum of squared residuals

Summary:

Number of observations:

112 from RV
96 from CPUE

Number of Parameters
35

The use of the density dependent RV calibration relationships and Hybrid CPUE rather than the traditional linear relationships resulted is an improved calibration fit. The estimates for the exponents in the density dependent RV calibration model are greater that 1.0 for all ages except age 3, suggesting that catchability is density dependent (Table 25). The linear trend in the Hybrid CPUE calibration was positive and significantly greater than zero. The pattern of residuals over time from the ADAPT calibrations also indicated an improved fit (Figure 30). For the RV results the following features were common to both treatments; the 1971-72 residuals were mainly negative suggesting relatively low catchability in these years, the 1981 residuals were all positive suggesting catchability in this year was abnormally high, and there was a step increase in residuals in 1988 followed by a decline to the most recent year. (The trend in RV residuals since 1988 was also evident in the XSA and LS calibrations (Tables 19 and 20)). The residual pattern differed in the period 1973-87. When the linear model was used, there was an increasing trend in residuals while when the density dependent model was used there was no trend. This is consistent with the hypothesis that RV catchability is density dependent. The average population size in the 1980's is estimated to be about three times larger than the population in the 1970's. Using a linear relationship between the RV and SPA when the true relationship was density dependent would produce such a trend in residuals. However, the density dependent calibration did not eliminate the pattern evident in 1971-72, 1981, and 1988 to the present. In a later section (5.2) we present evidence that the SPA results from the recent period may be biased by misreporting of catches and this could produce the residual pattern seen. Further investigation of the causes of these problems is warrented. The CPUE residuals increased from 1982 to 1992, the second last year in the series, then declined in 1993. The trend in the CPUE residuals was reduced using the Hybrid model.

A retrospective analysis of the SPA F (ages 7-12) and N (ages 4+) estimates from the Hybrid/density dependent calibration indicated a relatively strong pattern where F's increased and N decreased as more years are added to the analysis (Figure 29). However, the estimates in the last three years were much more consistent than those obtained for the late 1980's.

The fishing mortalities and population numbers from the ADAPT calibration are given in Tables 25-27.

4.3 Direct estimates of F

Sinclair et al. (1994, Section 7.2) described a new method for examining trends in fishing mortality using a relative estimate of fishing mortality obtained from the ratio of catch at age divided by the RV population estimates at age. The analysis was repeated here with the revised RV time series and the addition of the 1994 data.

The matrix of relative F at age was smoothed with a multiplicative analysis with age and year effects (ages 7-11, 1971-94) and with an analysis of covariance where age was treated as a cubic covariate (same ages and years). In both analyses the models explained a high percentage of the total variance ($R2 = 0.87$ for the multiplicative analysis, 0.98 for the analysis of covariance), all main effects were highly significant ($p < 0.0001$) and the residual distributions were not significantly different from normal.

The trends in relative F were very similar to those obtained last year (Figure 31 and Figure 34 in Sinclair et al. 1994). The fishing mortalities were very high in the early 1970's followed by a sharp decline at the time of extended fisheries jurisdiction in 1977. The relative F was stable in most of the 1980's but increased sharply beginning in 1988 until a peak in 1992. With the closure of the cod fishery in September 1993 the relative F dropped to the lowest level previously seen and with the continuance of the closure, the relative F declined more in 1994.

5. Assessment Results

5.1 Abundance, Biomass, Fishing mortality

All three SPA analyses provide a similar view of the state of the stock. Population abundance, total and spawning biomasses were low in the mid-1970's (Figure 32) then rapidly increased until the mid-eighties and declined since. With the closure of the fishery in 1993, the decline in abundance has stopped but biomass is close to the lowest level observed. Fishing mortality averaged approximately 0.6 up to 1988 but then increased to around 1.0 in 1992. Fishing effort was reduced markedly in 1993 with the closure of the fishery. The catch of slightly above 5,000 t in 1993 resulted in a fishing mortality near the $F_{0.1} = 0.2$ reference level. The further decrease in effort in 1994 resulted in a decline in F. Fishing mortality for 1994 is estimated at between 0.02 to 0.05 depending on the analysis.

5.2 Recruitment

The increase in population abundance in the late 1970's was due to the appearance of the large 1974 and 1975 year-classes. These were followed by two more above average year-classes, the 1979 and 1980 which supported the fishery through most of the 1980's.

The results of the RV analysis (Section 4.1) suggest that the 1985-87 year-classes experienced significantly higher total mortality than the three year-classes before and after. The most likely cause is increased exploitation in the late 1980's and early 1990's. This exploitation significantly depleted the 1985-87 year-classes and their potential contribution to the commercial stock. The period of high total mortality corresponds to the years with the highest fishing effort, 1989-92 (Figures 4 and 28). That Z^r declined on the 1988-90 year-classes corresponds with the increases in mesh size and reduced fishing in recent years. Based on current information, it is unlikely that Grey seal predation was the main cause of this trend in pre-recruit total mortality. Grey seal abundance in the Gulf of St. Lawrence is believed to have been increasing exponentially for several decades. Gut analysis indicates that most of the cod eaten by Grey seals are of pre-recruit sizes. Hammill and Mohn (1994) estimated Grey seal consumption of southern Gulf cod using a model that assumed cod was a constant fraction of the Grey seal diet. The results indicated that the tonnage of cod consumed also increased exponentially from 1970-93 (Hammill and Mohn (1994), Figure 2). This is inconsistent with the trend of total mortality of pre-recruit cod estimated from the RV results where there was a large increase on the 1985-87 year-classes, followed by a marked reduction. It is also unlikely that unfavorable environmental conditions are primarily responsible for this pattern. The most severe environmental indicator in the southern Gulf of St. Lawrence is the area of the sea bottom in contact with the cold intermediate layer (Chouinard and Swain 1994). This index has had its highest values in the period 1990-94 when the 1985-87 year-classes were at least half way through their pre-recruit years and during the pre-recruit period of the 1988-90 year-classes (Chouinard and Swain 1994, Figure 9).

These results are different than last year when it was concluded that the decline in the stock was caused by reduced recruitment and exacerbated by increased fishing. There are two likely reasons for the earlier impression. The first is that the catch data used in SPA are possibly biased in that they do not include discards. A comparison of the relative total mortality from the RV analysis and estimates of Z from SPA support this (Figure 33). The RV analysis indicates a much greater increase in total mortality than the SPA. The RV residuals in the SPA calibration are also abnormaly high in the late 1980's indicating that there is insufficient catch at age in the SPA to match the high population estimates in the research survey (Figure 34). A second reason is that the previous recruitment indices derived from the RV survey included ages exploited by the fishery. Important assumptions of the analytical model, that the exploitation rate and pattern were constant during the period covered by the analysis, were violated. The analysis used last year included ages 2-7 and it is likely that the estimates of the size of the 1985-87 year-classes were biased downwards by their high exploitation in the period 1989-92. We now conclude that the decline of biomass of the stock was driven more by increased exploitation.

This does not change the conclusion that year-classes produced in the 1990's are well below average in abundance. There is no indication of improvement.

5.3 Yield Projections

Catch projections were conducted with the population estimates from the ADAPT, LS, and XSA calibrations. The 1992 year-class age 3 abundance at the beginning of 1995 was set at 20-million based on a prediction from the research survey. There is currently no information available on the abundance of the 1993 year-class, however its abundance was set at 20 million at age 3 since all recent year-classes have been in this range. This year-class will contribute very little to catch projections to 1996. Weights at age were calculated as the average from 1992 to 1994. Partial recruitment was derived from fishing mortalities in the period 1992 to 1994 from the ADAPT analysis with full recruitment at age 9. In the absence of a TAC, but given that catches of cod in 1995 will likely occur as by-catch in other fisheries and in the recreational fisheries, it was assumed that catches in 1995 would be similar to 1994 (1,300 t). The input data for projections are given in Table 28.

A 1995 catch of 1,300 t would correspond to a fishing mortality of 0.017-0.025, depending on the SPA calibration used (Table 29). Spawning biomass would increase between 1995 and 1996 under all scenarios. The estimated $F_{0.1}$ catches in 1996 were between 11,000 t and 16,000 t, but this would result in a decline in spawning biomass between 1996 and 1997 of between 5% and 9%. The spawning biomass would remain stable for catches between 6,000 t and 8,000 t. If there was no catch in 1996, the projected increase in spawning biomass was between 6% to 10%.

5.4 Future Prospects

Prospects for a firm and steady stock recovery continue to be bleak. Biomass and stock abundance are currently very low, close to the lowest previously observed for this stock.

Recruitment has been poor in recent years; the 1988-92 year-classes are all estimated to be well below average in abundance. Growth continues to be below average. Although the closure of the fishery in 1993 has halted the precipitous decline which started in the mid-1980's and there are signs of increased adult biomass, fishing mortality must remain well below $F_{0.1}$ for this to continue.

The current management system did not prevent the high level of fishing that was exerted on this stock in the 1989-92 period and the ensuing stock crash. Only one quarter of the fishing effort will be required to harvest the resource if it does recover (Sinclair et al. 1994). In the initial years of the recovery fishing should occur well below this level. Heavy fishing and discarding of above average year-classes in the late 1980's and early-1990's was an important cause of the current status of the resource. Evidence is presented here and in the previous assessment that despite new regulations requiring landing of all cod catches, discarding of small fish continues in some areas within the southern Gulf. Reopening the fishery to the same fishing fleet and using the same management approach as before will likely result in immediate overfishing of the stock.

5.5 Uncertainties

During the late 1980's and early 1990's, DFO assigned a number of task forces to examine problems related to the exploitation of groundfish resources on the Atlantic coast of Canada. Most of these studies (Haché 1989; Martin 1990; Marshall 1990; Cashin 1993; Harris 1990) concluded that wasteful practices were widespread and represented a threat to the stocks in Atlantic Canada. For the Gulf of St. Lawrence, discarding was seen as a significant conservation problem (Martin 1990).

Unknown discarding practices particularly in the late 1980's and early 1990's probably have had an effect on the results of some of our analyses. This is apparent in the results of a comparison between estimates of Z derived from RV data only and those from SPA (section 5.1). The discarding probably affects ages 3 and 4 primarily and catch at age for these 2 age-groups should be seen as underestimates of the removals. This problem could be further investigated using simulations.

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Table 1: Landings (t) of southern Gulf of St. Lawrence cod, 1965-94. The column "stock" is the total for 4T, 4Vn (J-A), 4Vn (N-D), and 4Vs. The TAC's apply to the traditional management unit, 4TVn (J-A).

Year	4T	4Vn(J-A)	4Vn(N-D)	4Vs	Stock	4TVn(J-A)	TAC
65	46471	16556	2077		65104	63027	
66	38282	16603	2196		57081	54885	
67	34245	7071	2096		43412	41316	
68	37910	8641	2440		48991	46551	
69	40905	6914	2442		50261	47819	
70	43410	21055	1523		65988	64465	
71	40669	15706	1556		57931	56375	
72	42096	25704	1517		69317	67800	
73	25756	24879	1308		51943	50635	
74	28580	20167	1832		50579	48747	63000
75	28853	13618	795		43266	42471	50000
76	17600	15815	3928		37343	33415	30000
77	19536	2683	4665		26884	22219	15000
78	25453	12439	1128		39020	37892	38000
79	46695	9301	1700		57696	55996	46000
80	36157	18477	2592		57226	54634	54000
81	48132	17045	1970		67147	65177	53000
82	43418	14775	3476		61669	58193	60000
83	48222	13073	2695		63990	61295	62000
84	40652	14712	2200		57564	55364	67000
85	47819	14319	1835		63973	62138	67000
86	48066	15709	1444	3463	68682	63775	60000
87	43571	7555	1437	2029	54592	51126	45200
88	44616	7442	1165	2496	55719	52058	54000
89	43617	9191	1887	2574	57269	52808	54000
90	41552	9688	2031	4606	57877	51240	53000
91	31938	6781	1830	8911	49460	38719	48000
92	27899	6782	2282	4164	41127	34681	43000
93	4168	1015	56		5239	5183	13000
94	1150	137	1		1288	1287	

Table 2: Landings (t) by gear of the southern Gulf of St. Lawrence cod stock, 1965-94.

Year	Otter trawl	Seines	Gillnets	Longlines	Handlines	Misc.	Total
1965	48854	2735	3571	4713	0	5231	65104
1966	37023	2444	9414	3062	0	5138	57081
1967	24823	2293	9948	2536	2469	1343	43412
1968	29553	1064	12933	1344	2942	1155	48991
1969	28131	1234	9581	5014	5066	1235	50261
1970	43652	1798	9786	6258	3205	1289	65988
1971	36338	2267	9676	3600	4011	2039	57931
1972	50615	2121	7896	1792	2103	4790	69317
1973	36467	2137	8223	925	2135	2056	51943
1974	35815	1768	6141	1352	1292	4211	50579
1975	29080	1983	6330	245	3530	2098	43266
1976	28928	1384	4459	163	1191	1218	37343
1977	14695	3269	5931	692	1299	998	26884
1978	22669	4504	8929	1015	1449	454	39020
1979	31727	8845	12022	1622	1957	1523	57696
1980	32698	10095	4260	2827	1562	5784	57226
1981	34509	12563	4053	7017	1061	7944	67147
1982	32242	11360	4205	5481	916	7465	61669
1983	32880	13857	3010	4754	1286	8203	63990
1984	32316	10732	6891	5058	1903	664	57564
1985	40177	11935	5287	4261	2078	235	63973
1986	41653	15380	4328	5314	1975	32	68682
1987	31961	9759	4792	5926	2106	48	54592
1988	34055	12017	3936	4074	1602	35	55719
1989	34260	15492	2796	3396	1190	135	57269
1990	37354	14094	1962	3289	1048	130	57877
1991	35216	9282	1679	2502	778	3	49460
1992	28408	8660	1263	1890	875	31	41127
1993	2038	346	1301	845	703	6	5239
1994	206	408	295	105	120	154	1288

Table 3: 1994 southern Gulf cod landings by main species and gear.

Main Species	Fixed	Gillnet	Handline	Longline	Trawl	Seine	Unknown	Total
Unknown	0	0	0	0	1	0	0	1
Cod	4	200	109	77	15	281	119	805
Redfish	0	0	0	0	154	1	0	156
Halibut	0	0	0	3	0	0	1	4
Plaice	0	3	0	0	16	101	1	121
Yellowtail	0	0	0	0	0	5	0	5
Witch	0	0	0	0	2	15	0	17
Winter Flounder	0	6	0	0	16	0	0	22
Turbot	0	2	0	0	1	0	10	13
Flounder	0	0	0	0	0	1	0	1
Pollock	0	0	0	0	0	1	0	1
White Hake	0	25	1	14	1	2	0	43
Herring	0	5	0	0	0	0	0	5
Mackerel	0	12	8	2	0	0	18	41
Skate	0	0	0	2	1	0	0	3
Dogfish	0	42	2	6	0	0	0	51
Shrimp	0	0	0	0	0	0	0	0
Total	4	295	120	105	206	408	149	1288

Table 4: Age-length keys used in the calculation of the 1994 catch-at-age for southern Gulf of St. Lawrence cod.

KEY	FISHERY	SAMPLES	SAMPLE SIZE PORT	SAMPLE SIZE OBSERVER	TOTAL	CATCH (t)
1	OTB JAN-APR	(4Vn) JAN-APR OTB LENGTHS	981	6408	7389	135.826
		JAN-APR OTB AGES	53	28	81	
		JAN RV SURVEY AGES	640			
2	OTB APR-JUNE	APR-JUNE OTB LENGTHS	0	1637	1637	10.506
		APR-JUNE OTB+SNU AGES	518	292	810	
3	OTB JULY-SEPT	JULY-SEPT OTB LENGTHS	0	1275	1275	45.999
		JULY-SEPT OTB+SNU AGES	50	103	153	
		SEPT RV SURVEY AGES	2921			
4	OTB OCT - DEC	OCT-DEC OTB LENGTHS	175		175	13.740
		OCT-DEC OTB+SNU AGES	217		217	
		SEPT RV SURVEY AGES	2921			
5	SNU APR-JUNE	APR-JUNE SNU LENGTHS	1356	1240	2596	56.555
		APR-JUNE SNU AGES	518	160	678	
6	SNU JULY-SEPT	JULY-SEPT SNU LENGTHS	79	117	196	23.565
		JULY-SEPT OTB+SNU AGES	50	76	126	
		SEPT RV SURVEY AGES	2921			
7	SNU OCT - DEC	OCT-DEC SNU LENGTHS	619	162	781	62.716
		OCT-DEC OTB+SNU AGES	217		217	
		SEPT RV SURVEY AGES	2921			
8	GNS APR-OCT	APR-OCT GNS LENGTHS	572	1909	2481	261.930
		APR-OCT GNS AGES	374	2	376	
9	LLS MAY-NOV	MAY-NOV LLS LENGTHS	527	1207	1734	105.349
		MAY-NOV LLS AGES	231		231	
		SEPT RV SURVEY AGES	2921			
10	LHP JUNE-OCT	JUNE-OCT LHP LENGTHS	225		225	120.363
		JUNE-OCT LHP AGES	52		52	
		SEPT RV SURVEY AGES	2921			
11	LAST RIDGE ROPE	OCT-NOV SNU LENGTHS		70822	70822	220.859
		SEPT RV SURVEY AGES	2921		2921	
12	SENTINEL FISHERY	OCT-NOV SNU LENGTHS		9846	9846	42.720
		SEPT RV SURVEY AGES	629		629	
	UNSAMPLED CATCH					188.025
	TOTAL CATCH					1288.153

ABBREVIATIONS: OTB=otter trawl, SNU=seines, GNS=gillnets, LLS=longlines, LHP=handlines

Table 5: Landings at age by gear and time period, 1994. The age-key numbers correspond with Table 4.

Key	1	2	3	4	5	6	7	8	9	10	11	12		
Gear	OTB	OTB	OTB	OTB	SNU	SNU	SNU	GNS	LLS	LHP	LRR	SENT	Unsamp	Total
Quarter	1	2	3	4	2	3	4	2-4	2-4	2-4	4	4		
Age														
3	61	31	2115	9	521	22	187	3020	747	315	3887	13169	4116	28199
4	3188	441	4571	262	1034	572	913	5773	3336	3145	11715	10741	7809	53500
5	4977	1311	7342	1068	2257	2075	3484	6661	8566	9986	24270	9215	13880	95090
6	29259	2287	11513	2635	5025	4637	9778	12964	17808	22888	45681	11348	30050	205872
7	58511	2751	10302	3116	8814	4917	14529	24496	22453	28570	47478	8756	40112	274806
8	17862	1289	4936	1559	6435	2609	7856	33051	11896	14792	22670	2201	21733	148889
9	1629	405	1816	723	3471	1093	3666	20514	5380	6310	11258	1160	9815	67241
10	128	175	701	343	1691	397	1674	7664	2037	2226	4977	393	3830	26237
11	322	167	463	192	1629	329	1236	4256	1543	1726	3233	778	2713	18589
12	992	59	148	55	384	132	355	1915	624	545	1035		1067	7313
13	1122	40	88	45	195	79	247	359	350	499	609		621	4253
14		2	52	20	102	27	76	457	179	148	249	50	233	1596
15		17			109								22	148
16+		4			41								8	53
Total	118051	8978	44049	10027	31708	16888	44002	121130	74921	91150	177063	57812	136008	931787

OTB Otter Trawl
GNS Gillnet
SNU Seine
LLS Longline
LHP Handline
SENT Sentinel Fishery
LRR Last Ridge Rope Experiment

Table 6: Mean weight (kg) at age by gear and time period.

Key	1	2	3	4	5	6	7	8	9	10	11	12	Average
Gear	OTB	OTB	OTB	OTB	SNU	SNU	SNU	GNS	LLS	LHP	LRR	SENT	weight
Quarter	1	2	3	4	2	3	4	2-4	2-4	2-4	4	4	(kg)
Age													
3	0.263	0.349	0.362	0.654	0.342	0.627	0.411	0.398	0.462	0.509	0.384	0.329	0.357
4	0.561	0.507	0.518	0.737	0.529	0.694	0.641	0.649	0.604	0.659	0.572	0.501	0.570
5	0.619	0.737	0.723	0.876	0.828	0.818	0.940	0.878	0.829	0.847	0.772	0.712	0.786
6	0.930	0.877	0.942	1.044	1.092	0.984	1.172	1.528	1.083	1.038	0.986	0.916	1.039
7	1.194	1.234	1.304	1.433	1.604	1.504	1.460	2.173	1.537	1.433	1.417	1.175	1.449
8	1.434	1.581	1.558	1.751	2.012	1.906	1.580	2.464	1.796	1.637	1.653	1.404	1.856
9	2.168	1.886	1.611	1.940	2.381	2.109	1.849	2.769	1.965	1.797	2.027	1.443	2.250
10	2.426	2.237	1.702	1.884	2.907	2.080	1.789	2.494	2.139	1.695	1.956	1.368	2.178
11	2.226	2.413	1.710	1.914	3.240	2.452	2.016	3.227	2.042	1.810	2.255	1.827	2.493
12	1.803	1.967	2.470	1.992	3.111	2.721	2.316	2.554	2.516	2.260	2.485		2.406
13	1.684	2.204	1.942	2.026	2.741	2.115	1.889	2.791	2.005	2.061	1.990		2.023
14		5.088	2.042	2.105	3.759	2.226	1.776	2.426	2.145	1.954	2.018	2.425	2.307
15		1.916			2.451								2.379
16+		17.064			13.172								13.518
All	1.151	1.171	1.044	1.370	1.783	1.395	1.425	2.162	1.406	1.321	1.247	0.758	1.384

Table 7: Mean length (cm) at age by gear and time period, 1994.

Key	1	2	3	4	5	6	7	8	9	10	11	12	Average
Gear	OTB	OTB	OTB	OTB	SNU	SNU	SNU	GNS	LLS	LHP	LRR	SENT	length
Quarter	1	2	3	4	2	3	4	2-4	2-4	2-4	4	4	(cm)
Age													
3	31.00	34.00	34.10	41.67	33.38	41.10	35.58	35.36	37.01	38.31	34.75	0.33	16.04
4	39.53	38.17	38.32	43.26	38.49	42.39	41.08	41.18	40.35	41.60	39.57	0.50	30.71
5	40.80	42.98	42.61	45.61	44.45	44.62	46.51	45.22	44.60	45.00	43.62	0.71	39.08
6	46.38	45.41	46.43	48.05	48.68	47.12	49.95	53.59	48.54	47.98	47.10	0.92	44.89
7	50.36	50.75	51.57	53.01	55.02	53.52	53.62	60.99	54.30	53.09	52.72	1.17	51.36
8	53.39	54.84	54.62	56.35	59.20	58.09	55.09	63.79	57.19	55.55	55.53	1.40	56.78
9	60.38	58.18	55.22	58.21	62.49	59.94	57.50	66.27	58.86	57.13	58.94	1.44	60.24
10	64.00	60.73	56.08	58.10	66.02	59.74	57.04	63.83	60.29	56.33	58.51	1.37	59.72
11	62.19	62.38	56.63	58.54	68.41	63.14	58.99	69.53	59.63	57.65	61.03	1.83	60.42
12	57.63	57.95	63.49	59.87	67.39	65.88	62.15	64.79	64.08	61.99	63.65		63.04
13	54.68	57.76	59.34	60.14	64.25	60.90	58.90	67.00	59.90	60.41	59.82		59.20
14		80.53	60.16	60.80	71.49	62.00	57.51	64.00	61.20	59.29	59.93	2.42	60.11
15		58.88			63.71								63.05
16+		121.00			109.43								110.46
All	49.42	49.04	47.20	51.91	55.67	51.88	52.88	59.97	52.21	51.42	49.93	0.76	48.49

Table 8: Landings at age ('000) of southern Gulf of St. Lawrence cod, 1971-94. The table includes landings in 4T, 4Vn(Nov.-Apr.), and 4Vs (Jan.-Apr.).

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1971	6	2099	7272	9262	5916	2331	1251	520	130	354	75	120	154	68	29558
1972	3179	22247	12018	6666	7561	3551	952	547	372	120	51	14	47	38	57361
1973	1374	6999	14498	5325	3720	2800	1861	557	338	100	69	47	12	24	37723
1974	2993	5400	5033	9690	3102	1854	1772	1054	260	198	81	29	6	19	31490
1975	1567	8910	6933	2540	3297	1319	1119	801	680	151	53	76	7	67	27519
1976	508	4093	9996	6975	1708	1257	478	285	148	145	47	17	12	10	25679
1977	659	4960	5899	3320	1773	400	284	182	114	50	53	10	4	5	17712
1978	548	10037	10897	4596	2681	1108	244	248	110	72	44	5	13	6	30610
1979	148	5138	15913	11251	3509	1724	865	295	253	66	33	17	16	8	39235
1980	295	1920	14674	14142	9789	1522	808	404	143	30	18	8	14	26	43793
1981	98	3829	7380	19144	13116	6200	913	463	203	71	89	2	14	4	51526
1982	518	1621	10671	8700	12539	7663	2533	444	142	76	5	2	2	1	44917
1983	42	1147	6311	12124	11936	7646	5379	2668	139	51	18	10	5	5	47481
1984	30	1319	4210	7410	9085	6949	5173	2937	942	151	52	7	5	9	38278
1985	175	1561	10307	17163	8342	6094	3975	2277	971	353	26	6	8	6	51265
1986	136	3546	8295	23645	9739	4069	3041	2372	1197	803	159	19	3	2	57027
1987	80	1029	7400	10851	18933	7011	2250	1684	700	417	132	112	14	13	50627
1988	111	1725	5241	11259	9072	12151	6813	1818	970	466	202	51	44	8	49931
1989	71	1658	6065	12398	10714	7316	7628	5171	990	465	153	49	37	15	52730
1990	540	2973	7508	10613	10207	6983	4468	4644	2066	385	122	37	30	29	50605
1991	286	5178	10371	9586	8416	4735	3173	1754	955	587	91	25	16	9	45184
1992	487	3437	12511	9912	5290	3453	2059	910	510	375	112	12	5	9	39081
1993	53	264	914	1155	924	480	217	132	72	34	29	7	9	2	4292
1994	28	54	95	206	275	149	67	26	19	7	4	2	0	0	932

Table 9: Average weights at age (kg) of the southern Gulf of St. Lawrence cod stock.

AGE	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1971	0.76	0.82	1.11	1.40	2.15	3.67	3.83	5.25	6.00	4.78	6.85	7.42	7.96	17.72	1.96
1972	0.36	0.56	0.91	1.33	1.52	2.55	4.82	5.97	7.13	8.08	8.85	10.25	5.65	11.23	1.16
1973	0.46	0.67	0.92	1.28	1.69	2.31	3.59	5.51	6.03	7.95	6.16	6.72	8.86	6.12	1.37
1974	0.60	0.78	1.09	1.49	1.96	2.68	2.89	4.11	5.97	7.07	8.30	6.87	9.84	12.65	1.61
1975	0.48	0.74	1.15	1.76	2.36	2.75	3.22	3.70	4.46	6.95	9.20	6.30	8.39	6.19	1.57
1976	0.46	0.78	1.11	1.54	2.19	2.84	3.23	3.79	4.62	5.09	6.19	9.87	10.45	15.05	1.45
1977	0.52	0.81	1.27	1.79	2.42	3.51	4.27	4.31	5.10	5.57	6.45	8.61	12.56	9.88	1.52
1978	0.40	0.68	1.03	1.66	2.27	2.81	4.33	4.63	6.37	6.46	6.23	5.09	11.56	10.17	1.27
1979	0.51	0.71	1.01	1.42	2.22	3.31	4.07	7.14	6.96	6.69	4.70	8.79	15.52	17.34	1.47
1980	0.58	0.69	0.92	1.22	1.50	2.78	3.08	4.00	7.83	6.01	9.98	5.81	9.13	9.35	1.30
1981	0.50	0.68	0.85	1.13	1.39	1.84	3.19	4.17	4.47	5.60	6.11	7.08	3.49	8.35	1.30
1982	0.75	0.76	0.97	1.16	1.45	1.72	2.27	3.27	4.01	4.14	6.46	6.92	4.18	11.10	1.37
1983	0.33	0.61	0.89	1.14	1.31	1.58	1.73	2.01	4.84	7.63	8.55	10.51	12.09	14.76	1.35
1984	0.45	0.65	0.79	1.09	1.38	1.61	2.07	2.27	3.05	4.93	5.66	8.61	11.74	13.23	1.50
1985	0.44	0.57	0.76	0.99	1.42	1.67	1.83	2.14	2.41	2.89	8.33	5.71	11.41	12.97	1.24
1986	0.43	0.60	0.81	1.01	1.29	1.75	1.98	1.89	2.64	2.23	3.07	4.83	15.36	13.55	1.20
1987	0.27	0.49	0.70	0.86	0.99	1.25	1.85	2.16	2.24	3.15	3.57	4.03	12.41	14.21	1.08
1988	0.40	0.60	0.77	0.92	1.04	1.13	1.29	1.90	2.23	2.72	3.52	5.67	5.92	14.32	1.12
1989	0.53	0.63	0.77	0.90	1.07	1.19	1.22	1.40	1.94	2.15	2.55	3.49	3.41	2.76	1.09
1990	0.56	0.72	0.85	1.03	1.17	1.28	1.36	1.41	1.50	1.84	2.59	3.36	2.81	7.98	1.14
1991	0.53	0.65	0.85	1.01	1.22	1.41	1.51	1.60	1.63	1.73	2.20	2.50	3.08	3.80	1.09
1992	0.55	0.65	0.81	1.00	1.22	1.45	1.61	1.85	1.88	1.91	2.27	5.52	6.58	9.88	1.05
1993	0.41	0.56	0.70	1.00	1.40	1.82	1.93	2.22	2.31	2.11	2.07	2.98	5.73	13.19	1.22
1994	0.36	0.57	0.79	1.04	1.45	1.86	2.25	2.18	2.49	2.41	2.02	2.31	2.38	13.52	1.38

Table 10: Mean numbers per tow at age of southern Gulf of St. Lawrence cod from the annual research vessel surveys, 1971-94.

Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	0+	3+	5+
1971		0.10	0.73	8.72	8.84	7.90	6.09	3.99	1.24	0.32	0.35	0.25	0.11	0.02	0.11	0.13	0.28	39.16	29.62	12.88
1972		0.53	3.60	7.85	18.02	6.84	5.77	3.97	2.40	0.49	0.40	0.44	0.14	0.06	0.05	0.05	0.08	50.70	46.56	20.70
1973	0.03	0.12	6.20	12.24	5.79	9.25	4.32	3.07	2.25	1.43	0.38	0.11	0.27	0.04	0.07	0.02	0.19	45.77	39.42	21.40
1974		0.14	3.55	14.51	11.03	4.73	5.67	2.12	1.44	1.46	0.49	0.19	0.10	0.24		0.04	0.13	45.83	42.13	16.59
1975		0.54	8.19	6.27	9.24	7.24	2.46	1.73	1.14	0.51	0.35	0.43	0.11	0.05	0.01	0.01	0.00	38.27	29.54	14.03
1976		4.30	9.85	38.38	9.91	7.45	3.36	0.92	0.64	0.34	0.31	0.27	0.09	0.05	0.02	0.03	0.03	75.95	61.80	13.51
1977	0.01	1.05	30.27	26.58	18.98	7.08	3.69	1.91	0.91	0.64	0.41	0.34	0.33	0.32		0.06	0.10	92.66	61.33	15.77
1978		1.23	9.29	54.73	40.86	19.72	5.55	3.21	1.01	0.43	0.54	0.64	0.11		0.15	0.05	0.00	137.50	126.99	31.40
1979	0.19	0.18	32.52	31.85	65.04	39.17	15.98	4.14	1.71	0.82	0.26	0.26	0.21	0.07	0.06	0.04	0.02	192.51	159.63	62.74
1980	0.32	1.41	6.73	41.14	30.51	53.54	26.39	9.50	1.65	0.80	0.34	0.11	0.04	0.03	0.05	0.02	0.02	172.60	164.14	92.48
1981	0.28	5.34	21.91	21.92	67.15	56.53	55.54	23.42	12.72	1.77	0.74	0.36	0.14	0.06	0.06	0.10	0.14	268.18	240.66	151.59
1982	0.34	4.56	37.38	22.05	26.60	31.39	50.20	26.18	12.67	4.00	0.47	0.20	0.13	0.07	0.02		0.03	216.28	173.99	125.34
1983	0.01	7.57	24.58	52.76	47.60	25.97	18.45	15.91	10.59	5.01	3.26	0.85	0.17	0.45	0.05	0.07	0.00	213.30	181.15	80.79
1984		1.91	11.21	16.81	36.56	49.41	17.57	9.84	10.28	4.61	2.07	0.75	0.09	0.04	0.09	0.02	0.00	161.25	148.14	94.76
1985	4.42	9.95	15.51	39.65	41.67	68.46	69.44	15.64	6.70	4.61	2.18	1.59	0.53	0.17			0.07	280.59	250.71	169.39
1986	2.04	7.22	25.30	36.14	37.25	37.28	44.23	31.79	9.50	2.02	2.76	1.10	0.77	0.23	0.14		0.06	237.82	203.27	129.88
1987	0.44	0.91	12.86	25.16	23.22	31.93	24.02	31.15	11.19	2.51	1.78	0.66	0.53	0.23	0.12	0.03	0.02	166.76	152.56	104.17
1988	1.51	3.60	16.34	67.35	64.73	52.20	36.40	19.61	21.04	12.21	2.35	0.55	0.32	0.26	0.10	0.11	0.00	298.67	277.22	145.14
1989	0.29	12.62	25.58	31.10	30.03	27.98	29.86	16.67	10.72	10.49	7.02	1.33	0.44	0.23	0.19	0.05	0.12	204.71	166.23	105.10
1990	0.20	2.07	6.62	35.40	26.35	19.31	13.64	9.41	5.31	3.13	3.61	1.69	0.34	0.06	0.09	0.02	0.01	127.26	118.38	56.63
1991	1.30	2.57	7.83	16.01	33.75	26.36	10.31	5.89	4.01	1.70	1.07	1.10	0.65	0.08	0.02	0.01	0.01	112.66	100.96	51.20
1992	0.62	1.94	4.78	9.88	14.02	12.29	6.54	2.58	1.18	0.75	0.32	0.19	0.10	0.06	0.01		0.01	55.26	47.93	24.03
1993	0.66	0.61	6.50	9.34	14.11	16.53	10.90	4.99	1.63	0.66	0.37	0.11	0.06	0.12	0.02	0.02	0.01	66.62	58.85	35.40
1994	1.25	0.66	1.79	7.61	9.06	9.72	12.01	7.75	2.81	1.14	0.42	0.30	0.08	0.04	0.02		0.01	54.67	50.97	34.31

Table 11: Coefficients of variation of mean numbers per tow at age from research vessel surveys.

Age	1	2	3	4	5	6	7	8	9	10	11	12
1971	47.0	22.9	12.3	15.1	17.6	16.5	14.1	16.0	20.7	25.3	22.9	17.0
1972	49.0	26.0	19.0	13.4	13.2	12.8	12.1	13.1	13.9	17.5	22.5	30.0
1973	46.7	21.8	18.8	19.3	19.1	17.7	17.3	15.5	16.2	19.8	27.2	39.7
1974	43.4	22.6	12.4	13.3	19.7	21.4	17.4	19.7	18.9	17.2	23.5	27.8
1975	64.3	37.8	31.3	26.3	22.3	23.1	23.2	23.3	22.7	24.5	28.5	30.6
1976	27.7	15.5	15.0	14.8	21.6	24.4	27.4	25.2	30.8	27.6	32.6	36.8
1977	25.7	31.8	19.7	15.6	13.6	15.1	17.2	25.9	21.3	26.8	27.8	31.1
1978	48.2	20.7	29.0	32.3	35.7	29.7	26.5	22.4	42.8	37.7	71.0	51.4
1979	47.4	22.1	14.5	11.8	10.7	9.0	8.3	9.8	12.3	32.1	22.7	22.9
1980	32.9	18.6	26.2	16.4	14.0	13.0	11.2	13.1	16.5	21.2	21.1	28.8
1981	25.5	33.0	16.3	16.4	16.8	16.4	15.3	14.2	13.2	14.9	15.3	24.1
1982	24.7	28.8	23.9	19.0	21.9	22.5	18.9	16.2	14.0	25.0	32.4	51.9
1983	21.1	13.0	11.9	14.1	12.9	9.9	10.2	10.6	13.3	11.8	18.3	36.8
1984	16.8	16.2	13.8	14.7	15.8	10.4	8.0	7.7	8.3	8.0	10.1	22.7
1985	56.5	20.9	13.7	21.1	26.6	28.7	25.9	20.4	19.7	19.3	15.6	41.3
1986	43.2	28.1	23.2	15.6	13.8	12.5	12.2	12.0	9.6	11.5	12.0	12.6
1987	37.1	20.4	14.6	12.0	11.4	10.9	12.3	14.8	15.5	18.7	19.1	17.5
1988	63.5	46.9	40.9	27.2	20.7	15.9	14.3	13.1	12.9	14.7	19.7	18.0
1989	61.5	29.8	20.7	14.6	11.9	11.6	11.5	11.5	11.6	12.5	12.4	14.1
1990	20.2	19.8	14.4	12.4	11.1	10.3	10.1	9.8	10.1	10.0	10.0	12.0
1991	34.2	18.6	21.8	24.2	21.1	15.0	12.3	11.2	10.5	11.2	10.3	11.3
1992	31.0	24.6	16.4	13.6	13.5	12.8	13.0	13.0	12.8	13.4	16.3	12.0
1993	22.8	20.3	18.1	12.6	9.2	9.3	9.5	10.2	10.2	12.3	11.9	16.6
1994	25.1	18.3	17.2	13.7	11.0	10.1	10.1	11.2	13.1	13.4	15.3	24.7

Table 12: Research vessel survey biomass estimates by stratum for southern Gulf cod, 1971-1994.

Stratum	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
415	1485	2190	247	1364	0	0	1617	0	137	412	949	155
416	12582	9391	13777	15904	3194	2152	8220	10611	23262	27989	22106	15773
417	5416	5071	5170	2936	3215	5972	8163	10109	7903	19294	55027	7878
418	4922	3096	4874	1680	2698	2225	2954	5492	5918	2869	8551	5850
419	5870	3191	2733	11142	573	5938	4575	12140	12328	7477	7533	3513
420	3205	2927	10278	10020	1408	8497	3653	18690	14531	3046	5454	1486
421	1910	5028	831	512	1490	38	1844	4712	6420	622	9195	1720
422	13293	30865	17603	7414	18989	23504	19898	43396	44821	29970	49835	9533
423	16199	7672	14048	6014	1499	11181	7907	54547	42017	62553	98889	38141
424	1837	4559	1179	2874	3908	1950	3995	0	22457	18663	47175	118746
425	796	44	0	364	1428	87	216	0	0	1224	115	0
426	733	2778	891	2278	146	398	531	1767	7095	4629	16417	9020
427	6642	1576	336	2856	0	142	3061	3056	4811	5981	4530	43582
428	20	1254	341	159	753	1358	300	0	7872	1212	8003	3847
429	2778	3830	12002	10734	9705	2600	10563	5342	17156	15665	33377	21490
431	5235	766	2073	5927	4266	3562	8535	7393	15096	19115	14694	27513
432	365	6027	118	0	215	0	0	110	59	81	0	15
433	247	687	81	3001	3814	974	20624	2176	6846	212	11502	1732
434	231	5953	133	249	538	441	508	927	5910	6825	8423	5943
435	694	576	802	549	2743	4901	1042	974	1091	10125	2611	657
436	1591	581	314	756	116	555	219	609	2618	4929	7684	7580
437	40	592	232	21	1845	1432	945	866	2271	4449	3579	10890
438	793	1444	223	809	0	554	376	978	2561	3577	3311	1460
439	0	752	424	829	131	0	956	4717	836	0	4178	289
Total	86884	100851	88710	88395	62675	78460	110702	188611	254015	250920	423138	336810

Stratum	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
415	1260	745	284	240	93	174	1	5	288	13	340	291
416	34296	25236	43299	30105	22164	26058	10277	12313	3249	8470	4962	2139
417	16829	25074	22695	22332	11912	11417	26456	3487	1900	6570	1816	3276
418	7068	3785	8628	3958	6287	3893	2956	5891	1275	741	505	520
419	17696	2430	4970	7986	2907	4230	3196	2352	2614	1457	3646	2154
420	16859	4989	7615	7524	5856	2507	11826	5736	837	1324	1465	4789
421	0	1479	1823	1356	1468	0	2352	1483	782	383	157	479
422	14928	15789	25086	33443	32762	77291	33697	22384	19161	6719	14567	9619
423	36902	19100	32381	42673	31423	60108	36127	46928	31687	9452	8982	5770
424	9197	11674	91288	11360	10693	8068	12738	5715	2298	1498	1970	989
425	0	0	22	84	0	17	0	0	3	423	22	18
426	12579	7455	9353	8726	16452	12189	8261	1529	1831	791	2377	3741
427	12122	1092	3791	5093	4329	9339	1631	1527	1403	1173	1407	2277
428	4392	5925	3724	2203	2713	7744	11241	877	903	1493	779	3413
429	16798	17545	23813	28330	13213	37527	22881	13055	17659	4508	7486	5679
431	18667	11623	17292	18052	10962	34784	20416	15756	21585	6135	5720	5764
432	0	79	3	22	16	57	0	48	38	1	26	4
433	843	5170	6080	5877	5295	4073	3974	1533	6269	568	545	2546
434	21343	12155	9319	16984	12121	11774	21634	7720	4517	2463	3840	6727
435	5582	12415	19053	11286	8922	4138	8984	3862	2575	2707	1384	2831
436	3165	15999	19424	10030	8887	21097	4251	3107	2567	1104	5907	2125
437	3755	4656	1520	3729	1384	1858	1707	2818	712	1547	1595	3052
438	3281	1723	565	11939	1389	1751	619	766	521	303	3773	1520
439	969	271	453	142	137	476	16	946	267	221	49	454
Total	258530	206407	352481	283475	211383	340572	245239	159841	124940	60064	73322	70177

Table 13: Mean weights (kg) at age of southern Gulf cod from research vessel surveys.

Age	3	4	5	6	7	8	9	10	11	12	13	14	15
1960	0.35	0.67	1.12	1.72	2.00	2.77	3.57	3.25	3.71	3.31	4.29	12.85	5.98
1961	0.31	0.55	0.90	1.36	2.08	2.75	3.41	4.83	6.51	6.87	7.56	9.01	14.86
1962	0.36	0.65	0.93	1.33	1.96	2.86	5.64	7.22	7.90	11.03		14.86	
1963	0.38	0.61	0.92	1.09	1.46	2.00	2.79	4.91	2.99	8.15	9.04	5.98	
1964	0.40	0.58	0.91	1.20	1.35	1.95	2.55	4.28	6.71	8.99		4.53	
1965	0.40	0.69	1.18	1.24	1.66	2.01	2.52	2.88	4.93		8.31		9.38
1966	0.39	0.79	1.29	1.58	1.91	2.26	2.43	3.36	4.75	6.53	7.82	9.95	
1967	0.45	0.70	1.45	1.88	2.38	2.46	2.86	4.14	4.62	6.17	8.00	10.19	11.18
1968	0.41	0.79	1.34	1.88	2.64	3.85	2.58	3.08	3.90	5.61	6.41	10.22	10.60
1969	0.44	0.85	1.40	1.96	2.63	3.51	4.23	2.84	7.19	6.73	6.82	7.04	10.77
1970	0.42	0.75	1.22	1.73	2.49	3.30	4.44	4.77	3.70	4.25	5.29	4.96	8.62
1971	0.41	0.75	1.15	1.42	2.00	3.03	4.59	5.49	6.31	4.43	3.56	4.26	6.61
1972	0.39	0.73	1.22	1.55	1.95	2.72	3.92	4.61	6.00	6.30	5.08	10.77	6.13
1973	0.34	0.75	1.18	1.56	1.94	2.39	2.84	4.97	5.29	8.78	3.58	2.98	4.89
1974	0.46	0.74	1.20	1.67	2.13	2.31	2.42	3.51	4.39	5.66	11.03		4.31
1975	0.30	0.74	1.20	1.80	2.39	2.87	3.22	4.29	4.81	5.99	10.04	11.35	13.88
1976	0.26	0.73	1.32	1.87	2.50	3.04	3.06	4.07	5.31	4.41	6.97	4.90	3.37
1977	0.34	0.66	1.35	1.95	2.70	4.33	3.88	5.38	4.92	5.87	8.75		14.96
1978	0.33	0.74	1.22	2.06	2.49	3.63	5.40	6.57	9.46	9.03		7.37	10.47
1979	0.26	0.59	0.97	1.48	2.18	2.81	3.65	6.94	7.37	6.41	11.97	4.84	13.29
1980	0.35	0.61	0.94	1.24	1.64	3.05	3.79	4.61	5.16	6.45	9.35	10.22	7.77
1981	0.30	0.65	0.87	1.18	1.42	1.78	3.09	3.89	4.58	7.67	11.49	9.52	11.67
1982	0.28	0.60	0.95	1.13	1.43	1.67	2.18	4.03	5.76	9.93	7.56	13.10	—
1983	0.26	0.43	0.74	1.17	1.29	1.54	1.97	1.98	4.92	6.15	12.66	3.95	9.42
1984	0.27	0.42	0.60	1.00	1.37	1.45	1.90	2.21	3.45	11.62	7.45	11.62	7.45
1985	0.33	0.50	0.69	0.84	1.15	1.73	1.78	2.04	2.71	6.06	12.67		
1986	0.27	0.51	0.65	0.81	1.04	1.33	2.33	1.83	2.93	3.69	7.01	11.48	
1987	0.25	0.42	0.65	0.79	0.93	1.13	1.50	1.81	2.38	2.22	4.63	6.74	15.67
1988	0.30	0.47	0.66	0.85	0.94	1.05	1.26	2.40	2.48	3.57	4.08	13.93	15.37
1989	0.28	0.49	0.70	0.89	1.06	1.11	1.17	1.30	2.03	3.69	5.20	7.04	8.01
1990	0.33	0.54	0.76	0.96	1.14	1.24	1.27	1.35	1.44	2.34	6.47	8.74	5.66
1991	0.27	0.48	0.69	0.93	1.08	1.24	1.41	1.36	1.37	1.69	3.86	7.89	18.63
1992	0.30	0.43	0.72	0.94	1.10	1.25	1.49	1.89	1.99	1.41	1.43	1.62	
1993	0.30	0.45	0.64	0.90	1.06	1.26	1.41	2.20	1.49	2.46	1.53	5.17	8.77
1994	0.31	0.45	0.66	0.82	1.12	1.34	1.50	1.58	2.42	2.82	1.97	1.87	

Table 14: Strength of the effect of depth on cod catch rates during the 1994 survey. D is the percent of the total deviance explained by an effect, and P is the significance level associated with the effect. Results are for the 4T portion of the survey only.

	Overall		Quadratic		Linear	
Age	D	P	D	P	D	P
3	26.3	<0.0001	1.1	0.13	25.1	<0.0001
4	18.4	<0.0001	0.3	0.45	18.1	<0.0001
5	12.0	<0.0001	0.2	0.53	11.7	<0.0001
6	9.5	0.0003	1.3	0.14	8.2	0.0002
7	6.2	0.0063	2.7	0.035	3.5	0.018
8+	4.5	0.028	3.3	0.022	1.2	0.17

Table 15: Summary of effects of depth on cod catch rates in the September survey, 1971-1994. NS indicates no significant effect of depth (P > 0.05). - indicates a negative linear relationship (i.e., only the linear term is significant at P < 0.05). Numbers indicate that cod density is highest at some intermediate depth; numbers are the depth at which predicted catch rates are maximum.

Year	Age					
	3	4	5	6	7	8+
71	59	83	102	108	118	118
72	-	-	-	NS	NS	-
73	-	-	-	73	80	NS
74	-	-	-	NS	NS	NS
75	38	-	-	-	NS	NS
76	-	-	-	-	-	-
77	62	71	NS	NS	NS	NS
78	-	-	NS	NS	NS	NS
79	46	-	70	97	123	145
80	62	71	84	94	104	129
81	67	71	76	91	108	135
82	93	84	82	86	94	105
83	79	91	106	117	119	124
84	73	86	96	111	126	137
85	66	76	80	86	100	124
86	54	70	84	101	116	125
87	38	49	77	88	97	109
88	-	51	63	85	91	109
89	-	-	-	60	85	100
90	-	57	72	89	105	117
91	-	46	-	48	49	51
92	-	-	116	139	146	156
93	-	-	92	114	117	124
94	-	-	-	-	88	115

Table 16. Mean number per tow and coefficients of variation (CV) at age from the annual cod juvenile survey, 1990 to 1994. 1994b represents estimates with the 500 kg set included.

Number per tow

Age	1990	1991	1992	1993	1994	1994b
0	0.38	1.50	0.00	0.00	0.00	0.00
1	0.71	3.28	10.70	0.61	1.13	2.56
2	7.24	7.45	31.50	3.07	3.80	13.64
3	45.94	16.22	26.91	7.58	26.65	61.81
4	31.13	26.00	16.24	8.61	19.79	26.93
5	15.58	13.53	11.22	13.35	23.37	24.32
6	10.06	5.42	2.37	8.46	20.95	21.04
7	6.94	2.39	1.51	3.47	9.34	9.19
8	2.38	1.52	0.70	1.60	3.31	3.26
9	1.38	0.25	0.47	0.38	1.30	1.28
10	1.05	0.15	0.21	0.30	0.59	0.59
11	0.88	0.13	0.19	0.06	0.45	0.44
12	0.00	0.18	0.04	0.17	0.14	0.14
13	0.00	0.02	0.07	0.04	0.15	0.14
14	0.12	0.09	0.04	0.02	0.04	0.04
15	0.00	0.00	0.00	0.00	0.03	0.03
16+	0.36	0.05	0.05	0.09	0.00	0.00
0+	123.87	78.11	102.33	47.74	111.25	164.74
3+	115.54	65.88	60.14	44.07	106.33	148.52
5+	38.47	23.67	16.99	27.88	59.88	59.77

CV

Age	1990	1991	1992	1993	1994	1994b
0	41.20	44.49	0.00	0.00	0.00	0.00
1	37.37	32.94	84.34	70.78	28.80	57.81
2	27.62	33.48	44.24	76.99	28.77	72.54
3	22.81	21.32	33.42	22.82	33.24	58.42
4	21.62	21.93	28.39	17.04	22.94	30.85
5	14.74	16.85	24.66	14.91	16.94	15.98
6	12.68	16.94	22.73	12.27	15.40	14.82
7	12.19	18.37	20.69	11.74	13.92	13.78
8	11.75	15.12	20.70	12.32	14.62	14.28
9	14.48	21.82	49.04	18.66	13.74	13.52
10	10.44	36.27	21.50	11.26	14.09	13.22
11	15.31	25.10	53.48	0.00	17.10	16.18
12	0.00	24.57	0.00	26.94	22.43	23.08
13	0.00	0.00	48.65	0.00	30.84	32.17
14	44.17	37.20	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00
16+	52.40	105.33	91.26	49.69	0.00	0.00
0+	18.06	15.80	27.76	14.70	18.02	34.42

Table 17: Mean length (cm) and weight (g) at age of cod in juvenile surveys and mean length at age in the same area during September surveys, 1990-94.

Juvenile Survey

Length Age	Aug. 90	Aug. 91	Jul. 92	Jul. 93	Jul. 94
1	19.0	15.2	12.3	18.5	19.3
2	26.1	22.8	23.5	21.5	24.2
3	31.5	28.7	29.3	31.1	29.9
4	36.4	35.3	34.0	36.0	35.5
5	42.1	41.0	41.2	39.2	40.6
6	45.1	45.3	45.9	44.5	43.4
7	49.0	48.1	47.6	47.4	47.4
8	50.6	50.5	54.2	49.1	50.6
9	51.4	57.7	51.9	56.1	53.5
Weight					
1	62.9	32.1	22.7	54.7	60.1
2	157.1	105.0	160.3	85.3	122.2
3	286.8	216.5	320.1	265.3	229.6
4	449.1	392.6	504.4	407.0	389.4
5	695.7	623.3	892.1	523.4	584.8
6	872.5	850.6	1258.9	779.3	713.3
7	1170.4	1034.2	1399.8	940.6	947.4
8	1277.4	1208.6	2213.3	1042.0	1174.6
9	1318.9	1847.4	1812.7	1649.0	1398.3

September surveys

Length	90	91	92	93	94
1	19.4	17.6	16.3	16.5	16.5
2	27.8	25.7	27.7	24.8	26.7
3	32.0	32.4	33.0	32.4	33.1
4	38.7	37.6	37.3	37.3	37.5
5	43.6	42.8	43.9	42.7	42.5
6	48.4	46.7	46.9	46.4	45.3
7	49.6	48.7	50.1	49.1	48.8
8	49.7	51.3	52.3	53.6	53.5
9	51.4	58.7	50.3	61.0	52.9

Table 18. Summary of analysis of variance for multiplicative model of mean catch at age with age, year class, stratum, and age*stratum effects for juvenile cod surveys (in 4Tl) conducted from 1990 to 1994.

Source	df	F	p	R^2
Overall model				
Model	47	10.33	0.0001	0.79
Error	132			
Type I SS				
Year-class	12	12.93	0.0001	
Stratum	3	14.57	0.000	
Age	8	18.24	0.0001	
Stratum*Age	24	5.86	0.0001	
Type III SS				
Year-class	12	1.28	0.2367	
Stratum	3	14.57	0.0001	
Age	8	18.24	0.0001	
Stratum*Age	24	5.86	0.0001	

Table 19: Diagnostics of the calibration of SPA using RV mean numbers per tow at age and the method Laurec-Shepherd.

```
VPA Version 3.0 (MSDOS)
At 21/03/1995   7:52
4TVn (J-A) COD, March 20, 1995
CPUE data from file c:\laurec_s\data95\cod4t94.ind
Disaggregated Qs
Log transformation
No trend in Q (mean used)
Terminal Fs estimated using  Laurec-Shepherd
Tuning converged after    6 iterations
Log catchability residuals
 Fleet : rv mean numbers/tow
```

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
3	-.07	-.26	.00	-.33	-.90	-.33	-.84	.07	.20	.05	1.24	.44	.50	.04	.04	.13	.00
4	-.45	.02	-.40	.41	-.22	-.22	-.79	-.02	-.07	-.34	.91	.36	.21	.42	-.14	.32	.00
5	-.70	-.31	-.02	.33	-.20	-.12	-.11	-.07	-.01	-.08	.58	.22	.11	.48	-.25	.15	.00
6	-.39	-.55	-.35	.40	.51	-.36	-.19	.53	-.18	-.11	.41	.42	-.05	.05	-.21	.07	.00
7	-.21	-.01	-.52	.06	.24	-.12	-.42	.24	.24	.04	.23	.27	.03	.01	-.35	.26	.00
8	-.57	-.14	-.21	.41	.05	-.04	.11	-.15	.37	-.33	.31	.31	-.01	.18	-.29	.00	.00
9	-.17	-.06	-.11	.62	-.09	-.16	-.13	.05	-.61	-.32	.38	.43	.03	.06	-.19	.28	.00
10	-.02	-.20	-.30	.45	-.10	.26	-.43	-.27	.20	-.20	.13	.50	.27	-.05	-.25	.02	.00
11	1.31	-.25	-.28	.49	-.21	1.04	-.45	-.07	-.29	-.54	-.70	.33	.09	.20	-.52	-.14	.00
12	.03	1.02	-1.53	1.32	.46	.22	-.34	.04	.09	-.20	-.42	.14	.15	.55	-.96	-.58	.00

SUMMARY STATISTICS BY AGE

Age	Pred. q	SE(q)	Partial F	Raised F	SLOPE	SE Slope	INTRCPT	SE Intrcpt
3	-7.84	.505	.0004	.0015	.428E-01	.225E-01	-7.838	.119
4	-7.54	.420	.0005	.0032	.338E-01	.189E-01	-7.537	.099
5	-7.38	.314	.0006	.0061	.289E-01	.137E-01	-7.384	.074
6	-7.33	.352	.0007	.0113	.178E-01	.169E-01	-7.326	.083
7	-7.35	.256	.0006	.0228	.143E-01	.122E-01	-7.352	.060
8	-7.37	.277	.0006	.0336	.122E-01	.134E-01	-7.365	.065
9	-7.40	.304	.0006	.0358	.812E-02	.150E-01	-7.404	.072
10	-7.21	.275	.0007	.0456	.697E-02	.136E-01	-7.214	.065
11	-7.03	.562	.0009	.0561	-.358E-01	.264E-01	-7.030	.132
12	-6.98	.698	.0009	.0810	-.338E-01	.336E-01	-6.985	.165

Table 20: Diagnostics from the calibration of SPA using RV mean numbers per tow at age and the method of extended survivor analysis (XSA).

```
VPA Version 3.0 (MSDOS)
21/03/1995   8:29
 Extended Survivors Analysis
 4TVn (J-A) COD, March 20, 1995
 CPUE data from file c:\laurec_s\data95\cod4t94.ind
 Log catchability residuals.
```

Fleet : rv mean numbers/tow

Age ,	1978,	1979,	1980,	1981,	1982,	1983,	1984,	1985,	1986,	1987,	1988,	1989,	1990,	1991,	1992,	1993,	1994
3 ,	-.06,	-.25,	.03,	-.33,	-.93,	-.31,	-.81,	.09,	.21,	.06,	1.27,	.42,	.52,	.04,	-.03,	.08,	.00
4 ,	-.42,	.04,	-.39,	.44,	-.23,	-.26,	-.78,	.00,	-.05,	-.33,	.92,	.38,	.19,	.45,	-.13,	.23,	-.06
5 ,	-.68,	-.30,	-.01,	.33,	-.17,	-.14,	-.17,	-.08,	.01,	-.08,	.58,	.22,	.15,	.49,	-.16,	.11,	-.11
6 ,	-.43,	-.54,	-.36,	.42,	.48,	-.33,	-.23,	.47,	-.17,	-.10,	.42,	.45,	-.01,	.17,	-.18,	.02,	-.08
7 ,	-.22,	-.08,	-.51,	.07,	.24,	-.11,	-.38,	.22,	.13,	.05,	.25,	.32,	.11,	.12,	-.17,	.05,	-.08
8 ,	-.61,	-.14,	-.36,	.44,	.06,	-.04,	.12,	-.08,	.31,	-.44,	.33,	.38,	.11,	.27,	-.14,	.00,	-.24
9 ,	-.27,	-.07,	-.13,	.40,	-.08,	-.12,	-.09,	.08,	-.51,	-.41,	.28,	.49,	.20,	.28,	-.07,	.04,	-.02
10 ,	.33,	-.10,	-.21,	.55,	-.32,	.54,	-.20,	-.10,	.40,	.12,	.20,	.51,	.57,	.37,	.10,	-.10,	-.13
11 ,	.26,	.48,	-.17,	.60,	-.13,	.73,	-.07,	.23,	-.01,	-.33,	-.10,	.42,	-.10,	.36,	.08,	-.13,	-.03

Mean catchability and Standard error.

Age ,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13
Mean Q ,	-7.83,	-7.52,	-7.34,	-7.24,	-7.25,	-7.27,	-7.33,	-7.33,	-7.33,	-7.33,	
S.E ,	.49,	.41,	.30,	.34,	.23,	.30,	.27,	.44,	.55,	.83,	

Table 21: Fishing mortality for cod in the southern Gulf of St. Lawrence obtained with Laurec-Shepherd calibrations.

	3	4	5	6	7	8	9	10	11	12	13	14	9+	7-12
1971	0.000	0.060	0.294	0.390	0.415	0.559	0.543	0.458	0.283	1.186	0.606	0.606	0.613	0.574
1972	0.105	0.405	0.562	0.481	0.642	0.472	0.469	0.486	0.704	0.458	0.518	0.518	0.526	0.539
1973	0.032	0.353	0.506	0.525	0.546	0.525	0.488	0.557	0.638	0.411	0.524	0.524	0.524	0.528
1974	0.060	0.168	0.464	0.767	0.674	0.584	0.757	0.571	0.554	1.008	0.695	0.695	0.713	0.691
1975	0.038	0.253	0.336	0.452	0.654	0.692	0.872	0.976	0.924	0.741	0.844	0.844	0.867	0.810
1976	0.005	0.131	0.499	0.671	0.631	0.563	0.584	0.571	0.472	0.509	0.542	0.542	0.537	0.555
1977	0.004	0.057	0.281	0.306	0.354	0.292	0.236	0.461	0.473	0.287	0.352	0.352	0.360	0.350
1978	0.004	0.084	0.171	0.369	0.434	0.392	0.291	0.333	0.565	0.625	0.441	0.441	0.449	0.440
1979	0.001	0.043	0.184	0.268	0.536	0.555	0.608	0.685	0.671	0.808	0.665	0.665	0.684	0.644
1980	0.003	0.023	0.166	0.248	0.394	0.472	0.553	0.648	0.869	0.150	0.538	0.538	0.550	0.514
1981	0.001	0.046	0.113	0.339	0.383	0.467	0.581	0.723	0.817	1.764	0.871	0.871	0.938	0.789
1982	0.004	0.026	0.173	0.189	0.390	0.404	0.353	0.631	0.509	0.860	0.552	0.552	0.576	0.525
1983	0.000	0.010	0.134	0.303	0.427	0.438	0.555	0.779	0.412	0.345	0.506	0.506	0.517	0.493
1984	0.000	0.009	0.047	0.229	0.391	0.476	0.603	0.680	0.711	1.103	0.715	0.715	0.754	0.661
1985	0.002	0.020	0.087	0.276	0.436	0.496	0.554	0.588	0.502	0.644	0.557	0.557	0.567	0.537
1986	0.002	0.048	0.137	0.294	0.249	0.394	0.496	0.771	0.720	1.056	0.688	0.688	0.736	0.614
1987	0.001	0.017	0.132	0.267	0.406	0.285	0.395	0.569	0.545	0.597	0.478	0.478	0.510	0.466
1988	0.002	0.035	0.112	0.316	0.374	0.498	0.495	0.645	0.771	0.883	0.658	0.658	0.685	0.611
1989	0.001	0.042	0.168	0.415	0.538	0.588	0.679	0.890	0.918	1.130	0.841	0.841	0.883	0.791
1990	0.010	0.072	0.263	0.482	0.708	0.811	0.882	1.216	1.159	1.188	1.051	1.051	1.091	0.994
1991	0.007	0.124	0.393	0.644	0.922	0.887	1.199	1.147	0.936	1.447	1.123	1.123	1.163	1.090
1992	0.020	0.113	0.487	0.801	0.915	1.372	1.366	1.600	1.391	1.301	1.406	1.406	1.412	1.324
1993	0.003	0.014	0.040	0.075	0.155	0.187	0.265	0.269	0.501	0.293	0.303	0.303	0.323	0.278
1994	0.002	0.003	0.006	0.011	0.023	0.034	0.036	0.046	0.056	0.081	0.050	0.050	0.053	0.046

Table 22: Beginning of year population numbers of southern Gulf cod estimated with the Laurec Shepherd calibration, 1971-95.

	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL
1971	89369	39629	31312	31429	19095	5948	3266	1550	579	552	180	822	223731
1972	35033	73164	30551	19099	17419	10326	2783	1554	803	358	138	268	191496
1973	48505	25816	39940	14257	9663	7503	5271	1425	782	325	185	223	153896
1974	56783	38472	14851	19712	6904	4581	3636	2648	668	338	176	118	148888
1975	46664	43789	26634	7647	7496	2882	2092	1396	1225	315	101	286	140526
1976	120982	36791	27836	15578	3984	3190	1181	716	431	398	123	102	211311
1977	169352	98593	26432	13835	6523	1735	1487	539	331	220	196	70	319313
1978	164693	138058	76244	16337	8343	3748	1061	962	279	169	135	74	410104
1979	116022	134345	103978	52608	9249	4426	2074	649	565	130	74	92	424212
1980	115787	94857	105354	70800	32954	4431	2081	925	268	236	47	126	427865
1981	85052	94532	75929	73038	45243	18195	2263	980	396	92	167	37	395924
1982	151561	69546	73940	55511	42602	25269	9339	1036	389	143	13	13	429363
1983	204434	123620	55476	50925	37614	23626	13812	5372	452	192	50	55	515627
1984	108507	167339	100175	39731	30797	20090	12486	6494	2018	245	111	45	488038
1985	103089	88811	135814	78217	25861	17061	10220	5596	2693	811	67	51	468290
1986	82993	84244	71302	101898	48605	13692	8508	4810	2545	1335	349	53	420333
1987	66895	67826	65772	50901	62172	31033	7561	4241	1821	1014	380	400	360017
1988	54387	54704	54602	47180	31916	33914	19105	4171	1966	864	457	233	303498
1989	56045	44428	43230	39979	28159	17986	16880	9537	1791	744	293	193	259265
1990	60108	45827	34878	29932	21610	13464	8182	7007	3206	585	197	158	225153
1991	43305	48742	34916	21956	15141	8719	4898	2774	1701	823	146	87	183208
1992	26735	35196	35247	19303	9439	4930	2939	1209	721	546	159	39	136464
1993	22992	21450	25728	17739	7098	3095	1024	614	200	147	122	76	100284
1994	21307	18777	17324	20239	13481	4978	2101	643	384	99	90	45	99468
1995	0	17419	15324	14098	16385	10789	3941	1660	503	297	75	105	80596

Table 23: Fishing mortality for southern Gulf cod estimated with the extended survivors calibration, 1971-94.

	3	4	5	6	7	8	9	10	11	12	13	14	9+	7-12
1971	0.000	0.056	0.290	0.391	0.421	0.565	0.532	0.450	0.306	1.308	0.644	0.644	0.648	0.597
1972	0.104	0.406	0.512	0.472	0.648	0.484	0.476	0.470	0.687	0.517	0.644	0.644	0.573	0.547
1973	0.031	0.347	0.509	0.450	0.529	0.532	0.508	0.571	0.603	0.392	0.644	0.644	0.560	0.522
1974	0.059	0.165	0.453	0.779	0.517	0.553	0.781	0.611	0.578	0.897	0.644	0.644	0.693	0.656
1975	0.036	0.249	0.329	0.436	0.674	0.433	0.786	1.061	1.092	0.811	0.644	0.644	0.840	0.810
1976	0.005	0.125	0.490	0.653	0.596	0.595	0.275	0.465	0.556	0.725	0.644	0.644	0.551	0.535
1977	0.004	0.056	0.266	0.296	0.337	0.265	0.254	0.159	0.342	0.366	0.644	0.644	0.402	0.287
1978	0.004	0.082	0.169	0.342	0.416	0.365	0.257	0.369	0.136	0.377	0.644	0.644	0.405	0.320
1979	0.001	0.042	0.182	0.264	0.479	0.519	0.544	0.566	0.810	0.113	0.296	0.296	0.438	0.505
1980	0.003	0.022	0.163	0.244	0.388	0.394	0.494	0.531	0.600	0.199	0.041	0.041	0.318	0.434
1981	0.001	0.046	0.111	0.332	0.375	0.456	0.436	0.592	0.562	0.690	1.606	1.606	0.915	0.518
1982	0.004	0.025	0.173	0.185	0.379	0.392	0.340	0.392	0.361	0.423	0.089	0.089	0.282	0.381
1983	0.000	0.010	0.129	0.304	0.416	0.421	0.530	0.736	0.203	0.211	0.165	0.165	0.335	0.419
1984	0.000	0.009	0.045	0.219	0.392	0.457	0.566	0.628	0.633	0.355	0.347	0.347	0.479	0.505
1985	0.002	0.019	0.086	0.257	0.411	0.500	0.518	0.526	0.435	0.518	0.094	0.094	0.364	0.484
1986	0.002	0.047	0.136	0.289	0.227	0.360	0.504	0.682	0.588	0.800	0.467	0.467	0.584	0.527
1987	0.001	0.017	0.131	0.265	0.397	0.254	0.346	0.585	0.435	0.415	0.282	0.282	0.391	0.405
1988	0.002	0.035	0.110	0.312	0.370	0.481	0.419	0.524	0.820	0.585	0.363	0.363	0.513	0.533
1989	0.001	0.042	0.164	0.407	0.531	0.582	0.641	0.660	0.614	1.361	0.384	0.384	0.674	0.731
1990	0.010	0.068	0.262	0.469	0.688	0.795	0.871	1.064	0.595	0.500	2.292	2.292	1.269	0.752
1991	0.007	0.122	0.368	0.645	0.883	0.838	1.146	1.118	0.662	0.336	0.213	0.213	0.614	0.831
1992	0.018	0.109	0.481	0.718	0.923	1.217	1.169	1.360	1.281	0.586	0.097	0.097	0.765	1.089
1993	0.002	0.012	0.038	0.073	0.129	0.187	0.204	0.194	0.334	0.242	0.080	0.080	0.189	0.215
1994	0.001	0.003	0.005	0.011	0.022	0.028	0.036	0.034	0.038	0.048	0.040	0.040	0.039	0.034

Table 24: Beginning of the year population estimates for southern Gulf cod with the extended survivors calibration, 1971-95.

	3	4	5	6	7	8	9	10	11	12	13	14+	TOTAL
1971	89987	42792	31956	31641	19040	5972	3351	1585	545	536	174	786	228366
1972	35729	73670	33136	19584	17524	10235	2780	1612	827	329	119	228	195773
1973	49543	26376	40186	16255	10002	7506	5167	1415	825	341	161	191	157967
1974	57883	39319	15262	19783	8490	4823	3612	2547	654	369	188	124	153055
1975	48922	44682	27305	7941	7429	4144	2271	1354	1131	300	123	345	145950
1976	122832	38636	28521	16082	4204	3099	2200	847	384	311	109	90	217314
1977	172240	100106	27929	14306	6856	1896	1400	1368	436	180	123	44	326885
1978	168043	140422	77472	17529	8709	4009	1191	889	956	253	102	55	419630
1979	118765	137086	105886	53569	10193	4704	2280	754	504	683	142	176	434741
1980	116352	97103	107588	72294	33678	5170	2292	1084	350	183	499	1329	437921
1981	88569	94994	77764	74808	46393	18716	2856	1145	522	157	123	27	406073
1982	161615	72425	74310	56990	43925	26115	9713	1512	519	243	65	64	447497
1983	208671	131851	57830	51184	38787	24617	14448	5661	836	296	131	144	534455
1984	109769	170807	106912	41637	30936	20956	13236	6962	2220	559	196	79	504269
1985	104641	89844	138651	83723	27385	17108	10870	6156	3042	966	321	246	482953
1986	84831	85514	72146	104192	53017	14872	8493	5303	2980	1612	471	70	433501
1987	68638	69331	66805	51562	63910	34594	8497	4201	2194	1356	593	621	372304
1988	54938	56131	55832	47999	32397	35194	21980	4921	1916	1163	733	371	313575
1989	59415	44879	44395	40969	28757	18316	17820	11831	2385	691	531	347	270336
1990	61148	48586	35243	30861	22325	13852	8377	7688	5008	1057	145	113	234404
1991	44938	49593	37168	22215	15811	9185	5124	2870	2171	2262	525	310	192172
1992	29757	36533	35926	21071	9546	5353	3252	1334	768	917	1323	321	146100
1993	24945	23923	26811	18186	8415	3104	1298	827	280	175	418	259	108642
1994	22056	20375	19348	21124	13845	6053	2107	866	558	164	112	56	106665
1995	0	18033	16634	15755	17110	11087	4822	1665	686	440	128	132	86491

Table 25: Parameter estimates from ADAPT using a modified Hybrid and density dependent RV calibration.

Parameter	Estimate	Std. Err.	Rel. Err.	Bias	Rel. Bias
ln age 4	9.828	0.507	0.052	-0.041	-0.004
ln age 5	9.895	0.310	0.031	-0.013	-0.001
ln age 6	9.947	0.218	0.022	-0.004	0.000
ln age 7	9.824	0.165	0.017	0.000	0.000
ln age 8	9.683	0.155	0.016	0.000	0.000
ln age 9	8.914	0.158	0.018	0.000	0.000
ln age 10	7.984	0.169	0.021	-0.001	0.000
ln age11	6.867	0.198	0.029	-0.003	0.000
ln age 12	6.320	0.246	0.039	-0.007	-0.001
ln age 13	5.715	0.309	0.054	-0.013	-0.002
b3	0.850	0.155	0.183	0.001	0.001
b4	1.032	0.147	0.143	0.001	0.001
b5	1.245	0.130	0.105	0.000	0.000
b6	1.320	0.112	0.085	0.000	0.000
b7	1.253	0.100	0.080	0.000	0.000
b8	1.199	0.092	0.077	0.000	0.000
b9	1.126	0.091	0.081	0.000	0.000
b10	1.093	0.096	0.088	0.000	0.000
ln a3	-6.408	1.744	-0.272	-0.014	0.002
ln a4	-8.133	1.614	-0.199	-0.007	0.001
ln a5	-10.210	1.383	-0.136	-0.003	0.000
ln a6	-10.790	1.140	-0.106	-0.002	0.000
ln a7	-9.995	0.952	-0.095	-0.002	0.000
ln a8	-9.320	0.817	-0.088	-0.002	0.000
ln a9	-8.654	0.738	-0.085	-0.001	0.000
ln a10	-8.134	0.701	-0.086	0.000	0.000
δ	1.27E-05	2.27E-06	0.179	-6.85E-08	-5.41E-03
q5	3.26E-05	8.81E-06	0.271	9.51E-07	2.92E-02
q6	1.16E-04	2.00E-05	0.173	1.40E-06	1.21E-02
q7	1.95E-04	2.88E-05	0.148	1.80E-06	9.26E-03
q8	2.30E-04	3.27E-05	0.142	1.99E-06	8.65E-03
q9	2.56E-04	3.56E-05	0.139	2.18E-06	8.51E-03
q10	3.54E-04	4.65E-05	0.131	2.95E-06	8.34E-03
q11	2.59E-04	3.61E-05	0.139	2.59E-06	1.00E-02
q12	3.42E-04	4.47E-05	0.131	3.06E-06	8.96E-03

Table 26: Fishing mortality estimates of southern Gulf cod from an ADAPT calibration.

	3	4	5	6	7	8	9	10	11	12	13	14	15
1971	0.000	0.060	0.292	0.390	0.421	0.553	0.542	0.421	0.334	1.193	0.806	0.585	0.481
1972	0.104	0.406	0.564	0.478	0.645	0.484	0.460	0.485	0.611	0.593	0.518	0.332	0.472
1973	0.031	0.350	0.509	0.527	0.541	0.527	0.508	0.540	0.636	0.323	0.841	1.444	0.524
1974	0.060	0.167	0.459	0.781	0.682	0.574	0.767	0.612	0.525	1.011	0.474	1.128	0.690
1975	0.037	0.254	0.335	0.444	0.676	0.708	0.848	1.014	1.094	0.672	0.848	1.190	0.931
1976	0.005	0.129	0.504	0.670	0.615	0.598	0.609	0.537	0.505	0.729	0.453	0.740	0.573
1977	0.004	0.056	0.277	0.309	0.351	0.279	0.256	0.494	0.426	0.316	0.652	0.161	0.375
1978	0.004	0.083	0.169	0.363	0.441	0.387	0.274	0.373	0.638	0.528	0.510	0.112	0.323
1979	0.001	0.043	0.184	0.264	0.524	0.571	0.600	0.625	0.828	1.062	0.493	0.377	0.612
1980	0.003	0.022	0.166	0.248	0.386	0.454	0.582	0.632	0.721	0.207	0.994	0.209	0.607
1981	0.001	0.045	0.113	0.340	0.384	0.454	0.546	0.805	0.779	1.025	1.784	0.263	0.676
1982	0.004	0.026	0.172	0.189	0.392	0.406	0.338	0.565	0.622	0.775	0.167	0.146	0.452
1983	0.000	0.010	0.132	0.302	0.428	0.443	0.561	0.727	0.343	0.475	0.413	0.587	0.644
1984	0.000	0.009	0.047	0.226	0.391	0.478	0.617	0.696	0.618	0.785	1.416	0.279	0.656
1985	0.002	0.019	0.086	0.275	0.429	0.497	0.558	0.614	0.521	0.497	0.289	0.580	0.586
1986	0.002	0.046	0.134	0.291	0.247	0.385	0.498	0.788	0.786	1.172	0.437	0.355	0.643
1987	0.001	0.016	0.129	0.261	0.401	0.283	0.382	0.573	0.566	0.709	0.593	0.639	0.477
1988	0.002	0.034	0.108	0.296	0.363	0.489	0.491	0.614	0.785	0.963	0.943	0.481	0.552
1989	0.001	0.038	0.159	0.399	0.512	0.564	0.662	0.887	0.829	1.199	1.049	0.625	0.775
1990	0.008	0.060	0.239	0.458	0.679	0.761	0.834	1.196	1.195	0.949	1.359	0.794	1.015
1991	0.007	0.099	0.308	0.546	0.829	0.800	1.001	0.979	0.867	1.606	0.611	1.285	0.990
1992	0.014	0.102	0.366	0.547	0.672	1.040	1.052	0.924	0.891	1.083	2.632	0.146	0.988
1993	0.002	0.009	0.036	0.051	0.087	0.112	0.151	0.158	0.159	0.125	0.204	4.164	0.155
1994	0.001	0.002	0.004	0.010	0.015	0.018	0.020	0.024	0.030	0.021	0.019	0.019	0.019

Table 27: Beginning of year population estimates for southern Gulf cod from an ADAPT calibration.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1971	89952	39962	31717	31720	19037	6062	3305	1674	506	562	150	300	443	0	225390
1972	35518	73641	30819	19387	17590	10233	2854	1574	900	297	140	55	137	223	193368
1973	49013	26203	40162	14358	9841	7560	5165	1475	794	400	134	68	32	70	155275
1974	56994	38885	15120	19764	6937	4691	3656	2545	704	344	237	48	13	16	149954
1975	47400	43954	26950	7825	7413	2873	2163	1390	1130	341	102	121	13	5	141680
1976	123021	37390	27925	15792	4109	3086	1159	759	413	310	143	36	30	4	214177
1977	170274	100261	26909	13818	6618	1818	1389	516	363	204	123	74	14	14	322395
1978	165331	138812	77599	16693	8309	3814	1127	881	258	194	122	52	52	8	413252
1979	116766	134866	104568	53673	9509	4377	2120	702	497	112	94	60	38	31	427413
1980	116622	95466	105770	71214	33763	4610	2024	953	308	178	32	47	34	17	431038
1981	86389	95215	76424	73319	45509	18786	2397	926	415	122	118	10	31	15	399676
1982	153034	70640	74491	55893	42706	25392	9770	1137	339	156	36	16	6	13	433629
1983	207327	124825	56369	51332	37889	23619	13855	5707	529	149	59	25	12	3	521700
1984	110947	169707	101160	40440	31057	20221	12419	6477	2259	307	76	32	11	5	495118
1985	105509	90809	137751	79013	26405	17207	10268	5487	2645	997	115	15	20	5	476246
1986	86008	86225	72936	103455	49161	14070	8574	4810	2432	1287	497	71	7	9	429542
1987	70449	70295	67387	52209	63307	31437	7838	4268	1792	908	327	263	41	3	370524
1988	60475	57607	56621	48476	32927	34700	19395	4381	1971	833	366	148	114	21	318035
1989	68255	49413	45604	41615	29501	18749	17415	9715	1942	736	261	117	75	53	283451
1990	74307	55818	38955	31849	22854	14459	8731	7356	3275	694	182	75	52	28	258635
1991	47419	60349	43010	25101	16473	9475	5520	3105	1821	812	220	38	28	15	213386
1992	38347	38564	44724	25830	11877	5872	3473	1648	955	627	133	98	9	8	172165
1993	28684	30955	28464	25297	12179	4937	1683	981	526	321	174	8	69	3	134281
1994	20688	23436	25105	22477	19666	9135	3608	1182	683	365	232	116	0	49	126742
1995	0	16913	19139	20468	18216	15852	7344	2893	944	542	293	186	93	0	102883

Table 28: Input data for catch projections. See section 5.3 for details.

Age	Laurec-Shepherd	Extended Survivors	ADAPT	Partial Recruitment	Average Weight (kg)
3	20000	20000	20000	0.0093	0.44
4	17419	13552	16913	0.0977	0.59
5	15324	13218	19139	0.3349	0.77
6	14098	12805	20468	0.5349	1.01
7	16385	14605	18216	0.7442	1.36
8	10789	10217	15852	0.9116	1.71
9	3941	4698	7344	1.0000	1.93
10	1660	1677	2893	1.0000	2.08
11	503	751	944	1.0000	2.23
12	297	553	542	1.0000	2.14
13	75	232	293	1.0000	2.11
14	105	263	279	1.0000	3.68

Table 29: Summary of yield projections from the three calibrated SPA's.

Method		1995	1996	1997
Laurec Shepherd	F	0.024	0.2	
	Catch biomass	1300	12000	
	Population biomass	88000	96000	93000
	Spawning biomass	71000	80000	77000
Extended Survivors	F	0.025	0.2	
	Catch biomass	1300	11000	
	Population biomass	83000	91000	87000
	Spawning biomass	69000	75000	71000
ADAPT	F	0.017	0.2	
	Catch biomass	1300	16000	
	Population biomass	117000	124000	115000
	Spawning biomass	100000	108000	99000

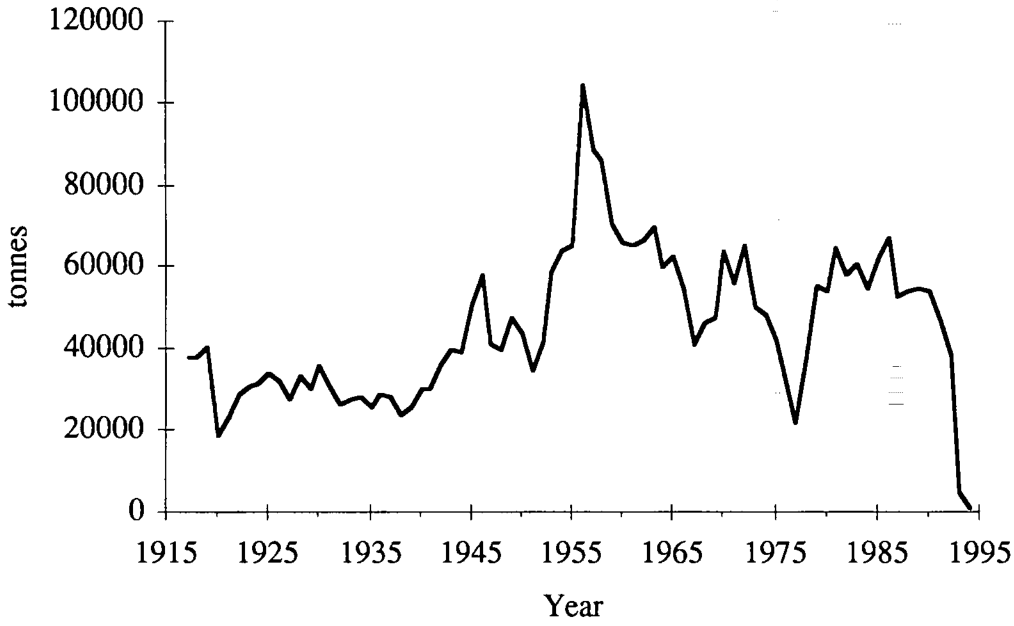

Figure 1: Landings of southern Gulf cod, 1917-94.

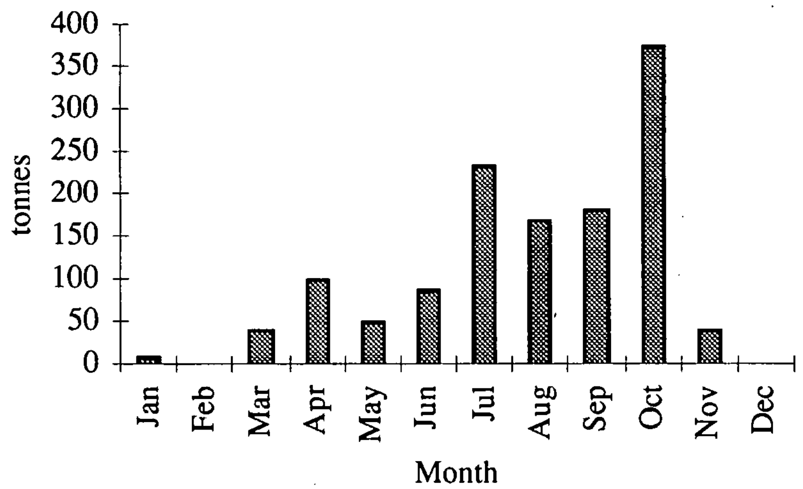

Figure 2: Monthly landings of southern Gulf cod, 1994.

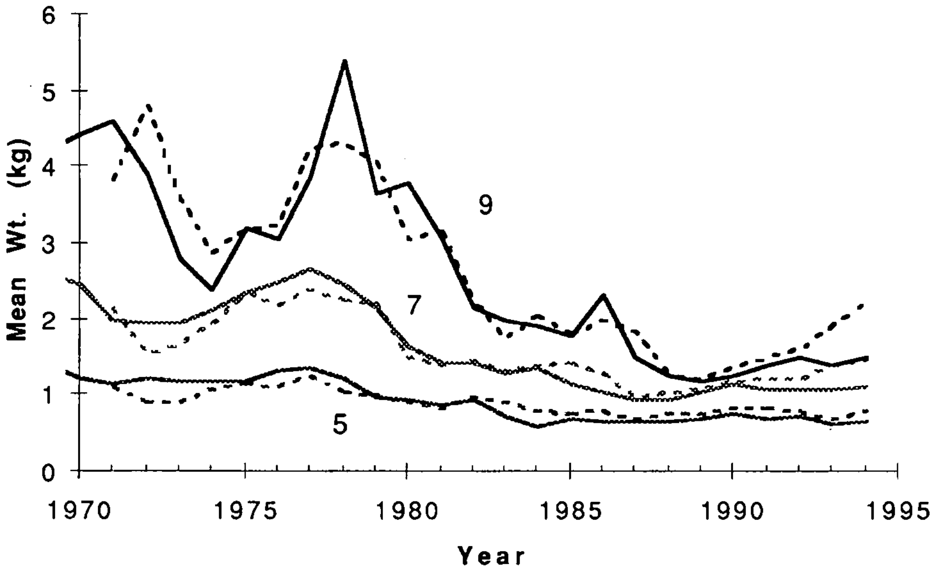

Figure 3: Trends in mean weights at age 5, 7, and 9 (kg) of southern Gulf cod from the commercial fishery (dashed lines) and the research vessel surveys (solid lines).

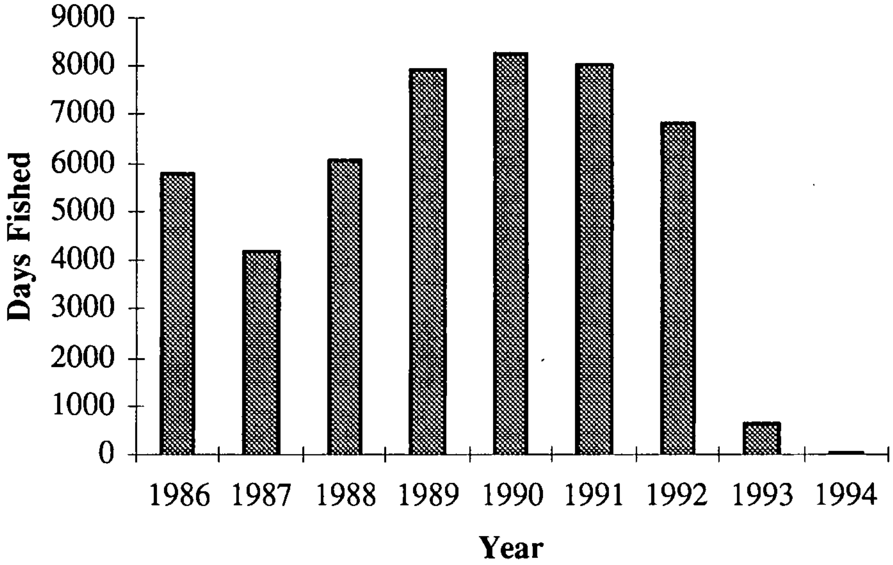

Figure 4: Cod directed nominal fishing effort (days fished) by mobile gear vessels.

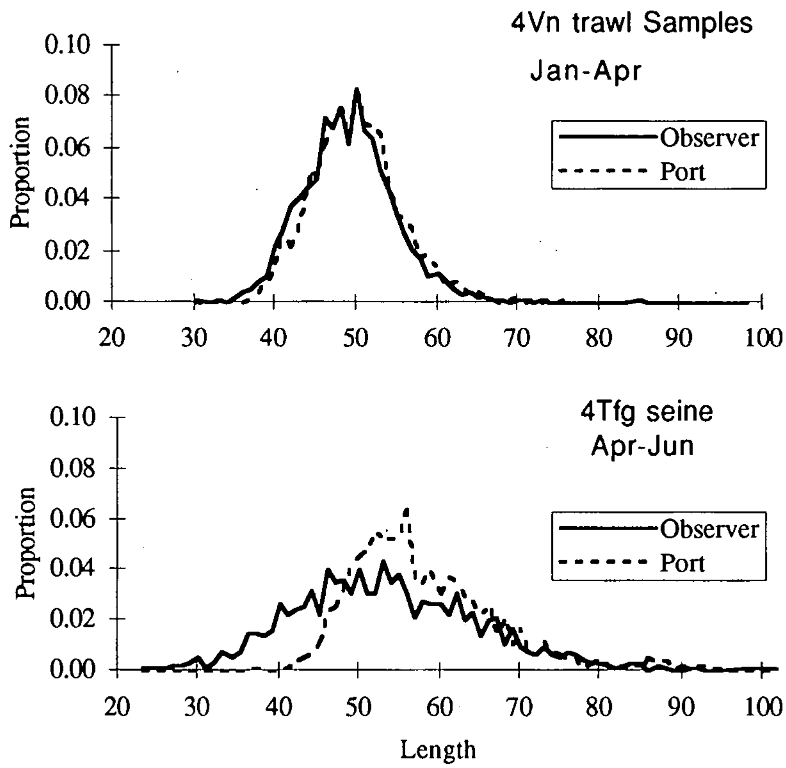

Figure 5: Observer and port sampled length frequencies in 1994.

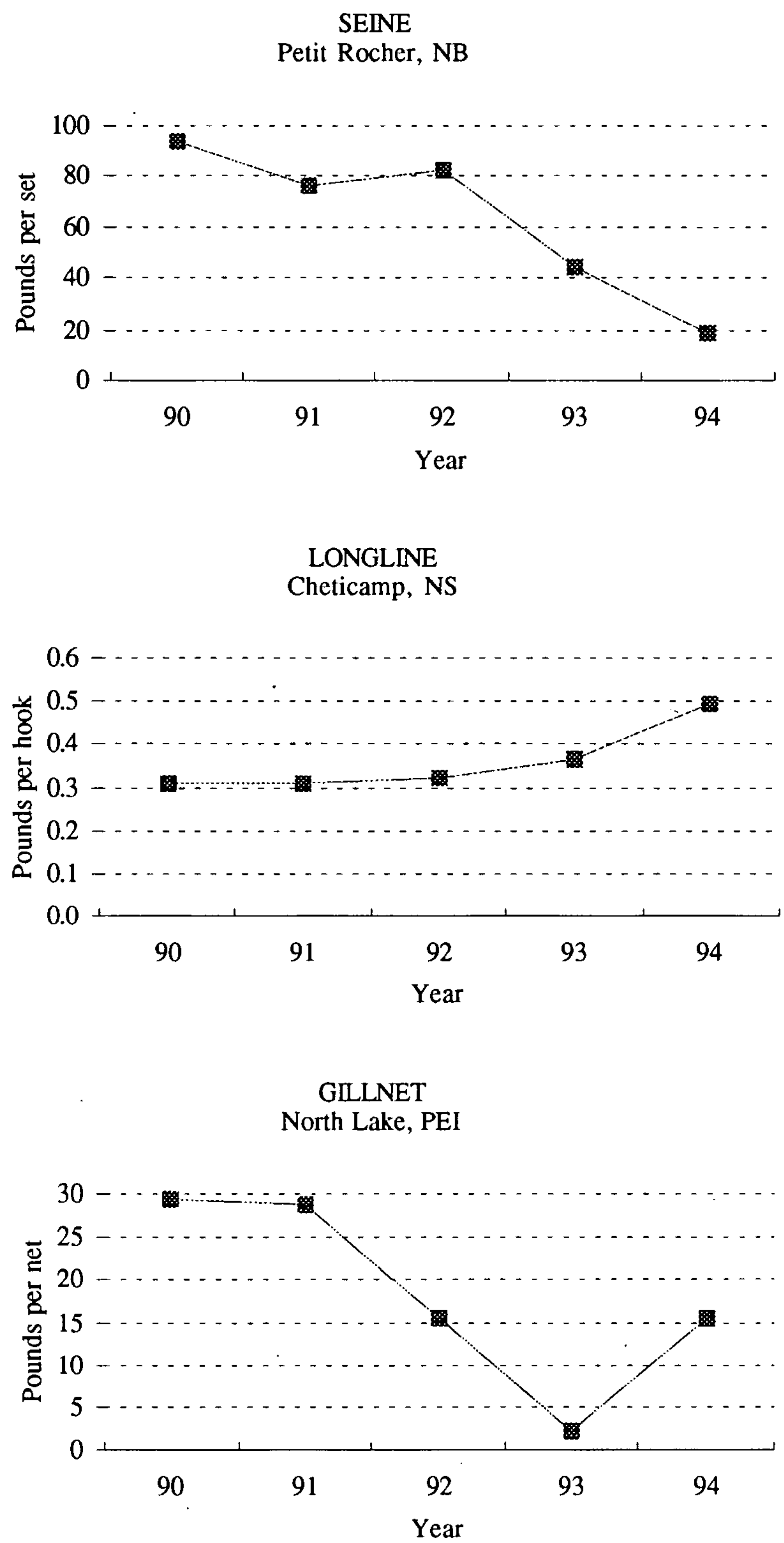

Figure 6: Catch rates for cod from 3 index fishers that submitted log records 1990-94.

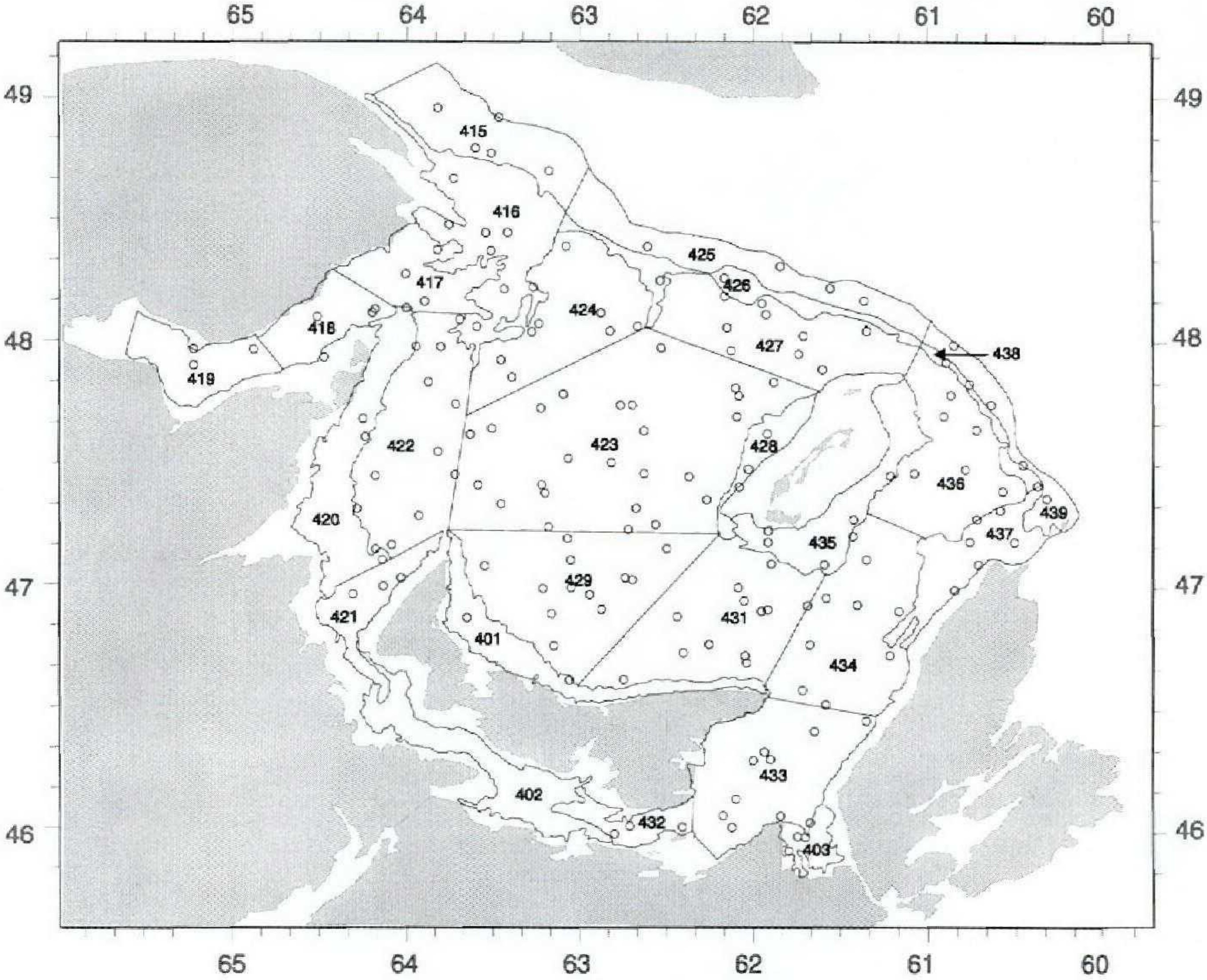

Figure 7: Strata boundaries and fishing locations for the 1994 southern Gulf groundfish survey.

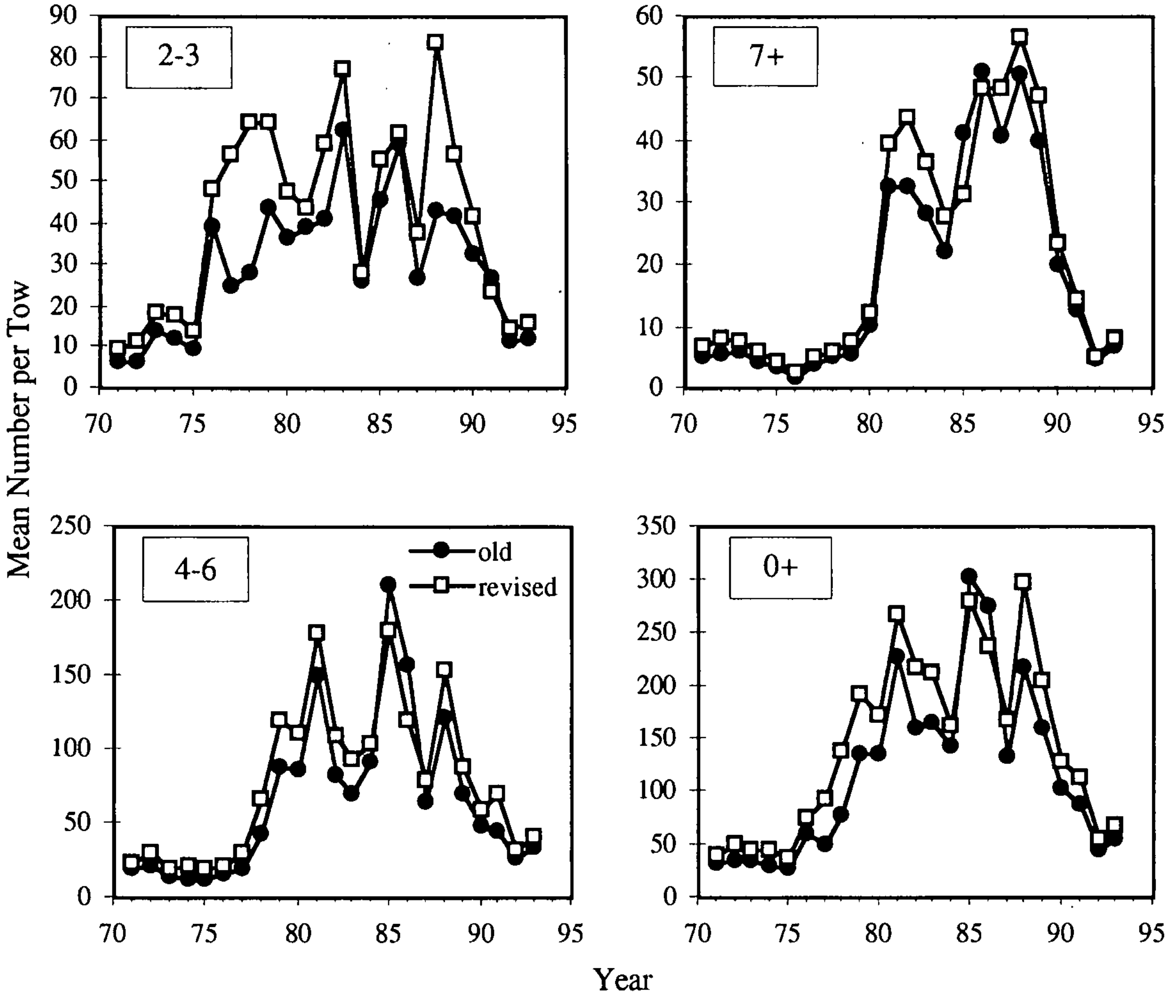

Figure 8: Comparison of revised and previously -used abundance indices for cod aged 2-3, 4-6, 7+ and 0+.

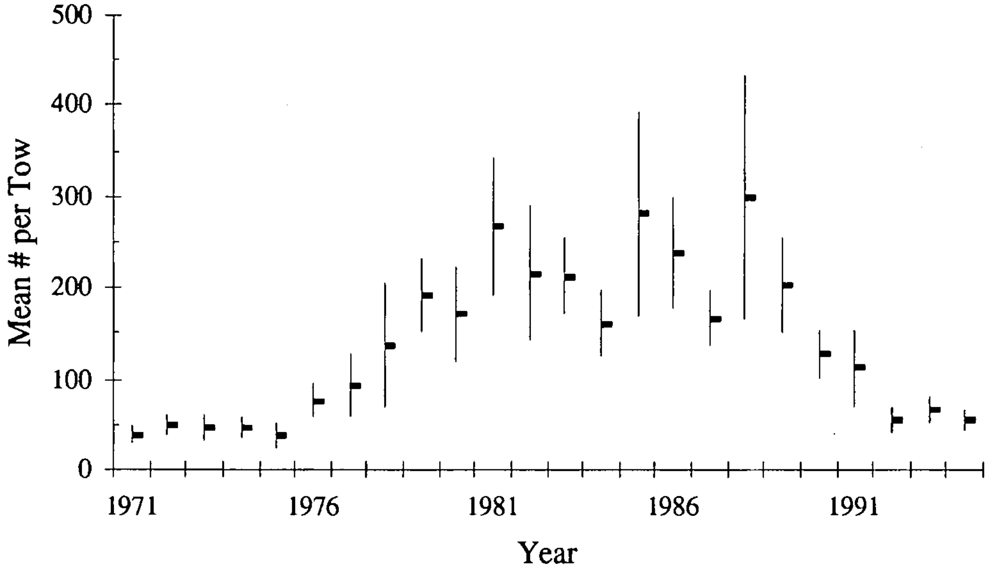

Figure 9: Mean numbers per tow (ages 0+) of southern Gulf cod from the September groundfish survey. Error bars give 2 standard errors.

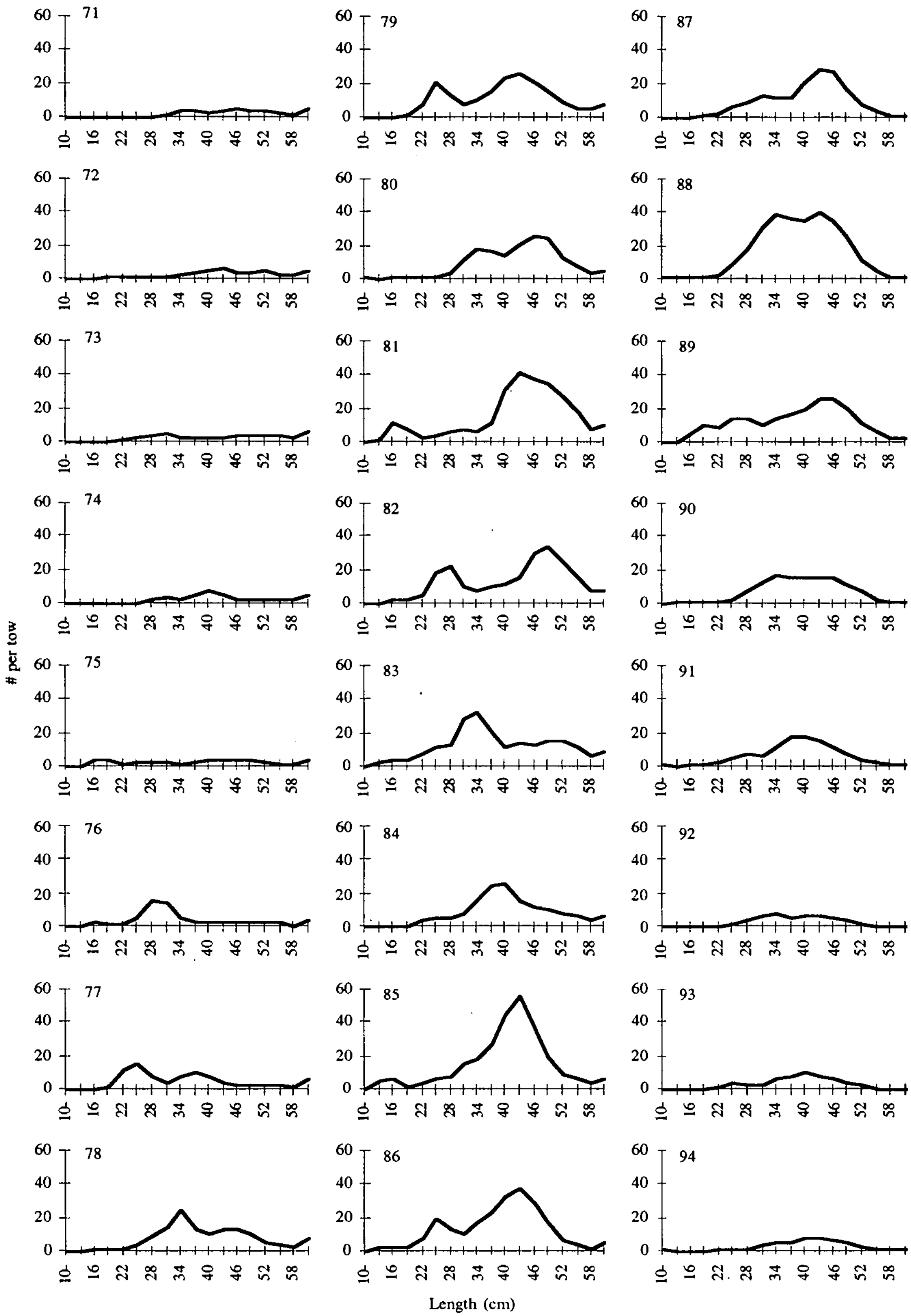

Figure 10: Annual length frequencies (mean numbers per tow at length) of southern Gulf cod from September groundfish surveys, 1971-94.

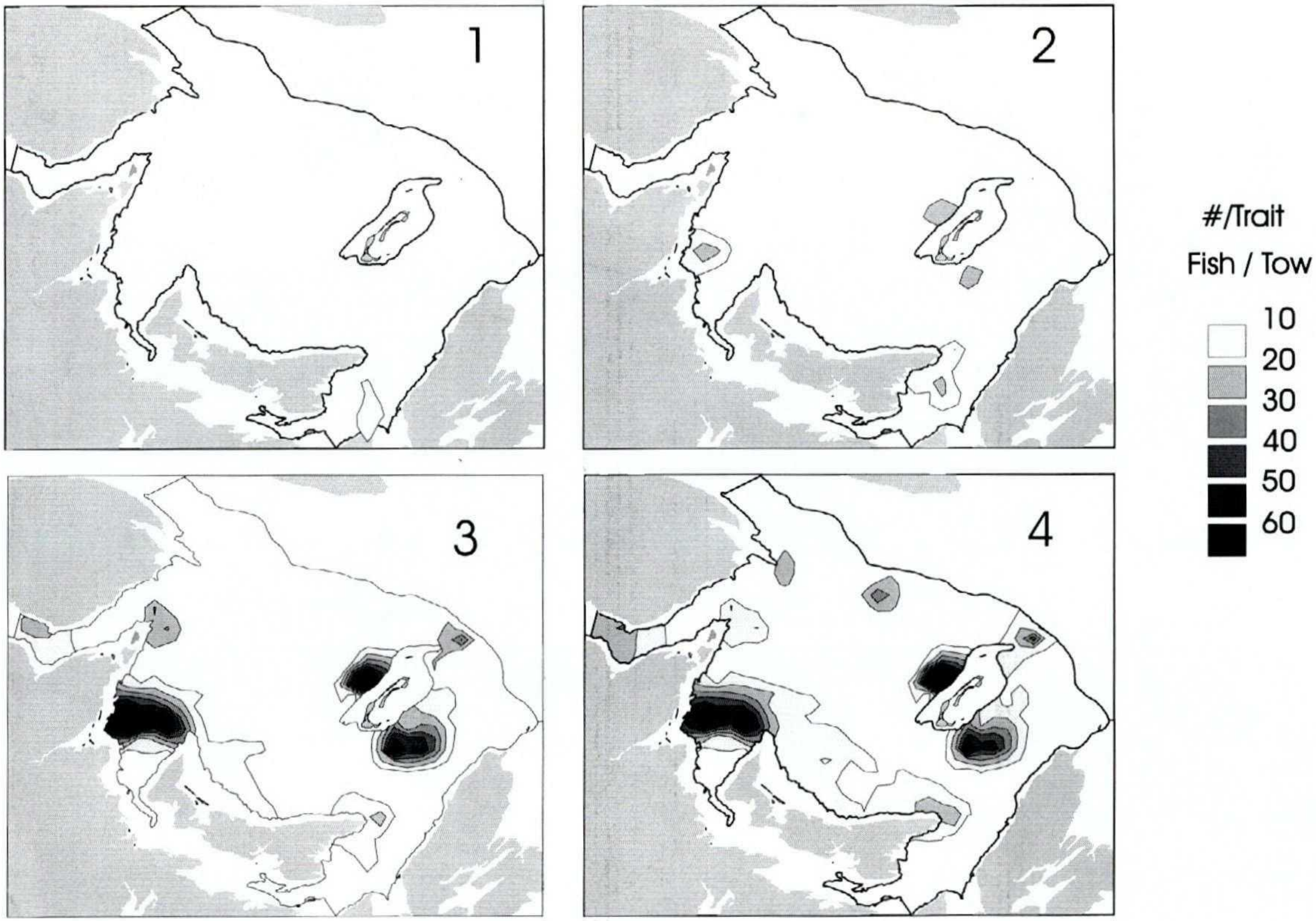

Figure 11 . Geographic distribution of cod by age during the 1994 September survey of the southern Gulf of St. Lawrence.

Distribution geographique de la morue selon l'age, durant le releve de 1994.

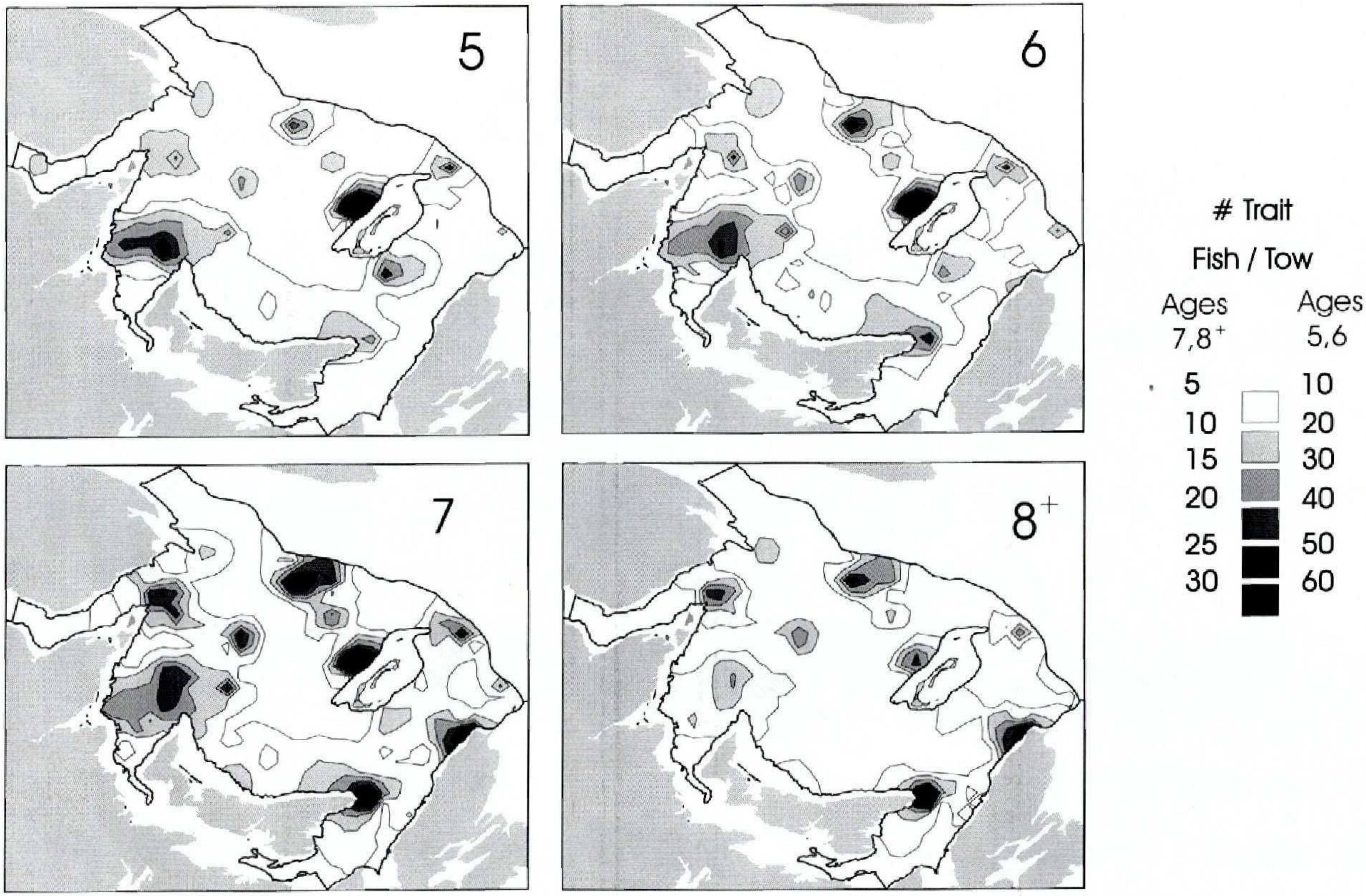

Fig. 11 .(cont'd./suite)

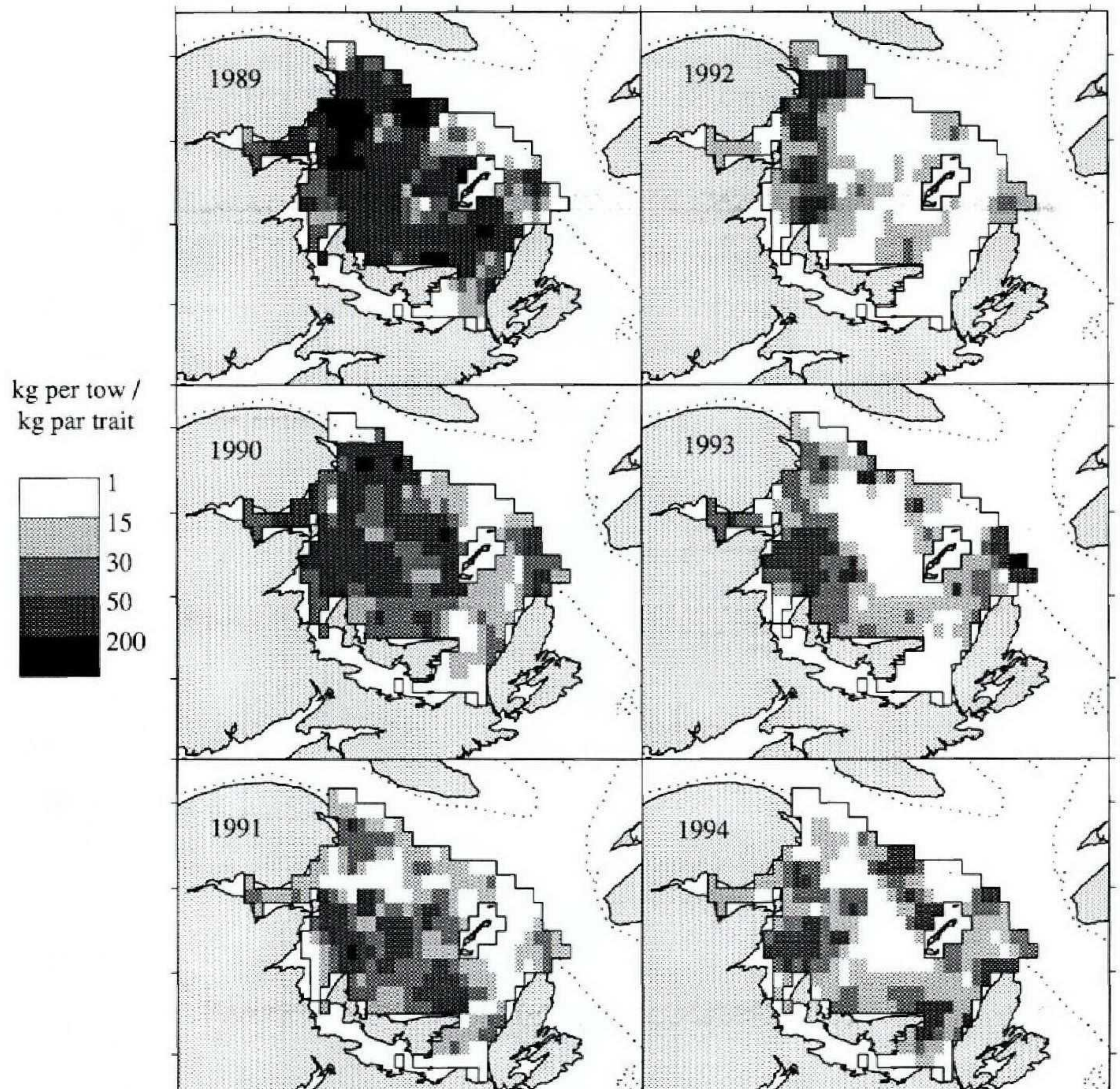

Figure 12: Distribution of research vessel catches of commercial sized cod (>41cm) 1989-94.

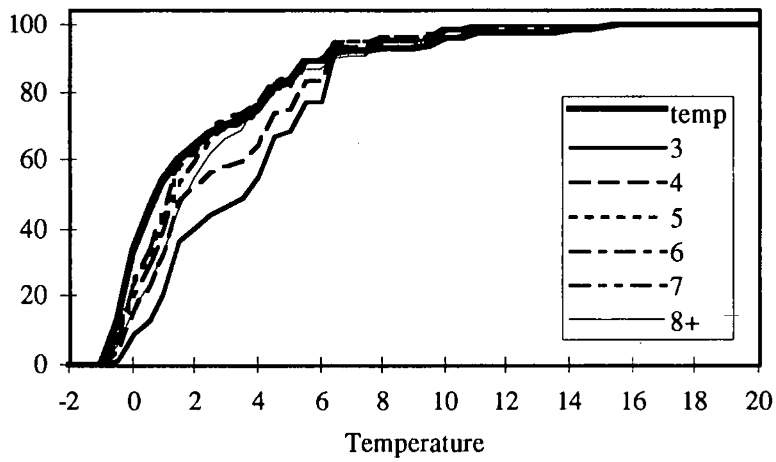

Figure 13: Cumulative frequency distributions of temperature and of cod catch in relation to temperature during the September 1994 southern Gulf groundfish survey.

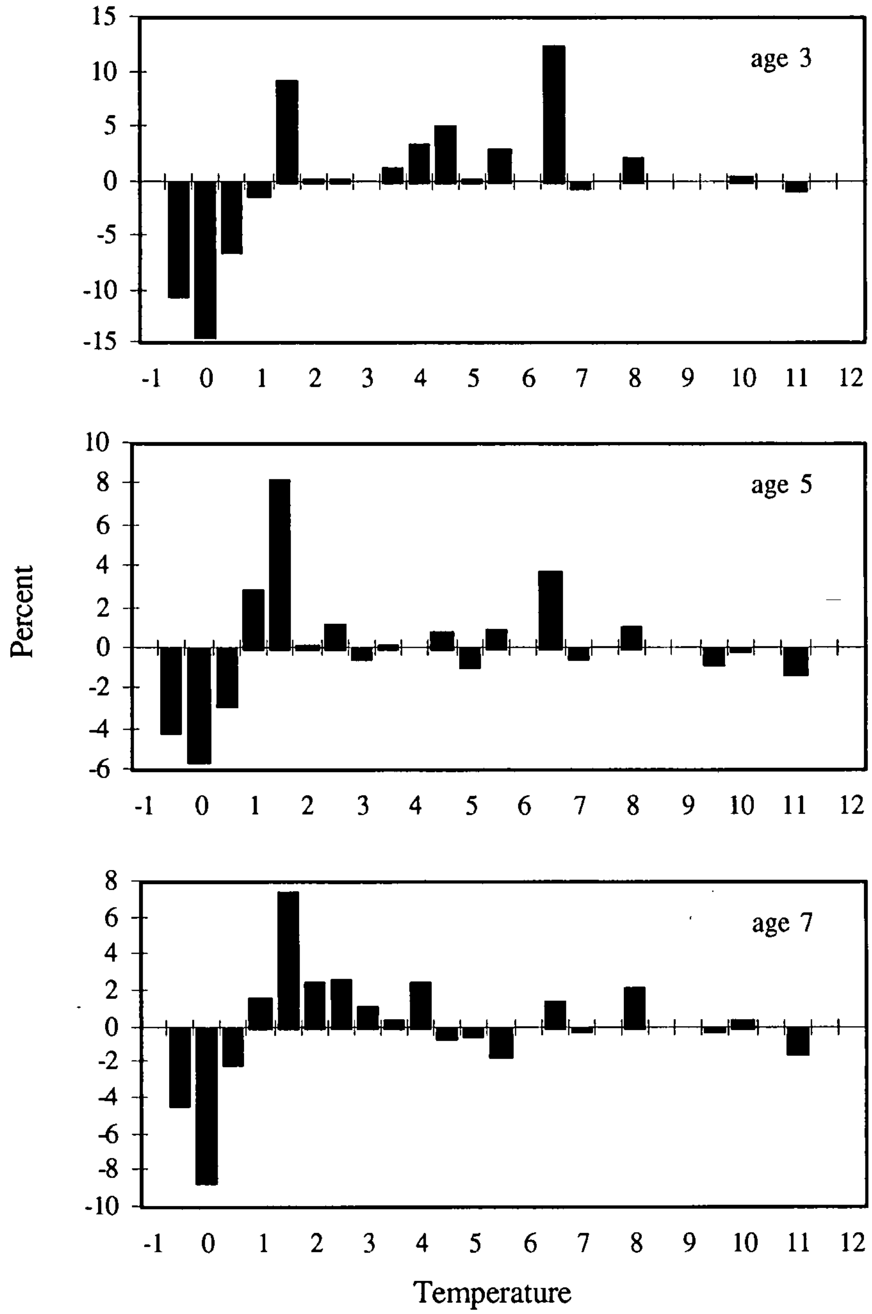

Figure 14: Cod distribution in relation to available temperature, September 1994. Bars are the estimated percent of the cod population occupying a particular temperature minus the estimated percent of the survey area with that bottom temperature.

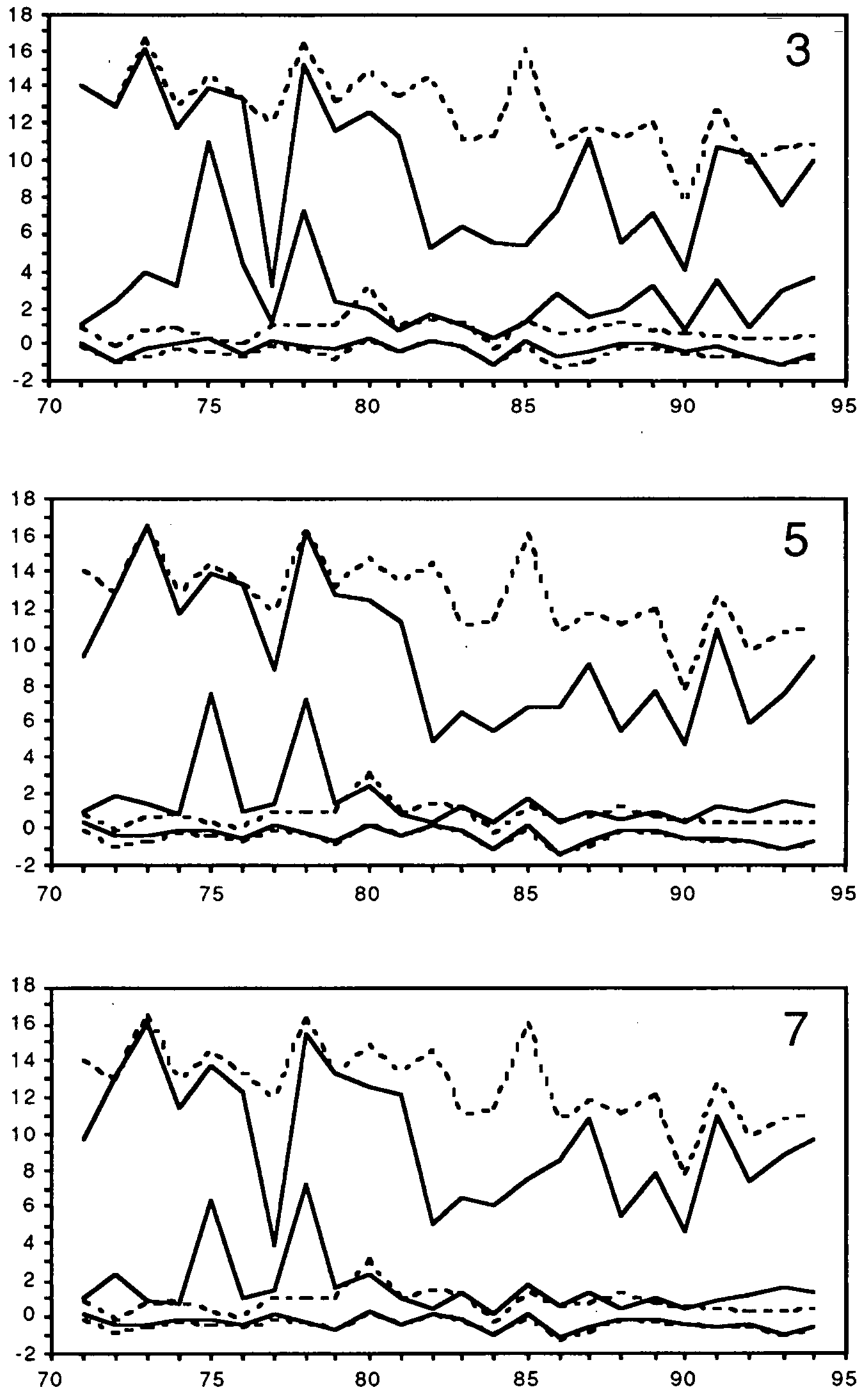

Figure 15: The 2.5, 50.0 and 97.5 percentiles of the distributions of temperature (dashed) and cod catch in relation to temperature (solid) in September in the southern Gulf of St. Lawrence, 1971-1994. Ages 3, 5 and 7 are shown in the upper, middle and bottom panels respectively.

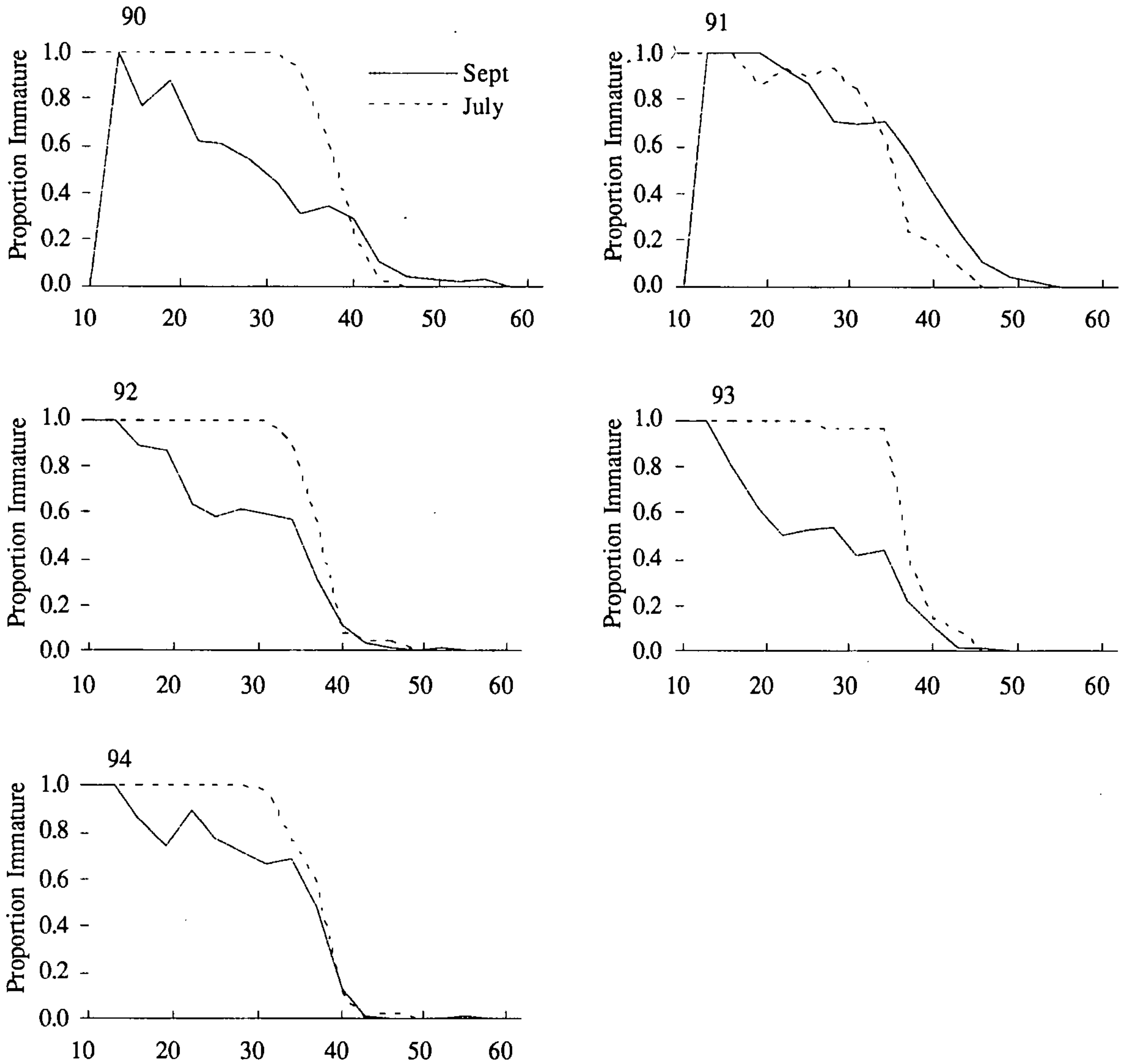

Figure 16: Proportions immature at length for southern Gulf cod from July juvenile (dashed lines) and September (solid lines) groundfish surveys, 1990-94.

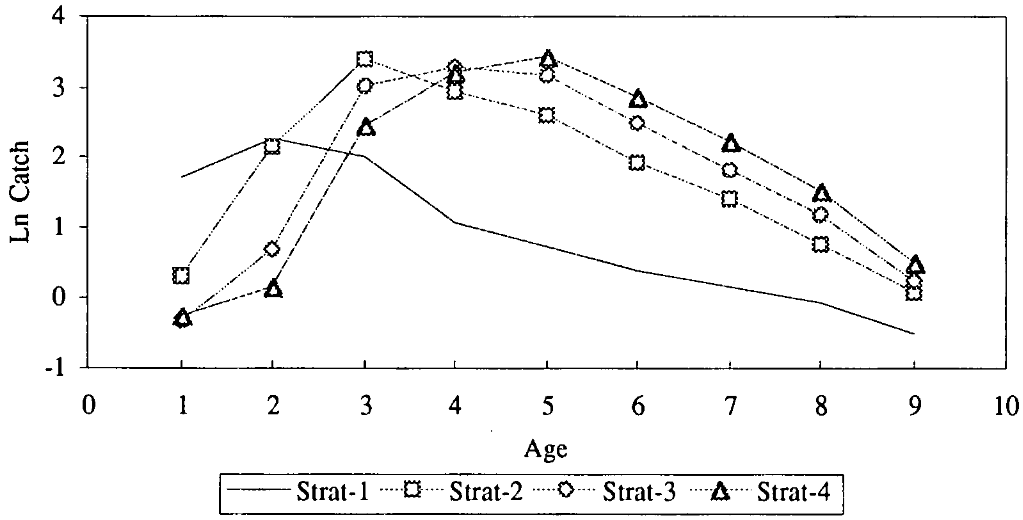

Figure 17: Least square mean estimates of mean catch per tow and stratum from the July juvenile cod survey.

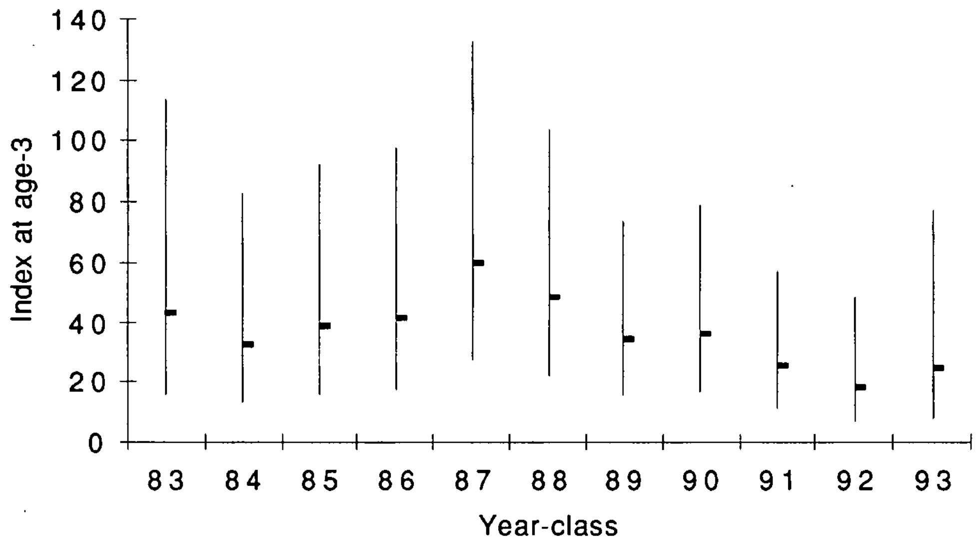

Figure 18: Year-class index (mean numbers per tow) from the juvenile cod survey . Error bars give the 95% confidence intervals.

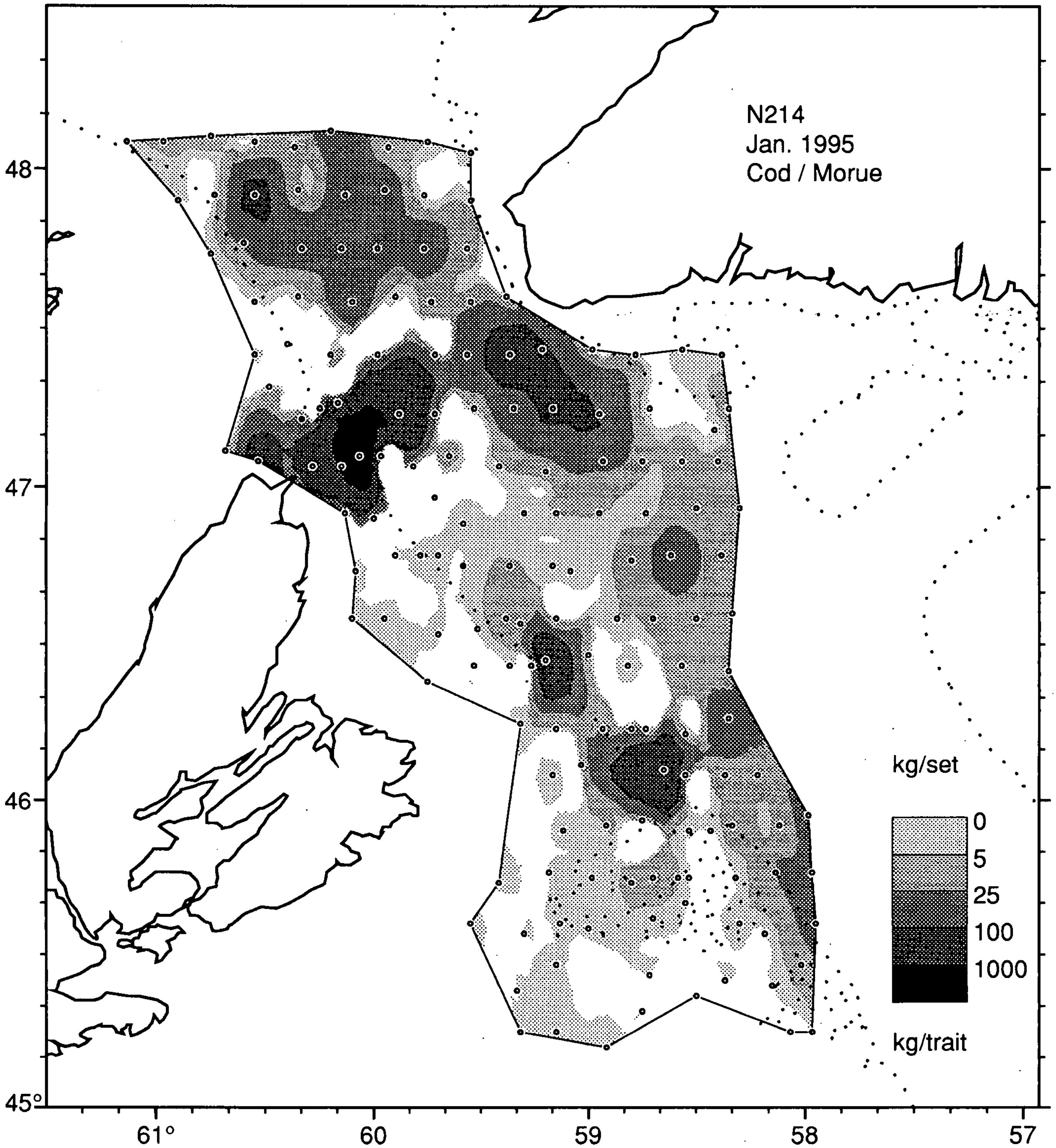

Figure 19: Catches of cod (kg/tow) during the January 1995 groundfish and herring survey in Cabot Strait. Open circles indicate set locations, dotted line is the 200 m isobath.

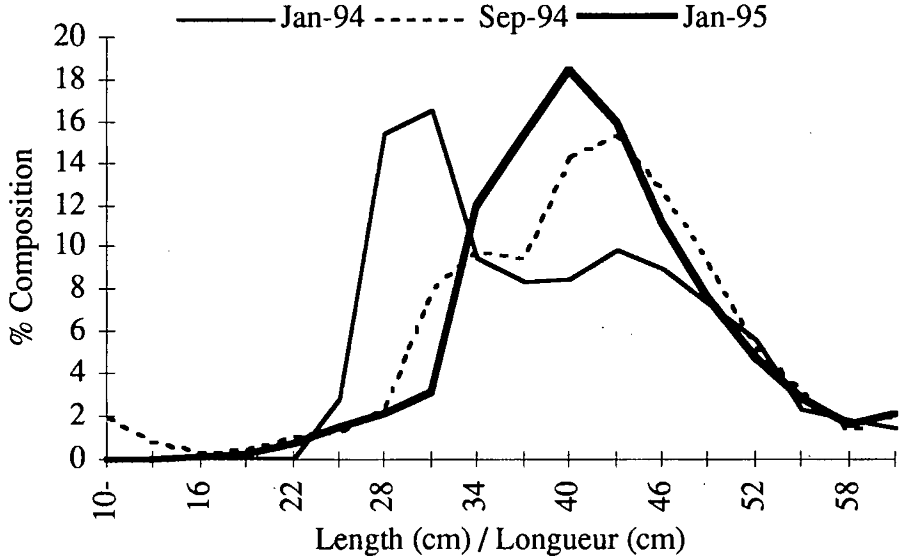

Figure 20: Length frequencies of cod captured during the January 1994-1995 and September 1994 groundfish surveys.

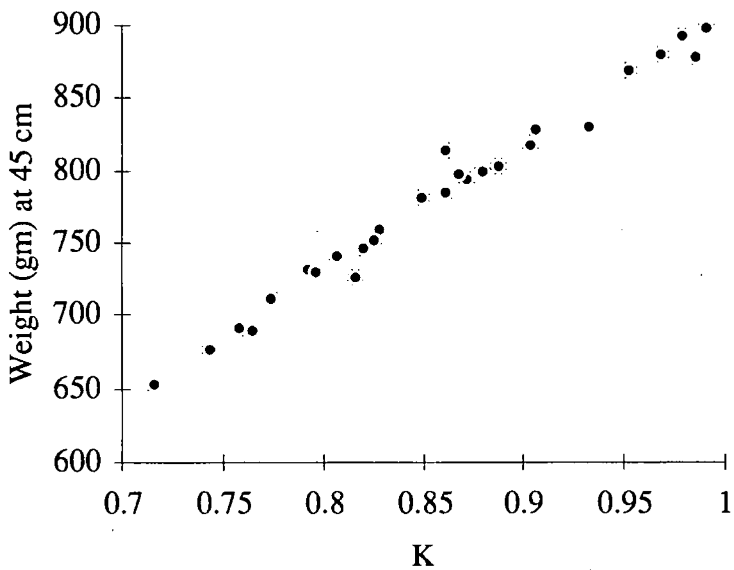

Figure 21: Relationship between K and the predicted weight (gm) of a 45 cm cod from length-weight least squares regression for seasonal samples.

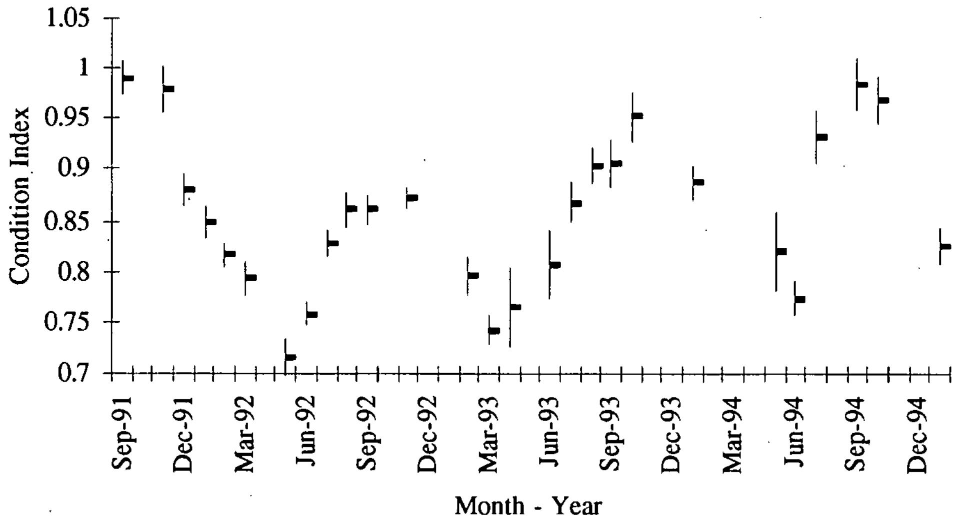

Figure 22: Seasonal change in Fulton's condition index (carcass weight/length^3) for southern Gulf of St. Lawrence cod of 40-50 cm between September 1991 and January 1995. Error bars give 2 standard errors.

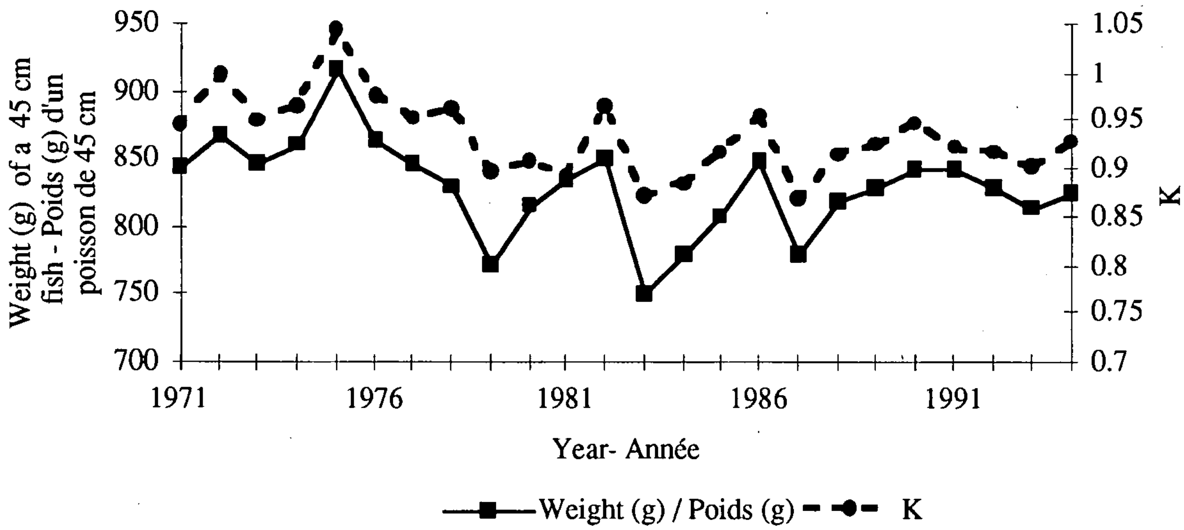

Figure 23: Trends in annual condition factors for southern Gulf cod.

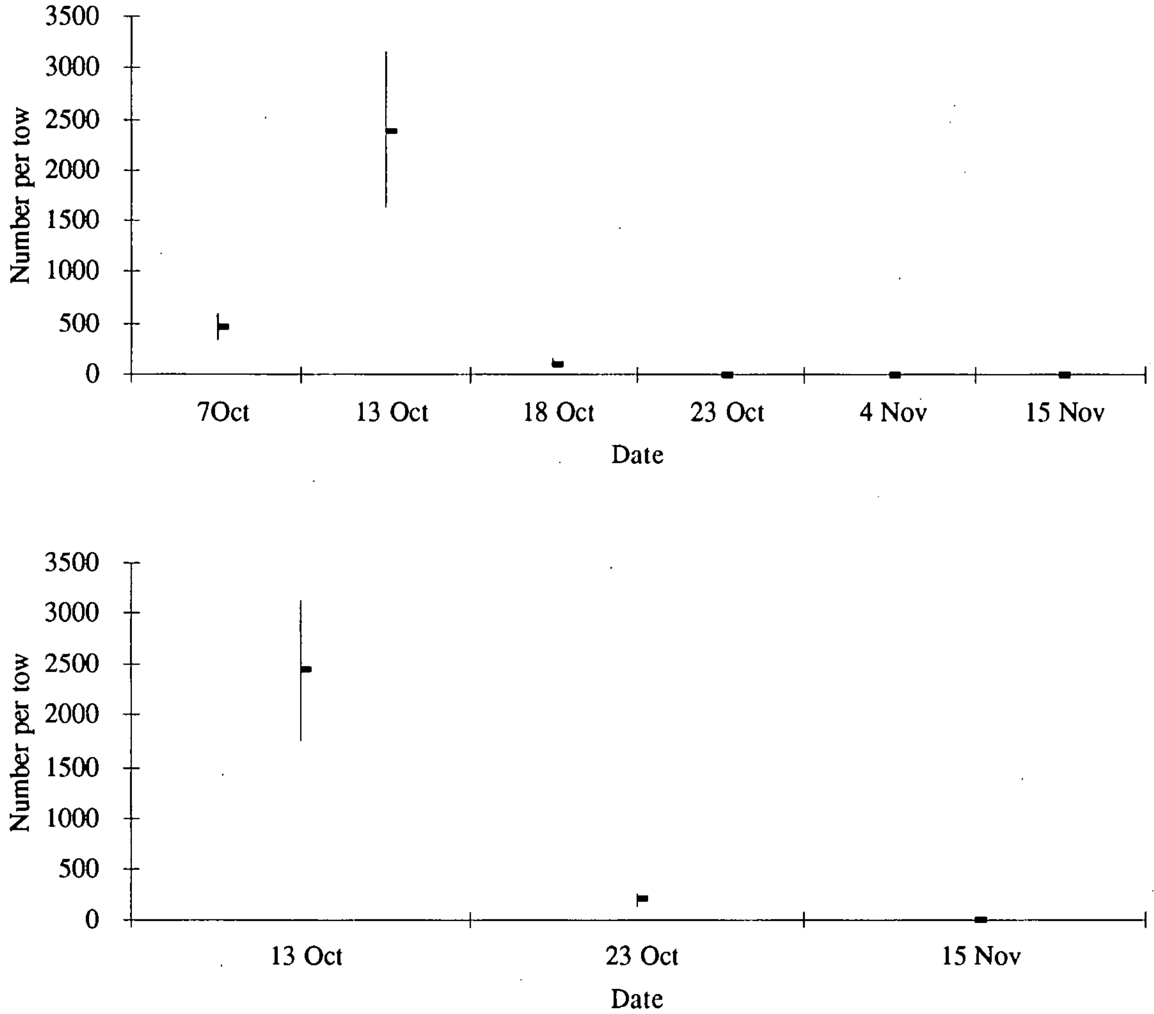

Figure 24: Catch rate (numbers per tow) of large (> 41 cm, upper panel) and small (<=41 cm, lower panel) cod in sentinel fishery trips in 1994.

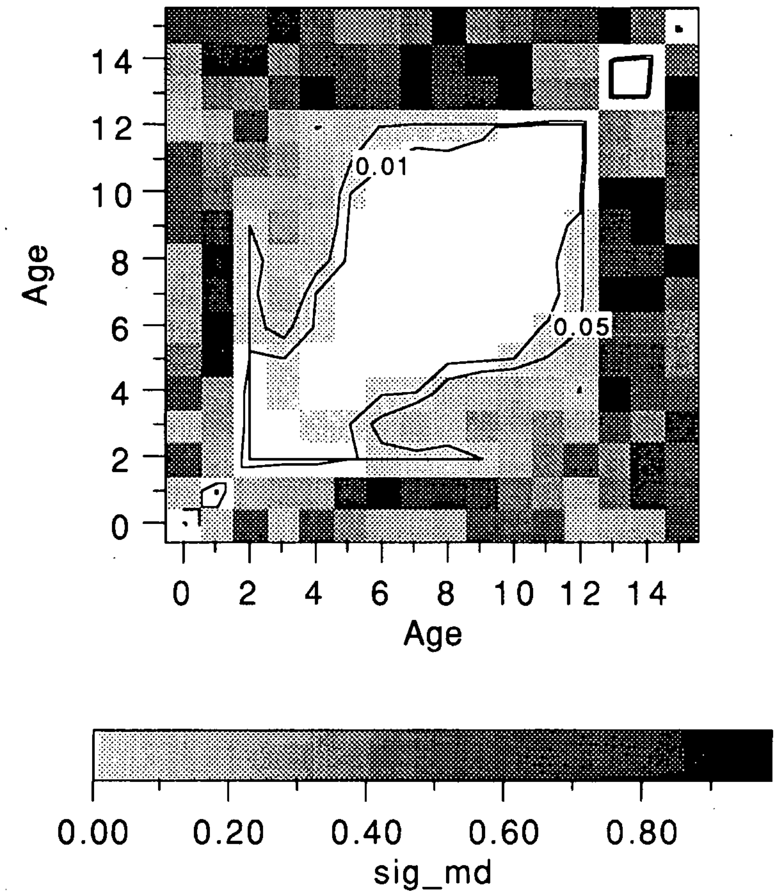

Figure 25: Significance of correlations among RV estimates of the same year-classes but at separate ages. Contours indicate the 0.05 and 0.01 significance levels.

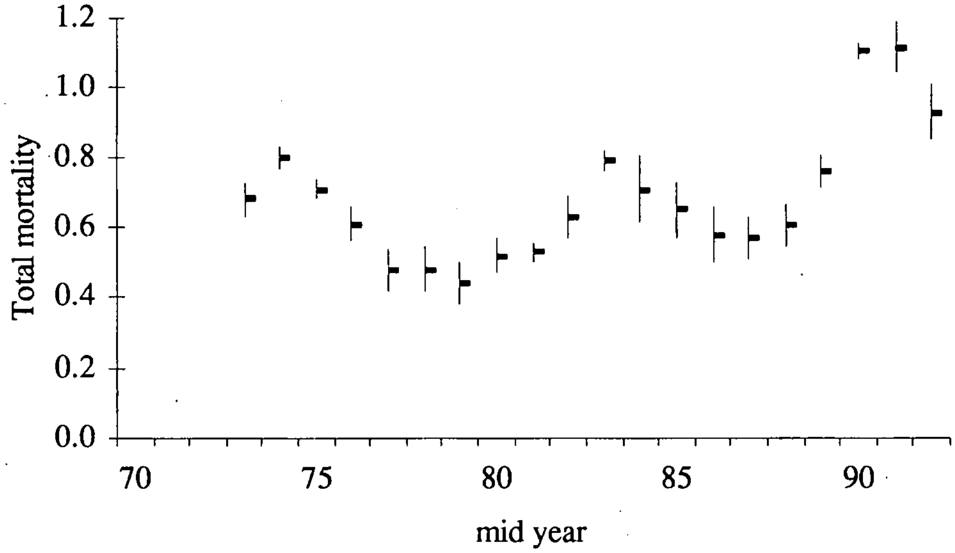

Figure 26: Total mortality (Z) estimates from separate multiplicative analyses of RV results which covered successive 5-year intervals. Z was estimated for ages 6-10. Error bars give 2 standard errors of the estimated slopes.

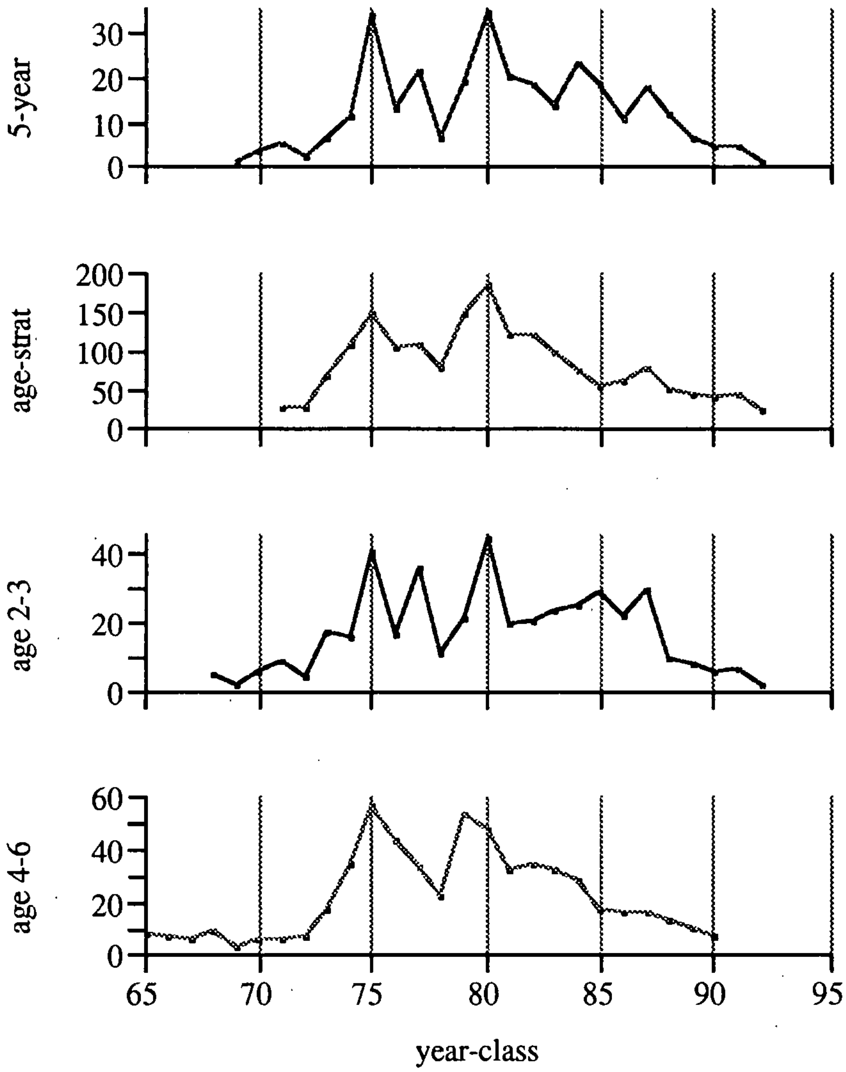

Figure 27: Relative year-class strengths of southern Gulf cod estimated from four multiplicative analyses of RV survey results. All estimates have been back-transformed to the arithmetic scale and are in units of mean numbers per tow. The upper panel is from analyses of successive 5-year intervals of the RV index, the second panel is from an analysis of mean numbers per tow at age and stratum, the third from an analysis of age 2-3 RV catches, and the last panel is from an analysis of ages 4-6 RV catches.

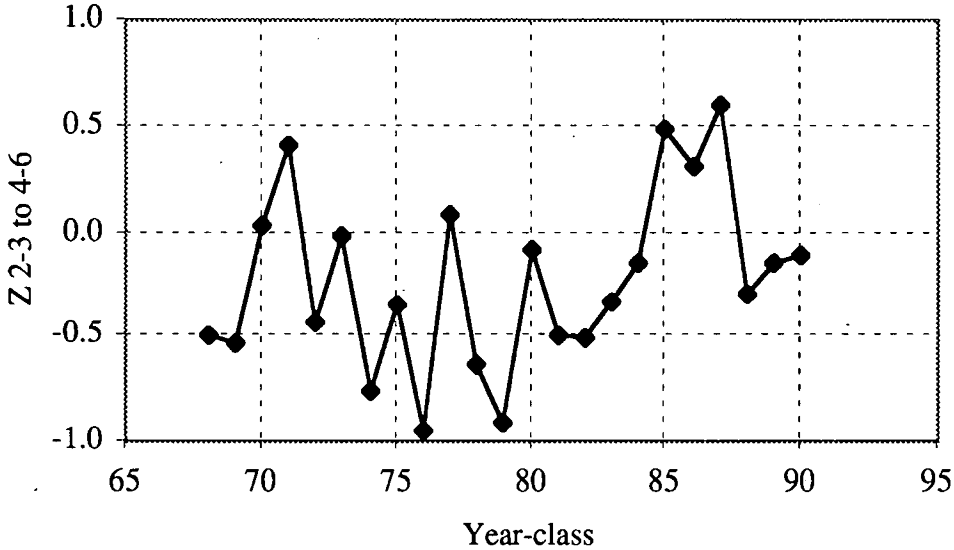

Figure 28: Trend in total mortality (relative) of the 1968-90 southern Gulf cod year-classes between the ages 2-3 and 4-6.

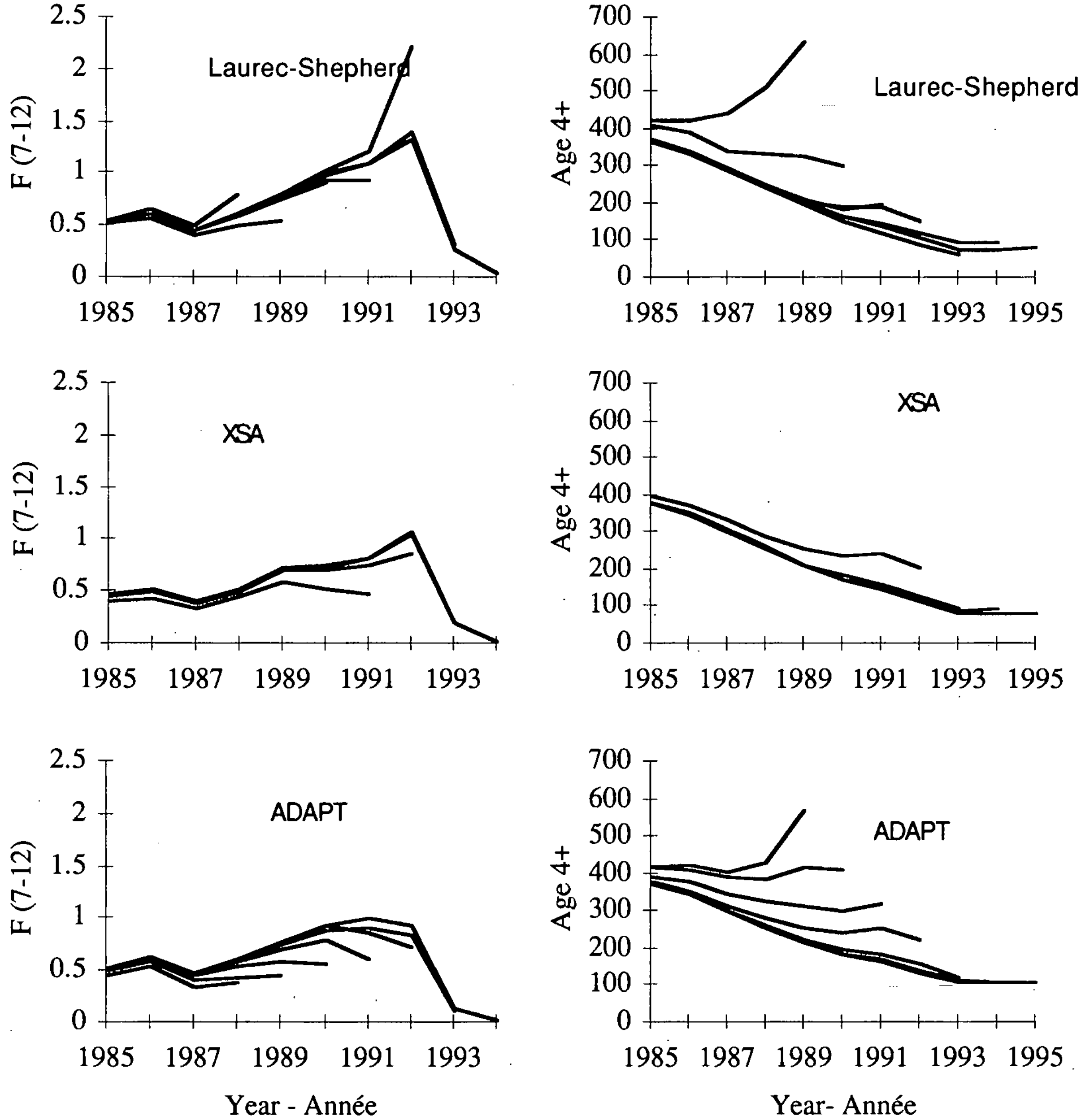

Figure 29: Retrospective patterns in fishing mortality and population numbers from the Laurec-Shepherd and Extended survivors calibrations.

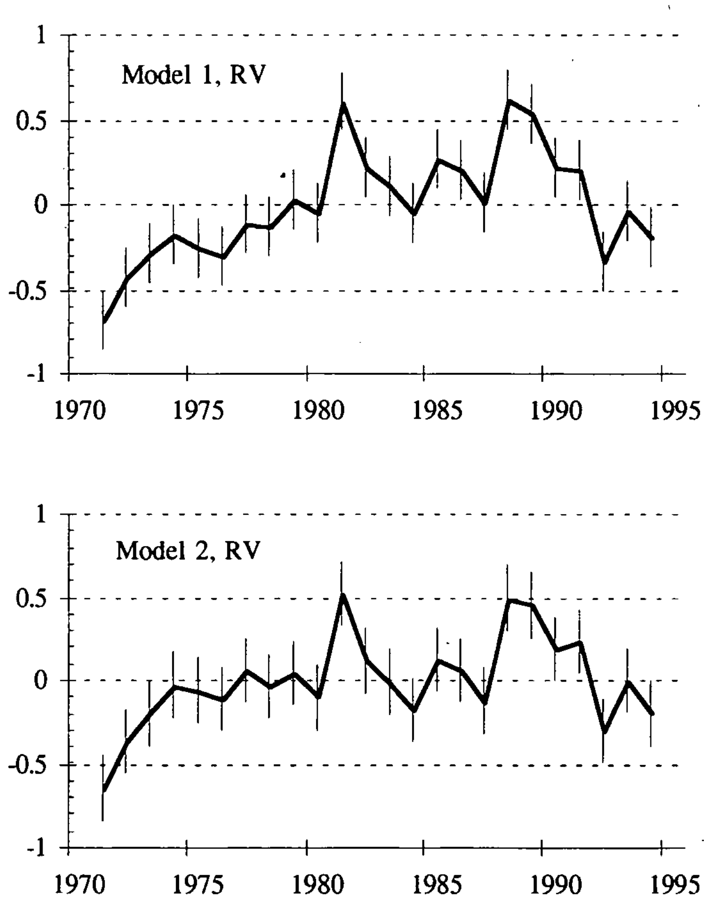

Figure 30: Residual patterns from ADAPT calibrations. Model 1 refers to the traditional linear calibration model. Model 2 estimated a time trend in otter trawl catchability and a density dependent catchability to the research survey. The error bars indicate the 95% confidence limits of the annual means.

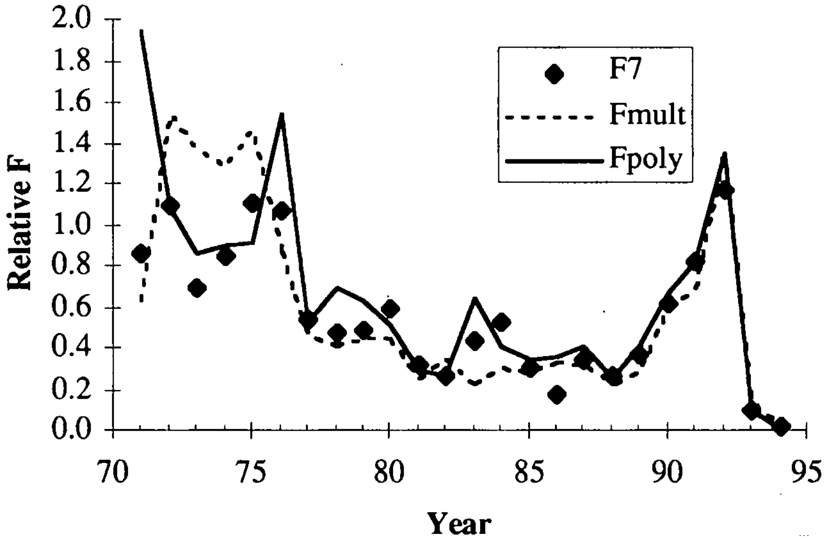

Figure 31: Estimates of relative fishing mortality obtained directly from the ratio of catch at age divided by RV population estimates at age. The observed age 7 relative F (F7) is compared to those predicted by a multiplicative analysis (Fmult) and an analysis of covariance (Fpoly) of the relative F's at age.

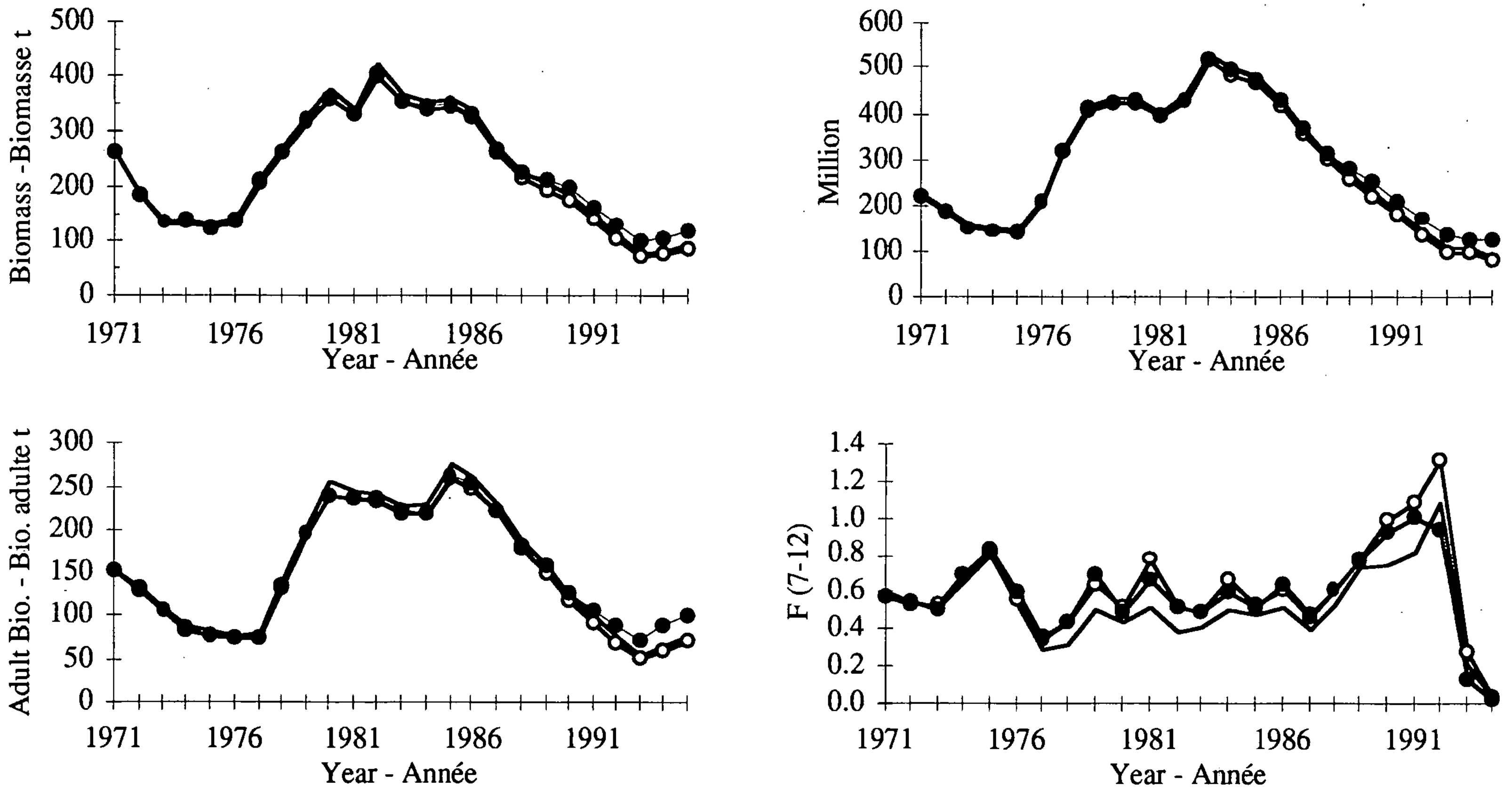

Figure 32: Total and adult biomass ('000 t), total abundance (million fish) and fishing mortality (7-12) for the three SPA calibrations. Open circles (LS), solid circles (ADAPT), and line (XSA).

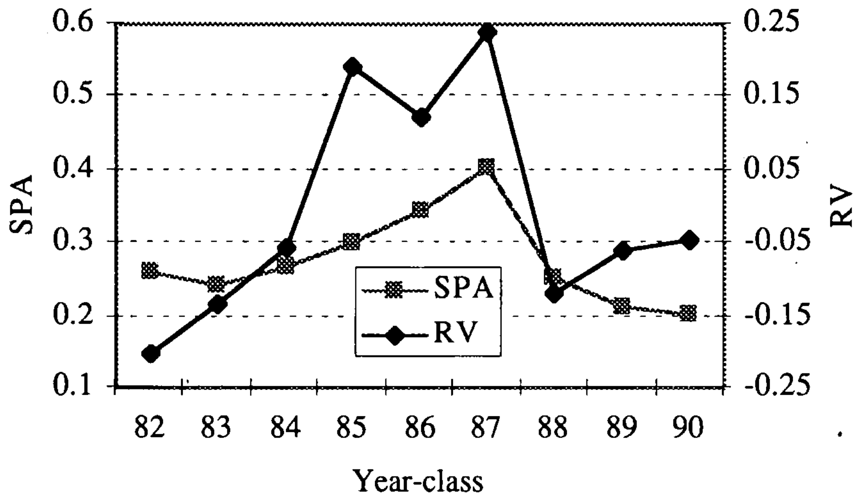

Figure 33: Comparison of instantaneous total mortality rates for 9 year-classes from two sources of information. The SPA estimates were taken from the estimated abundance at ages 3 and 6. The RV estimates are of relative total mortality and were obtained from the difference between age 2-3 and 4-6 year-class indices.

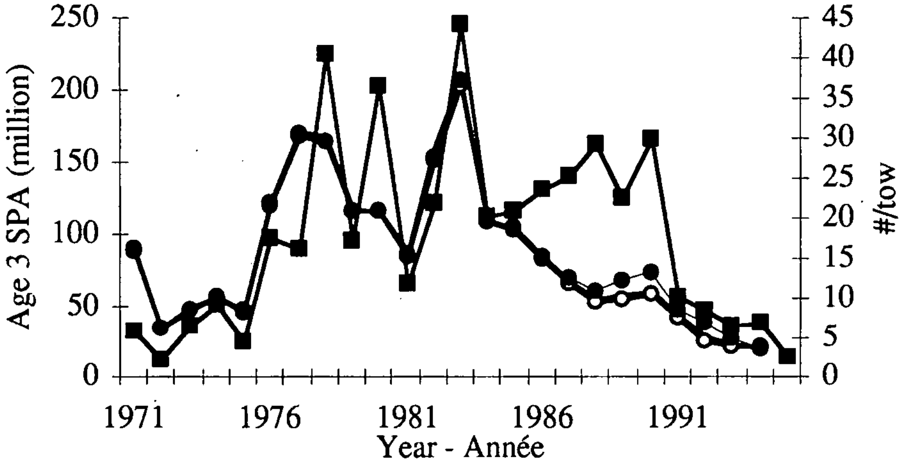

Figure 34: SPA and research survey (age 2-3) estimates of recruitment (age 3). The SPA lines are designated as in Figure 28. The solid squares are the research survey estimates.