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Assessment of the Southern Gulf of St. Lawrence Cod Stock, March 1996

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Abstract

Directed cod fishing in the southern Gulf of St. Lawrence was closed in September, 1993. Stock size had reached an historic low level because of high fishing mortality, reduced recruitment, and low growth rates. The results of the 1995 research vessel survey and data from other sources including sentinel surveys, indicate that the adult biomass has increased slightly since the closure due mainly to the growth of adult fish, but that the abundance of young fish is well below average. There are signs that the abundance of age 0, 1, and 2 cod may be improving, however the indications are highly variable and uncertain at this time. Stock production continues to be low and catches of as little as 6,000t could prevent any increase in spawning stock biomass. Continued low levels of fishing, similar to that in 1994-95, and improved recruitment are required for stock recovery.

Résumé

La pêche dirigée de la morue dans le sud du golfe du Saint-Laurent a été fermée en septembre 1993. Le niveau du stock était tombé à la valeur la plus faible jamais notée à cause d'une forte mortalité par pêche, d'une baisse du recrutement et de faibles taux de croissance. Le relevé par bateau de recherche de 1995 et des données d'autres sources, dont ceux de pêches de contrôle, indiquent qu'il y a eu une légère augmentation de la biomasse des adultes depuis la fermeture, surtout à cause de la croissance des individus adultes, mais que l'abondance des jeunes poissons est toujours bien en deçà de la moyenne. Il y a certains indices d'un accroissement de l'abondance des morues d'âges 0, 1 et 2, mais ceux-ci sont très variables et encore incertains. La production du stock continue d'être faible et un volume de captures d'aussi peu que 6 000 t pourrait interdire toute augmentation de la biomasse des géniteurs. Le rétablissement du stock exige le maintien de faibles niveaux de capture, semblables à celui de 1994-95, et une amélioration du recrutement.

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1. Description of the 1994 Fishery

Directed commercial cod fishing continued to be prohibited in 1995. Other fisheries which normally produce some cod by-catch were also closed in 1995, including Unit 1 redfish and 4T white hake. Fisheries for American plaice, witch flounder, winter flounder and dogfish were permitted. However, these fisheries were subject to a number of management measures designed to limit cod by-catch. A recreational fishery using hook and line gear was allowed. A sentinel survey conducted under a scientific protocol and designed to obtain additional indices of abundance of the stock was conducted. In this section, a summary of landings, management measures and input from industry about the status of the southern Gulf of St. Lawrence cod stock in 1995 is provided.

1.1. Landings by gear, area, season, fishery type

The total reported landings of southern Gulf cod was 1075t in 1995 (Table 1). This is slightly lower than landings for 1994 (1334 t) and represents the third consecutive lowest catch on record for this stock (Figure 1). The catches were entirely from NAFO Division 4T except for 6 tonnes caught in 4Vn in the period of November-December.

Landings decreased for all gear types except miscellaneous gears (mainly unspecified gear) which increased from 154t to 371t (Table 2). This component was composed primarily of catches from the recreational fishery (318 t). Fixed gear (gillnets, handlines, longlines) catches declined from 554 to 139 t.

Monthly landings peaked in October mainly due to the sentinel surveys. 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). Landings by fixed gears occurred predominantly in the period of August to October while the recreational fishery peaked in August.

1.2. Management measures

Management measures in 1995 were similar to those of 1994. With the continued closure of the fishery in 1995, DFO maintained the by-catch limits of 10% (by weight) of cod in fisheries directed toward other species. The cod by-catch protocol in existence in 1994 was continued whereby if a given fleet sector exceeded the limit of 10% in an area, the groundfish fishery would be closed for at least 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%. There was no redfish fishery in 4Vn in November, 1994 - April, 1995 because of the Unit 1 redfish closure. 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 whereby fisheries were closed if the percentage of small fish caught exceeded specific thresholds. 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.

In 1995, there were 36 closures due to either high by-catches of cod or of small fish. The closures affected both fixed and mobile gear fleets.

In addition to these measures, DFO introduced monitoring of small fish through the dockside monitoring system. Fisheries management personnel compared samples collected by dockside monitors to those collected by observers at sea. On two occasions, the plaice fishery was closed when dockside samples suggested that discarding at sea was taking place on vessels not covered by observers. Increased monitoring was also put in place in the fixed gear fishery. This coupled with the closure of the white hake fishery contributed to the reduced catches by this fleet sector.

1.3. Input from industry

The views from industry on the status of the cod stock were expressed at a number of meetings during 1995. Following the release of the 1994 stock status report on June 29, 1995 in Charlottetown, staff from the Groundfish Section held a series of information meetings in Charlottetown (June 30), Caraquet (July 4), Port Hawkesbury (July 7), Gaspé (July 12) and Cap-aux-Meules (July 13). Views of fishers expressed during Fisheries Resource Conservation Council (FRCC) public meetings were also noted. These meetings were held on September 11 (Halifax Airport), September 12 (Sydney and Moncton) and on September 13 (Gaspé).

In general, the views of fishers from the western southern Gulf differed from those from the eastern area. In the western area (Gaspé and northeast N.B. in particular), there was no indication of a significant increase in cod abundance. In the Magdalen Islands, the views were mixed with some indicating that cod abundance had increased particularly in inshore waters. In the eastern area (P.E.I. and Gulf Nova Scotia), fishers indicated that they had made numerous incidental catches of cod in various gears (lobster traps, handlines, etc) which indicated that cod abundance had increased. Fishers in these areas had made the same observation in 1994.

The pre-assessment consultation was comprised of a series of Science Workshops, designed specifically to obtain the views of industry on the status of the stocks. These were held throughout the southern Gulf of St. Lawrence in late November and early December 1995. The meetings were held in Grande Rivière, Québec on November 21, in Caraquet, N.B. on November 22, in Charlottetown, P.E.I. on November 23, in Port Hawkesbury , N.S., on December 5 and in Cap-aux-Meules, Magdalen Islands, on December 7.

Scientists presented a preliminary description of the 1995 fishery including fishery distribution , the summary results of the September 1995 fall groundfish survey, and some sentinel survey results at these meetings. Fishers were then invited to provide comments on these data and indicate whether or not this was consistent with their view of the stocks. Generally, the opinions regarding stock status expressed during the Science

Workshops were similar to those of other meetings. In the western southern Gulf, abundance of cod was considered to be low while fishers in the eastern area indicated that they had perceived a significant increase in the abundance of cod. The following is a short summary of comments made at these Science Workshops.

In Grande-Rivière, only a few fishers attended the meeting. The only comment received regarding cod abundance was that it had not increased along the south Gaspé shore (e.g. off Newport). There were no indications of increased abundance of cod in the area. Fishers noted the lack of fixed gear coverage along the Gaspé Peninsula in the sentinel survey.

The meeting in Caraquet was attended by 15-20 fishers. Some indicated that they thought there had been a marginal increase in abundance of cod in 1995. A fisherman who had participated in the sentinel survey remarked that cod were in abundance in some areas but that generally, there had not been a significant increase. Other fishers also indicated that cod abundance may be higher in specific areas and this had been observed in the past. Several fishers reported that cod had migrated outside of the Gulf early in the fall, as in previous years. Many fishers indicated that the catches from the recreational fishery were underestimated.

In Charlottetown, the Science Workshop was attended by few fishers. In general, fishers considered that cod were far more abundant in shallows along the north shore of P.E.I. and in an area of hard bottom off North Point, P.E.I. They thought the survey had underestimated cod abundance because some inshore areas had few sets. Generally, fishers thought that there was sufficient cod abundance to open the fishery. Occurrence of cod in lobster traps continued to be important in 1995. Fishers were concerned that the sentinel survey did not include any fixed gear participants from P.E.I. because it was those fishers who reported increased cod abundance. Participants felt that recreational fishery catches were underestimated by DFO.

In Port Hawkesbury, about 30 fishers attended the workshop. In terms of abundance, fishers indicated that they thought there were far more cod in the western Cape Breton area in 1995 than indicated in the research survey. They reported that cod were caught much closer to the shore (<30 fathoms) and that the survey does not cover the inshore areas adequately. Many participants interpreted the numerous closures in other fisheries as an indication that the cod abundance had increased. One participant indicated however that he had fished some longline gear where others were reporting cod concentrations but that he had failed to locate any. Another noted that it was difficult to compare cod abundance to past years because of the change in mesh sizes. A participant indicated that when the fishery closed in 1993, parasite abundance in cod had increased by 250-300% and that this was concomittant with the increasing seal population. Sentinel surveys were also discussed at length during the meeting, with many participants indicating that many more fishers should be involved.

The meeting in Cap-aux-Meules (Magdalen Islands) was attended by about 35 fishers. Participants were of a very strong opinion that seal predation is seriously affecting the abundance of cod and other fish species in the area. There were mixed opinions about the abundance of cod in the area. Some noted a decrease in abundance to the northwest of the Islands, while others noted an increase to the southwest and southeast. Many participants reported an increased incidence of cod in lobster traps. Many felt cod had migrated away from the area earlier than usual, in early September. There was little fishing effort in the area, and it was therefore difficult to have a clear idea of cod abundance. Many indicated that they would have to be allowed to fish in order to find out if the abundance had changed recently. Many were disappointed that there were no sentinel survey projects involving fishers from the area. They felt that fishers from other areas would not know the best locations to fish around the Magdalen Islands.

2. Commercial Fisheries Data

2.1. Data Updates

Commercial landings statistics were updated according to revised Canadian data for 1994. An extra 34t were reported in 1994 compared to last year. This increase was spread among otter trawls, handlines and gillnets. The 1994 estimated catch at age was modified accordingly and the results are given in Annex 1.

2.2. Age Calibration

Consistency of age determinations was verified by regular blind readings of a reference otolith collection. Tests were performed after about 1000 fish had been aged. The level of agreement with the reference collection was high and no bias was detected (see below).

Date	% agreement	direction of bias
951109	92	0
951127	93	0
951205	92	0
951213	89	0

2.3. Catch at Age

The calculation of the 1995 commercial catch at age was complicated by the limited fishery, as was the case in 1994. 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 July 1995 and September 1995 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.

A summary of the sampling data used in constructing the 1995 catch at age is given in Table 3.

At this time, we have treated the observer and port samples separately in calculating the catch at age. Comparisons of observer and port sample combined length frequencies for similar areas and time periods indicate important differences (Figure 2). For example, the observer length frequency for seines in April - June included large numbers of cod greater than 70 cm in length, while the port samples did not. Where the seine length frequency covered a broad range of lengths, and predominantly in the upper length range, the port samples had a more distinct mode in the smaller length range. A similar pattern was noted for seines in October - December. In previous assessments, these comparisons revealed a different pattern. The length distributions for observer and port samples were similar for commercial sized fish (> 41 cm), but the observer samples included more small fish, less than the commercial size. We have attributed these differences to discarding at sea. In 1995, discarding cannot explain the differences, and for the moment the cause is unresolved. For this reason, we calculated the catch at length of observed and unobserved fishing trips separately. The observer sampling was applied to observed trips only while the port sampling data were used to calculated the catch at length of unobserved trips. Further investigation is warranted.

The catch at length in the 1995 sentinel surveys was calculated exclusively from sea sampling data on sentinel vessels. Ageing material from these trips was not available in time for the assessment and the July and September RV otoliths were used instead. Sampling for length was extensive, with over 440000 fish measured. Details of the keys are given in Table 3.

The following length (L, in cm)-weight (W in grams) relationship was obtained from the September 1995 research vessel survey and was used to calculate mean weights at age

$$W = 0.00608 * L^{3.1036}$$

Landings numbers, mean weights at age, and mean lengths at age for each age-length key are presented in Tables 4 to 6.

The total number of fish landed in 1995 was the second lowest on record (Table 7). The modal age in the 1995 landings was 7 (1988 year-class) but relatively large numbers of age 4 - 8 were landed. The larger numbers of age 4 and 5 fish came predominantly from the sentinel surveys, where liners were used on several trips. Commercial weights at ages 3-9 declined in 1995 probably due to the influence of the sentinel gear catches with liners on the total landings at age (Table 8 and Figure 3). Where in the past 2 years, the commercial weights at age have been increasing relative to those in the RV survey, this trend has stopped. In 1993 and 1994, the fixed gears made up a higher proportion of the total landings, and these gears tend to land larger fish at age.

3. Research Data

3.1. September 1995 Survey

The annual groundfish survey in the southern Gulf of St. Lawrence was conducted September 7-30 on board the research vessel *Alfred Needler* (Mission N230). A total of 226 standard sets (30 minutes at 3.5 knots) were attempted, of which 210 were successful. One hundred and eighty-three of these were in 4T, and 27 stations were fished in 4Vn. This is the second year the survey coverage was extended into 4Vn to investigate the distribution of cod between the two areas in September. The location of the sets is shown in Figure 4.

The 1995 survey results were strongly affected by one large tow. The mean number per tow of cod of all ages (0+) in the 1995 survey (98.9 fish/tow) is greater than the 1994 estimate (54.7 fish/tow) (Table 9). This increase is due mostly to one large set (#127 - see Figure 4) near Miramichi Bay that yielded nearly 6600 juvenile fish (765 kg). When this set was included in the estimations, the CV's on ages 1-3 were the highest in the series (Table 10). If this set is excluded from the analysis, there were 65.9 fish/tow and the CV's are within the range previously observed.

The cod length frequency distribution from the September survey may provide some encouragement in terms of improved recruitment, however the results must be interpreted with caution (Figure 5). The catch of age 0 cod (10 cm and less) in 1995 was the highest seen in the survey and the catches were distributed in several areas including Chaleur Bay, the Shediac Valley, northern P.E.I., and eastern Northumberland Strait. Set 127 was dominated by age 1, 2, and 3 fish and this had a large influence on the total population estimate. However, the juvenile survey (see section 3.2) conducted in the same area in July failed to detect improved numbers of fish less than 3 years of age. Age 0 to 3 fish in 1995 will not be of commercial size for at least two more years and it would be prudent to reevaluate their abundance following the 1996 survey.

The estimated abundance of fish age 5 and over in the September 1995 survey was close to that predicted in last year's assessment (Sinclair et al. (1995) predicted 38.5 fish/tow, and the observed value was 36.2 fish/tow). The overall survey results since 1992 continue to be very low compared to those of previous years (Figure 6) and indicate that the southern Gulf cod stock has not yet recovered.

Weights at age estimated during the 1995 September survey are at the low end of the range observed since 1960 (Table 11, Figure 3). This indicates that individual growth rates remain very low and these have not increased despite low stock abundance and reduced fishing mortality.

The geographic distribution of catches indicates that the highest concentrations of cod were found close to shore in 1995 (Figure 7). Areas of higher concentrations include the Shediac Valley, inner Chaleur Bay, the north shore of P.E.I., and east of the Magdalen Islands. Few cod were caught in the central part of the survey area and along the edge of the Laurentian Channel. The density of cod in 4Vn was markedly lower than that found inside 4T (Figure 8). The distribution of cod catches was discontinuous between 4T and 4Vn.

Distributions of cod aged 0 to 8+ were mapped for September 1995 (Figures 9 and 10) using the methods outlined in Sinclair et al. (1994). Large catches of age-0 cod were made in Chaleur Bay and in the Miramichi area at the northwest end of Northumberland Strait (Figure 9). A smaller concentration of age-0 cod was also encountered at the southeast end of Northumberland Strait.

Catches of age-1 cod in the 1995 survey were greater and more widespread than in recent years. A large concentration of age-1 cod was encountered in the Miramichi area, with smaller catches also made southeast of the Magdalen Islands and along the north shore of PEI. Ages 2 and 3 showed a similar distribution, with the greatest concentration in the Miramichi area and smaller concentrations southeast of the Magdalen Islands and along the north shore of PEI. Densities of cod aged 4-6 were greatest in the southwest Gulf in the Miramichi-Miscou area, with a second less dense concentration between Cape Breton and the Magdalen Islands (Figure 10). Cod aged 7 and older were most dense in a band extending from Chaleur Bay, through the Shediac Valley-Miramichi areas, along the coast of PEI and between Cape Breton and the Magdalen Islands. Densities of these older cod were greatest in the Miscou area with smaller concentrations in the Miramichi area and east of the Magdalen Islands.

Swain (1996) compared the September distribution of age-5 cod in recent years (1994 and 1995) to the distribution throughout the 1970s and 1980s. Cod distribution differed between the 1970s and the 1980s (Swain 1993; Swain and Wade 1993). In the mid-1970s, when cod abundance was low, cod densities were highest in inshore areas of the western half of the southern Gulf, in Chaleur Bay and the Miramichi-Shediac Valley areas, and were relatively low in the central Magdalen Shallows and the eastern half of the southern Gulf. In the early to mid-1980s, when abundance was high, distribution expanded into the central Shallows and the eastern half of the southern Gulf, and the center of distribution shifted offshore to intermediate depths in areas off the Gaspé Peninsula and in the central Shallows. In 1994 and 1995, the distribution of age-5 cod in the western part of the southern Gulf shifted back to the pattern seen in the mid-1970s. Cod densities in 1994 and 1995 were highest in shallow water in near-shore regions of Chaleur Bay and the Miramichi-Shediac Valley area, and were relatively low in the central Magdalen Shallows. This recent shift in distribution provides further support for the hypothesis that cod distribution is density-dependent during the summer feeding season in the southern Gulf, with distribution shifting from warm (high cost) shallow waters at low abundance to colder (low cost) deeper water at high abundance (Swain 1993).

Cod distribution differs between the current low abundance period and the previous low abundance period in the 1970s in terms of relative densities in the eastern and western halves of the southern Gulf (Swain 1996). The relative density of cod is clearly higher in the east in recent years compared to the low abundance period in the mid-1970s. Swain (1996) compared trawlable biomass of cod between western (415-429) and eastern (431-439) strata. Declines in cod biomass in the late 1980s and early 1990s were steeper in the western strata than in the eastern strata. In recent years, biomass has fallen to levels similar to those of the early to mid-1970s in western strata but has remained above the earlier low levels in eastern strata.

3.2. July 1995 Juvenile Survey

The sixth annual juvenile cod survey was conducted in the Miramichi Bay - Shediac Valley area of the southern Gulf in July, 1995 on board the *CSS Calanus II*. The survey follows a stratified random design. The *CSS Calanus II*, which was also used in 1994, is the fourth vessel used in this survey. No comparative fishing experiments have been conducted among vessels, however, the same doors, bridles, and net have been used all years. A total of 42 valid sets were made.

The 1995 mean numbers per tow was the second lowest in the time series and less than half the 1994 value (Table 12). The highest catch was of age 7 (1988 year-class). The abundance of age 1-3 cod in the 1995 survey was low in comparison to other years, ranking 4, 5, and 6 respectively in the 6 year time series. The July survey is conducted in the same area that a large set of age 1-3 cod was made in the September 1995 groundfish survey. These fish were not seen in similar abundance in July.

The estimated mean numbers per tow in the July and September (all strata) surveys are quite similar in 4 of the 6 years available (Figure 11). The modal ages and relative abundance of other ages compare well in 1990, 1991, and 1993. There is also close agreement between the 1995 estimates, if set 127 is eliminated from the September survey results.

It is probable that the July survey is more susceptible to changes in cod distribution than is the September survey. One large set, comprised mainly of age 2-4 cod, was made during the July 1994 survey. Given the results in 1993 and 1995, this set now appears anomalous (Figure 11). In addition, the large numbers of cod observed at ages 4-7 in July 1994 did not appear at one year older in the July 1995 survey, nor did the large numbers of age 1-3 cod seen in the July 1992 survey appear as one year older in 1993. The July survey covers a relatively small portion of the total stock area and shifts in distribution have been noted in the September survey, which covers almost all of the stock area.

3.3. January 1996 Survey

A groundfish survey was conducted in Cabot Strait from January 3-25, 1996 on board the research vessel *Wilfred Templeman*. Similar surveys were conducted in January 1994 (Chouinard 1994) and in 1995 (Sinclair et al. 1995). The main objective of the 1994 and 1995 surveys was to determine the distribution and relative abundance of groundfish species and herring in Cabot Strait area during the winter. The 1996 survey was part of a project to identify the stock origin of cod concentrations in the area.

The survey design followed a grid pattern covering waters deeper than 50 m with increased sampling intensity between 200 and 400 m. The survey extended from about 45° 15' to 48° North and from about 58° to 61° West. The survey proceeded in a north-south direction to minimize problems with ice. At each location, a standard 15-minute tow (calculated from touchdown) using a Campelen 1800 trawl (with 19 mm liner in lengthening piece and codend), was conducted. Depth profiles of conductivity, temperature and oxygen concentrations were also made. A total of 139 sets were attempted, of which 138 were successful.

3.3.1. Spatial Distribution of catches

A contoured map of the cod catches in kg per tow (Figure 12) shows that the largest catches were made on the slope of the Laurentian Channel in 4Vn at depths of 200 to 300 m. Four large concentrations were detected : St. Paul's, Port-aux- Basques, Sydney and Burgeo Bank. Smaller concentrations were found off the Magdalen Islands, Codroy and Misaine Bank. Cod abundance appears to be lower 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 previous years (Chouinard 1994; Sinclair et al. 1995) both in terms of area and depth. Abundance in the southern section of 4Vn appeared to be lower than in 1995, not withstanding the difference in trawl and tow duration.

3.3.2. Length frequency distribution

The relative length frequency distribution for cod in area 4T and 4Vn in January 1996 indicates two modes (28 cm and 43 cm) (Figure 13). It is compared with the length frequencies from January and September 1995. Most significantly, the first mode in the

January 1996 survey appears to correspond with the mode seen at 28 cm (set 127 included) in the September 1995 survey. However, the relative height of this mode should be treated with caution because the Campelam 1800 trawl, which was used for the first time in 1996, is thought to be more efficient for small cod.

The length frequency distributions were also examined for each of the seven concentrations identified above (Figure 14, refer to map on Figure 12). The results indicate that juvenile fish (<35 cm) are found in the northern areas and that there is a north-south gradient in mean size with larger fish being found to the south. This observation is consistent with fishers' knowledge and previous studies of cod distribution in the area. This segregation between juvenile and adult cod may be useful as a management tool to avoid the capture of small fish in early winter.

3.4. Cod Condition

Both seasonal and annual conditon factors were examined. Two measures of condition were examined and compared. The first was Fulton's condition factor (K):

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

where W = fish weight (g). The seasonal index used carcass weight (total weight less stomach and gonad), and the annual index used total weight.
L = fork length (cm)
α = 100, a scaling factor to control the number of decimals

In many cases, there can be a relationship between the Fulton condition index and length. Therefore it is not valid to use mean condition index over the full range of length to monitor changes in condition as changes in length composition will affect the trends. Previous analyses (Sinclair et al. 1994) indicated that there was no significant relationship between length and condition factor for fish in the 40 to 50 cm range calculated from using total weight collected during research vessel surveys (e.g. annual values). 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 and length in all but three cases where the slope was marginally significant.

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_{45} = 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 condition 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. Since the fishery was closed in September 1993, samples were not always available.

Samples were collected in the sentinel surveys and the groundfish surveys in June to October, 1995 as well as from the January 1995 and 1996 groundfish surveys. 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 in summer.

A distinct seasonal cycle is evident in the Fulton's condition index, being low in the spring, before and during spawning, and reaching a maximum in the late fall (Figure 15). The fall condition is about 40% higher than that in the spring. Condition was lowest in 1992 for the period examined. Condition in 1995 was similar to 1991, 1993, and 1994.

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. Trends in condition using the two measures are highly correlated ($R^2 = 0.83$, $p < 0.0001$, Figure 16). This index is similar in 1994 and 1995, and close to the average for the period.

As indicated last year, caution should be exercised when interpreting the annual condition indices as they do not appear to correspond well with the indications from the seasonal samples . For example, seasonal samples suggest that condition in 1992 was the lowest in the period 1991-1995, however, the annual samples do not suggest the same trends. 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. Finally, there may be 'aliasing' due to minor shifts in the physiological cycle. Seasonal monitoring of condition (somatic weight) is likely to provide a more meaningful index of changes in condition than the annual values.

3.5. Sentinel Surveys

3.5.1. Description of 1995 program

A sentinel survey (also referred to as sentinel fishery) program to monitor changes in abundance and obtain biological information on groundfish was conducted in the southern Gulf of St. Lawrence in the fall of 1994. In 1995, funding for the projects was announced in mid-June and projects started between mid-July and early September.

Seven sentinel survey projects were conducted in the southern Gulf of St. Lawrence in 1995. Three types of projects were conducted. In general, the projects were designed to provide indices of annual changes in abundance, detect patterns in seasonal distribution, and monitor the timing of the autumn migration for all sizes of Atlantic cod and white hake, covering the entire southern Gulf. The projects were as follows:

Sponsoring Association	Province	Projects	Number of Vessels	Number of fishermen (inc. crew)
Association des pêcheurs professionnels acadiens	**N.B.**	**- Mobile gear abundance** **- Distribution and migration**	**2** **2**	**8** **7**
Association des pêcheurs de la MRC Pabok	**Québec**	**- Mobile gear abundance**	**2**	**8**
P.E.I. Groundfish Association	**P.E.I.**	**- Mobile gear abundance**	**2**	**8**
Chéticamp Development Commission	**N.S.**	**- Mobile gear abundance** **- Fixed gear abundance**	**2** **4**	**8** **12**
North of Smokey Fishermen Association	**N.S.**	**- Fixed gear abundance**	**2**	**6**
		Total	**16**	**57**

The first type of project was designed to establish a mobile gear index of abundance of groundfish in the area. For the four projects in this category, two mobile gear vessels from each of the three Maritime provinces and Québec (total of eight vessels) fished at pre-determined locations and times in traditional fishing areas (see Figure 17) . These projects used the same design as in the one project conducted in 1994 (Sinclair et al. 1995). The fishing areas were identified in consultation with the fishermen involved in the projects. Prior to each trip, randomly selected fishing locations, within each area, were assigned to each vessel. Typically, 4 sets were assigned in each area. Each vessel conducted between 5 and 10 trips between July and the end of November. Vessels used a 145 mm square mesh trawl or seine, and 58 mm liners were used on some of the trips. Trawlers did a standard set of 30 minutes at 3.5 knots which is shorter than a regular fishing set, but seiners fished as they normally would in a fishery.

The second type of project was a distribution and migration study. In this project, two mobile gear vessels from N.B. conducted three snapshot surveys of the entire southern Gulf. The first survey was done at the end of July and early August, the second survey was conducted in September while the third survey started in mid-October. All sets were done using a 60 mm liner in the cod-end and lengthening piece.

The last type of project involved fixed gear fishermen fishing longlines to establish an abundance index. Ten lines of 250 hooks (Number 12 circle) were fished at pre-determined fixed locations, once per week. Locations fished are also indicated in Figure 15.

3.5.2. Results

Total catches in the sentinel surveys amounted to 346 t. The mobile gear abundance projects caught 181 t, catches in the fixed gear abundance amounted to 44t and the catches in the mobile gear migration and distribution project were 121 t.

As the abundance index projects were designed to show year-to-year changes, only the results from the N.B. project, which began in October, 1994, can be used to investigate changes from 1994 - 1995. A comparison of catch rates does not indicate a significant increase (Figure 18).

However, these results allowed us to make some observations in terms of distribution, since many of the vessels are fishing more than one area. Both the New Brunswick and Québec projects indicate that abundance was higher in Shédiac Valley than in the Baie des Chaleurs or along the Gaspé Shore. Abundance appeared to be low in the Souris-Cape George and the Mabou-North areas.

In terms of migration, catch rates declined along the Gaspé Shore in early October and in mid-October in the Shédiac Valley. Catches subsequently increased in the eastern section of the southern Gulf in late October consistent with the known migration patterns for this stock. A comparison of the length frequency of set 127 in the September 1995 groundfish survey and a set done by the sentinel survey in the same area and time (Wayne and Randy, set 1, September 19) shows that the sentinel survey vessel also caught a significant quantity of small fish (Figure 19). Because of the different mesh size of the liners (58mm in sentinel vs 19mm in survey), only the larger fish were retained in the sentinel survey. This confirms that there were some small fish (< 35cm) in the area at that time.

Further analyses remain to be conducted on the data collected including more analysis of catch rates in both the mobile and fixed gear fisheries, length frequencies and spatial distribution. However, in general, the results of the 1995 sentinel survey corresponded to information from the research survey conducted in September.

4. Analysis Methods

4.1. Analysis of RV Data

4.1.1. Multiplicative Analyses

The RV mean numbers per tow at age were analyzed with a multiplicative model to obtain information on trends in recruitment and total mortality in the pre-recruit ages. 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
I = a matrix of 0 and 1 indicating age
J = a matrix of 0 and 1 indicating year-class

Sinclair et al. (1995) reported that the southern Gulf RV survey gave consistent estimates of relative year-class strength for cod beginning at age 2 and continuing to age 12. Results for two groups of ages, 2-3 (pre-recruit ages) and 4-6 (recruiting ages) were analyzed separately. In addition, two analyses were performed for the ages 2-3 data, one including set 127 in 1995 and the second excluding this observation. The main effect vector for year-class (β_2) was interpreted as an index of relative year-class strength. The difference between the year-class effects estimated for the two age groups was interpreted as an index of total mortality of the respective year-classes. Inter-year-class differences in the mortality index were interpreted as differences in total mortality (see Sinclair et al. 1995 for details).

4.1.2. Analysis of covariance

An analysis of covariance of the RV survey results was used to investigate trends in total mortality of adult cod. In previous assessments, we used a multiplicative model similar to equation 1 to obtain this information. 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. This year we have adopted a more parsimonious approach, in which only the fully recruited ages (6-12) are included in the analysis. The average total mortality for a time period is estimated as part of the model:

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

where A_{ij} = the RV index at age i and year-class j
I = a continuous variable indicating the age group

In this case the parameter β_1 is the slope of the catch curve, and is interpreted as the total mortality in the time period. This year we used a 4-year moving window. The final time period included data from the 1992-95 RV surveys. The commercial fishery was greatly reduced in 1993, and closed in September of that year. Thus, the total mortality for this last time period should reflect a very low amount of fishing mortality.

4.2. Direct Estimates of Relative 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 current data. The estimated relative F at ages 4, 7, and 10 were plotted.

4.3. Sequential Population Analysis

This year we updated the SPA to include the years 1950 to 1970 in order investigate a longer time series of stock status. The last analysis of the data for this earlier period was by Maguire et al. (1983), and we used their data on catch and weight at age. While the 1971 to 1995 data include landings from the revised management unit (4TVn (Nov.-Apr.) and part of 4Vs (Jan.-Apr.)), the earlier data include landings only for 4TVn (Jan.-Apr.) and does not include 4Vn (N-D). The sum of products of the earlier catch and weight at age matched the reported landings for this period in most years. However, they greatly exceeded the landings in 1954-55, 1958-59. The effect of these few years on the general patterns described below is minor. Nonetheless, these results are considered preliminary until the discrepencies can be resolved.

Two calibration methods were used for the SPA; ADAPT and Laurec Shepherd. Calibration affects terminal year population estimates and the estimates of the respective year-classes. Inclusion of earlier years (1950-70) in the SPA has no effect on the most recent population estimates since the SPA calibration includes only 1971-95.

4.3.1. ADAPT

The adaptive framework (ADAPT) (Gavaris 1988) was used as the basis for this year's SPA of southern Gulf cod. Two stock abundance indices were used, the RV results from 1971-95, and the commercial CPUE at age series for 1982-93 (see Sinclair et al. 1994). We used the same ADAPT formulation as last year (Sinclair et al. 1995). A temporal trend in the catchability of the CPUE indices was included 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 catchability at age I
N_{ik} = the SPA estimate of numbers at age i in year k
δ = coefficient of a temporal trend in catchability

Secondly, the ADAPT formulation included a density-dependent catchability function for the RV survey indices in the form:

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

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

Parameters

Terminal N estimates:

$N_{i,1996}$, 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=1971-1995
A_{ik} i=3 to 10, k=1971-1995
U_{ik} i=5 to 12, k=1982-93

Objective function:

Minimize sum of squared residuals

Summary:

Number of observations:
200 from RV
96 from CPUE

Number of Parameters
35

4.3.2. Laurec Shepherd

The Laurec-Shephard calibration method was used for comparison with the ADAPT results. The method is implemented as part of the Lowestoft tuning package (Darby and Flatman 1994), and while the method is well suited for stocks with multiple tuning indices, it requires each index to have data for the terminal year. Consequently, only the RV results could be used here. The RV index from 1978-1994 and ages 3 to 12 was used. 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.

4.4. Yield Projections

Two types of yield projections were made. In the first, input parameters were assumed to have no errors and projections were made in a deterministic manner, similar to what has been done in previous assessments using the method described by Rivard (1982).

We incorporated information on the uncertainty of key projection parameters into a risk analysis in the second set of projections. By risk, we mean the probability of something undesirable happening as a result of a management action. The action is the catch in a given year. We have focused on two population state variables, F and spawning stock biomass (SSB, assumed to be age 5+). F was chosen because the overall management strategy is to control fishing mortality. SSB is also important since low SSB was the main reason for closing the fishery for this stock. The Fisheries Resource Conservation Council (FRCC) has proposed criteria for re-opening fisheries which include an SSB level. In a recent discussion paper, they proposed re-opening the fishery when the SSB has increased to a level half way between the SSB when the fishery was closed and the long term average. We have estimated this to be approximtely 115,000t and have included this in our analysis. It is important to note that this criterion is only a discussion point at present, we use it only for illustrative purposes. Risk was expressed as the probability that a) the SSB would decrease, b) that the SSB would be less than 115,000 t, and c) that F would exceed 0.2 as a result of a range of yields in 1996 and 1997. The terminal year abundance estimates were assumed to be independent and lognormally distributed with mean and standard error corresponding to the analytical approximation results from ADAPT. This method was reviewed by the Statistics, Sampling and Surveys Committee in November, 1995 and is described by Sinclair and Gavaris (1996).

Two Monte Carlo simulations of a catch projection from the beginning of 1996 to the beginning of 1998 were performed. In the first, the 1996 and 1997 yields varied from 1,000t to 25,000t in 1,000t increments. Three hundred replicates were generated for each yield option and the frequency distributions of F and biomass were used to quantify the probability that the reference F and threshold biomass were exceeded. The same 300 initial 1996 population abundances were used for each yield level. In the second simulation, the

1996 yield was fixed at 2,000t for all replicates while the 1997 yield varied from 1,000t to 25,000t in 1,000t increments.

5. Assessment Results

5.1. September RV Survey

The fit of the three multiplicative models was good. The total variance explained was between 87 - 91% (Table 13). The assumption of normal distribution of residuals was not violated.

Set 127 in 1995 had an important effect on the results of the age 2-3 analysis. If the set was included, the 1993 year-class was estimated to be above average in abundance, similar to the high values of the late-1970s and early 1980s (Figure 20). If this is the case, this year-class would make a significant contribution to the recovery of the stock. However, if set 127 was removed, the 1993 year-class was estimated to be of similar abundance to the below average year-classes of the late 1980s and early 1990s. If this is the case, the year-class will not have a positive impact on stock recovery.

The age 4-6 RV mean numbers per tow in 1995 were virtually unaffected by the large catch in set 127, thus the inclusion or deletion of this set would have little effect on the results of this multiplicative analysis. The year-class effects from the analysis of the age 4-6 data indicate that the 1991 year-class is below average in abundance at these ages (Figure 21). The pattern for other year-classes is similar to that reported last year.

The trend in total mortality between ages 2-3 and 4-6 is similar to that reported last year. The estimate of relative Z for the 1991 year-class, the new observation this year, is similar to the three previous year-classes, and well below the estimates for the 1985-87 year-classes (Figure 22). The difference in the relative Z indicates that the 1985-87 year-classes experienced, on average, a total mortality 0.75 greater than the three previous and four following year-classes. In the normal scale, this suggests that only half as many of them survived the recruitment phase as did the year-classes before and after.

The fit of the analyses of covariance to the age 6-12 RV results were good. All analyses were highly significant and the slopes were all negative and significant (Table 14).

Total mortality peaked at about 0.8 in the early 1970s, then declined to 1979 to values less than 0.4 (Figure 23). Estimates increased to between 0.6 - 0.8 in the mid- to late- 1980s, then increased sharply to over 1.3 in the period 1989-92. Total mortality estimates have declined since then. The final analysis covered 1992-1995 and the estimated total mortality was about 0.5.

Provided the commercial fishery remains closed in 1996, this method may be used to estimate natural mortality for this stock. The September 1996 survey will be the fourth survey conducted in a period when fishing mortality will have been about as close to zero as possible.

This pattern in total mortality corresponds well with fishing mortality estimates and recent trends in fishing effort. Fishing mortality was low in the late-1970s when TAC's were reduced on this stock. F was somewhat higher in the 1980s, then increased substantially in the late-1980s to a maximum in 1991-92. With the closure of the fishery, F has declined substantially. We conclude that the pattern in total mortality shown in Figure 23 is driven largely by changes in fishing mortality.

5.2. Direct Estimates of Relative F

The relative fishing mortalities were very high in the early 1970s followed by a sharp decline at the time of extended fisheries jurisdiction in 1977 (Figure 24). The relative F was stable in most of the 1980s 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 further in 1994 and 1995.

5.3. Sequential Population Analysis

The fit of the ADAPT calibration was similar to that in last year's assessment. The exponents in the density dependent RV calibration model are greater than 1.0 for all ages except age 3, suggesting that catchability is density dependent (Table 15). The linear trend in the CPUE calibration was positive and significantly greater than zero. The residuals for the RV observations were mainly negative for 1971-72, 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 1993 (Figure 25). It is possible that the SPA results from the late 1980s and early 1990s are biased by under-reporting of catches and this could produce the residual pattern seen (Sinclair et al. 1995). The CPUE residuals increased from 1982 to 1992, the second last year in the series, then declined in 1993.

A retrospective analysis of the SPA F (ages 7-12) and N (ages 4+) estimates from the ADAPT calibration indicated a relatively strong pattern where F's increased and N decreased as more years are added to the analysis (Figure 26). However, the estimates in the last four years were much more consistent than those obtained for the late 1980s.

Fishing mortality, beginning of year population estimates, and beginning of year biomass estimates are given in Tables 16, 17, and 18 respectively. Beginning of year weights at age were estimated from the mid-year commercial weights (Table 8) using the approximations described by Rivard (1982).

.Diagnostics for the Laurec-Shepherd calibration indicate full recruitment to the survey at about age 5 (Table 19). The residual pattern is somewhat unbalanced with several negative residuals in the first few years (Table 20). Population numbers were the lowest in 1992 and appear to have only recovered slightly from this low level (Table 21). The estimates of year-classes produced in the 1990s are low, about 1/10 of the 1980 year-class. The analysis suggests fishing mortalities in the range of 0.03 in 1995.

The 1996 population estimates from the Laurec Shepherd calibration were approximately 20% lower than the ADAPT calibration. This could be largely due to the use of a density dependent calibration relationship for the RV data in ADAPT, and a linear relationship in Laurec-Sheperd.

5.4. Abundance, Biomass, Fishing Mortality

Population abundance was relatively high in the 1950s, varying between 300 to 400 million (Figure 27). Abundance declined throughout the 1960s and reached a minimum in the mid- 1970s of about 150 million. There was a sharp increase in abundance with the recruitment of strong year-classes born in 1974-75, and abundance reached a maximum of 500 million in 1983. This was followed by a continuous decline in abundance to 1993. The trend in total and spawning biomasses resembled that of abundance, except that the relative heights of the peaks in the 1950s and 1980s were reversed. Biomass was lower in the 1980s than the 1950s due to lower weights at age. With the closure of the fishery in 1993, the decline in abundance stopped and biomass is beginning to increase. Fishing mortality increased from about 0.3 in the early 1950s to about 0.7 in the mid-1970s, with the exception of a value of 1.4 in 1959. F was low in 1977 and 1978, but increased again and averaged approximately 0.6 up to 1988. Fishing mortality then increased to around 1.2 in 1992. Fishing effort was reduced markedly in 1993 with the closure of the fishery. The catch of slightly above 5,000t in 1993 resulted in a fishing mortality near the $F_{0.1} = 0.2$ reference level. The further decrease in effort in 1994 and 1995 resulted in declines in F to 0.03 and 0.01 respectively.

5.5. Recruitment

The increase in population abundance in the late 1970s 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 1980s.

The results of the RV analysis 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 1980s and early 1990s (Sinclair et al. 1995) and this significantly reduced their contribution to the commercial stock. It is important to note that SPA estimates of the sizes of these year-classes are probably biased in that they do not include discards (Figure 28). The close agreement between the age 2-3 index and the SPA recruitment estimates of more recent year-classes suggests that the discarding problem has been reduced. This corresponds with the period when minimum mesh sizes were increased (1992), and the reduction of fishing effort.

Year-classes produced in the late 1980s and early 1990s appear to be well below average in abundance. The September 1995 RV survey did find high numbers of age 0 cod, however, catches of this age group have never been used in a quantitative manner in this assessment. The survey also made one large set of age 1-3 cod in the Shediac Valley area. We recommend caution in interpreting this result because large numbers of similar aged cod were not found in other areas in September, or in the same area in the July juvenile survey. These fish will not be of a commercial size for another 2-3 years, and if they are indeed abundant, they should be found in future surveys.

5.6. Stock and Recruitment

A plot of the abundance of a year-class at age 3 vs the associated spawning biomass (age 5+) from SPA indicates that the chances of having a poor year-class (less than 50 million) diminishes as the spawning biomass increases (Figure 29). The 1950-57 year-classes were all above 50 million, and the spawning biomass was over 200,000 t. The 1988-93 year-classes are all estimated to be below 50 million, and the spawning biomass has been below 200,000t. This relationship is not, however, without exceptions. The 1973-77 year-classes were produced when the spawning biomass was relatively low, less than 120,000t, and the 1979-80 year-classes came from moderate spawning biomasses.

Relative to the rest of the time series, the 1973-77, and 1979-80 year-classes were produced under particularily favorable conditions. The ratio of the number of recruits divided by spawning biomass has been used as an indication of the relative survival of a year-class during its juvenile period (Serebryakov 1990). We calculated the ratios from both the SPA and RV data. The latter were used as a check given the uncertainties of the SPA estimates of recruitment due to unaccounted for discarding. The RV ratios were calculated from the age 2-3 recruitment index (Figure 18) and the age 5+ mean weight per tow. The latter was taken from the mean numbers per tow at age (Table 9) and the RV mean weights at age (Table 11). Both indices peaked in the mid-1970s (Figure 30).

5.7. Deterministic Projections

The input data for projections are given in Table 22 and were derived as follows. The begining of year 1996 population numbers at age were taken from the ADAPT calibration. The 1993 year-class age 3 abundance was set at 20-million based on the recruitment index from the September survey. There is currently no information available on the abundance of the 1994 year-class, however its abundance was set at 20 million at age 3 since all recent year-classes have been in this range. These year-classes will contribute very little to catches and spawning biomass in 1996-97. Partial recruitment was derived from fishing mortalities in the period 1993 to 1995 from the ADAPT analysis with full recruitment at age 9. Beginning of year and mid-year weights at age in 1996-98 were calculated as the average from 1993 to 1995.

Deterministic catch projections were made for two yield scenarios. In the first, projections were made for a range of 1996 yields, and the spawning biomass in 1997 was calculated. The 1996 yield at F=0.2 was approximately 16,000t (Figure 31). The resulting 1997 SSB was estimated to be 9% lower than the 1996. At a 1996 catch of 6000 t, the SSB remained the same. With no catch in 1996, the SSB was projected to increase by 5%.

In the second scenario, the 1996 yield was assumed to be 2000 t. This level was chosen because there is a possibility that the 1996 yield will be higher than the 1995 yield due to expanded sentinel surveys. A 1996 yield of 2000t was estimated to generate a fishing mortality of 0.02 and the 1997 SSB was estimated to be 115,000 t, up from 111,000t in 1996 (Figure 32). The 1997 yield at F=0.2 was 17,000 t, but the 1998 SSB would decline to 104,000t as a result. A 1997 yield of about 6,000t would result in no change in SSB between 1997 and 1998.

5.8. Risk Analysis

The standard errors for the 1996 population estimates were obtained from the ADAPT calibration, and the standard error for both the 1993 and 1994 year-classes was set at 20 million. When the 1996 yield was kept at 1,000 t, the probability that the 1997 SSB would be below the illustrative re-opening threshold was approximately 50% (Figure 33). The probability that the 1997 SSB would be less than the 1996 SSB increased from about 0% for a 1000t 1996 catch to about 50% for a 6,000t catch, and to about 90% for a 12,000t catch in 1996. The probability distribution for F exceeding 0.2 was steeper than those for biomass, and it increased from 0% at a 13,000t 1996 catch to almost 100% at an 18,000t catch.

If the 1996 catch was held at 2000 t, and the 1997 catch varied, the probability was lower that the 1998 SSB would be below the threshold and that the 1998 SSB would decrease relative to 1996 than in the first simulation (Figure 34). The probability distribution of fishing mortality shifted to the left.

The choice of any particular catch level will reflect the risk tolerance of the decision maker. A risk neutral decision maker would choose the deterministic catch projection as the best strategy; there would be a 50% chance that the target F or threshold biomass would be exceeded, and they would not be interested in probabilistic catch projections. A risk averse decision maker would favor lower catches, wishing a lower probability of the target F being exceeded or of the biomass being below the threshold, for example 10%. If such a decision maker wanted the SSB to exceed 115,000 t, they would not re-open the 1996 fishery, since at a 0 catch in 1996 there is a 50% probability that the biomass will be less than 115,000 t. A risk prone decision maker would favor a higher probability, let's say 90% for example. If such an individual was also interested in having the SSB > 115,000 t, but was willing to take a 90% risk that it wouldn't be, they would accept a 1996 TAC of about 14,000 t.

The probability distributions from these short term catch projections indicate a higher degree of certainty associated with statements about an F criterion in relation to catch than about a biomass criterion in relation to catch. The probability distributions of F are steeper and provide a relatively discrete range of catch to choose from. The probability distributions of biomass are shallower and cover a much larger range of catches. This is because F is much more sensitive to variations in catch than is stock biomass, especially in low F, short term projections.

This risk analysis is based on approximations and does not incude uncertainties in natural mortality, weight at age, and partial recruitment. However, it should provide rough guidelines.

5.9. Future Prospects

Prospects for a firm and steady stock recovery continue to be bleak. While some improvement in stock size has been noted in 1995, this was due mainly to a limited increase of adult cod biomass. This was only possible because of a very low level of fishing. Individual growth rates continue to be low and recruitment has not improved. Stock production continues to be low, even though the SPA estimates of spawning biomass are approximately 110,000 t, there is about a 50% chance that a catch of 6,000t in 1996 would prevent any further increase in SSB.

6. Uncertainties

The main source of uncertainty in the assessment is the abundance of recruiting year-classes, specifically the 1992-94 year-classes. The September RV estimate of these year-classes was strongly influenced by one large set made in the Shediac Valley area, a known area of juvenile distribution. A sentinel survey vessel also made a large set of juveniles in the same area and time, but in both cases the area of distribution was restricted. The July juvenile survey did not find large numbers of these year-classes in the Shediac Valley area. The cod length frequency from the January, 1996 survey in the Cabot Strait had a mode which corresponds to age 1-2 cod. However, this survey used the Campelen 1800 trawl which is thought to be more selective of small fish than the Western IIA trawl used on previous surveys in this area. Therefore it is difficult to interpret the January results. In any event, these year-classes will not be of commercial size for 2-3 years, and additional information on their abundance will be obtained on future surveys.

There are differences in opinion regarding stock status among fishers from the eastern and western portions of 4T. Fishers from P.E.I., Cape Breton, and from the Magdellan Islands indicated at several consultation meetings that cod are abundant and even increasing in abundance in their areas. They cite high incidence of cod by-catch in other fisheries, and high catches of cod in lobster traps. Fishers from Gaspé and northeast N.B. indicate that cod abundance is much lower than in the late 1980s and early 1990s, and they have not noticed increases in abundance. If one allows that fishers' perceptions of stock status may be more reflective of local conditions than of the total stock area, then the results from the September RV survey support the views of both the eastern and western area fishers. The surveys indicate that cod are distributed closer to shore in recent years, that cod are rarely found in the central part of the survey area, contrary to the early 1990s, and that the relative abundance of cod has increased in the eastern part of 4T (Swain 1996).

The difference in the length frequency distributions between observer and port samples is an important source of uncertainty in the assessment. The reason for the high abundance of larger cod in the observer samples relative to the port samples should be investigated.

7. Acknowledgements

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9. Tables

Table 1: Landings (t) of southern Gulf of St. Lawrence cod, 1965-95, by area and time period relevant to the management unit. The column "stock" indicates the landings used in the analytical assessment, and is the total for 4T, 4Vn (J-A), 4Vn (N-D), and 4Vs. The TAC applies 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	1196	137	1		1334	1333	
95	1069		6		1075		

Table 2: Landings (t) by gear of the southern Gulf of St. Lawrence cod stock, 1965-95.

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	216	410	295	105	154	154	1334
1995	98	388	95	79	44	371	1075

Table 3: Age-length keys used in the calculation of the 1995 catch-at-age for southern Gulf of St. Lawrence cod.

KEY	FISHERY	SAMPLES	SAMPLE SIZE PORT	SAMPLE SIZE OBSERVER	TOTAL	CATCH(t)
1	OTB MAY - DEC	MAY-DEC OTB LENGTHS	122	347	469	48.746
		MAY-DEC OTB AGES	46	70	116	
2	SNU APR-JUNE	APR-JUNE SNU LENGTHS	624	4761	5385	65.878
		APR-JUNE SNU AGES	219	9	228	
3	SNU JULY-SEPT	JULY-SEPT SNU LENGTHS	763	500	1263	23.459
		JULY-SEPT SNU AGES	291	19	310	
4	SNU APR-JUNE	OCT-DEC SNU LENGTHS	585	1285	1870	46.084
		OCT-DEC SNU AGES	227	51	278	
5	GNS MAY-OCT	MAY-OCT GNS LENGTHS	658	1082	1740	94.773
		MAY-OCT GNS AGES	146	74	220	
6	LLS MAY-NOV	MAY-DEC LLS LENGTHS		253	253	34.808
		MAY-DEC LLS AGES		34	34	
		SEPT RV SURVEY AGES	3076		3076	
7	SENTINEL SURVEY	JULY-AUG SENTINEL LENGTHS		110514	110514	79.743
		JULY-AUG SENTINEL AGES				
		JULY RV SURVEY AGES	518		518	
8	SENTINEL SURVEY	SEPT-DEC SENTINEL LENGTHS		336232	336232	266.472
		SEPT-DEC SENTINEL AGES				
		SEPT RV SURVEY AGES	3076		3076	
	UNSAMPLED CATCH					414.628
	TOTAL CATCH					1074.591

ABBREVIATIONS: OTB=otter trawl, SNU=seines, GNS=gillnets, LLS=longlines, RV=research vessel

Table 4: Landings (numbers) at age by gear and time period, 1995. The age-key numbers correspond with Table 3.

Key	1	2	3	4	5	6	7	8		
Gear	OTB	SNU	SNU	SNU	GNS	LLS	SENT	SENT	Unsamp	TOTAL
Quarter	2-4	2	3	4	2-4	2-4	July-Aug	Sept-Dec		
Age										
3				792	47	2	4578	38385	27521	71326
4	488		90	10483	1835	155	15466	57857	54266	140640
5	2726	1522	1424	11081	1798	674	19909	54563	58867	152565
6	5232	5230	3241	10174	1327	1535	14119	42870	52603	136332
7	10899	12559	6648	11781	7250	5865	27721	59594	89412	231729
8	8304	11409	3539	5116	6481	5611	14724	29584	53256	138023
9	2381	4771	1286	2256	7801	3197	3736	12293	23699	61420
10	792	3076	374	423	3583	1314	1752	3799	9495	24608
11		1713	57	151	2820	801	470	2095	5093	13201
12		1480	121	69	790	220		732	2144	5556
13		219	35	59	699	103		170	807	2091
14		140	34	9	169	55		101	318	825
15		84				39		11	85	218
16+				2	83				53	138
Total	30823	42202	16850	52397	34683	19570	102475	302053	377620	978672

OTB Otter Trawl
SNU Seine
GNS Gillnet
LLS Longline
SENT Sentinel Survey

Table 5: Mean weight (kg) at age by gear and time period, 1995.

Key	1	2	3	4	5	6	7	8	Average
Gear	OTB	SNU	SNU	SNU	GNS	LLS	SENT	SENT	weight
Quarter	2-4	2	3	4	2-4	2-4	July-Aug	Sept-Dec	(kg)
Age									
3				0.756	0.341	0.616	0.216	0.242	0.248
4	0.763		0.531	0.635	0.553	0.741	0.411	0.490	0.497
5	1.111	0.867	0.871	0.723	0.823	0.924	0.525	0.674	0.672
6	1.316	1.072	1.042	0.846	1.220	1.265	0.734	0.857	0.897
7	1.534	1.162	1.254	0.980	2.030	1.679	0.863	1.106	1.164
8	1.825	1.511	1.608	1.157	2.367	1.903	1.039	1.348	1.477
9	1.926	2.026	2.100	1.269	3.231	2.342	1.352	1.742	2.094
10	2.287	2.204	3.277	1.788	3.528	2.578	1.606	2.216	2.503
11		2.189	2.634	2.490	4.142	2.902	1.195	2.415	2.948
12		2.647	1.848	3.276	5.888	2.433		2.551	3.347
13		2.798	2.573	2.083	6.219	3.702		3.595	4.800
14		2.573	2.222	2.805	8.630	3.552		3.383	4.835
15		2.959				5.702		8.084	4.178
16+				12.799	10.103				10.176
All	1.575	1.519	1.374	0.873	2.739	1.928	0.740	0.843	1.073

Table 6: Mean length (cm) at age by gear and time period, 1995.

Key Gear Quarter	1 OTB 2-4	2 SNU 2	3 SNU 3	4 SNU 4	5 GNS 2-4	6 LLS 2-4	7 SENT July-Aug	8 SENT Sept-Dec	Average length (cm)
Age									
3				43.77	30.00	41.00	29.55	29.71	29.95
4	43.70		39.07	41.24	39.39	43.40	36.43	37.77	38.03
5	49.39	45.42	45.61	43.03	44.83	46.42	39.43	41.88	41.92
6	52.11	48.66	48.09	45.11	50.10	51.10	43.94	45.21	45.93
7	54.37	49.71	51.09	47.43	59.37	56.01	46.22	48.86	49.66
8	57.81	53.69	55.03	49.85	62.88	58.32	49.08	52.14	53.58
9	58.73	58.99	59.67	51.05	68.81	62.14	53.27	56.05	59.29
10	62.11	60.13	69.34	56.50	70.73	64.08	56.72	60.18	62.83
11		59.93	65.25	63.30	74.52	66.70	51.76	61.85	65.80
12		63.10	58.42	69.30	83.39	62.93		62.72	67.66
13		66.76	65.00	60.07	83.73	71.51		70.63	76.54
14		65.00	62.00	65.02	96.00	70.35		67.98	76.28
15		68.00				84.00		94.00	74.79
16+				109.00	101.00				101.22
All	54.84	53.37	52.03	45.32	63.67	58.09	43.24	43.42	46.73

Table 7: Landings at age ('000) of southern Gulf of St. Lawrence cod, 1971-95. 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	99	214	285	154	70	27	19	7	4	2	0	0	965
1995	71	141	153	136	232	138	61	25	13	6	2	1	0	0	979

Table 8: Average weights at age (kg) from the commercial fishery for the southern Gulf of St. Lawrence cod stock, 1971-1995.

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	1.85	2.23	2.16	2.47	2.40	2.03	2.29	2.38	13.52	1.38
1995	0.25	0.50	0.67	0.90	1.16	1.48	2.09	2.50	2.95	3.35	4.80	4.84	4.18	10.18	1.07

Table 9: Mean numbers per tow at age of southern Gulf of St. Lawrence cod from the annual research vessel surveys, 1971-95. Two entries are made for 1995, the first includes all sets, the second, 1995a, excludes set 127.

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
1995	8.10	13.58	16.91	13.43	11.09	10.16	7.94	10.24	4.63	1.75	0.56	0.29	0.12	0.03	0.03	0.02		98.88	60.29	35.77
1995a	8.25	1.12	4.17	5.86	10.23	10.11	8.01	10.39	4.82	1.82	0.57	0.30	0.12	0.03	0.03	0.02		65.85	52.31	36.22

Table 10: Coefficients of variation of mean numbers per tow at age from research vessel surveys. Two entries are made for 1995, the first includes all sets, the second, 1995a, excludes set 127.

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
1995	92.0	75.0	57.3	14.7	12.1	11.4	10.7	10.3	10.8	15.4	17.4	18.7
1995a	30.8	24.3	16.5	14.3	12.5	11.8	11.0	10.4	10.8	15.2	17.1	18.4

Table 11: 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	
1995	0.20	0.48	0.68	0.84	1.04	1.25	1.61	2.35	2.57	3.41	3.68	6.65	8.59
1995a	0.25	0.50	0.67	0.84	1.03	1.25	1.60	2.33	2.54	3.36	3.60	6.62	8.59

Table 12. Mean number per tow and coefficients of variation (CV) at age from the annual juvenile cod survey, 1990 to 1995. 1994b represents estimates with the 500 kg set included.

Number per tow

Age	1990	1991	1992	1993	1994	1994b	1995
0	0.38	1.50	0.00	0.00	0.00	0.00	0.00
1	0.71	3.28	10.70	0.61	1.13	2.56	1.15
2	7.24	7.45	31.50	3.07	3.80	13.64	4.05
3	45.94	16.22	26.91	7.58	26.65	61.81	2.67
4	31.13	26.00	16.24	8.61	19.79	26.93	6.44
5	15.58	13.53	11.22	13.35	23.37	24.32	8.47
6	10.06	5.42	2.37	8.46	20.95	21.04	6.24
7	6.94	2.39	1.51	3.47	9.34	9.19	11.94
8	2.38	1.52	0.70	1.60	3.31	3.26	6.28
9	1.38	0.25	0.47	0.38	1.30	1.28	1.60
10	1.05	0.15	0.21	0.30	0.59	0.59	0.66
11	0.88	0.13	0.19	0.06	0.45	0.44	0.16
12	0.00	0.18	0.04	0.17	0.14	0.14	0.00
13	0.00	0.02	0.07	0.04	0.15	0.14	0.00
14	0.12	0.09	0.04	0.02	0.04	0.04	0.00
15	0.00	0.00	0.00	0.00	0.03	0.03	0.00
16+	0.36	0.05	0.05	0.09	0.00	0.00	0.00
0+	123.87	78.11	102.33	47.74	111.25	164.74	49.66
3+	115.54	65.88	60.14	44.07	106.33	148.52	44.46
5+	38.47	23.67	16.99	27.88	59.88	59.77	35.35

CV

Age	1990	1991	1992	1993	1994	1994b	1995
0	41.20	44.49	0.00	0.00	0.00	0.00	0.00
1	37.37	32.94	84.34	70.78	28.80	57.81	74.22
2	27.62	33.48	44.24	76.99	28.77	72.54	58.83
3	22.81	21.32	33.42	22.82	33.24	58.42	23.42
4	21.62	21.93	28.39	17.04	22.94	30.85	15.18
5	14.74	16.85	24.66	14.91	16.94	15.98	13.44
6	12.68	16.94	22.73	12.27	15.40	14.82	9.95
7	12.19	18.37	20.69	11.74	13.92	13.78	9.04
8	11.75	15.12	20.70	12.32	14.62	14.28	8.50
9	14.48	21.82	49.04	18.66	13.74	13.52	12.31
10	10.44	36.27	21.50	11.26	14.09	13.22	19.41
11	15.31	25.10	53.48	0.00	17.10	16.18	20.09
12	0.00	24.57	0.00	26.94	22.43	23.08	0.00
13	0.00	0.00	48.65	0.00	30.84	32.17	0.00
14	44.17	37.20	0.00	0.00	0.00	0.00	0.00
15	0.00	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	0.00
0+	18.06	15.80	27.76	14.70	18.02	34.42	11.77

Table 13: Summary statistics from three multiplicative analysis of research survey catches at age of southern Gulf of St. Lawrence cod, 1971-95.

Analysis	N	R^2	Effect	DF	F-ratio	P
Age 2-3, all sets in 1995	50	0.87	age	1	35.2	0.0000
			year-class	25	5.0	0.0000
Age 2-3, set 127 in 1995 excluded	50	0.89	age	1	37.0	0.0000
			year-class	25	6.2	0.0000
Age 4-6, all sets in 1995	75	0.91	age	2	17.8	0.0000
			year-class	26	15.7	0.0000

Table 14: Summary statistics from analyses of covariance of research survey catches at ages 6-12 of southern Gulf of St. Lawrence cod, 1971-95. Analyses were done on 4-year moving windows for the periods indicated. The slope is an estimate of total mortality for these ages in that period.

Period	N	R^2	Slope	SE
71-74	28	0.98	-0.538	0.053
72-75	28	0.97	-0.685	0.052
73-76	28	0.97	-0.806	0.054
74-77	28	0.92	-0.594	0.079
75-78	28	0.91	-0.380	0.083
76-79	28	0.96	-0.340	0.066
77-80	28	0.97	-0.638	0.072
78-81	28	0.97	-0.492	0.083
79-82	28	0.98	-0.553	0.080
80-83	28	0.98	-0.508	0.077
81-84	28	0.98	-0.828	0.069
82-85	28	0.97	-0.723	0.075
83-86	28	0.97	-0.688	0.072
84-87	28	0.97	-0.698	0.055
85-88	28	0.98	-0.712	0.061
86-89	28	0.98	-0.566	0.061
87-90	28	0.97	-0.704	0.066
88-91	28	0.99	-0.987	0.042
89-92	28	0.98	-1.313	0.055
90-93	28	0.96	-1.221	0.077
91-94	28	0.94	-0.890	0.101
92-95	28	0.94	-0.513	0.039

Table 15: Parameter estimates from ADAPT.

Parameter	Estimate	Std. Err.	Rel. Err.	Bias	Rel. Bias
ln age 4	9.567	0.516	0.054	-0.042	-0.0044
ln age 5	9.861	0.315	0.032	-0.012	-0.0012
ln age 6	9.799	0.227	0.023	-0.005	-0.0005
ln age 7	9.696	0.181	0.019	-0.002	-0.0002
ln age 8	9.617	0.151	0.016	0.000	0.0000
ln age 9	9.423	0.141	0.015	0.001	0.0001
ln age 10	8.631	0.149	0.017	0.000	0.0000
ln age 11	7.532	0.170	0.023	-0.002	-0.0002
ln age 12	6.629	0.209	0.031	-0.004	-0.0006
ln age 13	6.077	0.258	0.042	-0.008	-0.0013
b3	0.873	0.150	0.172	0.001	0.0015
b4	1.013	0.144	0.142	0.001	0.0007
b5	1.224	0.130	0.106	0.000	0.0002
b6	1.317	0.114	0.087	0.000	0.0001
b7	1.251	0.101	0.081	0.000	0.0002
b8	1.173	0.093	0.079	0.000	0.0002
b9	1.105	0.092	0.083	0.000	0.0001
b10	1.076	0.098	0.091	0.000	-0.0001
ln a3	-6.674	1.678	-0.251	-0.015	0.0023
ln a4	-7.916	1.571	-0.199	-0.009	0.0011
ln a5	-9.976	1.380	-0.138	-0.003	0.0003
ln a6	-10.760	1.155	-0.107	-0.002	0.0002
ln a7	-9.957	0.965	-0.097	-0.002	0.0002
ln a8	-9.095	0.821	-0.090	-0.002	0.0002
ln a9	-8.490	0.746	-0.088	-0.001	0.0001
ln a10	-8.026	0.711	-0.089	0.001	-0.0001
δ	1.41E-05	2.35E-06	0.167	-7.90E-08	-0.0056
q5	3.08E-05	8.75E-06	0.284	1.01E-06	0.0329
q6	1.12E-04	2.04E-05	0.182	1.51E-06	0.0135
q7	1.93E-04	2.98E-05	0.155	1.97E-06	0.0102
q8	2.28E-04	3.38E-05	0.148	2.20E-06	0.0096
q9	2.52E-04	3.65E-05	0.145	2.44E-06	0.0097
q10	3.57E-04	4.83E-05	0.135	3.27E-06	0.0092
q11	2.67E-04	3.81E-05	0.142	2.65E-06	0.0099
q12	3.63E-04	4.86E-05	0.134	3.28E-06	0.0090

Table 16: Fishing mortality estimates of southern Gulf cod from an ADAPT calibration.

	3	4	5	6	7	8	9	10	11	12	13	14	15	7-12
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	0.577
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	0.546
1973	0.032	0.350	0.509	0.527	0.541	0.527	0.508	0.540	0.636	0.323	0.841	1.444	0.524	0.513
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	0.695
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	0.836
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	0.599
1977	0.004	0.056	0.278	0.309	0.351	0.279	0.256	0.494	0.426	0.316	0.652	0.161	0.375	0.354
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	0.440
1979	0.001	0.043	0.184	0.264	0.524	0.572	0.600	0.625	0.828	1.062	0.493	0.377	0.612	0.702
1980	0.003	0.023	0.167	0.248	0.386	0.454	0.582	0.632	0.722	0.207	0.994	0.209	0.607	0.497
1981	0.001	0.046	0.113	0.341	0.384	0.454	0.547	0.805	0.779	1.025	1.784	0.263	0.676	0.665
1982	0.004	0.026	0.172	0.189	0.392	0.406	0.338	0.566	0.622	0.775	0.167	0.146	0.452	0.516
1983	0.000	0.010	0.132	0.303	0.428	0.443	0.561	0.727	0.344	0.475	0.414	0.587	0.644	0.496
1984	0.000	0.009	0.047	0.226	0.391	0.478	0.617	0.696	0.618	0.785	1.417	0.279	0.657	0.597
1985	0.002	0.019	0.087	0.274	0.430	0.497	0.559	0.614	0.521	0.497	0.289	0.580	0.587	0.520
1986	0.002	0.047	0.135	0.293	0.247	0.385	0.498	0.789	0.787	1.173	0.438	0.355	0.643	0.646
1987	0.001	0.016	0.130	0.263	0.404	0.283	0.382	0.573	0.567	0.712	0.594	0.639	0.478	0.487
1988	0.002	0.034	0.108	0.299	0.367	0.495	0.491	0.614	0.786	0.968	0.952	0.483	0.553	0.620
1989	0.001	0.039	0.159	0.400	0.518	0.575	0.675	0.886	0.831	1.202	1.062	0.638	0.780	0.781
1990	0.008	0.062	0.251	0.460	0.681	0.778	0.865	1.262	1.189	0.955	1.369	0.818	1.064	0.955
1991	0.007	0.102	0.318	0.589	0.832	0.805	1.060	1.077	1.012	1.570	0.620	1.321	1.069	1.059
1992	0.015	0.102	0.381	0.575	0.778	1.052	1.068	1.082	1.164	1.827	2.181	0.149	1.075	1.162
1993	0.002	0.010	0.035	0.054	0.093	0.140	0.154	0.162	0.209	0.198	0.679	0.915	0.158	0.159
1994	0.001	0.002	0.005	0.010	0.017	0.020	0.027	0.026	0.031	0.028	0.032	0.085	0.026	0.025
1995	0.005	0.007	0.008	0.008	0.014	0.010	0.010	0.012	0.015	0.012	0.010	0.010	0.011	0.012

Table 17: Beginning of year population numbers ('000) for southern Gulf cod using 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	170269	100261	26909	13818	6618	1818	1389	516	363	204	123	74	14	14	322390
1978	165316	138809	77599	16693	8309	3814	1127	881	258	194	122	52	52	8	413234
1979	116753	134853	104565	53673	9509	4377	2120	702	497	112	94	60	38	31	427384
1980	116617	95455	105760	71212	33763	4610	2024	953	308	178	32	47	34	17	431010
1981	86373	95211	76415	73311	45507	18785	2397	926	415	122	118	10	31	15	399636
1982	153079	70627	74488	55886	42700	25390	9770	1136	339	156	36	16	6	13	433642
1983	206524	124862	56358	51330	37883	23614	13854	5707	529	149	59	25	12	3	520909
1984	110274	169050	101190	40432	31055	20216	12415	6476	2259	307	76	32	11	5	493798
1985	104996	90258	137213	79038	26398	17205	10264	5484	2644	997	115	15	20	5	474652
1986	85907	85805	72484	103014	49181	14064	8572	4807	2429	1286	497	70	7	9	428132
1987	70346	70212	67042	51840	62946	31454	7833	4267	1789	906	327	263	41	3	369269
1988	57993	57522	56553	48194	32624	34405	19409	4377	1970	831	364	148	114	21	314525
1989	66579	47380	45534	41560	29270	18502	17173	9726	1939	735	259	116	75	53	278901
1990	72267	54446	37292	31792	22808	14270	8528	7158	3284	692	181	74	50	28	252870
1991	47811	58679	41886	23738	16426	9438	5365	2939	1659	819	218	38	27	14	209057
1992	36969	38885	43357	24910	10761	5834	3443	1521	820	494	140	96	8	7	167245
1993	32507	29827	28727	24177	11426	4024	1652	956	422	210	65	13	68	2	134076
1994	27741	26566	24181	22692	18749	8518	2860	1156	663	280	141	27	4	47	133625
1995	15937	22687	21702	19708	18385	15093	6835	2279	922	526	223	112	20	3	124432
1996	20000	12984	18447	17630	16013	14843	12232	5541	1843	743	425	181	91	16	120989

Table 18: Beginning of year population biomass (t) estimates for southern Gulf cod from an ADAPT calibration.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	3+	5+
1971	79641	31547	30259	39542	33029	17029	12391	7506	2840	3008	858	2140	3404	0	263194	152006
1972	9373	48042	26622	23556	25659	23961	12004	7526	5506	2066	908	460	888	1841	188412	130997
1973	17314	12869	28828	15496	14755	14165	15629	7603	4762	3013	948	525	308	344	136559	106376
1974	30792	23292	12921	23140	10988	9984	9446	9776	4038	2246	1927	309	108	129	139096	85012
1975	17848	29288	25525	10839	13902	6670	6355	4544	4838	2197	827	874	96	64	123867	76731
1976	42645	22878	25308	21015	8066	7990	3453	2651	1708	1477	936	343	245	38	138753	73230
1977	77426	61200	26782	19478	12776	5041	4839	1925	1597	1036	702	542	157	187	213688	75062
1978	49634	82542	70879	24238	16749	9946	4393	3916	1351	1115	719	300	516	112	266410	134234
1979	51192	71866	86657	64911	18254	11998	7170	3902	2819	728	518	444	341	410	321210	198152
1980	62467	56625	85476	79048	49276	11452	6462	3846	2300	1149	258	246	303	459	359367	240275
1981	35029	59794	58521	74748	59261	31209	7139	3318	1754	811	717	81	141	139	332662	237839
1982	127304	43538	60496	55493	54657	39259	19968	3671	1386	671	217	106	33	35	406834	235992
1983	48561	84455	46351	53977	46699	35742	23898	12191	2103	825	350	206	106	10	355474	222458
1984	44092	78294	70245	39823	38952	29359	22452	12833	5592	1500	499	274	127	79	344121	221735
1985	39562	45712	96440	69899	32842	26119	17618	11542	6185	2959	736	86	196	60	349956	264682
1986	34605	44087	49252	90254	55579	22171	15588	8939	5775	2982	1480	447	65	118	331342	252650
1987	12741	32229	43448	43267	62943	39942	14094	8824	3681	2613	921	924	314	75	266016	221046
1988	18484	23152	34738	38675	30854	36389	24646	8207	4323	2052	1214	666	556	408	224364	182728
1989	30275	23785	30950	34597	29041	20583	20164	13070	3723	1609	682	405	330	383	209597	155537
1990	37563	33633	27289	28313	23405	16700	10849	9389	4759	1307	427	215	158	74	194081	122885
1991	22881	35402	32768	21995	18414	12122	7458	4336	2515	1320	438	98	87	35	159869	101586
1992	20151	22823	31653	22966	11946	7759	5187	2543	1421	871	275	342	33	23	127993	85019
1993	11304	16553	19377	21893	13519	5996	2763	1807	873	417	129	33	389	22	95075	67218
1994	8474	12843	16084	19362	22577	13709	5763	2360	1552	660	291	59	11	271	104016	82699
1995	4868	9625	13411	16618	20194	22110	13440	5380	2327	1512	758	350	62	7	110662	96169
1996	6391	6330	12038	15291	18606	22582	23053	11624	4259	1789	1055	477	346	95	123936	111215

Table 19: Parameter and fishing mortality estimates from the Laurec-Shepherd calibration.

Age	Pred. q	SE(q)	Partial F	Raised F
3	-7.84	0.512	0.0004	0.0048
4	-7.53	0.428	0.0005	0.0074
5	-7.36	0.305	0.0006	0.0096
6	-7.29	0.350	0.0007	0.0115
7	-7.30	0.257	0.0007	0.0151
8	-7.30	0.304	0.0007	0.0193
9	-7.32	0.354	0.0007	0.0221
10	-7.13	0.314	0.0008	0.0350
11	-6.92	0.554	0.0010	0.0426
12	-6.86	0.629	0.0011	0.0525

Table 20: Residuals from the Laurec Shephard calibration.

Age	3	4	5	6	7	8	9	10	11	12
1978	-0.07	-0.46	-0.72	-0.42	-0.26	-0.63	-0.25	-0.04	1.22	-0.03
1979	-0.26	0.02	-0.33	-0.57	-0.07	-0.19	-0.13	-0.27	-0.25	0.93
1980	0.00	-0.40	-0.04	-0.38	-0.56	-0.27	-0.17	-0.38	-0.37	-1.50
1981	-0.32	0.40	0.31	0.37	0.01	0.36	0.54	0.41	0.40	1.27
1982	-0.90	-0.23	-0.22	0.48	0.19	0.00	-0.15	-0.17	-0.24	0.37
1983	-0.32	-0.23	-0.14	-0.39	-0.17	-0.10	-0.23	0.21	0.96	0.20
1984	-0.83	-0.80	-0.13	-0.22	-0.47	0.05	-0.19	-0.49	-0.49	-0.42
1985	0.08	-0.03	-0.09	0.50	0.19	-0.21	-0.02	-0.32	-0.14	0.05
1986	0.21	-0.07	-0.03	-0.21	0.18	0.31	-0.69	0.13	-0.35	0.06
1987	0.06	-0.34	-0.10	-0.14	-0.01	-0.40	-0.41	-0.28	-0.62	-0.23
1988	1.30	0.91	0.57	0.38	0.18	0.24	0.29	0.04	-0.80	-0.48
1989	0.49	0.40	0.20	0.40	0.21	0.25	0.34	0.41	0.23	0.05
1990	0.64	0.25	0.16	-0.07	0.00	-0.08	-0.04	0.20	-0.02	0.04
1991	0.00	0.55	0.52	0.15	-0.01	0.18	-0.01	-0.08	0.16	0.47
1992	0.12	-0.19	-0.07	-0.11	-0.08	-0.22	-0.01	-0.25	-0.40	-0.84
1993	-0.01	0.38	0.09	0.32	0.43	0.54	0.51	0.58	0.00	-0.15
1994	-0.19	-0.15	0.05	-0.07	0.25	0.18	0.63	0.29	0.69	0.22
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 21: Beginning of the year population numbers ('000) for southern Gulf cod from a Laurec-Shepherd calibration.

	3	4	5	6	7	8	9	10	11	12	13	14+	Total
1978	164273	137683	75946	16315	8296	3742	1056	914	275	161	117	13	408791
1979	115798	134000	103671	52364	9231	4388	2069	645	525	127	68	35	422921
1980	115709	94674	105072	70548	32754	4416	2050	921	265	204	45	20	426678
1981	85065	94468	75779	72807	45038	18032	2252	955	393	89	140	3	395021
1982	151667	69557	73888	55388	42413	25101	9206	1027	369	141	11	4	428772
1983	204507	123707	55484	50883	37514	23472	13675	5263	444	175	47	26	515197
1984	108437	167398	100247	39739	30762	20008	12360	6382	1930	239	97	13	487612
1985	102557	88754	135862	78275	25867	17032	10153	5494	2603	740	61	14	467412
1986	82448	83808	71256	101938	48653	13697	8485	4755	2461	1261	291	35	419088
1987	66587	67380	65416	50863	62204	31072	7562	4222	1778	947	321	272	358624
1988	51356	54444	54237	46888	31885	33940	19137	4172	1950	829	403	102	299343
1989	53585	41947	43018	39680	28270	17961	16902	9563	1791	732	264	85	253798
1990	52581	43807	32846	29757	21365	13552	8160	7024	3226	585	187	57	213147
1991	44845	42562	33184	20143	14854	8383	4872	2704	1640	810	138	38	174173
1992	24894	36457	30181	17865	7936	4677	2652	1179	660	494	146	16	127157
1993	26422	19941	26750	13520	5807	1816	787	363	165	92	74	18	95755
1994	25718	21585	16088	21076	10028	3923	1055	450	179	71	45	23	100241
1995	16465	21031	17623	13082	17062	7953	3073	801	344	129	52	21	97636
1996	20000	13417	17091	14291	10588	13760	6387	2461	633	270	100	57	99055

Table 22: Input data for catch projections.

Age	1996 Population	SE Pop.	Mid Year Wt	Beg. Year Wt	PR
3	20000	20000	0.34	0.32	0.038
4	12984	6705	0.54	0.48	0.095
5	18447	5818	0.72	0.65	0.243
6	17630	3997	0.98	0.87	0.366
7	16013	2890	1.34	1.16	0.631
8	14843	2235	1.72	1.52	0.868
9	12232	1722	2.08	1.88	1.000
10	5541	824	2.29	2.10	1.000
11	1843	312	2.58	2.31	1.000
12	743	155	2.62	2.41	1.000
13	425	109	2.97	2.48	1.000
14	181	19	3.37	2.63	1.000

10. Figures

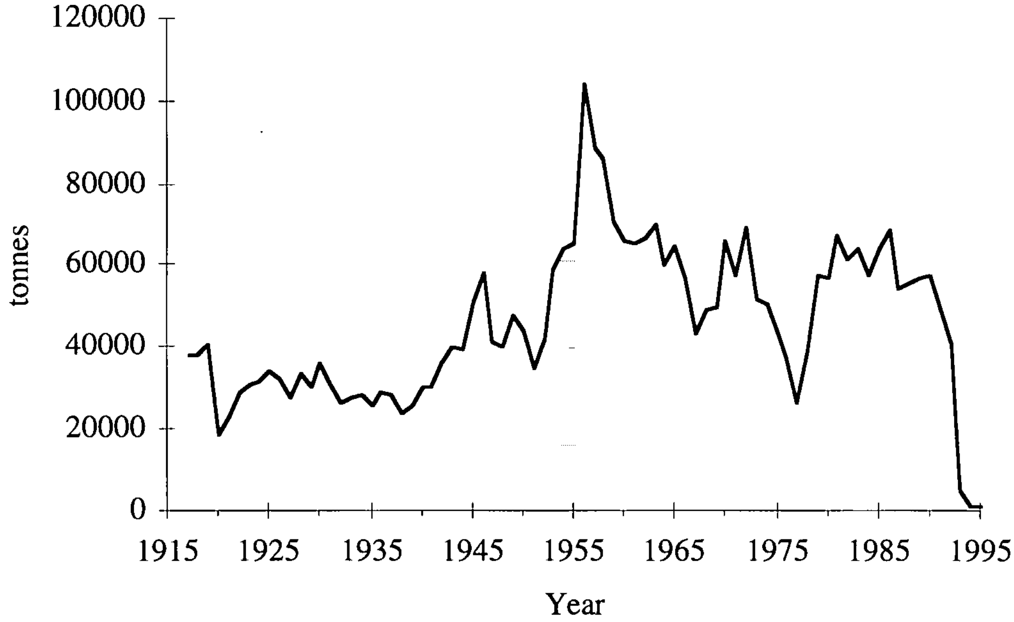

Figure 1: Landings of southern Gulf cod, 1917-95.

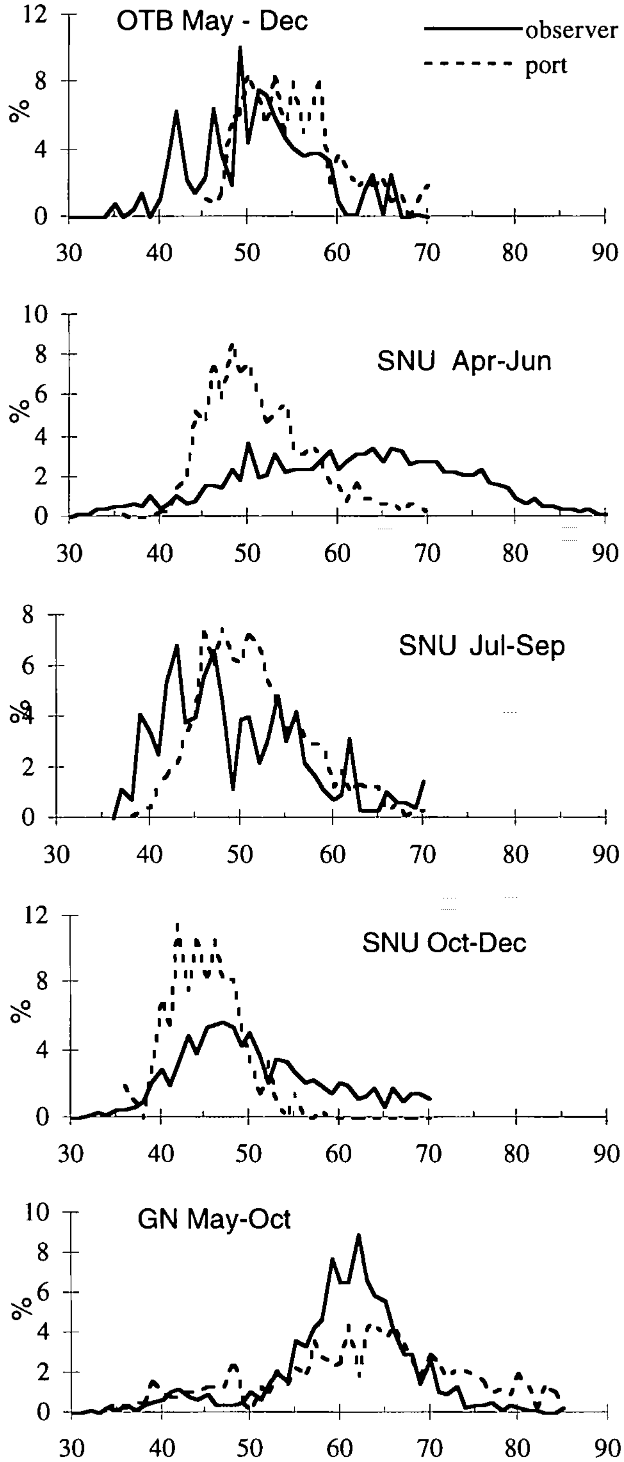

Figure 2: Observer and port sampled length frequencies in 1995.

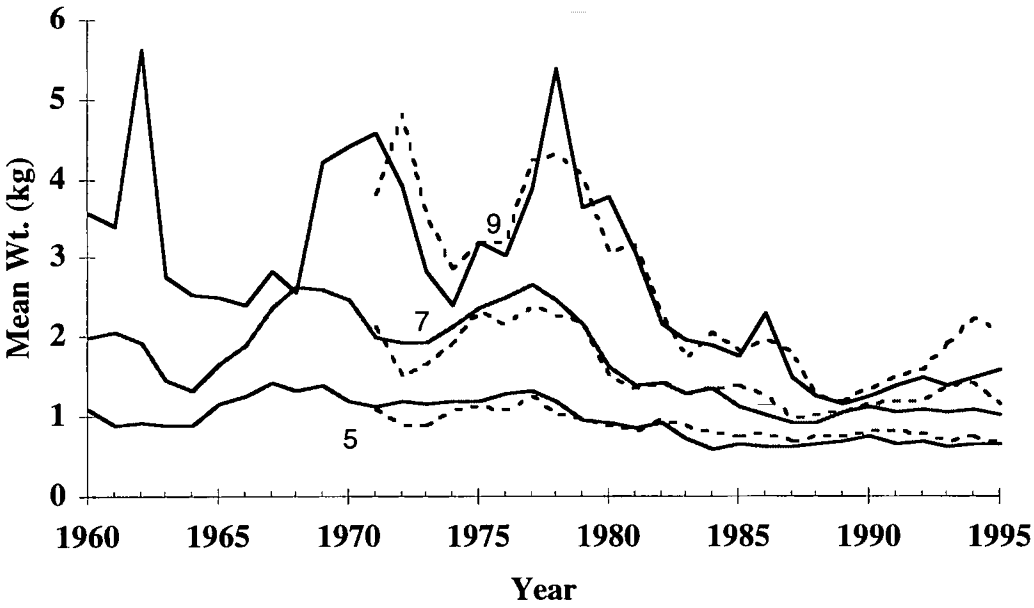

Figure 3: Trends in mean weights at age 5, 7, and 9 (kg) of southern Gulf cod from the commercial fishery (dashed lines) and the research vessel surveys (solid lines).

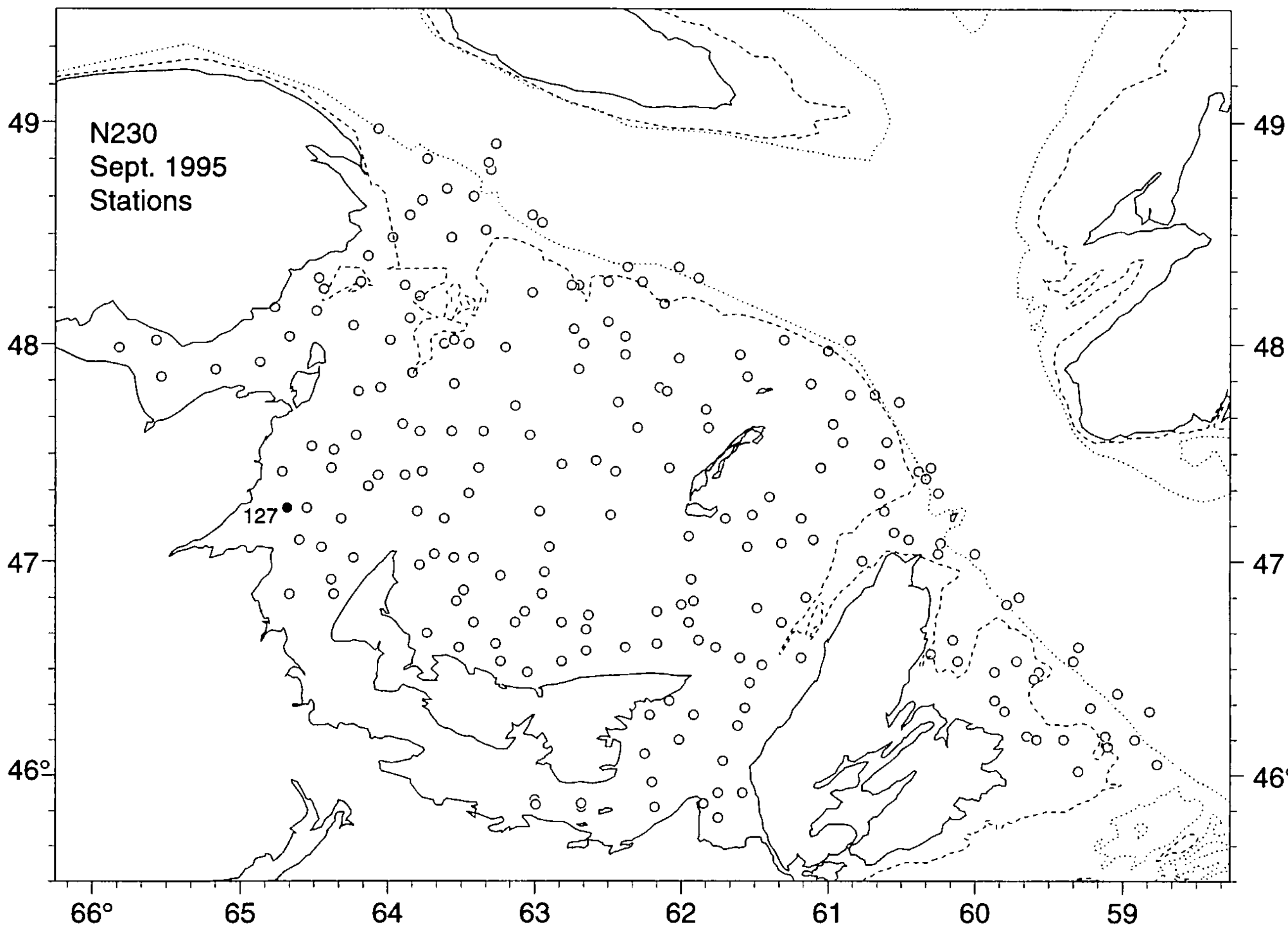

Figure 4. Set locations for the September 1995 groundfish survey (N230) conducted in the southern Gulf of St. Lawrence. The location of set 127 is indicated.

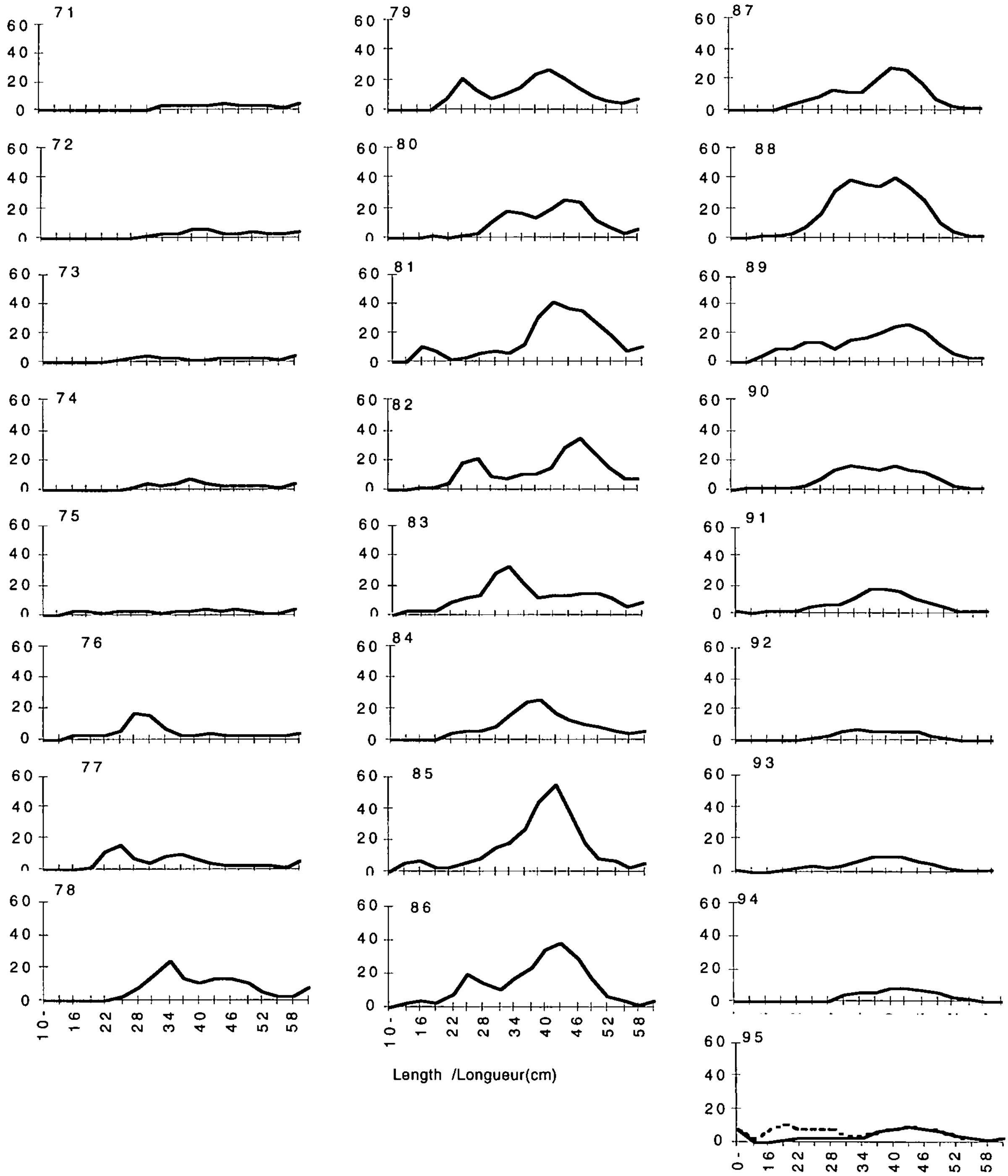

Figure 5: Annual length frequencies (mean numbers per tow at length) of southern Gulf cod from September groundfish surveys, 1971-95. In 1995, the dashed line includes set 127, the solid line does not.

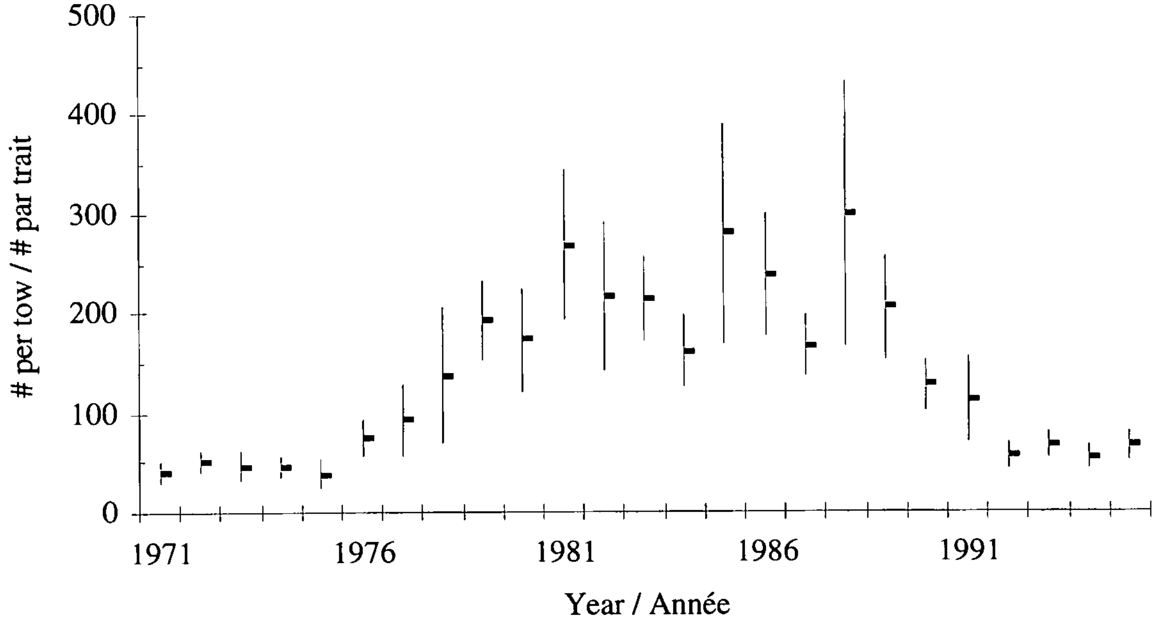

Figure 6: Mean numbers per tow (ages 0+) of southern Gulf cod from the September groundfish survey. Vertical bars give 2 standard errors.

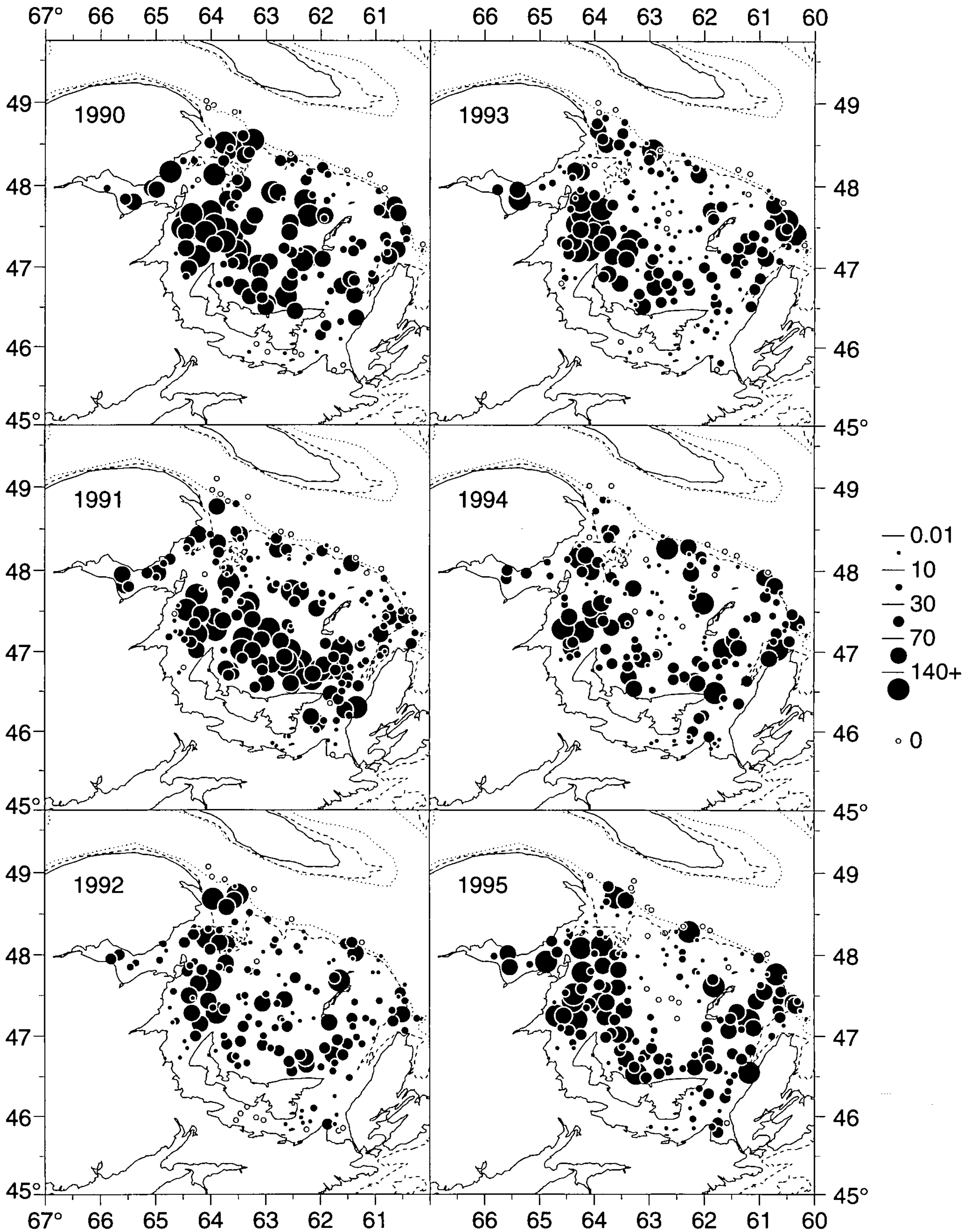

Figure 7. Cod catches (kg) in the southern Gulf of St. Lawrence September groundfish surveys from 1990 to 1995.

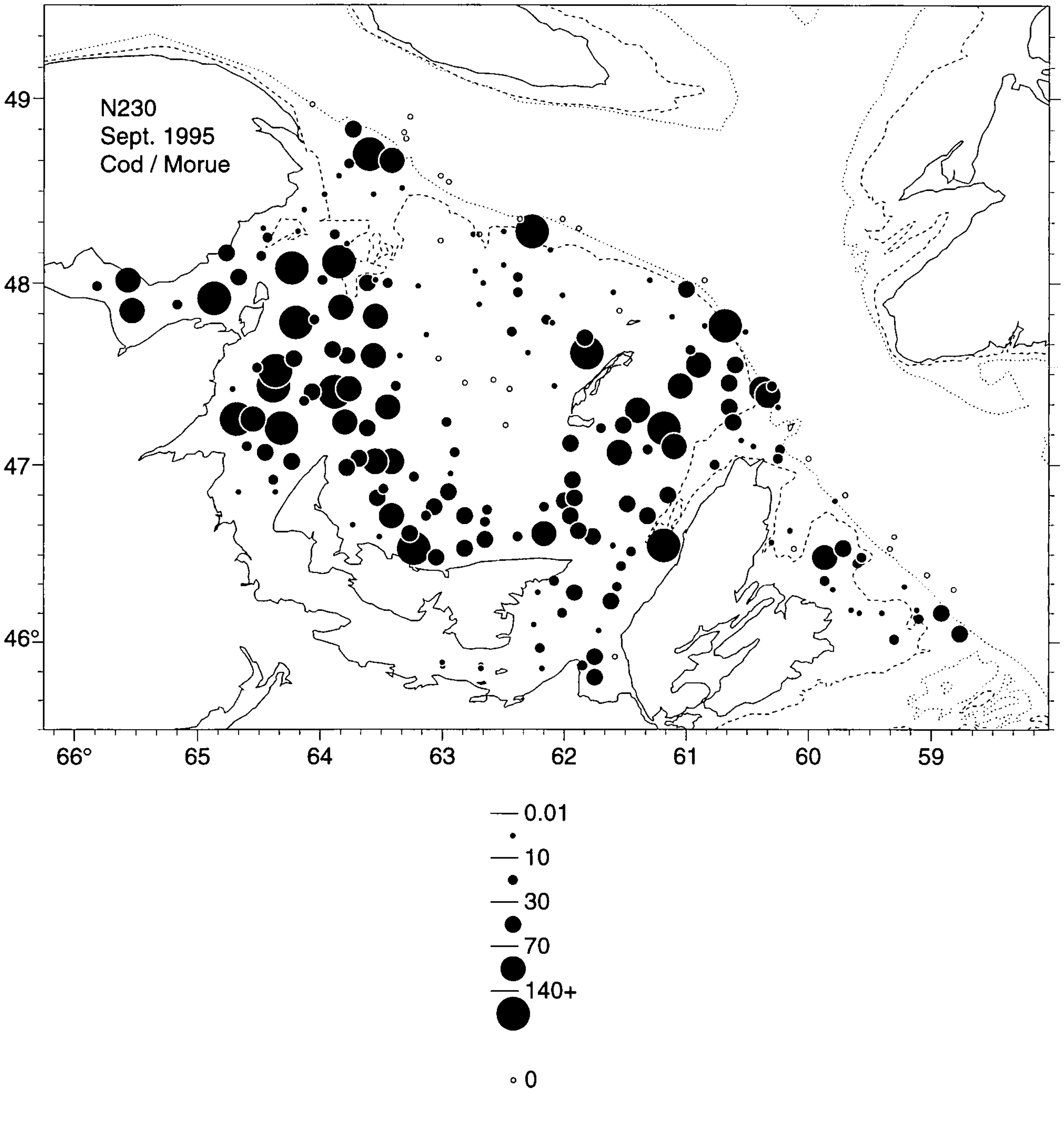

Figure 8. Cod catches (kg) in 4T and 4Vn in the September 1995 groundfish survey

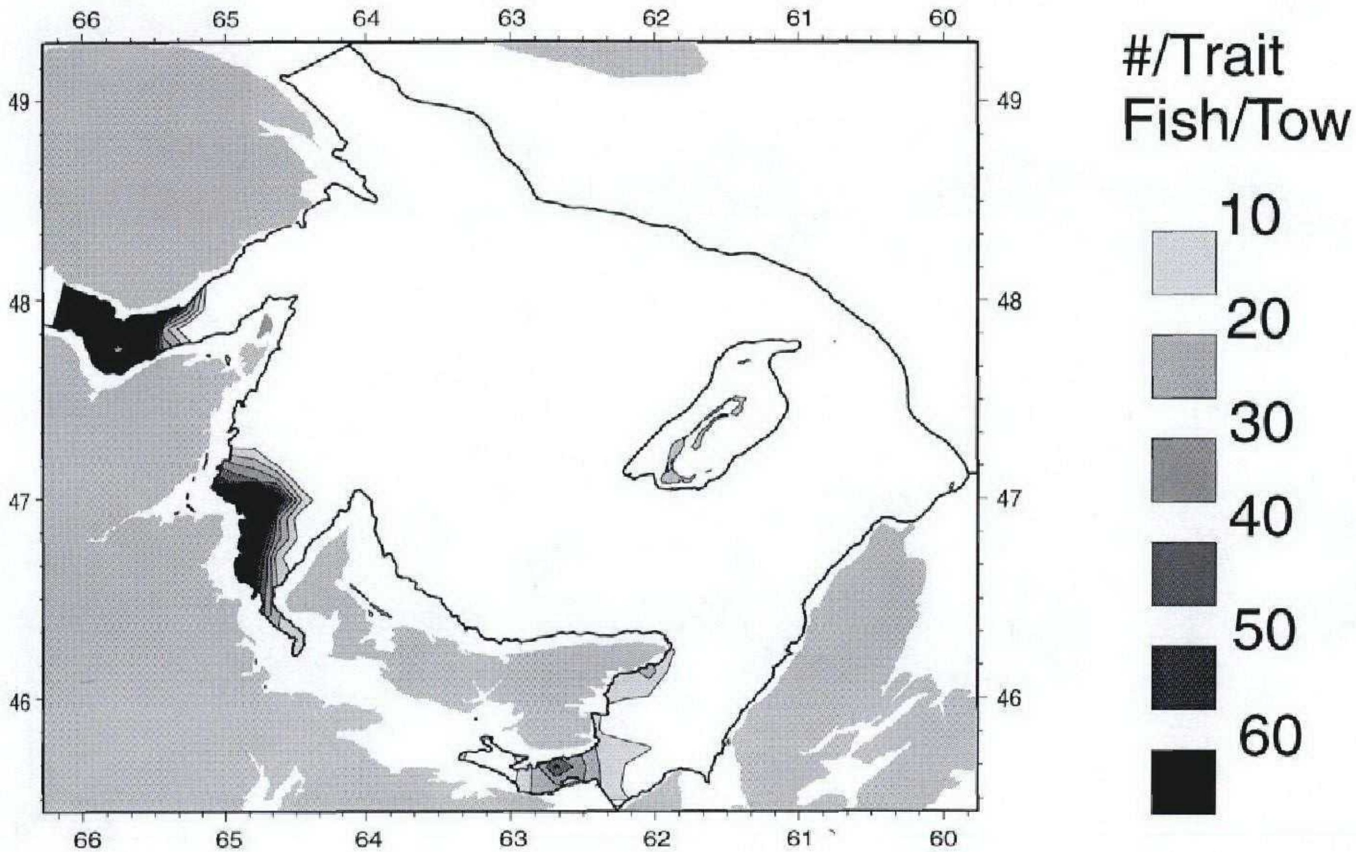

Figure 9: 1995 RV catches of age 0 cod.

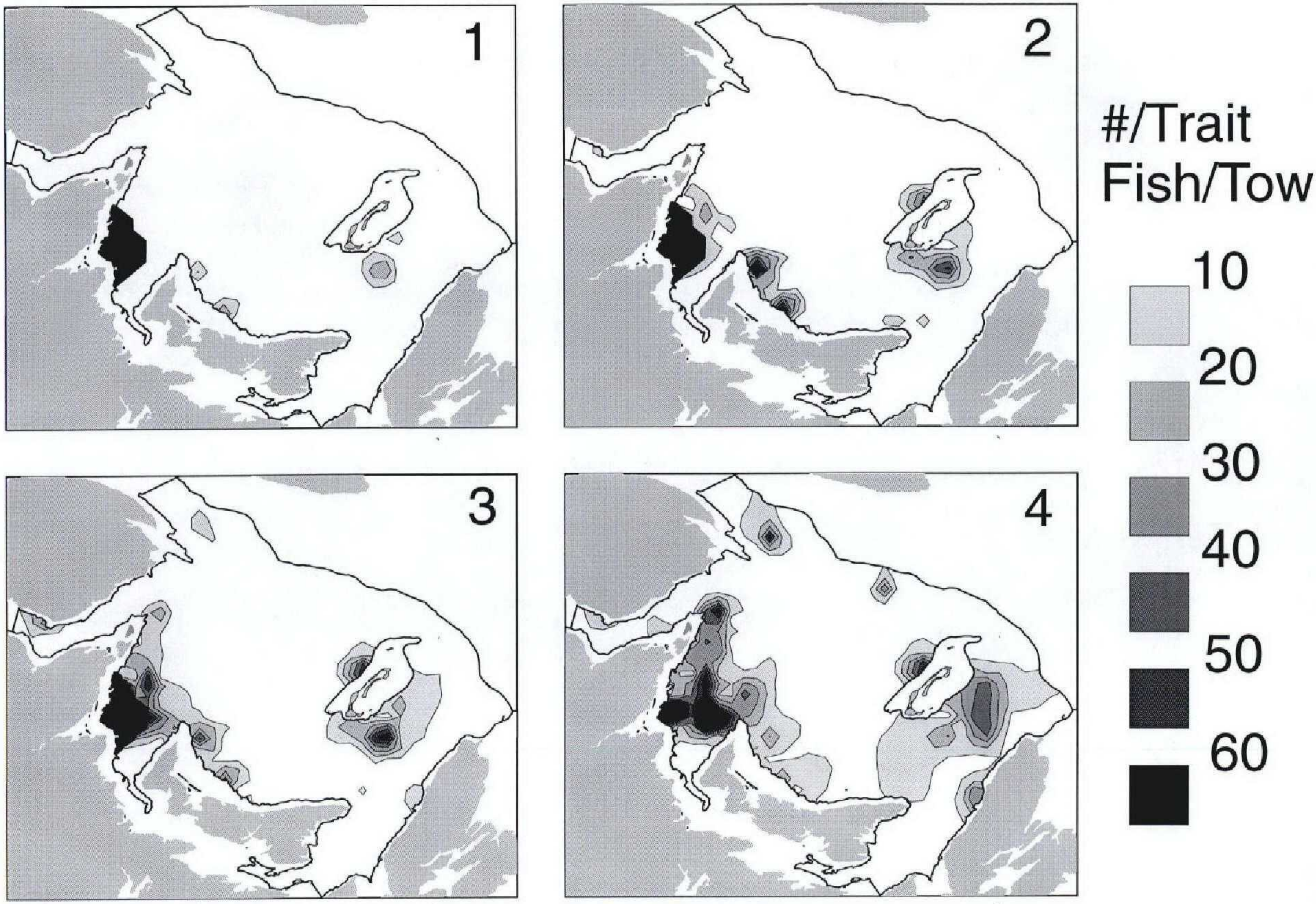

Figure 10: 1995 RV catches of age 1-8+ cod.

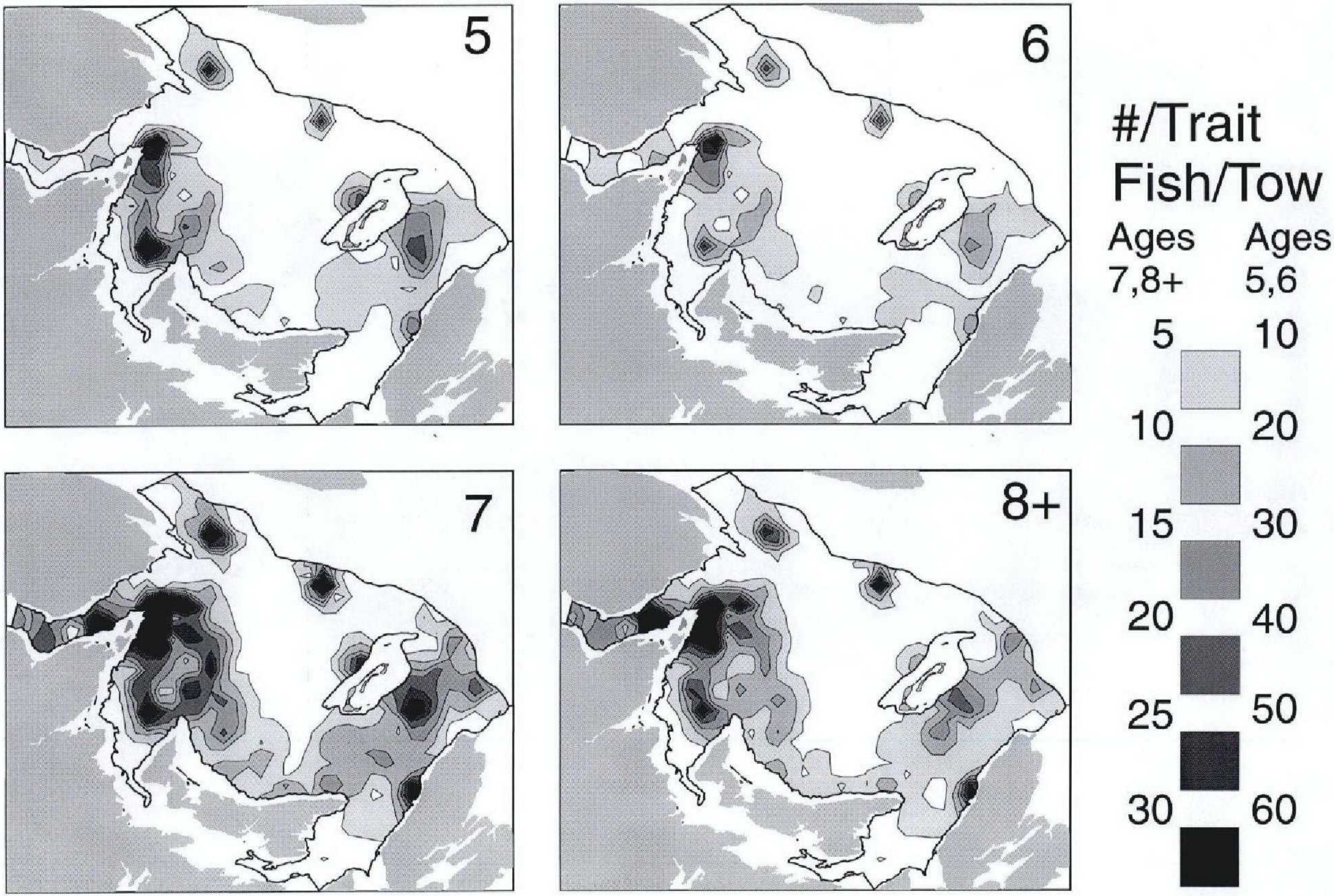

Figure 10: cont'd.

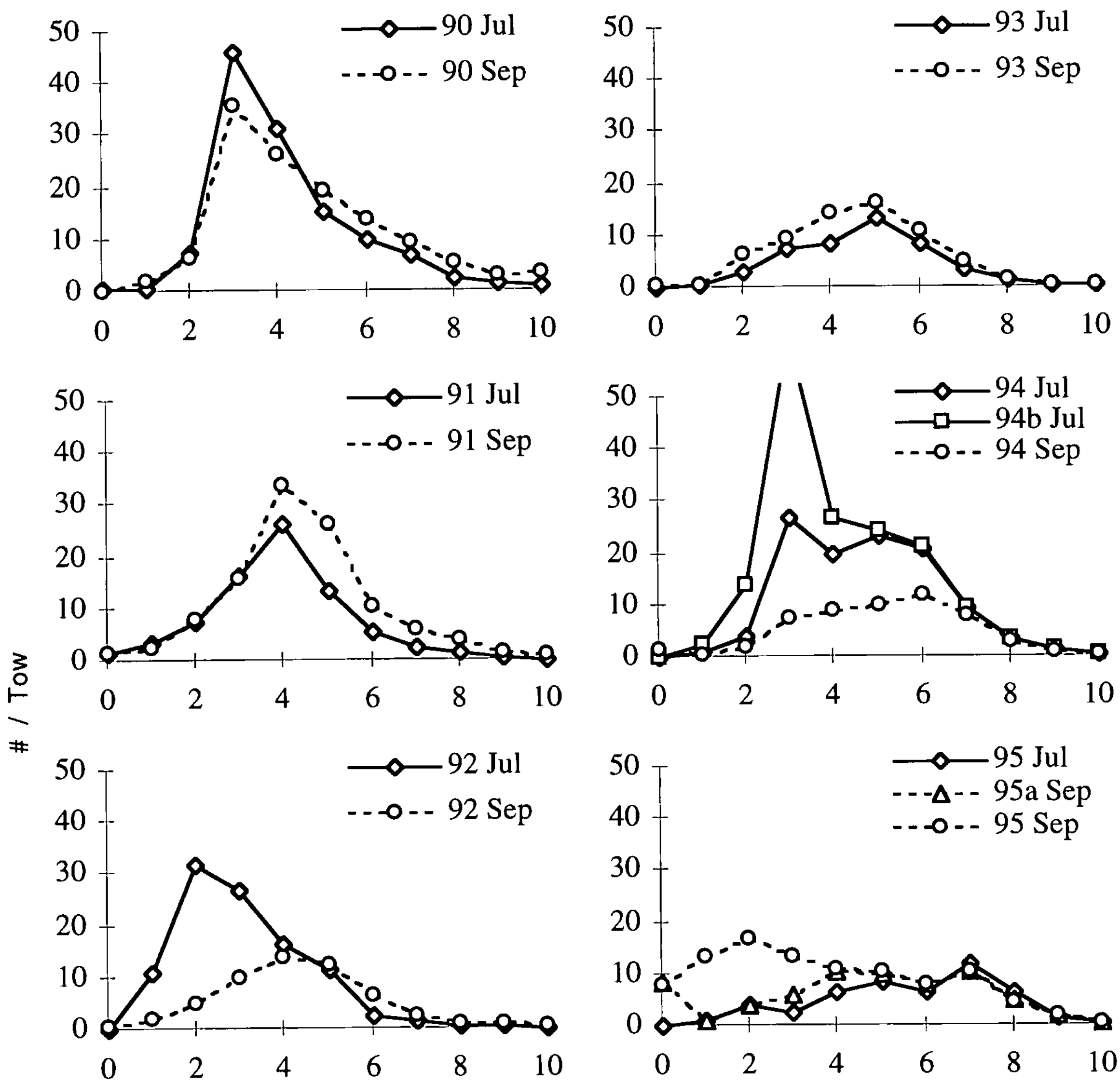

Figure 11: Comparison of mean numbers of cod per tow at age from the July juvenile cod survey and the September groundfish survey, 1990 - 1995. Two lines are shown for the 1994 juvenile survey, line 94 does not include a large set while 94b does. Two lines are also shown for the 1995 September survey, 95 includes set 127, 95a does not.

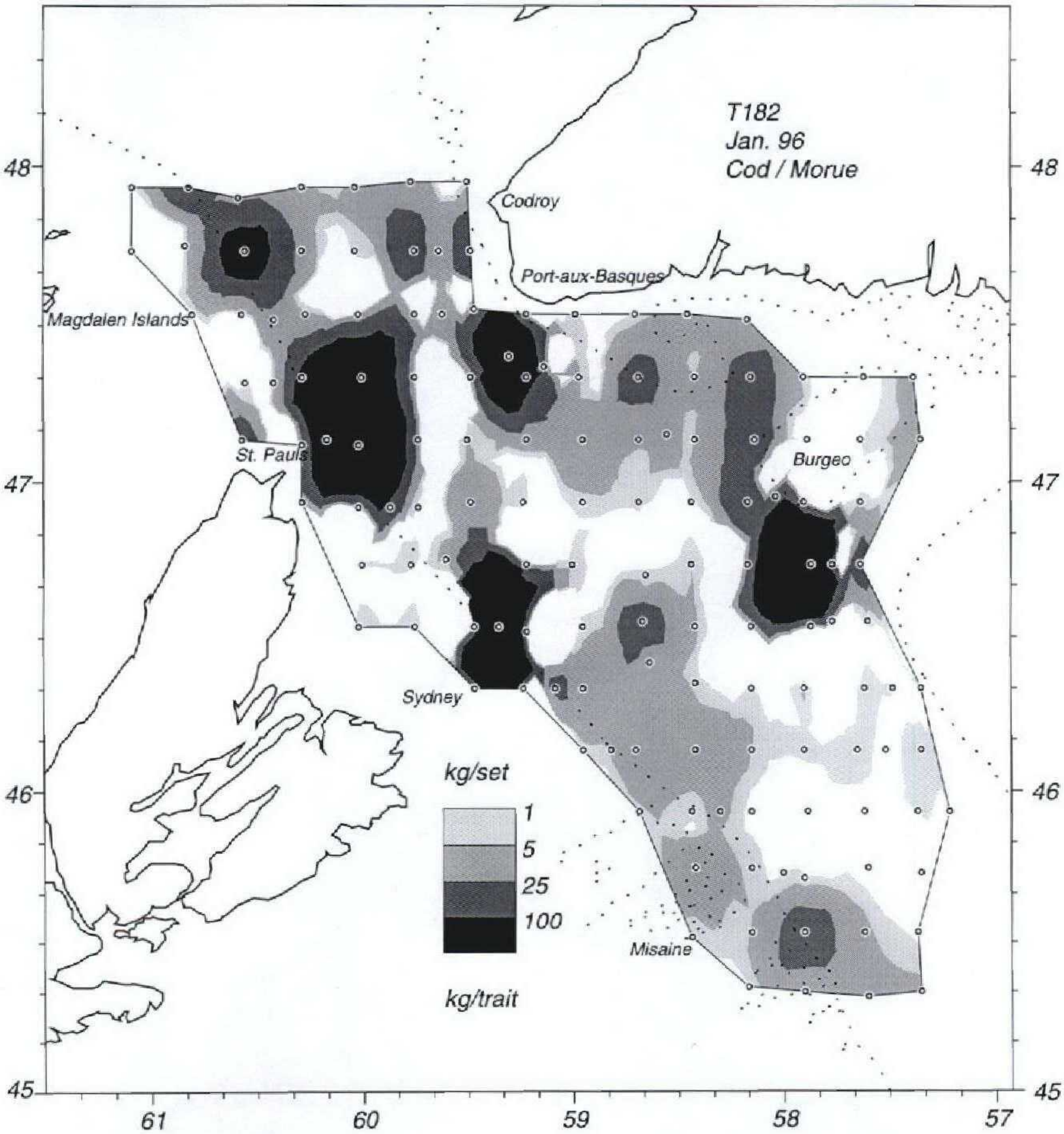

Figure 12: Cod catches (kg/set) in the January 1996 groundfish survey in Cabot Strait. Open circles are set locations and dotted line is 200 m contours. Names refer to concentrations discussed in the text

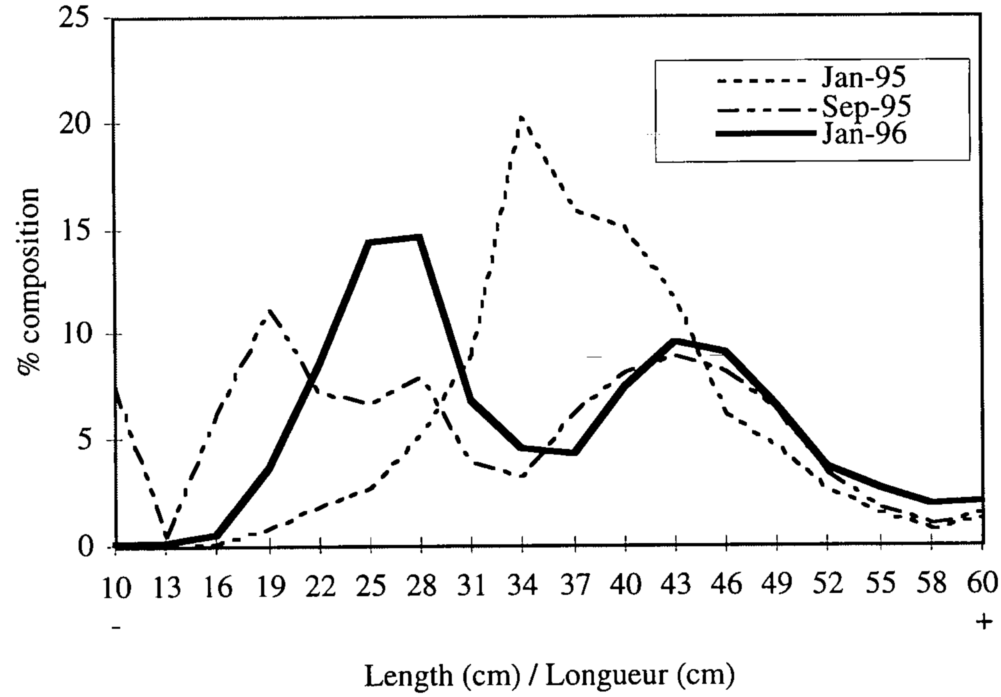

Figure 13: Length frequencies of cod captured during the January 1995-1996 and September 1995 groundfish surveys.

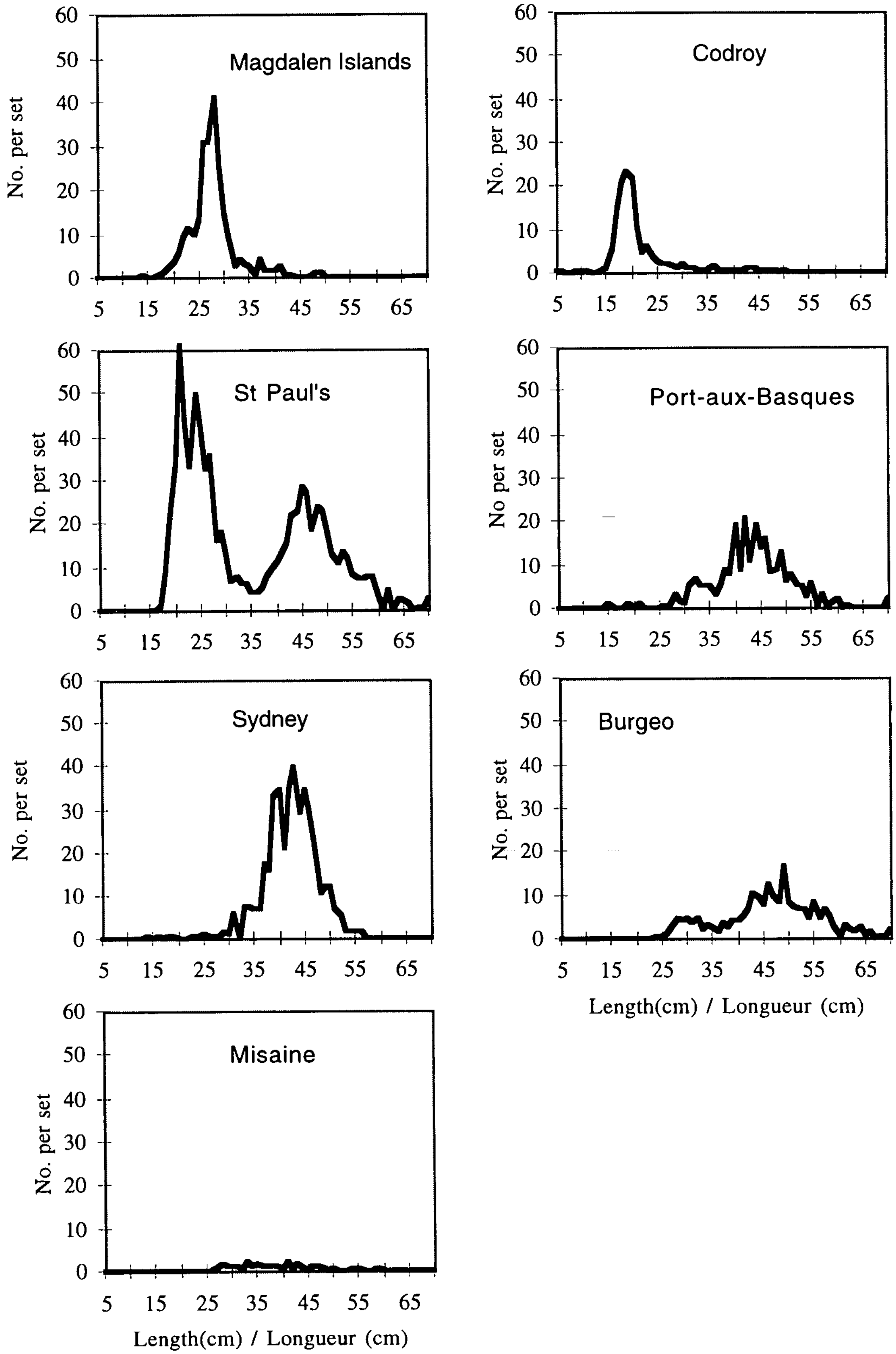

Figure 14: Length frequencies of cod concentrations encountered during the January 1996 groundfish survey in Cabot Strait.

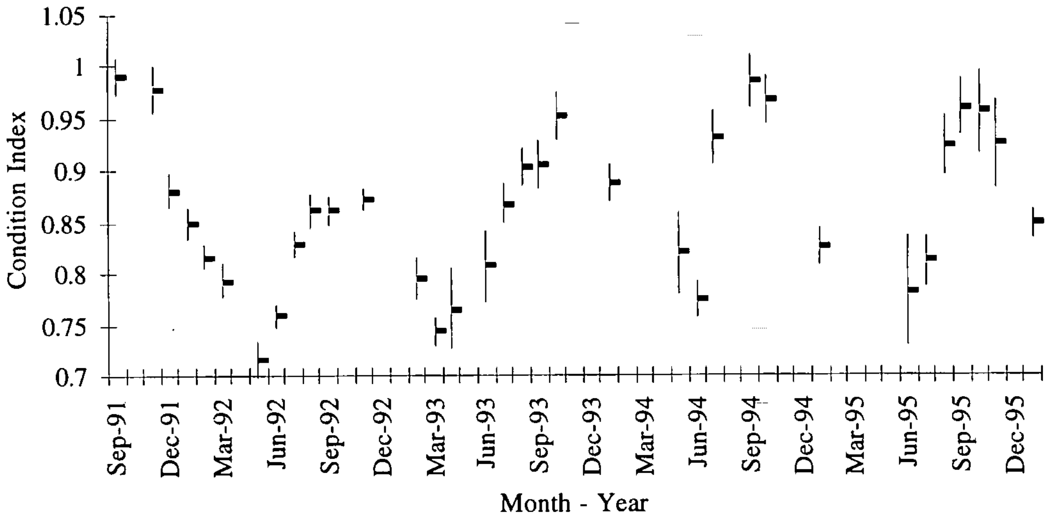

Figure 15: Seasonal change in condition index (carcass weight/length^3) for southern Gulf of St. Lawrence cod of 40-50 cm between September 1991 and January 1996. Error bars give 2 standard errors.

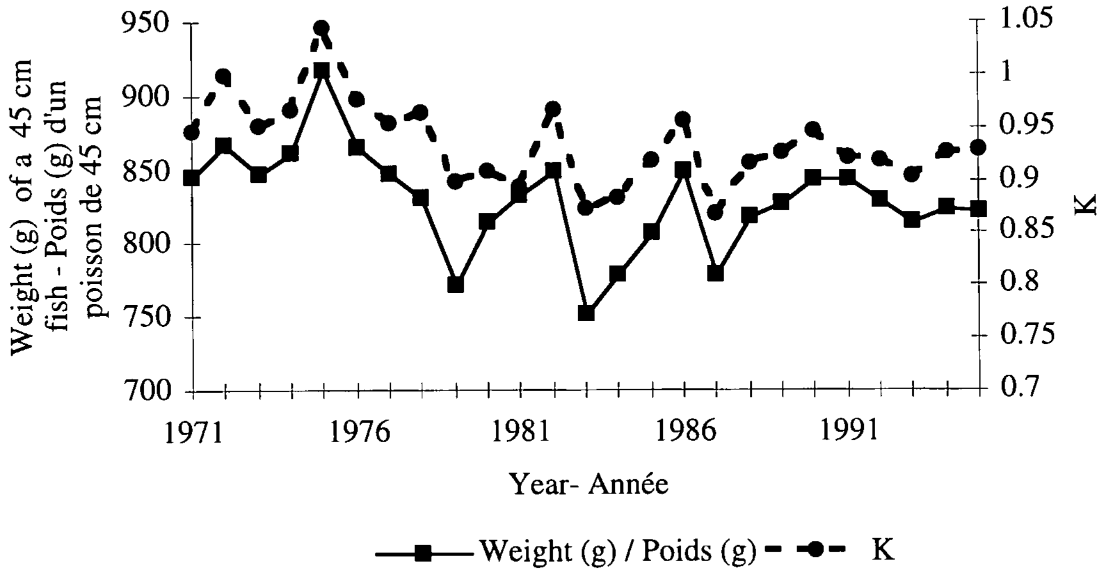

Figure 16: Trends in annual condition factors for southern Gulf cod.

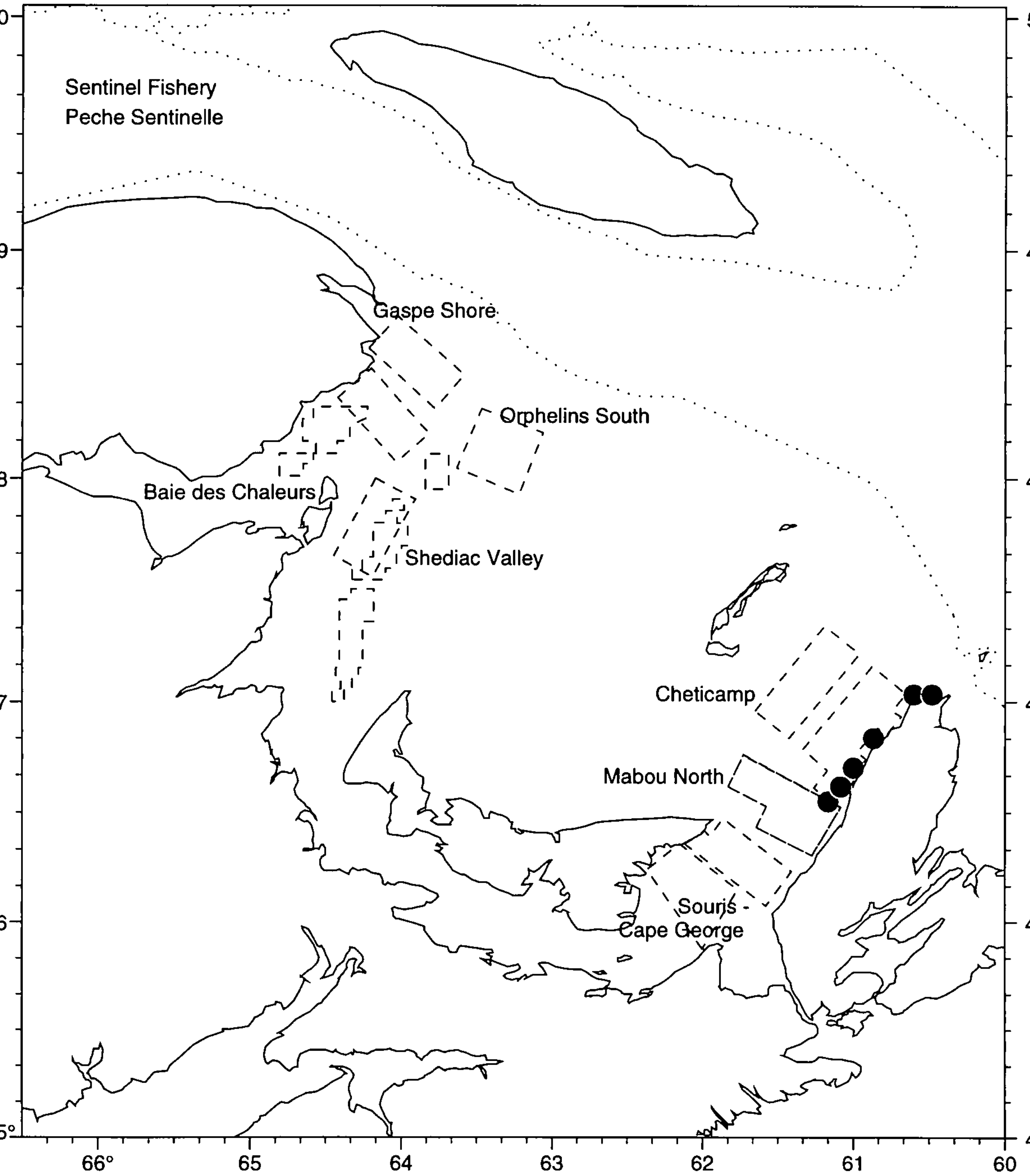

Figure 17: Areas fished by the abundance projects of the sentinel surveys program. Polygons are areas fished by the mobile gears and filled circles are areas fished by fixed gears. Areas fished by mobile gears were as follows: Quebec - Baie des Chaleurs, Gaspe Shore,Orphelins South and Shediac Valley; N.B. - Baie des Chaleurs and Shediac Valley; N.S. - Mabou North and Cheticamp; P.E.I. - Mabou north and Souris-Cape George.

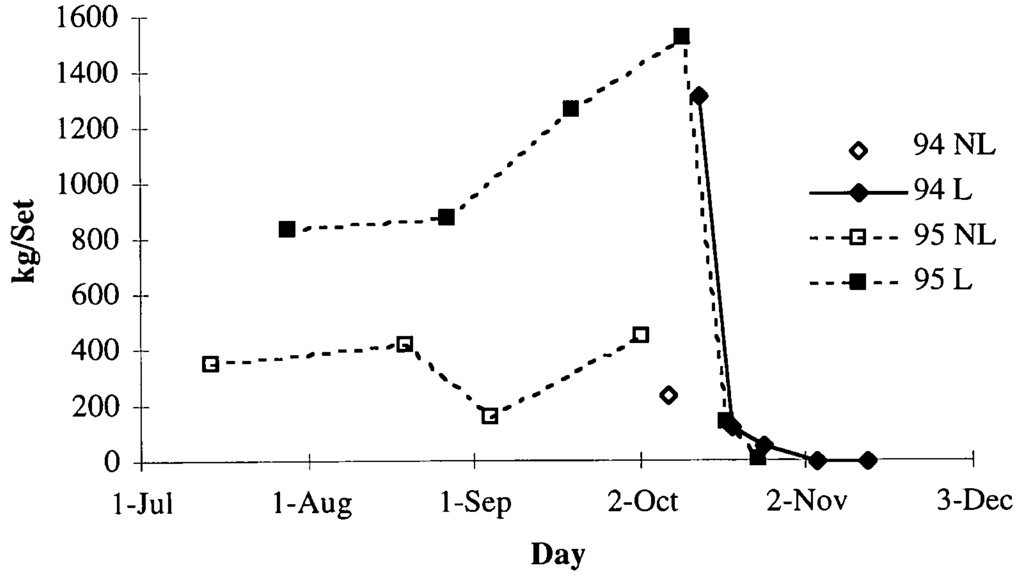

Figure 18: Comparison of cod catch rates (kg/tow) for the one vessel involved in the 1994 and 1995 sentinel survey in the southern Gulf of St. Lawrence. Data are presented for sets with (L) and without (NL) a liner.

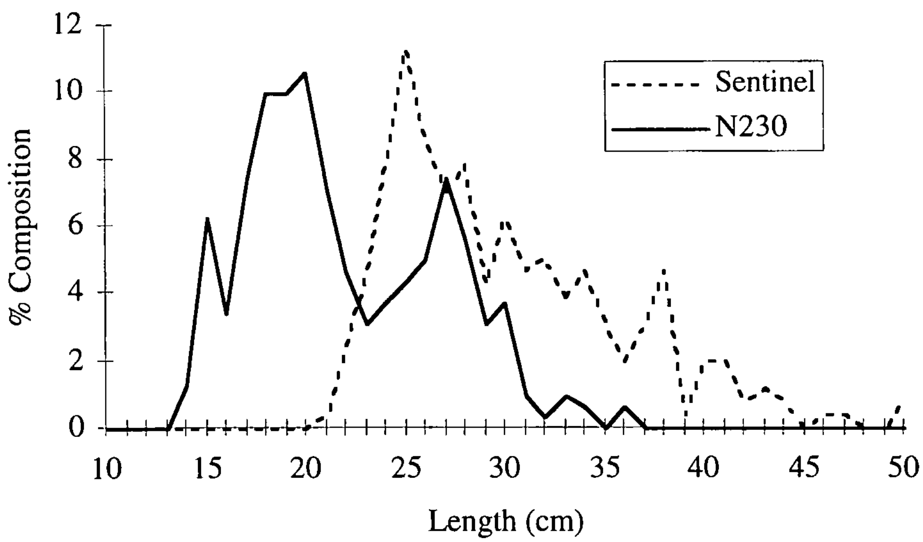

Figure 19: Comparison of length frequencies from the sentinel survey (Wayne and Randy, Set 1, September 19, 1995, Shediac Valley) and the groundfish survey (N230, set 127, September 20, 1995) in similar location and date.

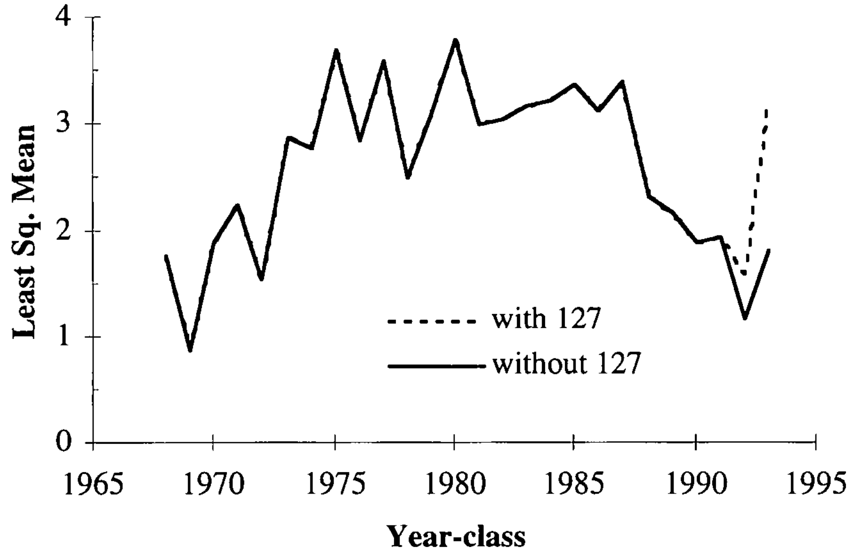

Figure 20: Relative year-class strengths of southern Gulf cod shown as least square means from multiplicative analyses of September RV survey mean numbers per tow for ages 2 and 3. The solid line is from an analysis that excludes set 127 in 1995, the dashed line includes this set.

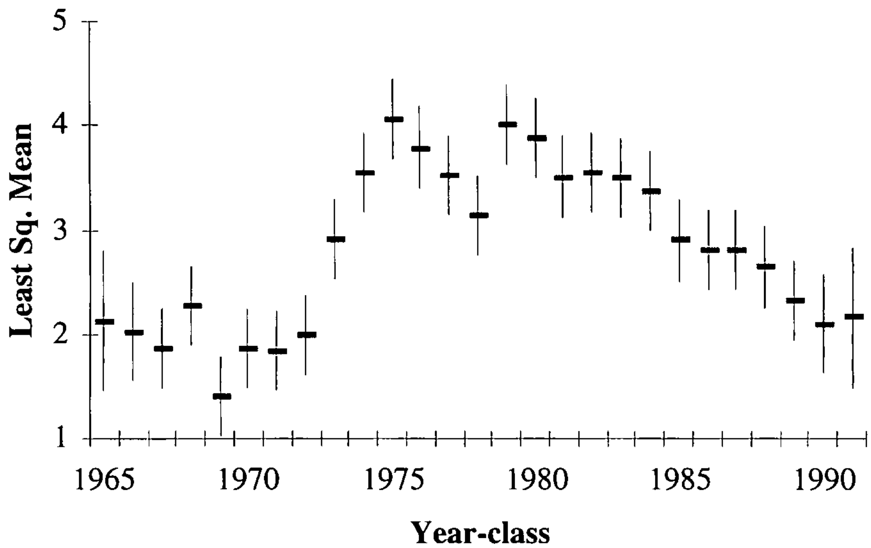

Figure 21: Relative year-class strengths of southern Gulf cod shown as least square means from multiplicative analyses of September RV survey mean numbers per tow for ages 4, 5, and 6. Vertical bars show 2 standard errors.

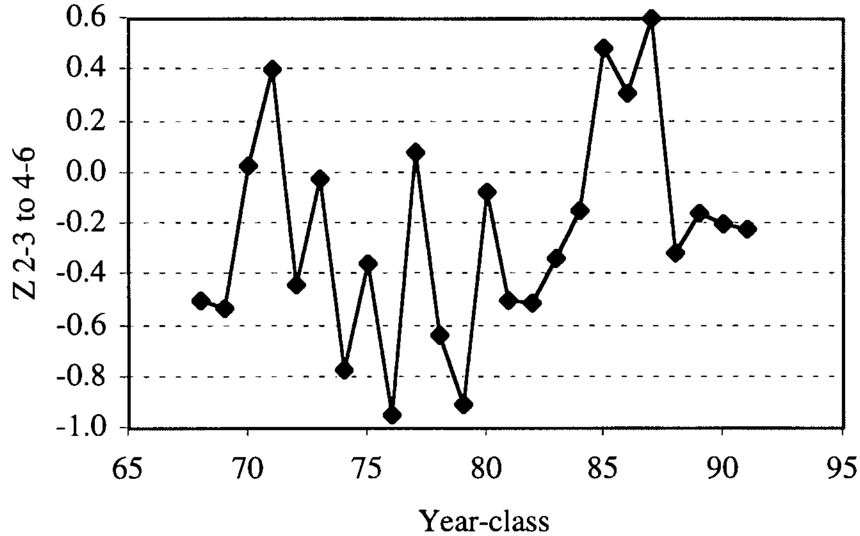

Figure 22: Trend in total mortality (relative) of the 1968-91 southern Gulf cod year-classes between the ages 2-3 and 4-6, estimated from September RV mean numbers per tow.

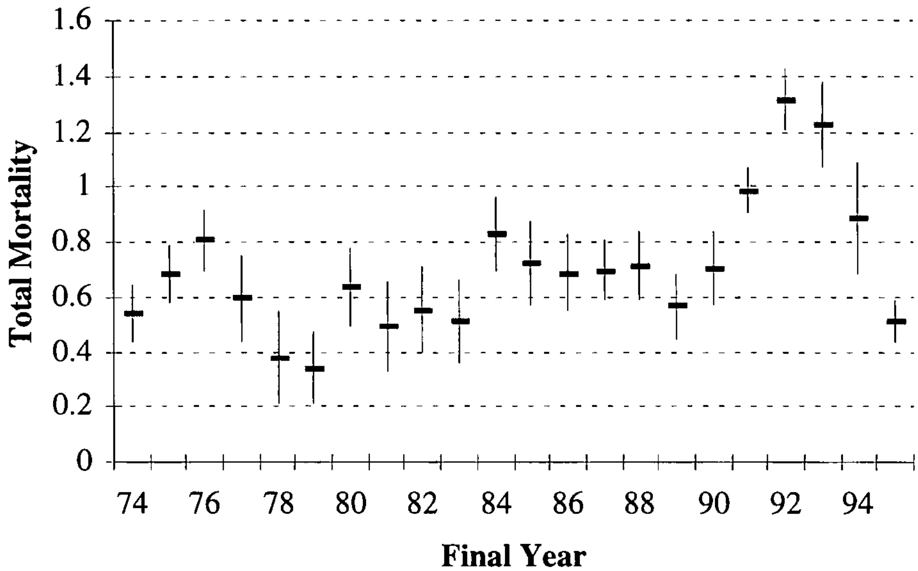

Figure 23: Total mortality (Z) estimates from separate multiplicative analyses of RV results which covered successive 4-year intervals. Z was estimated for ages 6-12. Vertical bars give 2 standard errors of the estimated slopes.

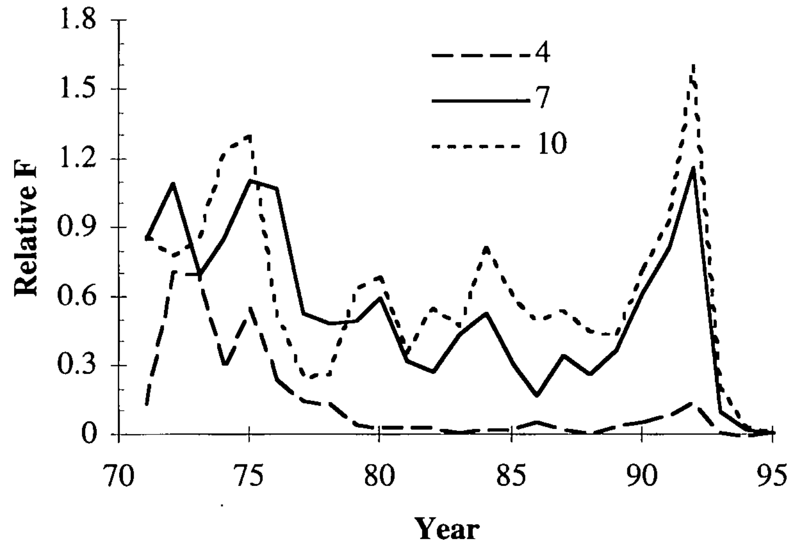

Figure 24: Estimates of relative fishing mortality for ages 4, 7, and 10 obtained directly from the ratio of catch at age divided by RV population estimates at age.

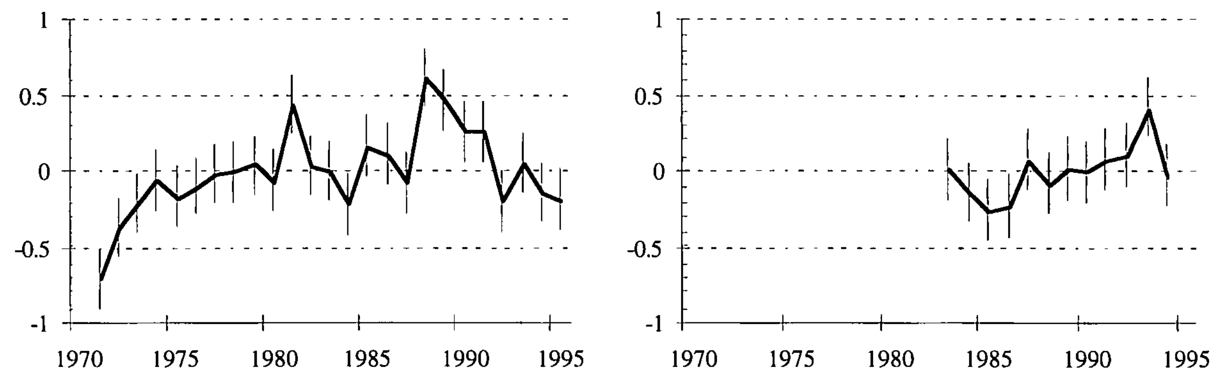

Figure 25: Residual patterns from ADAPT calibrations. The error bars indicate the 95% confidence limits of the annual means.

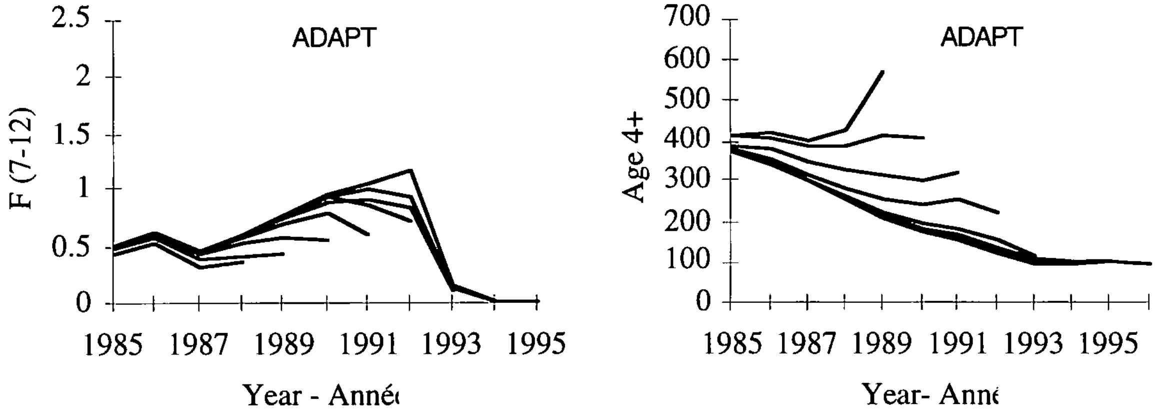

Figure 26: Retrospective patterns in fishing mortality and population numbers from the ADAPT calibration.

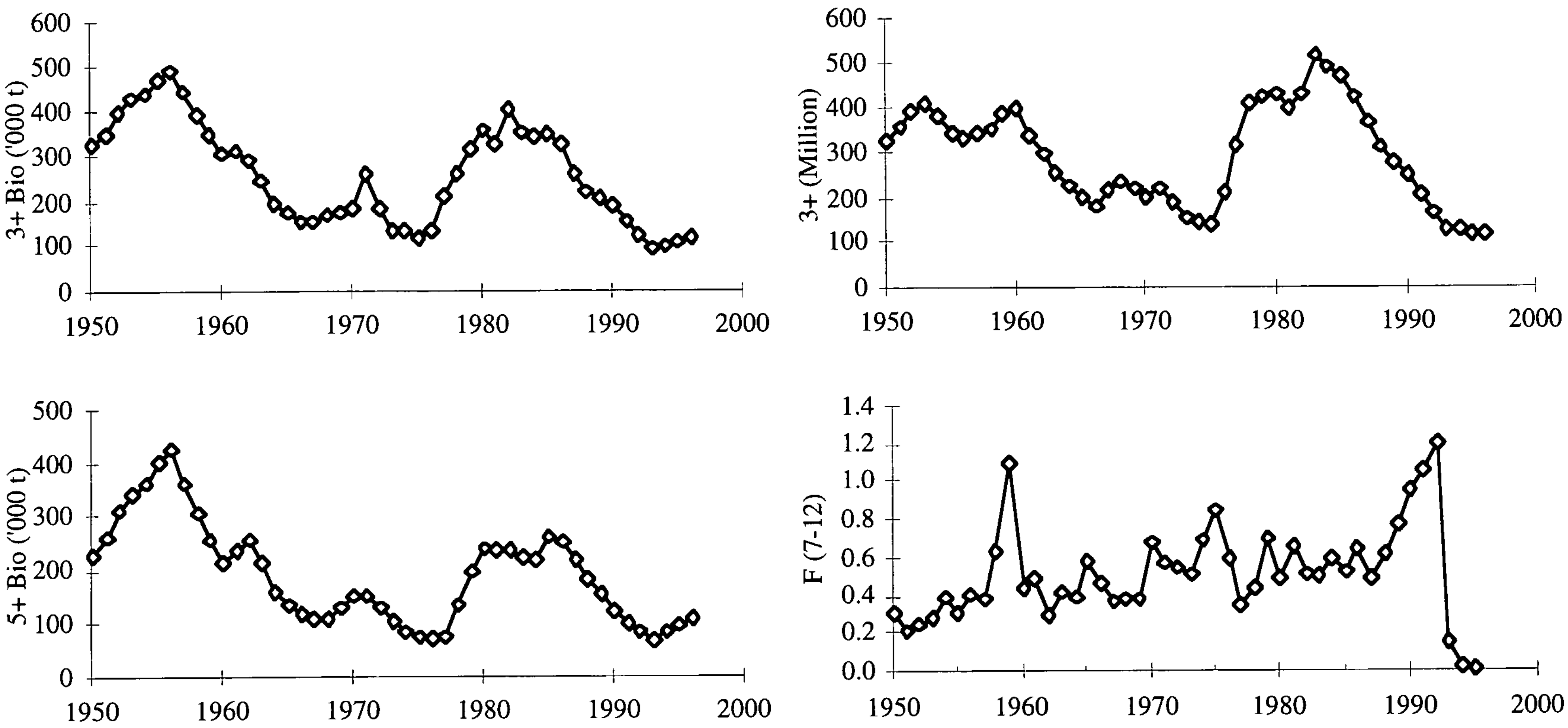

Figure 27: Total (3+) and adult (5+) biomass ('000 t), total abundance (million) and fishing mortality (7-12) of southern Gulf of St. Lawrence cod. ADAPT was used for SPA calibration.

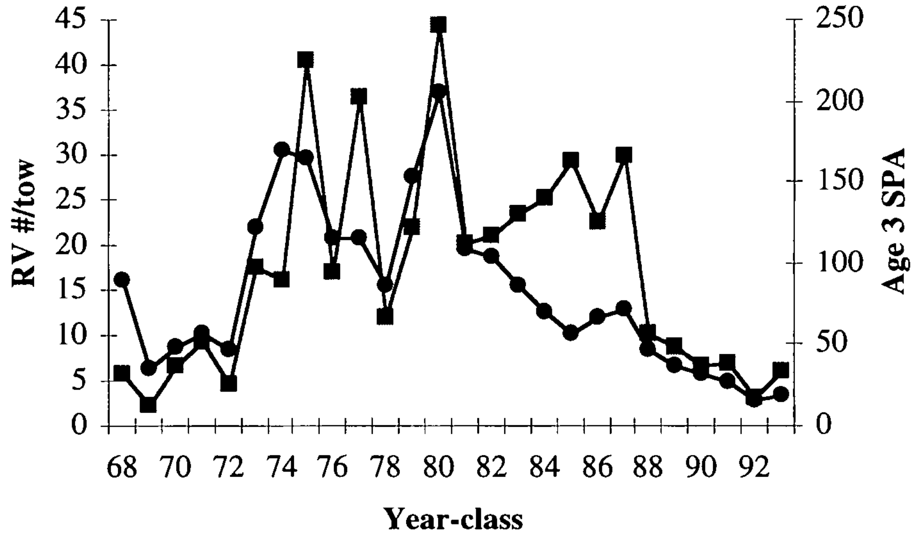

Figure 28: SPA (age 3) and research survey (age 2-3) estimates of recruitment. The solid squares are the research survey estimates.

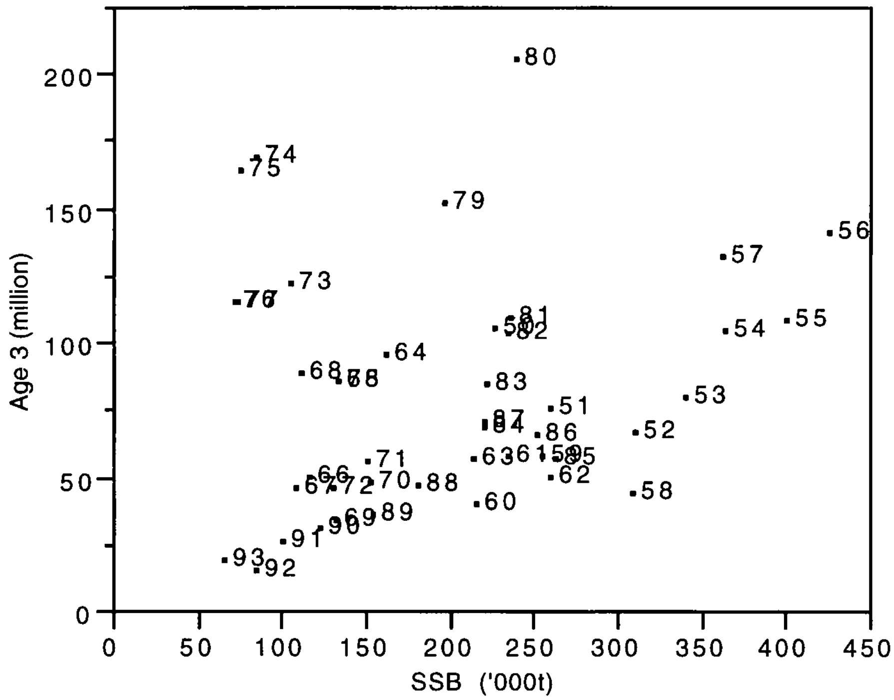

Figure 29: Stock (SSB) and recruitment (age 3 numbers) plot for 4TVn cod. The year-class is labeled.

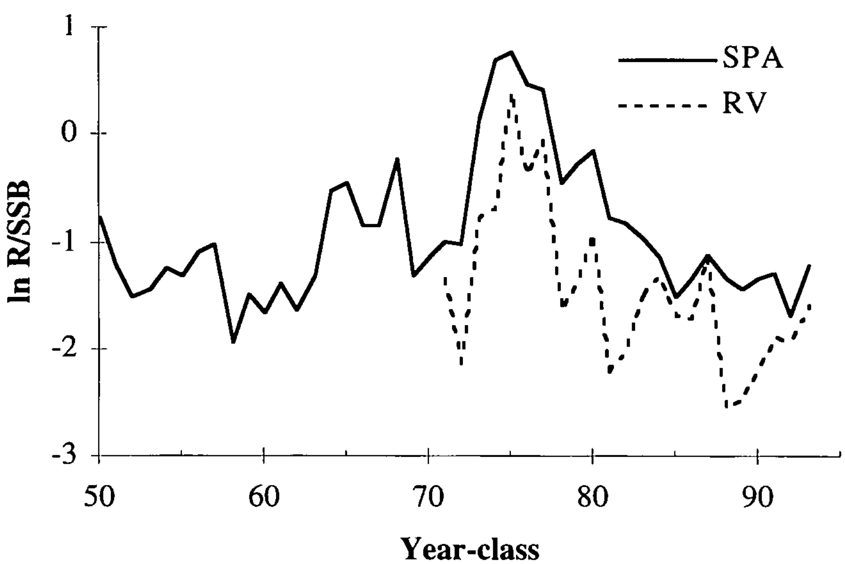

Figure 30: Juvenile survival rates, calculated as the ratio of year-class size (numbers) at age 3 and age 5+ SSB. Estimates from two independent sources are presented, SPA and RV results.

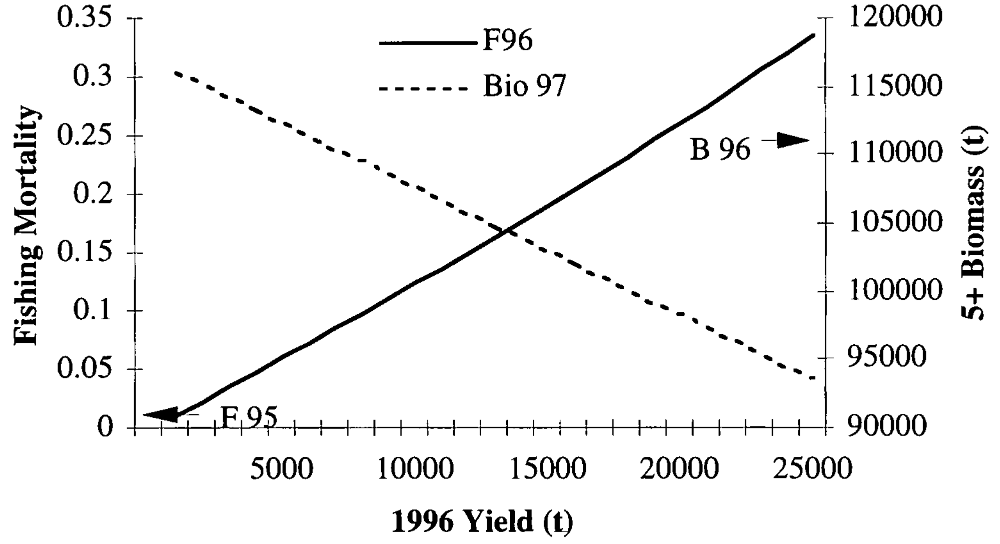

Figure 31: Deterministic catch projections for 1996 for southern Gulf of St. Lawrence cod. The graph presents the 1996 F (solid line) and the 1997 SSB as a function of the yield in 1996. The 1995 F and 1996 SSB are indicated by arrows.

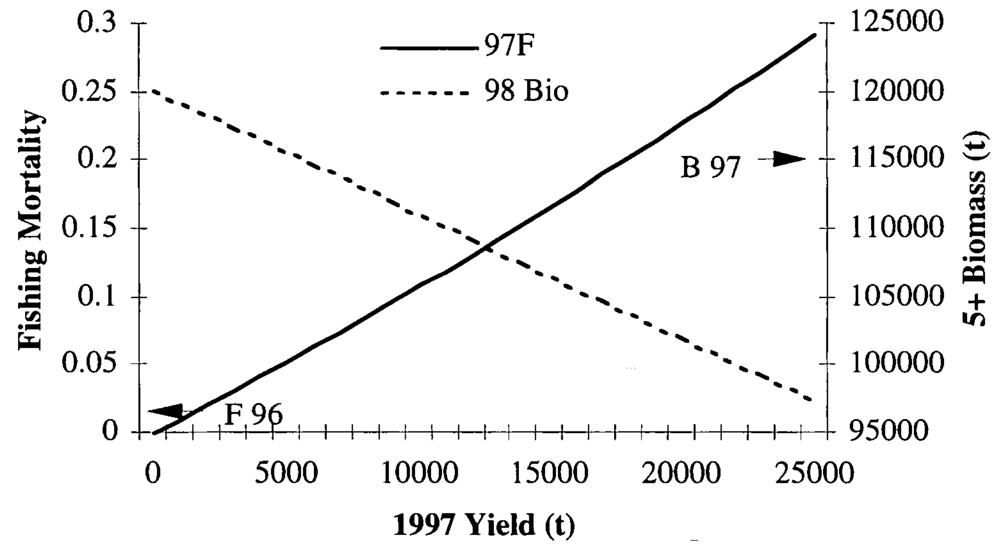

Figure 32: Deterministic catch projections for 1997 for southern Gulf of St. Lawrence cod. The graph presents the 1997 F (solid line) and the 1998 SSB as a function of the yield in 1997. The 1996 F and 1997 SSB are indicated by arrows. The 1996 yield was assumed to be 2,000 t.

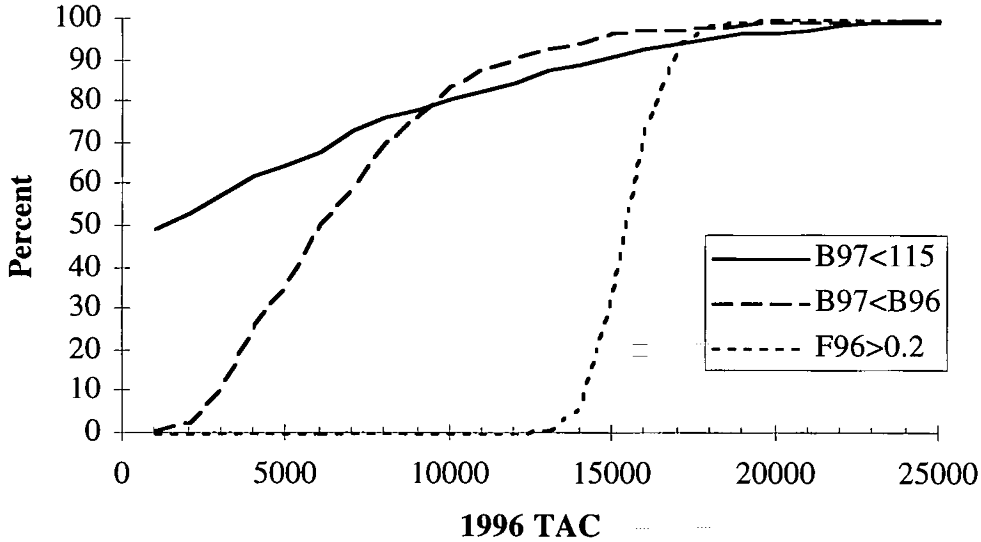

Figure 33: Risk analysis of a one year catch projection for southern Gulf cod. Three probability distributions are shown in relation to the catch in 1996: the probability that the 1997 spawning biomass is greater than 115000t; the probability that the 1997 spawning biomass will be greater than the 1996 level; and the probability that F will exceed 0.2.

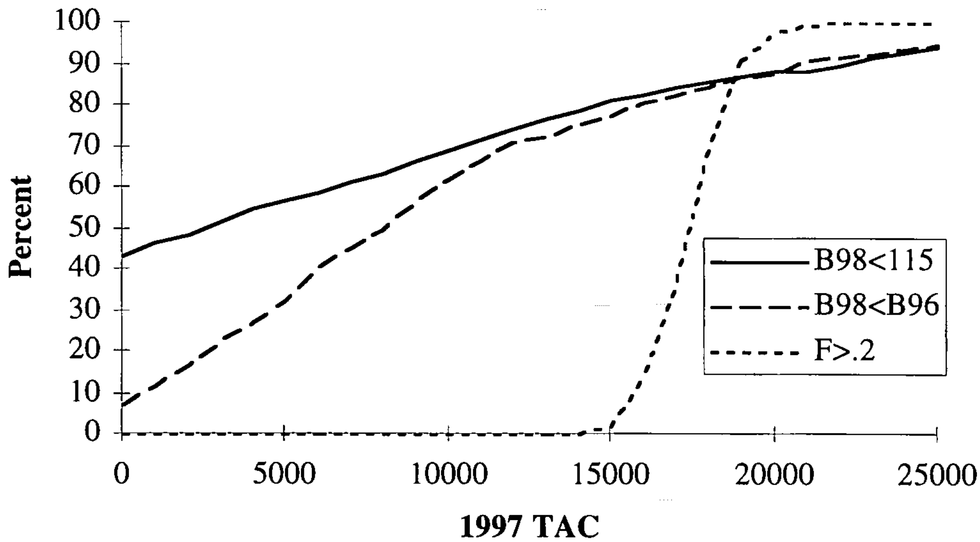

Figure 34: Risk analysis of a two year catch projection for southern Gulf cod. The 1996 catch was held constant at 2,000 t. Three probability distributions are shown in relation to the catch in 1997: the probability that the 1998 spawning biomass is greater than 115000t; the probability that the 1998 spawning biomass will be greater than the 1996 level; and the probability that the 1997 F will exceed 0.2.

Annex 1: Landings at age by gear and time period, 1994.

Age-Key	OTB 1	OTB 2	OTB 3	OTB 4	SNU 5	SNU 6	SNU 7	GNS 8	LLS 9	LHP 10	LRR 11	SENT 12	UNSAM	TOTAL
Age														
3	61	31	2115	15	521	22	187	3020	747	404	3887	13169	3968	28147
4	3188	441	4571	453	1034	572	913	5773	3336	4028	11715	10741	7675	54440
5	4977	1311	7342	1845	2257	2075	3484	6661	8566	12788	24270	9215	13917	98706
6	29259	2287	11513	4552	5025	4637	9778	12964	17808	29311	45681	11348	30227	214390
7	58511	2751	10302	5384	8814	4917	14529	24496	22453	36588	47478	8756	40209	285188
8	17862	1289	4936	2693	6435	2609	7856	33051	11896	18944	22670	2201	21738	154181
9	1629	405	1816	1248	3471	1093	3666	20514	5380	8081	11258	1160	9802	69525
10	128	175	701	593	1691	397	1674	7664	2037	2850	4977	393	3821	27103
11	322	167	463	332	1629	329	1236	4256	1543	2210	3233	778	2708	19208
12	992	59	148	95	384	132	355	1915	624	698	1035		1057	7496
13	1122	40	88	78	195	79	247	359	350	639	609		625	4430
14		2	52	35	102	27	76	457	179	190	249	50	233	1652
15		17			109								21	147
16+		4			41								7	52
Total	118051	8978	44049	17324	31708	16888	44002	121130	74921	116731	177063	57812	136008	964666

Annex 1: Mean weight (kg) at age by gear and time period, 1994.

Age-Key	OTB 1	OTB 2	OTB 3	OTB 4	SNU 5	SNU 6	SNU 7	GNS 8	LLS 9	LHP 10	LRR 11	SENT 12	AVERAGE WEIGHT
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	0.358
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	0.572
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	0.789
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	1.848
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	2.233
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	2.162
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	2.468
12	1.803	1.967	2.470	1.992	3.111	2.721	2.316	2.554	2.516	2.260	2.485		2.400
13	1.684	2.204	1.942	2.026	2.741	2.115	1.889	2.791	2.005	2.061	1.990		2.025
14		5.088	2.042	2.105	3.759	2.226	1.776	2.426	2.145	1.954	2.018	2.425	2.294
15		1.916			2.451								2.379
16+		17.064			13.172								13.518
Average	1.151	1.171	1.044	1.370	1.783	1.395	1.425	2.162	1.406	1.321	1.247	0.758	1.382

Annex 1: Mean length (cm) at age by gear and time period, 1994.

Age-Key	OTB 1	OTB 2	OTB 3	OTB 4	SNU 5	SNU 6	SNU 7	GNS 8	LLS 9	LHP 10	LRR 11	SENT 12	AVERAGE LENGTH
Age													
3	31.00	34.00	34.10	41.67	33.38	41.10	35.58	35.36	37.01	38.31	34.75	33.04	33.94
4	39.53	38.17	38.32	43.26	38.49	42.39	41.08	41.18	40.35	41.60	39.57	37.89	39.55
5	40.80	42.98	42.61	45.61	44.45	44.62	46.51	45.22	44.60	45.00	43.62	42.58	43.88
6	46.38	45.41	46.43	48.05	48.68	47.12	49.95	53.59	48.54	47.98	47.10	46.22	47.82
7	50.36	50.75	51.57	53.01	55.02	53.52	53.62	60.99	54.30	53.09	52.72	50.08	53.18
8	53.39	54.84	54.62	56.35	59.20	58.09	55.09	63.79	57.19	55.55	55.53	53.09	57.59
9	60.38	58.18	55.22	58.21	62.49	59.94	57.50	66.27	58.86	57.13	58.94	53.56	61.14
10	64.00	60.73	56.08	58.10	66.02	59.74	57.04	63.83	60.29	56.33	58.51	52.58	60.47
11	62.19	62.38	56.63	58.54	68.41	63.14	58.99	69.53	59.63	57.65	61.03	57.84	62.97
12	57.63	57.95	63.49	59.87	67.39	65.88	62.15	64.79	64.08	61.99	63.65		63.00
13	54.68	57.76	59.34	60.14	64.25	60.90	58.90	67.00	59.90	60.41	59.82		59.25
14		80.53	60.16	60.80	71.49	62.00	57.51	64.00	61.20	59.29	59.93	64.00	62.26
15		58.88			63.71								63.05
16+		121.00			109.43								110.46
Average	49.42	49.04	47.20	51.91	55.67	51.88	52.88	59.97	52.21	51.42	49.93	42.30	51.51