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Assessment of Cod in the Southern Gulf of St. Lawrence, March 1999

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Abstract

The directed fishery for cod in the southern Gulf of St. Lawrence has been closed since September 1993. In 1998, it remained closed but an allocation of 3,000 t was established for by-catch in other fisheries, sentinel surveys, recreational catch and an index fishery designed to provide information on stock status. Total landings amounted to 2588 t. Population abundance in the September survey remained unchanged. For the first time, sentinel survey indices could be used in the age-structured analysis. An increase in natural mortality (M) in the mid-1980s, reported in the previous assessment, was re-examined but the new analyses supported the view that M had indeed increased around that time. The assessment indicates that population biomass has remained low, close to the lowest seen since 1950. Spawning stock biomass is estimated to be about 89,000 t. Recruitment has been well below the historical average over the last decade but the 1995 and 1996 year-classes are estimated to be more abundant than the ones produced in the early 1990s. Exploitation rates in recent years have been low (2-3%) but the low productivity of the stock and high natural mortality have not led to a recovery. Catch projections, assuming continued high natural mortality (0.4); indicate that the spawning stock biomass may increase by about 5-6% if there is no catch in 1999. Spawning biomass at the beginning of 2000 would remain unchanged with a catch of 6,000 t in 1999. If the 1996 year-class is not as large as estimated then there would be little increase in spawning stock biomass at the level of catches seen in recent years (2600 t). Otherwise, a 10% increase in spawning biomass could be expected by 2001.

Résumé

La pêche dirigée à la morue dans le sud du Golfe du St. Laurent est interdite depuis septembre 1993. La fermeture de cette pêche s'est poursuivie en 1998 mais une allocation de 3,000 t a été permise pour les prises accidentelles dans les autres pêcheries, les relevés sentinelles, les prises récréatives ainsi qu'une pêcherie indicatrice pour fournir des informations additionnelles sur l'état du stock. Les débarquements totaux se chiffraient à 2588 t. L'abondance de la population telle qu'estimée par le relevé scientifique de septembre est demeurée inchangée. Pour la première fois, les indices des relevés sentinelles ont pu être utilisées dans l'analyse séquentielle de la population. L'augmentation de la mortalité naturelle (M) au milieu des années 1980 qui avait été détectée dans l'évaluation précédente, a fait l'objet d'une nouvelle analyse. Cette analyse est arrivée à la même conclusion d'une augmentation de M. L'évaluation indique que la biomasse reproductrice demeure faible, se rapprochant de la valeur la plus faible depuis 1950. La biomasse reproductrice est estimée à 89,000 t. Le recrutement a été bien en deça de la moyenne historique au cours de la dernière décennie mais les classes de 1995 et 1996 sont plus abondantes que celles du début des années 1990. Le taux d'exploitation des dernières années est bas (2 à 3 %) mais la productivité faible du stock et le taux de mortalité naturelle élevé ne favorisent pas le rétablissement. Une projection de captures fondée sur le maintien d'un taux de mortalité naturelle élevé (0.4) indique que la biomasse de reproducteurs augmenterait d'environ 5 à 6% en l'absence de prises en 1999. Si les prises étaient de 6 000 t en 1999, il n'y aurait pas d'augmentation de la biomasse de reproducteurs. Si la classe d'âge de 1996 n'est pas aussi importante que prévue, l'augmentation de la biomasse de reproducteurs serait faible aux niveaux de prises observés ces dernières années (2600 t). Dans le cas contraire, on pourrait compter sur un accroissement de 10 % de la biomasse d'ici 2001.

1. Introduction

The southern Gulf of St. Lawrence cod undergoes a large annual migration. During the summer, the cod are widely distributed in the southern Gulf and feed heavily on a wide variety of fish and invertebrates. The fall migration begins in October with cod first leaving the areas off Gaspé and Chaleur Bay, becoming concentrated off western Cape Breton and then moving into 4Vn (Fig. 1) in mid-November. The stock over-winters in 4Vn and northern 4Vs, along the edge of the Laurentian Channel. The return migration begins in mid-April, although in some years (1991-92) this was delayed by the late break-up of the winter ice. The return to the waters of the southern Gulf of St. Lawrence continues over the months of April and May. Spawning occurs in the Shediac Valley and around the Magdalen Islands from late April to early July.

The management unit for this stock originally included all of 4T and catches in 4Vn during January-April. However, it was recently recognised that a substantial part of the stock migrates into 4Vn in November and that by January significant catches were being made in northern 4Vs. As a result, the management unit and the stock assessment data were modified to include all of 4T, catches in 4Vn during November-April, and some catches in 4Vs in January-April (Sinclair et al. 1994). Recent work to identify the stock origin of over-wintering cod in Cabot Strait (Campana et al. 1999) suggests that there is very little mixing of southern Gulf cod with the northern Gulf stock (3Pn, 4RS). The results were consistent with a migration extending in 4Vs; however, the study was unable to differentiate between 4Vn resident cod and the 4TVn stock.

Southern Gulf of St. Lawrence cod are relatively long lived and may reach ages of 20 or more when mortality is low. They begin to reach commercial size at age 4 and are fully available to the commercial fishery by age 7 to 9. They start to mature sexually at about 35-40 cm, below the regulated commercial size of 43 cm. In the last assessment of this stock (Sinclair et al 1998), the analysis indicated that natural mortality (M) had increased in the mid-1980s. Reasons for this change are not clear.

The stock has been exploited at least since the 16th century. Landings varied between 20,000 - 40,000 t annually between 1917-1940, and then began to increase to a peak of over 100,000 t in 1958 (Fig. 2). The fishery was primarily prosecuted with hook and line until the late 1940s, when a ban on otter trawling was lifted (Chouinard and Fréchet 1994). Landings remained relatively high in the 1960s and early 1970s, in the range of 60,000 t. TAC's were first imposed in 1974, and these became restrictive as the stock declined in the mid-1970s. The stock recovered somewhat and landings returned to the 60,000 t range during the 1980s. During the 1980s, the fixed gear fishery declined drastically and the fishery was mainly prosecuted by mobile gear until it was closed in September 1993, due to low abundance. In 1998, the commercial fishery remained closed; however, a 3,000 t allocation was established to monitor stock through sentinel surveys and an index fishery and to account for by-catches in open groundfish fisheries.

Assessments of this stock have been conducted annually since the mid-1970's using cohort or virtual population analysis. Until the late 1980's, calibration of the population re-constructions was *ad hoc* using indices of abundance from research surveys and commercial catch rate. Since then, the ADAPT framework (Gavaris 1988) has been the main tool used in the calibration of the age-structured population model.

The present document describes the 1998 fishery, the input data and analyses used in the March 1999 assessment of the stock. Stock projections and risk analyses are also included.

2. Description of the 1998 fishery

In 1998, although no commercial fishing of the 4TVn (N-A) cod stock was permitted, an allocation of 3,000 t was allowed for sentinel surveys, an index fishery and to account for by-catches of cod in fisheries directed for other species. Fisheries for American plaice, witch flounder, winter flounder, yellowtail, Atlantic halibut, Greenland halibut and dogfish were permitted in NAFO Division 4T, but these were subject to a number of management measures designed to limit cod by-catch. A recreational fishery using hook and line gear was allowed. The sentinel survey, which is conducted under a scientific protocol designed to obtain additional indices of abundance of the stock, was continued. As opposed to 1997, no experimental fisheries were conducted. In this section, a summary of landings, management measures and input from industry on the status of the southern Gulf of St. Lawrence cod stock in 1998 are provided.

2.1. Landings by gear, area, month, fishery type

Total estimated landings of southern Gulf cod were 2588 tonnes in 1998 (Table 1). This comprised 568 t of cod by-catch from fisheries directed at other species (mostly flatfish), 629 t landed in the sentinel fishery and 1221 t reported from the index fishery (Table 2). The 1998 landings also included over 100 tonnes fished by gillnets on Miscou Bank during a time when the fishery was prohibited in mid-August 1998. An additional 160 t were estimated from the hook and line recreational fishery by DFO Fisheries Management Branch (R. Hébert, Fisheries and Oceans P.O. Box 5030, Moncton, N.B. E1C 9B6; pers. comm.), including 40 t in Québec (Gaspé Peninsula and Magdalen Islands), 50 t in New Brunswick, 38 t in P.E.I. and 32 t from Nova Scotia.

The by-catch, sentinel and index landings are supported by purchase slip data. The catches by the sentinel boats reported in the DFO catch and effort statistics were slightly lower (9.5 tonnes) than the set-by-set observed catches at sea through the observer program. The estimates from the observers were used in the analyses. The recreational fishery estimate is based on few direct observations. This gap should be addressed to obtain a better estimate of removals by this sector in future.

Total landings in 1998 were higher than in the previous three years, but the 1993 to 1998 catches remain the lowest on record (Fig.1). All catches were reported from NAFO Division 4T, except for 30 kg from 4Vn in February and 120 kg taken in 4Vs during February to April. Landings increased over 1997 catches for all gear types except handlines (Table 3). Monthly landings for all gears combined were highest in August and September due to the sentinel and index fisheries. Otter trawls, seines and gillnets experienced largest catches in August, while longline landings peaked in September (Table 2).

2.2. Management measures

In March of 1998, the Fisheries Resource Conservation Council (FRCC) recommended that the southern Gulf cod directed commercial fishery remain closed (Anon. 1998). However, the FRCC recommended that removals of up to 3,000 t be allowed for the purpose of conducting an index fishery, a program to collect additional information on the stock, the sentinel surveys and to cover by-catches in other fisheries. The Minister of Fisheries and Oceans accepted this advice in an announcement made on May 27, 1998.

Prior to the start of the sentinel survey program, it was estimated that about 650 t would be caught in the surveys. The estimate was based on anticipated catch rates and the fishing effort that was planned in the various projects. This amount was deducted from the 3,000 t. The remainder (2350 t) was partitioned according to historical shares for fixed and mobile gears. Each fleet sector sub-divided these amounts for by-catch (891 t) and index fisheries (1459 t).

2.2.1. By-catch fisheries

The management measures regarding the by-catch of cod in other fisheries were similar to those used in previous years with some minor modifications. DFO maintained the by-catch limits of cod in fisheries directed toward winter flounder and witch flounder at 20% per trip and 25% for American plaice. For Unit 1 and 2 redfish, the limits were set at a maximum of 5% by week with a 2% cap over the season.

In by-catch fisheries, the minimum mesh size for winter flounder, witch and American plaice was maintained at those established in previous years and varied between 130 mm and 155 mm depending on the species and the area. Small fish protocols were maintained whereby fishing was closed if the percentage of small fish caught exceeded specific thresholds. In 1998, the minimum fish size for cod was increased from 41 cm in previous years to 43 cm. The target for observer coverage in the open fisheries was set at 10% for mobile gears and 5% for fixed gears. Other minimum fish sizes were as follows:

- 30 cm for American plaice and witch flounder
- 45 cm for white hake
- 25 cm for winter flounder and yellowtail

As in previous years, a fleet sector would be closed for a specific groundfish fishing sub-area if it exceeded its by-catch or small fish protocols. An optional provision was made to close individual vessels if their fishing activities appeared particularly abusive.

2.2.2. Index Fishery

Management for the index fishery included measures to ensure that fishing effort would be distributed throughout the southern Gulf and not concentrated in one area. Therefore, mobile gear fishers were restricted to prescribed areas that were determined prior to the start of the season in consultation with each gear sector representatives. The table below describes the fishing zones (see Fig. 3; Fig. 1 for NAFO Unit areas) that were assigned to each group of fishers.

Area	Groundfish Fishing Sub-area
Gaspé Peninsula	$4T3_{A,B}$
New Brunswick	$4T3_B$, 4T5 – and 4T2 (only at the end of season)
Prince Edward Island	$4T2_B$, 4T1
Nova Scotia	4T1, $4T9_{A,B}$
Magdalen Islands	$4T2_A$, $4T9_B$
Newfoundland	$4T9_{A,B}$

A proposed mobile gear index fishery in 4Vn during the late fall was not allowed to proceed.

For fixed gear, the index fishery allocation was originally set at 600 t but then reduced to 592 t because some of the tonnage was required for by-catch fisheries. The allocation was divided equally between fishers from Québec, New Brunswick, Prince Edward Island and Nova Scotia. For each province, 15 fishers were selected at random from groundfish licensed fishers for each of two-10 day fishing seasons (30 fishers per province). Each fisher was allowed to fish up to 5 t. Dates for this fishery were as follows:

Area	First fishing period	Second fishing period
Gaspé Peninsula	23 Aug – 1 Sept.	2 Sept. – 11 Sept.
New Brunswick	23 Aug – 1 Sept.	2 Sept. – 11 Sept.
Prince Edward Island	3 Sept. – 12 Sept.	15 Sept. – 24 Sept.
Nova Scotia	22 Sept. – 1 Oct.	6 Oct. – 31 Oct.
Magdalen Islands	30 Aug –Sept. 6 (2 fishers) 7 Sept. – 13 Sept. (5 fishers) 14 Sept – 20 Sept. (7 fishers)	21 Sept – 27 Sept. (7 fishers) 28 Sept. – 4 Oct. (5 fishers)

In the cod index fisheries for mobile gears, the regulated minimum mesh size was 145 mm (diamond mesh). For longlines, a number 12 circle hook or equivalent was established as minimum hook size. For gillnets, the regulated minimum mesh size was140 mm. The level of observer coverage was set at a minimum of 20 % and a maximum of 50%. The actual observer coverage in the mobile gear index fishery was 35% (R. Hébert, Fisheries and Oceans P.O. Box 5030, Moncton, N.B. E1C 9B6; pers. comm.). For fixed gear, the level of observer coverage was set at 10%; however, about 4% of the trips were actually covered.

2.2.3. Sentinel surveys and recreational fisheries

As in previous years, observers were deployed on all sentinel survey vessels. Mandatory dockside monitoring was also in effect. The vessels adhered to the protocols established for the work (Chouinard et al. 1999).

The season for the recreational fishery extended from July 1 to September 7, 1998. The daily limit for the recreational fishery was reduced from 10 groundfish, in previous years, to 5 fish per day per person with a maximum of 25 fish per vessel. Atlantic halibut were not allowed to be retained in the recreational fisheries. In addition, the Miscou Bank area (see Fig. 4) was closed to the recreational fishery.

2.3. Input from industry

Prior to 1998, Science Workshops were held in late fall to obtain the views of industry on the status of the stocks. In 1998 and 1999, the views of industry were obtained at meetings held in Mont-Joli (Dec. 16, 1998), Rimouski (Dec. 17, 1998) , Gaspé (Jan. 11, 1999) and at the Gulf Groundfish Advisory Committee meeting in Moncton on January 20-21, 1999. Organisations participating in the sentinel survey programs were asked to submit a report detailing the views of the fishers that participated in the work on the status of the stock. A summary of their views can be found in Chouinard et al. (1999). In addition, a telephone survey of groundfish fishers was conducted to obtain their views on the status of the stocks. These results are reported in the next section.

In general, fishers in the southern Gulf have noted an increase in the size of cod that are being caught. Views on the abundance of the stocks vary according to geographic location. Abundance is still considered to be low in the near-shore waters of the Gaspé and New Brunswick coasts; however, the catches experienced on Miscou Bank by Gaspé fishers were an indication to them that there has been some recovery. The catches in the Shediac Valley and P.E.I. during the index fishery also suggested to some that the stock has increased.

However, comments received during the Gulf Groundfish Advisory Committee meeting indicate that there continues to be concern regarding the state of the stock within the industry. The rapid exit of the population from the southern Gulf is considered by some as a sign that the population continues to be low. Comments were made regarding the size of cod and fishers seemed to be almost unanimous that the abundance of larger fish is higher than it has been at least since the moratorium.

2.4. End-of-season telephone survey

A telephone survey of active fishers in the groundfish fishery in the southern Gulf in 1998 was conducted between Nov. 16 and Dec. 16, 1998 (Hurlbut & Daigle 1999). The primary purpose of the survey was to obtain their views and opinions on groundfish abundance for inclusion in stock assessments. The survey has been conducted since 1995 during late fall-early winter.

Interview subjects were selected from a list of all southern Gulf purchase slips that were received and processed by Nov. 1, 1998. This list identified 434 fishers from New Brunswick, Nova Scotia, Prince Edward Island, Quebec and the Magdalen Islands.

Of these, 192 (44%) were successfully interviewed. Seventy-five of these respondents indicated that they directed for cod to some extent in 1998 (i.e., cod was their first, second or third priority), and of them, 62 said that cod was their first priority. Eighteen of these 62 respondents were participants in the 1998 sentinel fishery and 43 were participants in the index fishery. As well, 14 of the 75 respondents indicated that they fished for cod in the recreational fishery.

The geographical distribution of the 75 respondents who indicated that they fished for cod ‘most of the time’ in 1998 is shown in Fig. 5. The majority (71%) of these respondents fished fixed gears (24 gillnets, 29 longlines, 10 otter trawls, 12 seines) (Fig. 6).

When asked to compare the average size of the cod they caught in 1998 to previous years, the majority of the respondents whose first priority was cod indicated that the cod were larger in 1998 (Fig. 7).

2.4.1. Non-sentinel participants

As in the past, the protocols for the 1998 sentinel fishery in the southern Gulf required the participants to fish specific types and quantities of fishing gear at predetermined locations and times. As a result, the perceptions and opinions of sentinel fishers concerning groundfish abundance may not be comparable to those expressed by fishers that were not participants in the sentinel fishery. Consequently, the opinions of sentinel fishers were excluded from the following discussion of views and opinions on cod abundance in 1998.

The respondents were asked to compare the abundance of their most preferred species (i.e., First Priority) in 1998, with its abundance in three previous time periods (1997, 1993 to 1997, and in all their years fishing commercially for cod).

When asked to relate the abundance of cod in 1998 with its abundance in 1997, more than half of the respondents indicated that the question was not applicable to them (Fig. 8). This result may be a reflection of the large number of respondents (43) that fished for cod in the index fishery in 1998, who would have been prohibited from fishing cod in 1997 because of the moratorium. Of the remaining respondents that identified cod as their first priority, more than half described its abundance as higher or much higher than in 1997, but three fishers (19%) considered it to be lower or much lower. Of the respondents that identified cod as their first priority in 1998, the majority that expressed opinions (11 out of 13) described its abundance as higher or much higher in 1998 than during the period from 1993 to 1997 (Fig. 9). Again, more than half of the respondents indicated that the question was not applicable to them. When asked to compare the abundance of cod in 1998 with its abundance during all the years they fished for this species, the majority of those that offered opinions (58%) regarded the abundance as higher or much higher in 1998 (Fig. 10). However, 28% considered it to be lower or much lower in 1998.

2.4.2. Sentinel participants

Eighteen of the 62 respondents that identified cod as their first priority were participants in the 1998 sentinel fishery. These 18 respondents were asked to compare the abundance of their most preferred species (i.e., first priority) in 1998, with its abundance in three previous time periods (1997, 1993 to 1997, and in all their years fishing commercially for cod).

When asked to relate the abundance of cod in 1998 with its abundance in 1997, a considerable proportion (39%) of the respondents indicated that this question was not applicable to them. The majority of the remaining respondents regarded the abundance as higher in 1998 as in 1997. These responses are generally consistent with those of their counterparts that were not participants in the sentinel fishery, more than half of which described its abundance as higher or much higher than in 1997. There were no obvious trends in the responses of these fishers when they were asked to compare the abundance of cod in 1998 with its abundance during the period from 1993 to 1997. In contrast, most of the respondents that were not participants in the sentinel fishery considered the abundance as higher or much higher in 1998 than during the period from 1993 to 1997. Again, a considerable proportion of the respondents indicated that the question was not applicable to them. Of the respondents that expressed opinions, the majority (11 out of 16) described cod abundance as lower or much lower in 1998 than during all the years they fished for this species (Fig. 11). In contrast, most of the respondents that were not participants in the sentinel fishery described the abundance as higher or much higher in 1998 (Fig. 10).

2.4.3. Other topics

The respondents were asked to categorise the discarding of cod by other fishers in the 1998 fishery. More than half (56%) of the respondents that identified cod as their first priority indicated that they believed there was no discarding of cod in the 1998 fishery (16% described the discarding of cod as low). On the other hand, 16% of the respondents considered that discarding of cod by other fishers was at a high or very high level in 1998.

When asked if they were aware of any unreported catches of cod in 1998 (i.e., through poaching, excessive recreational fishing, black market fishing, or other similar activities), 44% of the respondents that directed for cod indicated they were aware of such activities (7% had no opinion on this issue). The areas with the highest percentage of respondents indicating they were aware of such activities were the Gaspé (69%), the Magdalen Islands (55%) and New Brunswick (47%). The respondents who indicated they were aware of unreported catches of cod in 1998 were also asked to estimate approximately how much cod was landed through these activities in the ports where they landed their catches (i.e., in 100’s or 1,000’s of tonnes). The majority of these respondents (61%) were unable to quantify the amount of cod landed in this manner. Of the respondents that provided estimates in the 1,000’s of tonnes of cod landed through these activities, most (> 80%) were from Gaspé and New Brunswick.

The opinion survey may provide a more objective manner to input fisher information on stock status in the stock assessment process. The opinion surveys has been conducted for a few years and work will be required to develop a time series that could be examined as an index of stock status.

3. Age Determination

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

Date	% agreement	direction of bias	Notes
Reader # 1			
Nov. 3, 1998	91	-	Followed by recalibration
Nov. 6, 1998	86	+	Followed by recalibration
Nov. 9, 1998	92	0	Age reading
Nov. 25, 1998	90	0	Age reading
Jan. 29, 1999	89	0	Age reading
Reader #2			
Nov. 23, 1998	93	0	Age reading
Dec. 1, 1998	93	0	Age reading
Dec. 11, 1998	90	0	Age reading
Jan. 28, 1999	91	0	Age reading

In the previous assessment, comparisons of readings by the 2 age readers revealed a difference in interpretation of otoliths from age 0-2 cod from the September survey. Corrective action was taken in the form of re-calibration of the reader and re-ageing of the otoliths. The reason for the difference in interpretation appears to be related to the method of age determination of these small otoliths. The usual method of embedding otoliths in resin and sectioning with a diamond blade cannot be used because of the small size of the otoliths. Instead, small otoliths are broken and examined under the microscope. The unevenness of the surface of broken otoliths appears to be at the source of the problem.

In 1998, both age readers were asked to read the small otoliths. Comparisons of the age reading between the two readers again showed lower than average agreement (level of agreement of 67%) for these small otoliths. After some re-calibration, the age readers were then asked to review each of the otoliths where the first readings were not in agreement. Only the otoliths that both readers agreed upon were used in the calculation of age composition. This resulted in 20 otoliths out of the 115 examined not being included.

4. Commercial Fisheries Data

4.1. Catch at Age

Calculation of catch at age for southern Gulf of St. Lawrence cod was stratified by gear type and duration of the various fisheries that have taken place since the closure of the fishery. There was an increase in the number of commercial samples taken in 1998 and there were sufficient otoliths for age-keys. In 1996 and 1997, otoliths from the sentinel surveys were used to supplement the age-keys. Fish from the second quarter Gulf and Quebec region observer programs were aged to augment commercial samples for the second quarter catch at age keys. There were insufficient age data from the commercial fisheries for the fourth quarter thus the third and fourth quarters were combined in the keys. Most of the landings in the fourth quarter were from October.

Catch at age was estimated separately for the sentinel surveys because of differences in fishing gear (liners in some cases), season and selected areas. As in 1997, there was insufficient time to conduct age reading of the fourth quarter otoliths in the sentinel surveys. Since most of these landings occurred in early October, the catch at age by gear for the third quarter was prorated to include fourth quarter sentinel landings. The September research vessel survey ages were added to the lined mobile gear catch at age to include the fish at smaller lengths observed in the fourth quarter sentinel length frequencies. Catch at age for the un-sampled catch was calculated by prorating the catch at age by the ratio of un-sampled landings to sampled landings. A summary of the samples and landings for each gear/time sector used in the calculation of the 1998 catch at age is given in Table 4.

The following length (cm)-weight (g) relationship from the 1998 annual September research vessel survey was used to calculate mean weights at age:

$$W=0.005827 * L^{3.1151}$$

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

The total number of aged 3+ fish removed in 1998 was 1,728,000, (Table 8). Details of the updated removals at age for 1997 adjusted to the final landings can be found in Appendix I. The modal age in the 1998 landings was 7 (the 1991 year-class); however, large numbers of ages 6 to 10 were also caught. A comparison of the index boats' catches to those of the unlined sentinel catches indicates the mode occurred at age 6 for the index boats, and at age 7 for the sentinel vessels (Chouinard et al. 1999). The larger mesh size used by most of the sentinel boats would account for this difference. Commercial weights at age have increased moderately since the early 1990s but are still low when compared to the historical time series (Table 9 and Fig. 12). The 1998 commercial weights at age were lower for most ages than in 1997, but remained slightly higher than those of the research vessel survey. Weights at age have been higher since the beginning of the moratorium, a result of the fixed gears contributing to a larger proportion of the landings than pre-1993. Fixed gears tend to catch larger fish at age (Table 6).

4.2. Index fishery

The goal of the index fishery was to provide another index of abundance of the stock that is more consistent with the commercial fishing experience. One of the concerns expressed by industry was that the research survey does not fish in a commercial manner (i.e. seeking concentrations) while the sentinel survey does not cover some potentially important areas. Therefore, the management measures for the index fishery attempted to address many of these concerns. In practical terms, catches were to be distributed in time and space. Although restricted to particular areas (see Section 2.2 on management measures), the participating fishers were free to choose fishing grounds within these broad areas.

Catch rates for the fixed gear index fishery were obtained from logbooks. The information contained in the statistics files is almost exclusively from the Maritime Provinces (N.B., P.E.I. and N.S.). The overall mean catch rate for gillnets was 49.0 kg per net per haul. For longlines the average catch rate was 528 kg/1000 hooks. There was insufficient information from the statistics files during the pre-moratorium period for comparison as these vessels were not previously required to complete logbooks. The 1998 index fishery for fixed gears was relatively restricted in time. During the period of the fishery, catch rates were quite variable for longlines but with no particular trends, however, there is an indication that catch rates for gillnets were lower in August than in September (Fig. 13). Fishing by gillnets took place in the western area of 4T in August.

The distribution of catch and effort for the mobile gears (seines and otter trawls) revealed that although vessels were allowed to fish in fairly broad areas, most of the fishing activity was concentrated off the coast of northern N.B. and the Gaspé Peninsula as well as the area between the Magdalen Islands and Cape Breton (Figs. 14 and 15). Catch rates were generally higher in the area near Miscou Bank for seiners. The large catch rates for otter trawls observed near the tip of Cape Breton were obtained in December, at a time when a large portion of the stock is thought to have migrated to the deeper waters of eastern 4T near the Laurentian Channel and into 4Vn. Except for these catches, and some made along the north coast of the Gaspé Peninsula, all of the catches were made in areas where sentinel surveys are being conducted.

Catch rate analyses using General Linear Models (GLM procedure, SAS Institute Inc. 1990) were conducted for seines and otter trawls separately. Observations of catch and effort were aggregated by vessel (CFV number) and month. Information was for the same vessels fishing during July to December in the period 1990 to 1993. In 1993, the fishery closed on September 1 and fishing activity was reduced over the summer. As a result, 1993 was excluded from the analysis.

The catch per unit of effort was analysed using a multiplicative model to obtain a relative catch rate index. The model was:

$$\ln\ A_{ijk} = \beta_0 + \beta_1 I + \beta_2 J + \beta_3 K + \varepsilon$$

where A_{ijk} = the catch rate for vessel i during year j and month k
I = a matrix of 0 and I indicating vessel
J = a matrix of 0 and I indicating year
K = a matrix of 0 and I indicating month

For the otter trawls, interactions between years and vessels made it impossible to establish an annual catch rate index for the 7 vessels for which information was available.

For the seiners (also 7 vessels), there was a significant year*vessel interaction; however, it was found that this was caused by one vessel that had significantly lower catch rates in 1998 compared to the previous years. All other vessels showed higher catch rates in 1998. When the information for this vessel was removed from the analysis, the interaction term became non-significant (Table 10). The resulting catch rate index suggests that catch rates for the six remaining vessel participating in the 1998 index fishery were about double the catch rates observed in the pre-moratoria period. Taking into account the trend for the vessel removed from the analysis, catch rates in 1998 would be lower but likely above those in the early 1990s.

The comparisons were made recognizing that the mesh size used in the 1998 index fishery was 145 mm diamond compared to the 130 mm used in the earlier period. These results are somewhat consistent with the results of the previous assessment that indicated that spawning biomass was lowest in the early 1990s.

5. Research Data

5.1. September research vessel survey

A stratified random groundfish survey of the southern Gulf of St. Lawrence has been conducted annually in September since 1971. Three survey vessels have been used, the *E. E. Prince* from 1971-1985, the *Lady Hammond* from 1985 - 1991, and the *Alfred Needler* from 1992 to the present. The *E. E. Prince* fished 12-hour days and used a Yankee 36 trawl, while the other two vessels fished 24-hour days and used a Western IIA trawl. Comparative fishing experiments were conducted each time the vessel changed and conversion factors have been applied where necessary (Nielsen 1989, Nielsen 1994, Swain et al. 1995). Catches by the *E. E. Prince* were multiplied by 1.3 to make them comparable with the rest of the time series and there was a depth-dependent correction applied to the results of the *Lady Hammond* missions. In addition, a series of 13 fixed stations were occupied between 1971 and 1987. These have been incorporated into the time series, along with the comparative fishing stations occupied during the 1985 survey (Nielsen 1995). When the survey was conducted aboard the *E.E. Prince*, 61 to 70 stations were occupied each year. Now, with 24-hour fishing operations, between 180 to 230 fishing sets can be made. The original survey design included 24 strata which cover over 95% of the southern Gulf. Three inshore strata were added in 1985 (strata 401, 402, and 403) (Fig. 16) to increase coverage of white hake and inshore flounder habitat. Catches of cod in these strata are small and the results are not included in the abundance index.

In 1998, the groundfish survey in the southern Gulf of St. Lawrence was conducted from September 4-25 on board the research vessel CCGS Alfred Needler (Mission N98-46). During the survey, 217 standard sets (30 minutes at 3.5 knots) were attempted, of which 206 were successful. At 26 locations, fishing sets were done both during the day and the night. These sets were part of a multi-year experiment designed to determine whether daylight affects survey catch rates of American plaice and white hake. For cod, where previous work has shown no significant differences between day and night catches, the repeat day and night sets were averaged and used in the calculation of the index of abundance.

The mean number per tow of all ages (0+) in the 1998 survey was 52.06 fish/tow (Fig.17) and is similar to the 1997 estimate of 52.93 fish/tow reported in Sinclair et al. (1998). Mean numbers per tow at age (Table 11) indicate that the 1995 year-class was the most abundant in the survey. The results suggest that the 1993 and 1994 year-classes (ages 4 and 5) are amongst the lowest seen in the time series of the survey. With the moratorium, the abundance of older fish (10+) has increased over the last few years. The coefficients of variation of the mean numbers per tow for ages 3 to 10 were below 15% (Table 12). The catch rate (Fig. 17) in weight (kg/tow), is also similar to that of 1997 at approximately 44 kg per tow. Differences among recent years are within the range of variation of the surveys and suggest that there has been no significant change in overall stock abundance or biomass since 1992.

The mean weights and lengths at age from research vessel surveys are given in Tables 13 and 14, respectively. Mean weights at age in the survey were generally higher throughout the 1960s and 1970's than in recent years. An analysis of the factors involved in the change in size at age over time suggests that density, size-selectivity and temperature are involved (Rivard 1999).

A comparison of the length frequency distributions (Fig. 18) from the last six years and those in the period of the last recovery (1977-1982) shows that the abundance of incoming year-classes is much smaller than those that promoted the recovery in the late seventies and early eighties. Modes at 22, 34 and around 50 cm seen in 1998 correspond to the modes observed in the 1997 survey at smaller sizes (10, 22 and 49 cm). The first two modes in 1998 likely correspond to the 1996 and 1995 year-classes. These year-classes appear to be somewhat more abundant than the very poor 1994 year-class. It is also noted that the proportion of larger fish (over 60 cm) increased marginally again in 1998.

Since the late 1980's, an increasing proportion of the cod biomass is found in the eastern parts of the southern Gulf (Swain 1996; Swain and Poirier 1997). In 1998, the eastern area (strata 431-439) contributed 45% of the survey biomass (Fig. 19), the highest proportion seen in this area in the time series of the survey. The survey biomass by strata is presented in Table 15.

The geographic distribution of catches indicates that cod were predominantly found in the waters north of PEI and off western Cape Breton in 1998 (Fig. 20). Few cod were caught in Chaleur Bay (strata 418-419), along the Gaspé coast or on Bradelle (stratum 423) and Orphan Banks (northern part of stratum 424). Although some large catches were made near the edge of the Laurentian Channel, sets made in deeper water produced very small catches. When compared to the mid-1980's (Fig. 21 – 1986 presented), the largest change in the distribution has occurred near the Gaspé coast where cod were virtually absent in 1998. An analysis of the spatial distribution of cod in relation to abundance can be found in section 6.1.5.

5.2. Cod condition

5.2.1. Seasonal index

Cod condition in the southern Gulf of St. Lawrence has been monitored on a regular basis since September 1991. Samples were to be collected on a monthly basis; however, since the fishery closed in September 1993, samples have not always been available. Nevertheless, it has been possible to collect sufficient samples to characterise the annual cycle of cod condition.

Each sample of cod consisted of 130 fish (5 fish/cm for fish 35 to 60 cm). For the stock, the fish were collected from the main areas of concentration. Because of the migratory nature of the southern Gulf cod stock, samples were taken in 4Vn during winter, in 4Tfg (western Cape Breton shore) in early spring and late fall, and from 4Tklm (Gaspé coast - eastern N.B.- see Fig. 1) during June to September. The fish were kept on ice and/or temporarily frozen and then dissected in the laboratory where individual body components (liver, stomach, gonads, intestinal track, etc.) were weighed.

For seasonal monitoring, the Fulton's condition factor (K) was used:

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

where W = carcass weight (g) which is defined as the total weight less stomach and gonad,
L = fork length (cm)
α = 100, a scaling factor to control the number of decimals

Dutil et al. (1995) showed that Fulton's condition factor can be dependent on fish size for southern Gulf cod, larger cod (>60 cm) tended to have a higher condition index. Previous analyses indicated that condition of fish in the 40-50 cm range is independent of size and consequently only fish in this length range were used in the calculation of the condition index. This resulted in samples of up to 55 fish uniformly distributed over the length interval. Dutil et al. (1995) suggested that samples of 30 fish are desirable to monitor condition.

During 1998, samples were obtained for the months of July to November from either the sentinel surveys (lined gears) or the September groundfish survey. Laboratory analysis is ongoing but has been completed for samples collected up to September.

A distinct seasonal cycle is evident in the Fulton's condition index (K), being low in the spring, before and during spawning, and reaching a maximum in the late fall (Fig. 22). Generally, the condition of cod in the fall is 25- 30% higher than that in the spring (Schwalme and Chouinard 1999). Condition was lowest in 1992, as well as during the winter and spring of 1997 for the period examined. Condition in 1998 was comparable to 1997 in July but was slightly lower than in previous years in August and September.

5.2.2. Annual Index

Monitoring condition using one annual value can present problems of aliasing (see Dutil et al. 1995) and as such may not be reliable for detecting trends in condition. Despite this potential problem, cod condition has also been calculated on an annual basis from data collected during the annual research vessel for groundfish in the southern Gulf. In this index, round weight for cod 40 to 50 cm are used in the calculations of K using the equation presented previously.

Another measure of annual condition is the predicted weight of 45 cm and 55 cm cod calculated from annual length-weight relationships derived from the research vessel data:

$$W_{45 \text{ or } 55} = a\, L^{b}$$

where $W_{45 \text{ or } 55}$ = predicted weight for a 45 cm or a 55 cm fish
a and b = parameters of the length-weight relationship
L = length of fish (here 45 cm or 55 cm)

All these annual measures of condition suggest relatively similar condition indices during the month of September (Fig. 23). It would appear from this information that cod condition was higher in the early 1970's, declined to lower levels in the late 1970's and early 1980's and is presently at intermediate levels over the time series. As indicated previously, because of potential aliasing problems these results should be viewed with caution.

5.3. Sentinel surveys

Sentinel surveys have been conducted in the southern Gulf of St. Lawrence since 1994. At first, the program consisted of only one project (2 seiners) in northern New Brunswick. Since then, the program was been expanded to the four provinces (Québec, N.B., N.S. and P.E.I.) bordering the NAFO Division 4T. Essentially, the sentinel surveys consist of limited removals from the stock following a scientific protocol established in consultation with the industry. The objective of the program is to provide additional abundance indices for stocks under moratoria such as the southern Gulf of St. Lawrence cod (4T-Vn) and white hake stocks (4T).

In 1998, 11 sentinel survey projects were conducted in the southern Gulf. There were 5 fixed gear projects and 6 mobile gear projects involving a total of 27 and 9 vessels respectively. On each fishing trip, detailed information is collected by fisheries observers on the catch composition, length frequency, as well as material for age determination. The sentinel surveys are also used as a tool to study the distribution, condition and feeding of cod and to collect oceanographic information.

In this assessment, the objective was to include, more formally, indices of abundance from these surveys. Further details of the program as well as a description of the calculation of catch at age and the analyses of catch rates for the various gears can be found in Chouinard et al. (1999).

The abundance indices calculated for the various gear types (Table 16) suggest that there is a gradual increase in the catch rates of older fish in the population (ages 9-11). Recruitment appears to have been particularly poor in 1994.

6. Analysis Methods and Results

6.1. Analysis of RV and Sentinel Survey Data

Traditional analytical stock assessments have used the survey indices to calibrate sequential population analyses (SPA) of commercial catch at age data; essentially, the survey results were given less weight in the assessment than the commercial data. However, in the late 1980s, SPAs were considered problematic due to apparent biasing of the results as shown by retrospective patterns (Sinclair et al. 1991). Possible causes for these patterns are changes in the rate of catch reporting, changes in the survey catchability, and changes in natural mortality. This prompted us to develop analytical methods that could be used on survey results alone, less subject to errors because of incorrect assumptions. The importance of survey data in the assessment has increased since the closure of the commercial fishery and surveys are now the main source of quantitative information on stock abundance. There have been 6 research vessel surveys since the fishery closed in 1993. The RV survey covers over 95% of cod habitat in the area, has relatively low annual CVs and high correlations in year-class estimates among years. Sentinel survey results are also available this year and were added to the analysis. We have focused on five indices: seine lined, seine unlined, otter trawl lined, otter trawl unlined, and longline. The term 'survey ' has been used for both research vessel and sentinel surveys.

6.1.1. Multiplicative Analyses

The research and sentinel surveys catch per unit effort at age data were analysed with a multiplicative model to obtain information on relative year-class abundance and trends in total mortality in the pre-recruit ages. The model was

$$\ln\ A_{ijs} = \beta_0 + \beta_1 I + \beta_2 J + \beta_3 S + \beta_4 S * I + \varepsilon$$

where $Aijs$ = the RV index at age *i*, year-class *j* and survey type *s*
I = a matrix of 0 and 1 indicating age
J = a matrix of 0 and 1 indicating year-class
S = a matrix of 0 and 1 indicating the source of the survey results

The *S*I* interaction term was included to account for differences in recruitment at age to the respective surveys. Survey results for two groups of ages, 2-3 (pre-recruit ages) and 4-6 (recruiting ages) were analysed separately. The analyses did not include one large research vessel survey set in 1995 (set 127) in which about 6600 small cod were taken. Previous analyses indicated that this result was anomalous and produced an unreliable estimate of year-class abundance (Sinclair et al. 1997). The age 2-3 analysis used the research vessel, seine lined and otter trawl lined survey series. The age 4-6 analysis used these same three series plus the seine unlined, otter trawl unlined, and longline series. The main effect vector for year-class 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).

The main effects in the two analyses were statistically significant (Table 17) and the assumption of normal distribution of residuals was not violated.

The trend in relative year-class strength from the age 2-3 and age 4-6 analyses indicates similar patterns in recruitment (Fig. 24). The year-classes in the early 1970s were of low abundance. The estimates then increased to high values in the late-1970s reaching a maximum for the 1980 year-class. The recruitment index (age 2-3) remained high until the 1987 year-class, then declined sharply in 1988 and has remained low. The age 2-3 index in for the 1995 and 1996 year-classes were somewhat higher than others from the 1990s, suggesting a modest increase in recruitment. However, the values are still well below average. The main difference between the two analyses was in the estimates for the 1985-1987 year-classes. The age 2-3 indices suggested these year-classes were above average in abundance, and similar to those from the early 1980s and late 1970s. The age 4-6 indices, however, suggested that these year-classes were about average.

The trend in total mortality between ages 2-3 and 4-6 is similar to that reported last year. The highest values were for the 1985-87 year-classes that likely experienced high levels of discarding in the 2-3 years prior to the fishery closure. The estimates of relative Z for the 1992 and 1994 year-classes are the lowest in the time series (Fig. 25). Other year-classes that would have been protected from fishing by the closure (1988-1991, 1993) have average values of relative total mortality. It is unlikely that this trend in pre-recruit mortality resulted from adverse environmental conditions such as low water temperatures or heavy winter ice, since these conditions persisted for most of the 1990s. Similarly, it is unlikely that seal predation was the cause for this trend given that seal abundance has been estimated to have increased steadily throughout the 1990s (Sinclair et al. 1995).

6.1.2. Direct Estimates of Relative F

Sinclair (1998) described a new method for examining trends in fishing mortality using a relative index obtained from the ratio of fishery catch at age divided by the RV population estimates at age. Provided that the survey index is taken close to when the population is at its average abundance for the year, these relative fishing mortality estimates are not affected by changes in natural mortality. However, the trends can be affected by changes in the rate of catch reporting and changes in survey catchability. The analysis was repeated here with the current data.

The relative fishing mortalities were high in the early 1970s, followed by a decline at the time of extended fisheries jurisdiction in 1977 (Fig. 26). The relative F was stable in most of the 1980s, but increased 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 continued closure, the relative F declined further in 1994 and 1995, and has remained very low.

6.1.3. Total mortality

The closure of the cod fishery in the southern Gulf of St. Lawrence, and the availability of reliable research vessel and sentinel surveys of the stock, have provided a unique opportunity to directly estimate the instantaneous rate of natural mortality (M) of a commercial cod stock (Sinclair 1999). Survey results may be used to estimate the instantaneous rate of total mortality (Z). Annual catches of cod in other fisheries (either commercial fisheries for other species, the cod sentinel survey, experimental or recreational fisheries) have been restricted to low levels since the closure of the commercial cod fishery, compared to annual landings in excess of 40,000 t prior to the closure. This observation, and the pattern of relative F shown above, indicate that F has been negligible and most of the post moratorium Z may be attributed to natural causes (i.e. M).

A modified catch curve analysis was used to estimate total mortality using RV survey results. The model was an analysis of covariance;

$$\ln Aij = \beta_0 + \beta_1 Y + \beta_2 I + \varepsilon$$

where Aij = the stratified mean catch per tow of age i in year j

Y = a matrix of 0 and 1 indicating year-class Y

I = the covariate age

The slope parameter, β_2, is an estimate of total mortality. The inclusion of Y is to account for variation in year-class strengths, and the parameters β_1 are separate intercepts for the year-classes. The trend in Z was estimated from the RV survey using separate analyses of 4-year moving windows. Ages 7 - 11 were initially selected based on examination of residual patterns with respect to age. A convex pattern was observed if younger ages were included, suggesting that not all ages were experiencing the same level of total mortality. This was consistent with the age of full recruitment to the commercial fishery being around age 7. A broader age range (5-11) was included this year for the years following the fishery closure. The time trend in total mortality was not affected by the selected age range (Fig. 27). Within a 4-year window, only year-classes that had 2 or more estimates were included. These analyses are not independent, of course, given that there are 3 years of data overlap between adjacent windows.

The trend in total mortality corresponds to the fishing history of this stock. Total mortality was relatively high in the early 1970s, when was heavily exploited by Canadian and foreign fisheries. With the extension of fisheries jurisdiction in 1977, the rate of fishing declined and this is reflected in total mortality estimates that declined to a minimum of close to 0.25 in the periods 1975-1978 and 1976-1979. Total mortality increased subsequently and varied between 0.6 - 0.8 throughout the mid-1980s. There was then a rapid increase in total mortality as the fishery intensified in the late 1980s and early 1990s. Total mortality then declined sharply when the fishery was closed, however, not to as low a level as in the mid-1970s.

The same analysis of covariance was used for the results of the five sentinel surveys and the results were compared to those from the RV survey for the same years (1995-98). Patterns of selectivity at age varied considerably between the different surveys reflecting the difference in fishing gear. The lined seine survey had a selectivity pattern similar to the RV survey. The otter trawl lined survey also caught relatively young fish. The unlined seine and otter trawl gears caught intermediate aged fish while the longline survey caught the oldest fish. As a result, different age ranges were used in the respective analyses of covariance. The results are summarised in Table 18.

Point estimates of Z varied from 0.33 (unlined otter trawls) and 0.59 (lined seines) and there was considerable overlap in the 95% confidence intervals of the estimates. The overall mean of the five sentinel surveys and the RV survey was 0.46. Allowing for the limited catches of cod since the closure, this indicates that natural mortality has been close to 0.4 during the post-moratorium years. That recent values of total mortality have been higher than those in the mid-1970s indicates that natural mortality may have increased at some point in the 1980s.

6.1.4. Trends in spawning stock biomass and recruitment

Fishery-independent indices of spawning stock biomass and recruitment were obtained from the RV and sentinel survey results. Recruitment estimates were obtained from the back transformed ln estimates from the multiplicative analysis of ages 2 and 3 survey catch rates (section 6.1.1). Spawning stock biomass (Table 19) was estimated from the RV survey estimates of mean weight (kg) per tow at age multiplied by a single maturity ogive obtained from July surveys conducted in 1990-1995. While it is preferable to use annual maturity ogives, these were not available for this assessment. Examination of the maturity determinations from the September surveys revealed difficulties in distinguishing resting spawners from immature fish at that time of year (Trippel et al. 1997). Surveys conducted in July are closer to the spawning period and provide more reliable maturity determinations.

The scatter of spawning biomass and recruitment suggests a weak relationship, albeit with some exceptions (Fig. 28). The 1975 and 1977 year-classes were the second and third largest in the time series, but were produced from relatively low spawning biomass. Similarly, the 1988 and 1989 year-classes were small, but came from relatively large spawning biomass. With the exception of these 4 points, all 9 year-classes produced from a spawning biomass index of 75 kg/tow or greater were larger than all 13 year-classes produced from a lower spawning biomass index.

A Ricker stock-recruitment relationship was fit to these data by regressing ln (R/S), where R are the recruits and S the spawners, on S as suggested by Hilborn and Walters (1992, p. 268-269). The residuals from the fitted line indicated periods of favourable (high residuals, 1968-87 year-classes) and poor (low residuals, 1988-96 year-classes) conditions for juvenile survival and thus recruitment. The year-classes produced in the mid-1970s, which generated the recovery of the stock from a previous period of low abundance, and the 1980 year-class, which maintained the stock through the last decade, had the highest residuals. The year-classes produced in the mid-1980s (1983-87), that should have supported the fishery in the early 1990s when the fishery was closed, had positive residuals. Subsequent year-classes have all had negative residuals. The regression was repeated with an additional term to separate these two time periods, and to account for a change in juvenile survival conditions. This substantially improved the model fit (see summary statistics from fitting a Ricker stock recruitment curve to survey estimates for southern Gulf of St. Lawrence cod - below).

Analysis	N	R^2	Effect	DF	F-ratio	P
Ln(R/S) vs. S, 2 time periods:	26	0.57	S	1	15.15	<.0004
1971-87, 1988-94			Period	1	23.26	<.0001

The resulting two stock/recruitment curves are shown in Fig. 28.

6.1.5. Spatial analysis of the Research Survey Data

A number of studies have reported relationships between abundance and the distribution of marine fishes (see references in Swain 1999a). On the basis of optimal foraging considerations, habitat selection has been predicted to be density-dependent, with selectivity declining as density and competition for resources increase (Fretwell and Lucas 1970). Consequently, as abundance increases, distribution is expected to expand into marginal habitat and geographical range is predicted to increase (MacCall 1990).

The annual groundfish survey of the southern Gulf is conducted during the feeding season when competiton for density-dependent resources (i.e., food) might be expected to occur. Thus, data from this survey provide a rare opportunity for population-level tests for density-dependent habitat selection. Swain and Sinclair (1994) reported that the geographic range of cod in the southern Gulf in September did tend to expand (up to an asymptote) as abundance increased. However, instead of expanding and contracting around a single ‘preferred’ region, cod distribution appeared to shift with changes in abundance, with the highest cod density occurring in different habitats at different population sizes (Swain 1993, Swain and Wade 1993). Cod density tended to be highest in shallow inshore areas when abundance was low and in areas further offshore at intermediate depths (50-120 m) when abundance was high. Swain and Kramer (1995) provided an explanation for these shifts in distribution based on bioenergetic considerations. They suggested that these shifts reflected density-dependent temperature preferences, with cod tending to occupy colder temperatures at higher levels of abundance in order to reduce metabolic costs when rations were low.

Density-independent responses to changing environmental conditions could provide an alternate explanation for these shifts in cod distribution, with cod avoiding intermediate depths in the central Shallows when conditions there are particularly cold. Swain (1999) tested these two hypotheses and concluded that shifts in cod distribution in the southern Gulf appeared to be more closely linked to density-dependent changes in environmental preferences than to responses to changing environmental conditions.

The purpose of this section is to update indices of September cod distribution in the southern Gulf to 1998 and compare recent distributions to those seen since 1971.

6.1.5.1. Methods

6.1.5.1.1. Geographic Range

Following Swain and Sinclair (1994), we used the minimum area containing 95% of cod as an index of geographic range. This index increases as cod distribution spreads out; unlike many indices of geographic range, it does not increase with abundance if density increases uniformly over all areas. To calculate this index, we first calculated catch-weighted cumulative distribution functions (cdf) of cod catch:

$$F(c) = \sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{W_h}{n_h} \frac{Y_{hi}}{\overline{Y}} I \text{ where } I = \begin{cases} 1, \text{if } Y_{hi} \le c \\ 0, \quad \text{otherwise} \end{cases}$$

where n_h is the number of trawl tows in stratum *h*, W_h is the proportion of the survey area covered by stratum *h*, Y_{hi} is the number of cod of a particular age caught in tow *i* in stratum *h*, *Y* bar is the stratified mean catch rate of cod of that age, *L* is the number of strata and *c* is a level of cod catch (number per standard tow). *F(c)* provides an estimate of the proportion of cod that occur at a local density of *c* or less. We evaluated *F* at intervals of 0.1 and calculated the density c_{05} corresponding to *F*=0.05. This is the density at or below which the most sparsely distributed 5% of cod are estimated to occur. We estimated the area containing the most sparsely distributed 5% of cod (including areas where no cod were caught) as follows

$$G(c_{05}) = \sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{A_h}{n_h} I \text{ where } I = \begin{cases} 1 \text{ if } Y_{hi} \le c_{05} \\ 0 \text{ otherwise} \end{cases}$$

where A_h is the area of stratum *h*. Thus, the minimum area containing 95% of cod (D_{95}) is given by

$$D_{95}=A_T-G(c_{05})$$

where A_T is the total survey area (70075 km^2).

6.1.5.1.2. Depth Distribution

We used Poisson regression models to describe cod depth distribution:

$$E[Y_i]=\mu_i=\exp(\beta_0+\beta_1 X_i+\beta_2 X_i^2)$$

$$Var[Y_i]=\phi\mu_I$$

where X_i is the depth of tow *i* and ϕ is a parameter for extra-Poisson variation, expected because fish typically show a contagious rather than a random spatial pattern. We used the percent of the deviance in cod catch rates explained by the quadratic term as an index of cod bathymetric pattern, D_Q. High values of D_Q are associated with a tendency for cod densities to be highest at intermediate depths (ca. 50-120 m), and low values with a tendency for cod densities to be highest in shallow water (younger cod) or unrelated to depth (older cod). See Swain (1993) for details.

6.1.5.1.3. Geographic Distribution

We mapped the distribution of 5-yr old cod in 1998 and in three earlier periods: 1973-1975, a low-abundance period; 1980-1982, a high-abundance period; and 1993-1995, a low-abundance period. In order to display variation in distribution rather than variation in overall abundance, catch rates were adjusted to the same average level (25 fish/tow) in all years (see details in Swain 1996). We mapped log-transformed catch rate $L=\ln(Y+1)$ because spatial continuity was stronger and more easily modelled on the log scale (e.g., Fig. 29). We estimated cod density at each point on a 11.75×9.75 km grid using ordinary point kriging, calculated using the MATLAB program COKRI (Marcotte 1991). Interpolations used the five nearest neighbours. Contours were drawn using Surfer (Golden Software 1991).

6.1.5.2. Results and Discussion

6.1.5.2.1. Geographic Range

Swain and Sinclair (1994) reported that the geographic range (i.e., D_{95}) of southern Gulf cod in September tended to increase with abundance in the 1971-1991 period. During the 1992-1998 period, the geographic range of 4-yr old cod tended to be at relatively low levels, comparable to those seen during the low-abundance period in the mid-1970s (Fig. 30). The geographic range of 6-yr old cod declined steadily from 1992 to 1998, with recent estimates again comparable to those observed in the mid-1970s (Fig. 30). Likewise, geographic range of cod 8-yr and older has contracted from moderate values in 1992-1995 to relatively low values in 1996-1998 (Fig. 30). Thus, in recent years, estimates of cod geographic range in the southern Gulf in September have declined to the low values that appear to be characteristic of a low level of abundance.

6.1.5.2.2. Depth Distribution

In the mid-1970s, when cod abundance was low, cod density tended to be highest in shallow water, whereas in the early to mid 1980s, when abundance was high, density tended to be highest at intermediate depths (Fig. 31). This shift in depth distribution between the 1970s and the 1980s is reflected in the distribution index D_Q (Fig. 32). D_Q was low throughout the mid 1970s and high throughout the early to mid 1980s. Coincident with the decline to low abundance during the late 1980s and early 1990s, D_Q declined to low values in the late 1980s, particularly for young cod. D_Q has remained at low values throughout the 1990s, except for moderately high values for older cod in 1993, 1996 and 1997. In 1998, this index was at a very low level for all ages of cod, reflecting a tendency for catch rates to be highest in shallow water (e.g., Fig. 31). Thus, like geographic range, the depth distribution of cod in September 1998 resembles the pattern that appears to be characteristic of a low level of abundance.

6.1.5.2.3. Geographic Distribution

The distribution of 5-yr old cod in September 1998 is compared with their distribution in three earlier periods in Fig. 33. In the low abundance period of the mid 1970s, cod were most concentrated in nearshore areas in the western half of the southern Gulf, with very low densities in the central shallows and eastern regions of the southern Gulf. Distribution expanded into the central Shallows during the high abundance period in the early 1980s, and the region where cod were most concentrated shifted offshore toward the central Shallows.

During the recent period of low abundance (i.e., 1993-1995, 1998 in the figure), distribution resembled that in the earlier low abundance period in the 1970s in that cod concentration was highest in nearshore areas and very low in the central Shallows. However, a higher proportion of cod occurred in the eastern areas of the southern Gulf in recent years than in the earlier low abundance period. This shift to the east was particularly dramatic in 1998. The proportion of cod that occupied the eastern survey strata in 1998 was higher than in any other year in the 28-yr time series (Fig. 19). The cause of this eastward shift in cod distribution in recent years is unknown. This has also been observed for the other dominant groundfish species in the southern Gulf, American plaice (e.g., Swain and Poirier 1997, their Fig. 5; Chouinard et al. 1998, their Fig. 4).

6.1.6 General Conclusions

In summary, the analyses of the research vessel data on its own indicate the following :

1) The stock is currently of low abundance, biomass and recruitment. The spatial distribution of the stock is consistent with the previous low abundance period in the mid1970s.
2) The recovery of the stock in the late 1970s was driven by a period of very high juvenile survival.
3) Year-classes that should have supported the fishery in the early 1990s, i.e. the 1985-87 year-classes) experienced average to above average juvenile survival. Their low abundance when the fishery was closed in 1993 occurred as a result of high mortality after age 3 likely caused by discarding.
4) Juvenile survival for year-classes produced since 1988 (inclusive) has been below average.

7. Sequential population analysis

7.1. Sequential population analysis

Sequential population analysis (SPA) uses commercial fishery catch at age data to estimate stock size and fishing mortality. Starting parameters, in terms of stock abundance in the final year, are determined by calibration with an independent index of stock size. Several assumptions need to be made: what is the natural mortality rate; what is the functional form of the calibration relationship; how does one estimate the abundance of year-classes at the oldest ages in the analysis? The following section deals with the SPA of southern Gulf cod. All analyses were conducted using the run-time version of ADAPT Version 2.0 (Gavaris 1998).

In the 1998 assessment, only the research vessel index was used in the calibration as index of stock size. In this assessment, the five extra indices available from the sentinel surveys were added to the model and the CPUE index (catch rate at age) used in previous assessment but which ends in 1993 was also included. A trend parameter was estimated for the CPUE index to take into account any increase of fishing efficiency that is common when commercial fishery indices are used in assessments.

7.1.1. Estimating M within ADAPT

In the previous assessment of this stock, several analyses indicated strong evidence of an increase in natural mortality for this stock (Sinclair et al. 1998; Sinclair 1999). The analyses of the abundance indices presented section 6.1.3 tend to confirm this indication. The estimates are calculated for blocks of years and ages. In this assessment, the ADAPT software was also used to estimate M values. As with the analyses of the abundance estimates on their own, it is not possible to estimate individual values of M (year and ages) as the number of parameters becomes too large.

ADAPT was used to estimate M in a relatively small number of year and age blocks in order to investigate possible scenarios of changes in this important parameter. Previous work has indicated that the calibration becomes progressively unstable as M is allowed to vary, and it has never been possible to estimate M annually, let alone by age and year. This is very preliminary work and it is unclear how sensitive the population estimates are to the choice of year and age blocks for M estimation. However, the results are encouraging and further work is warranted.

7.1.1.1 Formulation

The following approach was used. M was fixed at 0.2 for all ages during 1971-81. This corresponds to previously published estimates of M for this and other Northwest Atlantic cod stocks (Dickie 1963; Beverton 1965; Pinhorn 1975; Myers and Doyle 1983) and covers a time period when the SPA calibration was relatively stable. A single M parameter was estimated for all ages during 1982-87. At Regional Advisory Process (RAP) meetings following the fishery closure, the industry indicated that there was considerable discarding of young fish in the years preceding the fishery closure. This is also indicated by trends in pre-recruit mortality estimated using survey data (see section 6.1.1). Consequently, separate M values were estimated for ages 3-6 and 7-15 during the period 1988-93. The same age groups were used in the period 1994-98. We acknowledge that this choice of age and time periods is somewhat arbitrary and, due to time constraints, we have not examined the impact of these choices on the calibration results. This should be the subject of future work. In this analysis the index of recruitment (Fig. 24; ages 2-3) derived from the multiplicative analysis of research and sentinel surveys was included; however later analyses excluded this index because age 3 from the research and lined sentinel surveys which was used in the development of this index was also part of the other indices used for calibration.

The ADAPT formulation was:

Parameters (see description of codes in Table 20)

- Terminal N estimates:
    - $N_{i,1999}$, i=3 to 12 where i represent ages

- Calibration coefficients:
    - RV i=3 to 10
    - CPUE i=5 to 12 (2 parameters per age)
    - L i=3 to 11
    - S1 i=3 to 10
    - S0 i=5 to 11
    - O1 i=3 to 10
    - O0 i=5 to 10

- Natural Mortality
    - M1 1982-87 all ages
    - M2 1988-93 ages 3 to 6
    - M3 1988-93 ages 7 to 15
    - M4 1994-98 ages 3 to 6
    - M5 1994-98 ages 7 to 15

Structure Imposed:

- Error in catch at age assumed negligible
- PR on ages 12 - 15 in 1998 = 1.0
- F on oldest age equal to average (unweighted) at ages 9-10
- M = 0.2 1971-81 for all ages

Input:

- C_{ik} i=3 to 15, k=1971-1998
- RV i=3 to 10, k=1971-1998
- CPUE i=5 to 12, k=1982-93
- Rec Index i=3, k=1971-99

L i=3 to 11, k=1995-98
S1 i=3 to 10, k=1995-98
S0 i=5 to 11, k=1996-98
O1 i=3 to 10, k=1995-98
O0 i=5 to 10, k=1995-98

Objective function:
Minimise sum of squared ln residuals

Summary:
Number of observations: 494

Number of Parameters: 78

7.1.1.2 Parameter Estimates

The M estimates varied widely and the standard errors were relatively small, suggesting that there may have been large changes in M during the time period of the SPA (Table 20). The estimate for the first period was 0.316. This was followed by a high estimate of 0.593 for the younger fish in the 1988-93 period. The estimate for the older fish in the same time period was comparable to that for the first time period. This pattern changed in the last time period where the estimate for the younger fish was lower than that for the older fish. The young fish estimate in 1994-98 was the lowest, 0.149, suggesting that M may be returning to more normal levels.

The estimated catchability coefficients indicated an increasing trend with age. While this might be expected for longline gear, which tends to catch large fish, it is not expected for the RV and lined seine and otter trawl indices. Anticipating that the estimates of M and catchability may be confounded, another calibration was run with the RV index alone and forcing the catchabilities to be constant for ages 5+. There was little difference in the resulting M estimates, as shown below

block	Age Specific k	Constant k
82-87	.32	.29
88-93/3-6	.59	.55
88-93/7-15	.36	.35
94-98/3-6	.15	.13
94-98/7-15	.57	.55

7.1.1.3 Spawning Biomass and Recruitment

Two cycles of spawning stock biomass are apparent in the SPA estimates (Fig. 34). SSB reached a peak of over 400,000 t in the mid-1950s, then declined to a minimum of 75,000 t in the mid-1970s. This was followed by a rapid increase to the mid-1980s, then a decline to a second minimum in 1994. The recruitment estimates were relatively low in the 1950s and 1960s, varying between 50 to 150 million fish at age 3. There was a large increase in the estimates in the 1970s and 1980s, due mainly to the higher estimated M in this period, and reached a maximum of 400 million for the 1980 year-class. There was a large decrease in recruitment estimates for the 1989 year-class and further declines for the 1990-94, reaching a minimum of 30 million. The last 2 year-classes (1995 and 1996) were estimated to have increased in abundance.

The stock/recruitment scatter plot is shown in Fig. 35. Examining residuals from a line fit to ln(R/S) vs. S revealed two distinct periods of production, low production of year-classes from

1950-72 and 1989-96; and high production of year-classes from 1973-88. An additional "period" term was added to the regression, and 2 curves were estimated. These are shown in the graph.

7.1.1.4 Fishing mortality

Fishing mortality estimates from this SPA increased from 1950 to 1975, with a spike in 1959 (Fig. 36). There was a declining trend from 1975 to 1987, then a rapid increase to a very high level in 1992. There was a large decline in 1993, and then very low values in 1994-98.

7.1.2. Final SPA Calibrations

Several calibrations were conducted to determine the sensitivity of the results to the new sentinel indices that are being included in the assessment for the first time. The analyses of the abundance indices on their own (the research vessel survey and sentinel indices) and the exploratory analysis of M conducted with ADAPT both suggested that M has been higher in the recent time period. However, refinement of the estimates would require further analysis. It was decided to use the same assumption for the increase of M that was used in the previous assessment (Sinclair et al. 1998). While it is recognized that the stepped increase may not be the most appropriate, this will require further work. For the new sentinel indices; exploratory analyses were conducted to determine which age should be used. Generally, age groups with very high mean square residuals were excluded.

Several calibrations were conducted. In order to obtain an estimate of the population at age 3 in 1999, age 2 was added to the research vessel and lined sentinel survey indices. Catches at age 2 in the fishery are negligible and were set at 0 for all years. First, a similar calibration to the one conducted in the 1998 assessment was done with the updated catch-at-age and research vessel index (including 1998). M was set at 0.2 from 1971 to 1985 and 0.4 from 1986 thereafter as in Sinclair et al. (1998). In the other analyses, the CPUE index (OTB, 1982-1993) and the 5 sentinel survey (without and then with ages 2-4) were included. The formulation of the model including all indices was as follows:

<u>Parameters</u>

- Terminal N estimates:
  - $N_{i,1999}$, i=3 to 12

- Calibration coefficients:
  - Research Vessel (RV), ages 2 to 10
  - Otter trawl CPUE (CPUE), ages 5 to 12 (2 parameters per age; catchability and trend)
  - Longline sentinel survey (L), ages 3 to 11
  - Seine (lined) sentinel survey (S1), ages 2 to 10
  - Seine (unlined) sentinel survey (S0), ages 5 to 11
  - Otter trawl (lined) sentinel survey (O1), ages 2 to 10
  - Otter trawl (unlined) sentinel survey (O0), ages 5 to 10

<u>Structure Imposed:</u>

- Error in catch at age assumed negligible
- PR on ages 12 - 15 in 1998 = 1.0
- F on oldest age equal to average (un-weighted) at ages 9-10
- Natural Mortality: M=0.2 (1971-1985); M=0.4 (1986-1998)

Input:

C_{ik} i=2 to 15, k=1971-1998 (note: catch at age 2 for all years set at 0)
RV i=2 to 10, k=1971-1998
CPUE i=5 to 12, k=1982-93
L i=3 to 11, k=1995-98
S1 i=2 to 10, k=1995-98
S0 i=5 to 11, k=1996-98
O1 i=2 to 10, k=1995-98
O0 i=5 to 10, k=1995-98

Objective function:

Minimise sum of squared ln residuals

Summary:

Number of observations: 411

Number of Parameters: 75

The parameter variance was estimated analytically. Analyses using all indices produced more precise estimates for population and RV catchability than using only the RV index. The RV residuals showed a similar pattern in calibrations with and without the other indices. The RV catchability estimates were very similar in all four analyses. However, using only the RV index tended to give lower estimates for recruiting age groups in 1999 than when combined with the other indices (Fig. 37). It should be noted that the RV covers the entire area of the southern Gulf while the sentinel surveys are predominantly conducted closer to shore where younger fish are found. All analyses gave similar trends in population abundance. Given the lower variance, the analysis with all indices included was used to describe the stock trajectory.

The diagnostics for the model (Table 21), indicate that the population estimates for younger age – classes were not as well estimated as those for older fish. Despite the difference, coefficients of variation were relatively low compared to similar analyses for other stocks. As well, the estimated bias was small. Examination of the correlation matrix did not indicate any high values that would render the parameter estimates suspect. The residual plots for all indices (Fig. 38 to 40) do not exhibit strong time trends and few outliers are apparent.

8. Assessment Results

The beginning of the year population abundance and biomass (corrected for the estimated bias) from the calibrated SPA are shown in Tables 22 and 23. Fishing mortality declined sharply with the closure of the fishery in 1993 and has been below 0.05 in recent years (Table 24).

8.1. Trends in Population Abundance and Recruitment

The long-term view of the resource is obtained by extending the calibrated SPA to 1950, using the catch at age described in Maguire et al. (1983) and assuming a natural mortality of 0.2. Population abundance (Fig. 41) declined from the mid-1950s to the mid-1970s. Following strong recruitment in the late seventies and early eighties, population abundance increased to the highest levels but then declined rapidly due to the estimated high levels of both natural and fishing mortality and the lower recruitment.

Recruitment (Fig. 41) has declined almost steadily since the mid-1980s but two recent year-classes (1995 and particularly the 1996 year-class) are estimated to be higher than the ones produced in the period 1992-1994. The 1994 year-class appears to be the lowest ever observed for the stock. Despite the increase, the 1995 year-class is below the long–term average values while the 1996 year-class is estimated to be of average abundance. This year-class will start contributing significantly to the spawning stock biomass in 2001.

8.2. Spawning, Population Biomass and Exploitation Rate

Spawning and population biomass were at their highest levels in the mid-1950s but declined progressively to low values in the mid-1970s due to the high exploitation rates which reduced population abundance (Fig. 41). With the strong recruitment observed in the late 1970s and early 1980s, population biomass increased. Because of the decline in growth rate, the increase in biomass was not as strong as could have been expected. Biomass then declined rapidly to the early 1990s. With the closure of the fishery in 1993, the decline in biomass was arrested. Despite this measure, both spawning and population biomass have only increased marginally since 1993, because of low recruitment and high natural mortality. Both of these factors suggest that the productivity of the resource is currently low.

The exploitation rate increased steadily from the early 1950s to the mid-1970s, with the exception of a high value in 1959. There was a decrease in 1977 and 1978 with the extension of fisheries jurisdiction. The exploitation rate increased again and averaged approximately 40% up to 1988. The exploitation rate then increased sharply and reached 60% in 1992. Fishing effort was reduced markedly in 1993 with the closure of the fishery; since then, exploitation rates have ranged between two and three percent (Fig 41).

8.3. Stock and Recruit

A plot of spawning biomass and recruitment indicates that more recruits were produced per unit of spawning biomass in the 1970s and early 1980s. (Fig. 42) The low spawning biomass in the mid-1990s also coincides with the lowest production of recruits.

9. Management Alternatives

9.1. Yield projections

Deterministic catch projections were conducted using the bias-corrected point estimates of population abundance at the beginning of 1999 and mean weights and partial recruitment calculated for the period 1996 to 1998. Given the high estimates of natural mortality in recent years and the uncertainty as to whether it is declining or not (see section 7.1.1), a coefficient of 0.4 was used in the projections. Input parameters are documented in Table 25. Projections were conducted for catch levels in 1999 ranging from 0 to 20,000 t.

The results of the projection indicate that the spawning biomass is expected to increase by about 5% to 6% if there is no catch in 1999. A catch of 6,000 t in 1999 would result in no increase in spawning biomass (Fig. 43). Under either scenario, the spawning biomass would remain low and well below the average observed over the period 1950-1999.

9.2. Risk Analysis

Uncertainties regarding stock size were used in conducting risk analyses to determine the probability of various stock levels not being attained given specific catch levels in 1999. The analyses used the bootstrap procedure contained within the ADAPT software. One thousand bootstraps of population estimates at the beginning of 1999 were obtained and used for the population projections. The range of catch considered for 1999 was 0 to 25,000 t at intervals of 1000 t. Input parameters used for weight at age, partial recruitment and M were the same as in the deterministic projections.

As such, the risk analyses include uncertainties of the population estimates but not those associated with natural mortality, weight at age and partial recruitment. However, they do provide some guidelines for decision making.

The risk analyses considered were: a) the probability that the 2000 spawning biomass would be less than the 1999 biomass, b) the probability that the spawning biomass would increase by <u>less</u> than 5% from 1999 to 2000, and c) the probability that the spawning biomass would increase by <u>less</u> than 10% from 1999 to 2000.

The risk analyses highlight the current low productivity of the stock. Results indicated that there is a 90% probability that spawning biomass would not increase by 10% in 1999 with no catch (Fig. 44). The chance that the spawning biomass would decline if landings in 1999 were the same as in 1998 (2588 t) is about 13%.

10. Ecosystem considerations

10.1. Information on seals in the southern Gulf

Over the last 10 years, the progressive increase of seal populations and the low abundance of groundfish populations, particularly Atlantic cod, have raised concerns of the impact of seal predation on these populations. For the southern Gulf of St. Lawrence cod population, a summary of the available information is presented in Hammill et al. (1999). Compared to other cod stocks currently under moratoria (2J3KL, 3Pn 4RS, 4VsW), there is a paucity of information on the consumption of cod by seals in this area, such that the impact cannot be quantified. Based on this limited information and the geographic location of the more abundant harp and grey seal populations, it would appear that the consumption by harp seals in the southern Gulf is lower than in the northern Gulf and the East Coast of Newfoundland. The current estimate of cod consumption by grey seal in the southern Gulf is estimated at between 5,000 and 13,000 t. This is lower than estimates in the northern Gulf of St. Lawrence or the eastern Scotian Shelf. Although no direct estimates of seal consumption of cod were included in this assessment, their impact on the population is accounted by the change in natural mortality that would include all sources of mortality other than fishing.

10.2. The Northwest Atlantic cod outburst of the 1970s

Spawning stock biomasses of all the northern stocks of cod in the Northwest Atlantic (i.e., 2J+3KL, 3NO, 3Ps, 3Pn4RS, 4TVn, 4VsW) had fallen to low levels by the mid1970s (e.g. Sinclair 1996). However, in contrast to the very slow recovery from the recent collapses of these stocks, recovery from these earlier collapses was rapid. This rapid recovery was fuelled by good recruitment produced by low spawning stock biomass. An index of juvenile or pre-recruit survival can be calculated by dividing the number of recruits by the spawning stock biomass that produced them. This index suggests that pre-recruit survival was remarkable in the mid-1970s (Chouinard and Fréchet 1994). Hypotheses for the cause of high pre-recruit survival of southern Gulf cod in the 1970s have been explored (see Swain 1999b). They examined three types of explanatory variables: 1) climatic forcing (e.g., indices of air temperature, freshwater discharge, timing of ice-out); 2) spawning stock characteristics (e.g., condition and size of spawners); and 3) herring and mackerel biomass (predators or competitors of cod eggs and larvae). The strongest support was for the hypothesis that unusually high cod pre-recruit survival in the 1970s was related to the low abundance of herring and mackerel in that period. For example, variation in herring biomass accounted for 71% of the apparent variation in pre-recruit survival (R=0.842). A similar coincidence between collapses of herring and mackerel stocks and improved gadoid recruitment has been noted for the North Sea (the gadoid outburst; e.g., Daan et al. 1994).

10.3. Environmental influences

Preliminary data on bottom temperature from the 1998 groundfish survey were mapped using ordinary point kriging. Bottom temperatures were coldest over the central Magdalen Shallows. Bottom temperature increased shoreward as depth decreased and along the Laurentian Channel as depth increased. The area of the Shallows covered by cold bottom temperatures (below 0^{o} C or below 1^{o} C) remained large as in previous years (Chouinard et al; 1998). However, the area of the southern Gulf bottom temperature below -0.5^{o}C was below the very high values seen in 1993-1995.

11. Acknowledgements

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Table 1: Landings (t) of southern Gulf of St. Lawrence cod, 1965-98, 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	4121	1161	55		5337	5282	13000
94	1198	139	1		1338	1337	
95	1032		4		1036		
96	1140		2		1142		
97	1725	0	1		1726		
98	2588	0		0	2588		

Table 2: Landings (t) by month, gear and fishery type for southern Gulf of St. Lawrence cod in 1998. (OTB = otter trawls, SNU =seines, GNS = gillnets, LLS = longlines)

Gear	Fishery	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL
OTB	By-Catch	0.0	0.0	0.1	5.2	13.6	10.4	6.6	8.1	3.5	0.0		47.6
	Sentinel						8.4	17.1	16.9	27.1	0.0	0.0	69.4
	Index						0.1	172.1	170.4	144.7	57.9	44.7	589.8
	All	0.0	0.0	0.1	5.2	13.6	18.9	195.7	195.3	175.2	57.9	44.7	706.8
SNU	By-Catch			0.1	29.5	29.6	1.0	10.0	25.5	24.2			119.8
	Sentinel						136.5	149.2	39.3	66.7	0.0		391.7
	Index						52.1	114.7	39.3	86.3	19.6		312.0
	All			0.1	29.5	29.6	189.6	273.8	104.1	177.2	19.6		823.5
GNS	By-Catch				2.6	100.4	9.4	119.6	29.2	1.6	0.0		262.9
	Sentinel						9.8	21.9	19.4	3.5	0.0		54.6
	Index						0.9	41.5	121.4	19.8			183.7
	All				2.6	100.4	20.1	183.0	170.1	25.0	0.0		501.2
LLS	By-Catch			4.6	70.3	27.1	1.2	21.8	12.4	0.3			137.6
	Sentinel						10.6	40.4	58.2	3.7			112.9
	Index						0.4	16.1	106.3	12.5			135.3
	All			4.6	70.3	27.1	12.3	78.3	176.8	16.4			385.9
TOTAL		0.0	0.0	4.8	107.6	170.7	241.0	730.9	646.3	393.8	77.5	44.7	2417.3
Recreational + Other					0.9	3.0	2.3	4.1	0.5	0.1	all year =	160.0	170.7

Total 4T-Vn(N-A)	**2588.1**
Total By-catch	567.9
Total Sentinel	628.6
Total Index	1220.8

Table 3: Landings (t) by gear of the southern Gulf of St. Lawrence cod stock, 1965-98.

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	37923	1765	6141	1352	1292	2106	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	2143	328	1313	842	705	6	5337
1994	213	412	302	103	153	155	1338
1995	110	379	101	78	101	267	1036
1996	269	398	134	127	214		1142
1997	337	599	280	247	195	68	1726
1998	707	823	501	386	167*	4	2588

*Includes 160 tonnes from the recreational fishery

Table 4: Age-length keys used in the calculation of the 1998 catch at age for southern Gulf of St. Lawrence cod.

KEY	FISHERY	SAMPLES	SAMPLE SIZE	LANDINGS (t)
1	OTB APR-JUN	APR-JUN OTB LENGTHS	334	18.830
		APR-JUN OTB & SNU AGES	928	
2	OTB JUL-DEC	JUL-DEC OTB LENGTHS	1276	618.401
		JUL-DEC OTB & SNU AGES	477	
3	SNU APR-JUN	APR-JUN SNU LENGTHS	754	59.170
		APR-JUN OTB & SNU AGES	928	
4	SNU JUL-DEC	JUL-DEC SNU LENGTHS	2412	372.636
		JUL-DEC OTB & SNU AGES	477	
5	GNS APR-JUN	APR-JUNE GNS LENGTHS	518	102.990
		APR-JUNE GNS & LLS AGES	795	
6	GNS JUL-DEC	JUL-DEC GNS LENGTHS	1196	343.608
		JUL-DEC GNS & LLS AGES	437	
7	LLS APR-JUN	APR-JUNE LLS LENGTHS	1534	102.047
		APR-SEPT LLS & GNSAGES	795	
8	LLS JUL-DEC	JUL-DEC LLS LENGTHS	1263	177.939
	LHP APR-DEC	JUL-DEC GNS & LLS AGES	437	
9	MOBILE SENTINEL JUL-SEP	JUL-DEC OTB & SNU SENTINEL LENGTHS	117146	461.106
		JUL-SEP OTB & SNU SENTINEL & RV AGES	3605	
10	FIXED SENTINEL JUL-SEP	JUL-DEC GNS & LLS SENTINEL LENGTHS	64553	167.531
		JUL-SEP GNS & LLS SENTINEL AGES	745	
	UNSAMPLED			163.800
	TOTAL LANDINGS			2588.058

Table 5: Landings (numbers) at age by gear and time period, 1998. The age-key numbers correspond with Table 4.

KEY	1	2	3	4	5	6	7	8	9	10	11	
GEAR	OTB	OTB	SNU	SNU	GNS	GNS	LLS	LLS+LHP	Mobile	Fixed	Unsamp.	TOTAL
QUARTER	2	3-4	2	3-4	2	3-4	2	3-4,2-4				
Age												
0									54		4	58
1									7267		491	7758
2									37814		2555	40369
3		444		511	49	15	36	837	65105	573	4565	72134
4	36	6897	23	3164	76	233	79	8150	57102	2154	5264	83177
5	1083	70874	1186	39559	554	2485	1132	10763	64435	6224	13398	211693
6	1848	112038	1931	58364	1609	12159	2857	16376	84340	12592	20548	324660
7	1862	99341	2556	57031	5395	28517	6027	14830	77039	13910	20710	327218
8	1751	63108	3608	37753	7089	34054	7416	16999	38904	12970	15111	238761
9	1413	55690	3996	32196	7186	25452	6948	12201	29222	11088	12526	197917
10	1280	36167	4292	21754	7999	27231	8171	15789	24717	12227	10785	170411
11	546	10956	2030	8140	5204	11815	4882	5109	10085	7325	4466	70556
12	250	4486	896	3093	1665	3169	1644	1641	2482	2679	1487	23492
13	25	179	85	88	596	2370	574	901	296	1055	417	6586
14	24	179	97	186	43		40		125	291	67	1051
15	8		12	108					78		14	220
16+					68		44			26	9	147
Total 3+	10124	460360	20711	261946	37532	147499	39849	103595	453927	83113	109368	1728024
All	10124	460360	20711	261946	37532.1	147499	39848.8	103595	499062	83113	112417	1776208

Table 6: Mean weight (kg) at age by gear and time period, 1998. The age-key numbers correspond with Table 4.

KEY	1	2	3	4	5	6	7	8	9	10	
GEAR	OTB	OTB	SNU	SNU	GNS	GNS	LLS	LLS+LHP	Mobile	Fixed	AVERAGE
QUARTER	2	3-4	2	3-4	2	3-4	2	3-4,2-4			
Age											
0									0.017		0.017
1									0.048		0.048
2									0.142		0.142
3		0.714		0.600	0.768	0.616	0.714	0.636	0.278	0.475	0.290
4	0.674	0.663	0.699	0.682	0.635	0.808	0.575	0.583	0.453	0.744	0.504
5	0.987	1.021	1.004	1.035	1.117	1.359	1.114	0.953	0.808	1.077	0.957
6	1.128	1.177	1.190	1.193	1.693	1.937	1.413	1.259	1.031	1.573	1.195
7	1.541	1.348	1.798	1.391	2.133	2.367	1.935	1.961	1.300	1.860	1.522
8	1.746	1.507	2.422	1.557	2.292	2.267	2.157	1.927	1.378	2.056	1.735
9	2.316	1.584	3.281	1.681	2.874	2.518	2.681	2.251	1.624	2.199	1.949
10	2.711	1.674	3.760	1.890	2.877	2.334	2.819	2.162	1.812	2.429	2.127
11	3.130	1.761	4.158	2.036	3.433	2.418	3.645	2.472	1.896	2.796	2.458
12	4.210	2.462	4.265	2.527	4.606	3.073	4.317	2.403	2.349	2.821	2.980
13	4.187	3.558	4.037	3.558	3.523	2.473	3.602	1.989	3.203	3.308	2.862
14	3.190	3.558	4.180	4.826	5.931		6.095		2.013	3.009	3.696
15	5.967		5.967	5.967					0.858		4.036
16+					3.714		3.714			4.746	3.910
3+	1.860	1.343	2.857	1.423	2.744	2.330	2.561	1.718	1.003	2.016	1.494
All	1.860	1.343	2.857	1.423	2.744	2.330	2.561	1.718	0.924	2.016	1.457

Table 7 :   Mean length (cm) at age by gear and time period, 1998. The age-key numbers correspond with Table 4.

KEY	1	2	3	4	5	6	7	8	9	10	
GEAR	OTB	OTB	SNU	SNU	GNS	GNS	LLS	LLS+LHP	Mobile	Fixed	AVERAGE
QUARTER	2	3-4	2	3-4	2	3-4	2	3-4,2-4			
Age											
0									12.76		12.76
1									17.56		17.56
2									25.32		25.32
3		43.00		40.22	43.92	41.00	42.80	41.41	31.12	37.48	31.47
4	42.20	41.88	42.70	41.99	41.36	43.96	39.97	40.08	36.61	42.79	37.86
5	47.38	47.79	47.65	48.06	49.19	52.59	49.29	46.63	44.35	48.68	46.76
6	49.40	50.00	50.17	50.24	55.84	58.60	52.75	50.74	47.94	54.72	50.11
7	54.34	52.31	57.03	52.73	60.35	62.71	58.34	58.37	51.64	57.85	54.04
8	56.46	54.22	62.31	54.65	61.74	61.86	60.40	58.17	52.58	59.67	56.38
9	61.04	54.98	68.47	55.82	65.70	63.72	64.19	60.89	54.98	60.66	58.15
10	63.90	56.15	71.55	57.88	65.66	62.02	64.92	59.86	56.45	62.67	59.70
11	66.63	57.04	73.83	59.33	69.58	62.94	70.57	62.75	57.74	65.47	62.44
12	72.88	63.57	74.46	63.92	75.95	67.44	74.50	61.80	61.62	65.92	66.41
13	74.92	72.00	74.45	72.00	70.49	63.85	71.00	59.09	66.78	69.41	66.09
14	66.44	72.00	73.83	78.78	84.82		85.57		62.16	67.81	71.94
15	85.00		85.00	85.00					66.87		78.14
16+					73.00		73.00			79.00	74.14
3+	56.38	52.01	64.54	52.77	64.53	62.16	62.77	55.14	45.85	58.65	52.61
All	56.38	52.01	64.54	52.77	64.53	62.16	62.77	55.14	43.88	58.65	51.84

Table 8: Landings at age ('000) of southern Gulf of St. Lawrence cod, 1971-1998. 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 3+
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	262	904	1174	946	499	223	135	74	36	31	7	9	2	4353
1994	26	54	98	211	281	156	71	28	19	8	4	2	0	0	957
1995	69	133	145	130	223	134	60	24	13	5	2	1	0	0	939
1996	39	84	134	142	124	174	89	34	11	7	3	1	0	0	842
1997	27	53	120	182	174	180	208	109	38	10	3	2	1	0	1107
1998	72	83	212	325	327	239	198	170	71	23	7	1	0	0	1728

Table 9: Average weights at age (kg) for ages 3 - 16+ of removals for the southern Gulf of St. Lawrence cod stock, 1971-1998.

AGE	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Ave 3+.
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	1.81	1.93	2.21	2.29	2.09	2.04	3.00	5.84	13.18	1.23
1994	0.35	0.56	0.79	1.04	1.46	1.87	2.26	2.18	2.52	2.41	2.03	2.29	2.38	13.53	1.40
1995	0.25	0.49	0.67	0.90	1.17	1.49	2.11	2.52	2.98	3.39	4.87	4.93	4.19	10.16	1.08
1996	0.36	0.47	0.81	0.99	1.37	1.68	2.07	2.64	3.29	2.88	3.59	4.82	6.03	5.40	1.32
1997	0.24	0.56	0.80	1.15	1.42	1.85	2.03	2.28	2.56	2.89	2.77	3.36	2.21	4.67	1.57
1998	0.29	0.50	0.96	1.20	1.52	1.74	1.95	2.13	2.46	2.98	2.86	3.70	4.04	3.91	1.49

Table 10: Results from the multiplicative analysis of catch rates for seiners participating in the 1998 index fishery.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	9	90 91 92 98
MONTH	5	7 8 9 10 11
CFV	6	5573 5664 5712 17810 150783 151651

Number of observations in data set = 56
General Linear Models Procedure

Dependent Variable: CAT_EFF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	22.72526186	1.89377182	8.23	0.0001
Error	43	9.89337671	0.23007853		
Corrected Total	55	32.61863857			

R-Square	C.V.	Root MSE	CAT_EFF Mean
0.696696	-31.43238	0.4796650	-1.5260220

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	3	7.98992596	2.66330865	11.58	0.0001
MONTH	4	9.25528936	2.31382234	10.06	0.0001
CFV	5	5.48004654	1.09600931	4.76	0.0015

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	3	8.91958166	2.97319389	12.92	0.0001
MONTH	4	9.85998098	2.46499525	10.71	0.0001
CFV	5	5.48004654	1.09600931	4.76	0.0015

Least Squares Means

CAT_EFF T for H0: LSMEAN(i)=LSMEAN(j) / Pr > |T|

YEAR	LSMEAN	i/j	1	2	3	4
90	-1.46420959	1	.	1.774068 0.0831	0.75596 0.4538	-2.21685 0.0320
91	-1.94721408	2	-1.77407 0.0831	.	-1.68963 0.0983	-6.16713 0.0001
92	-1.67252990	3	-0.75596 0.4538	1.68963 0.0983	.	-4.40585 0.0001
98	-0.84860535	4	2.216847 0.0320	6.167127 0.0001	4.405849 0.0001	.

Table 11: Mean numbers per tow at age of southern Gulf of St. Lawrence cod from the annual research vessel surveys, 1971-1998. Line 1995a contains set 127, a very large set where approximately 6600 age 1-3 cod were caught. This set is considered anomalous and has not been included in the index (see Sinclair et al. 1997)

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	38.34	20.78
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	30.26	26.55	19.01	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	4.74	38.42	23.22	27.50	31.90	50.82	26.51	12.83	4.05	0.47	0.20	0.13	0.07	0.02		0.03	221.25	177.75	127.03
1983	0.01	7.62	24.76	53.29	48.05	26.14	18.58	16.02	10.65	5.03	3.28	0.82	0.16	0.43	0.05	0.07		214.96	182.57	81.23
1984		1.91	11.39	16.73	37.11	49.22	17.56	9.89	10.34	4.70	2.09	0.79	0.07	0.04	0.07	0.02	0.02	161.95	148.65	94.81
1985	4.31	9.73	15.60	38.91	41.96	67.95	70.28	15.59	6.49	4.46	2.06	1.52	0.39	0.17			0.07	279.49	249.85	168.98
1986	2.06	7.11	24.72	35.35	36.85	37.13	44.32	32.04	9.52	2.01	2.76	1.09	0.77	0.21	0.13		0.05	236.12	202.23	130.03
1987	0.43	0.84	12.75	25.03	23.10	31.71	23.94	31.04	11.11	2.49	1.76	0.66	0.53	0.23	0.11	0.03	0.02	165.78	151.76	103.63
1988	1.70	3.89	19.05	70.02	64.56	51.26	35.85	19.35	20.93	12.17	2.38	0.54	0.32	0.27	0.10	0.11		302.50	277.86	143.28
1989	0.28	12.78	27.01	34.63	32.49	29.46	30.93	16.98	10.84	10.62	6.99	1.33	0.43	0.23	0.18	0.05	0.12	215.35	175.27	108.16
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	1.47	2.74	7.70	15.89	33.24	26.37	10.18	5.85	3.97	1.66	1.05	1.08	0.63	0.08	0.02	0.01	0.01	111.95	100.05	50.91
1992	0.61	1.92	4.69	9.81	13.78	12.24	6.58	2.55	1.20	0.75	0.32	0.20	0.10	0.06	0.01		0.01	54.83	47.61	24.02
1993	0.66	0.60	6.51	9.17	14.01	16.45	10.80	4.94	1.61	0.65	0.37	0.11	0.05	0.12	0.02	0.02	0.01	66.09	58.31	35.14
1994	1.25	0.66	1.79	7.61	9.07	9.73	12.03	7.76	2.79	1.12	0.41	0.30	0.08	0.04	0.02		0.01	54.67	50.97	34.29
1995	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		65.84	52.29	36.21
1995a	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
1996	0.78	2.73	2.20	7.20	12.49	11.03	9.70	7.42	8.06	3.81	1.11	0.38	0.11	0.10	0.01	0.01	0.03	67.17	61.46	41.77
1997	2.46	2.41	4.70	5.54	6.17	10.37	7.03	5.04	3.38	3.84	1.42	0.39	0.06	0.02	0.01		0.01	52.85	43.28	31.57
1998	0.42	3.12	5.23	7.93	7.38	5.85	7.59	4.88	3.29	2.80	2.46	0.77	0.17	0.10	0.06	0.01		52.06	43.29	27.99

Table 12: Coefficients of variation of mean numbers per tow at age from research vessel surveys, 1971-1998.

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	25.8	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	24.5	28.2	24.2	18.8	21.6	22.2	18.6	16.0	13.9	24.8	32.1	51.1
1983	20.9	12.9	11.8	13.9	12.8	9.8	10.2	10.5	13.2	11.7	18.0	37.6
1984	16.6	16.4	13.7	14.6	15.8	10.5	7.9	7.7	8.3	7.9	10.1	17.1
1985	57.5	22.0	14.0	21.0	26.5	28.7	25.2	18.5	17.2	15.5	12.3	25.7
1986	43.7	28.6	23.3	15.6	13.9	12.6	12.2	12.0	9.6	11.5	11.4	12.1
1987	30.4	20.4	14.9	12.1	11.4	10.9	12.3	14.8	15.5	18.8	19.2	17.5
1988	59.2	42.4	38.9	26.0	18.7	14.5	13.4	12.6	12.8	14.5	19.8	18.1
1989	60.0	28.7	20.2	14.6	11.7	11.4	11.3	11.3	11.5	12.4	12.2	13.5
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	32.4	18.7	22.0	24.5	21.3	15.0	12.3	11.1	10.4	11.0	10.1	11.0
1992	31.3	24.7	16.6	13.7	13.6	12.9	13.0	12.9	12.7	13.3	16.3	11.9
1993	22.7	20.3	18.3	12.7	9.3	9.3	9.6	10.2	10.2	12.3	11.7	16.7
1994	25.1	18.3	17.2	13.7	11.0	10.0	10.1	11.2	13.0	13.4	15.3	24.8
1995	30.8	24.3	16.5	14.3	12.5	11.8	11.0	10.4	10.8	15.2	17.1	18.4
1996	16.0	24.6	26.3	23.9	19.0	16.2	15.5	15.0	15.4	16.5	18.0	22.4
1997	32.5	26.5	15.5	22.5	24.2	22.7	21.9	21.5	21.1	21.4	21.6	23.5
1998	22.3	18.2	13.6	13.1	13.9	13.2	13.2	13.5	14.1	14.6	18.4	17.4

Table 13: Mean weights (kg) at age of southern Gulf cod from research vessel surveys, 1960-1998.

Age	1	2	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	0.03	0.12	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	0.05	0.15	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	0.03	0.17	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	0.04	0.21	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	0.04	0.09	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	0.05	0.15	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	0.05	0.13	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	0.03	0.16	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	0.02	0.11	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	0.03	0.12	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	0.03	0.08	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	0.06	0.17	0.28	0.60	0.94	1.13	1.43	1.67	2.18	4.03	5.77	9.91	7.61	13.10	
1983	0.04	0.13	0.26	0.43	0.74	1.17	1.29	1.54	1.97	1.97	4.60	5.94	12.38	3.94	9.41
1984	0.07	0.13	0.27	0.42	0.60	1.00	1.37	1.45	1.92	2.21	3.45	11.59	7.44	11.59	7.44
1985	0.03	0.13	0.32	0.50	0.69	0.83	1.14	1.72	1.70	1.92	2.65	5.90	12.66		
1986	0.05	0.14	0.27	0.51	0.65	0.81	1.04	1.32	2.29	1.79	2.73	3.56	6.65	11.55	
1987	0.06	0.12	0.25	0.42	0.65	0.79	0.93	1.13	1.49	1.79	2.36	2.18	4.45	6.77	15.66
1988	0.05	0.16	0.30	0.47	0.66	0.85	0.94	1.06	1.27	2.40	2.48	3.62	3.97	13.91	15.32
1989	0.05	0.13	0.28	0.49	0.70	0.89	1.06	1.11	1.17	1.29	2.03	3.59	5.16	6.94	7.66
1990	0.05	0.18	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	0.05	0.15	0.27	0.48	0.69	0.93	1.08	1.24	1.40	1.36	1.37	1.68	3.88	7.91	18.61
1992	0.04	0.17	0.30	0.43	0.72	0.93	1.10	1.25	1.49	1.89	1.98	1.41	1.43	1.62	
1993	0.05	0.14	0.30	0.45	0.64	0.91	1.06	1.26	1.41	2.21	1.49	2.47	1.53	5.23	8.81
1994	0.04	0.14	0.31	0.46	0.66	0.83	1.12	1.34	1.49	1.58	2.42	2.83	1.96	1.83	
1995	0.06	0.14	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
1996	0.03	0.19	0.34	0.45	0.77	0.93	1.11	1.29	1.58	2.36	2.59	4.33	3.54	1.76	4.19
1997	0.03	0.13	0.22	0.56	0.77	1.09	1.28	1.55	1.63	1.97	2.25	2.34	3.02	2.97	
1998	0.04	0.13	0.30	0.45	0.79	1.05	1.36	1.49	1.76	1.83	2.32	2.39	3.09	3.47	3.55

Table 14: Mean lengths (cm) at age of southern Gulf cod from research vessel surveys, 1971-1998.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1971	14.45	22.93	35.16	43.00	49.51	53.14	59.49	67.84	77.80	82.60	85.99	74.35	73.00	75.68	87.61
1972	17.01	24.83	34.42	42.17	49.97	53.87	57.72	64.12	71.81	75.87	82.03	82.34	77.65	101.00	85.00
1973	14.27	26.44	33.26	43.11	49.79	54.40	58.27	61.97	65.25	77.88	79.50	93.98	70.66	66.41	79.00
1974	16.87	28.19	36.20	42.46	49.60	55.42	59.70	61.20	62.02	69.96	73.39	80.96	102.15		76.00
1975	15.80	19.71	30.51	41.58	48.93	56.08	61.48	65.44	67.83	73.45	77.41	82.36	100.30	104.67	112.00
1976	17.23	25.16	30.29	42.25	51.39	57.44	62.87	66.70	66.53	73.49	79.62	74.67	85.04	79.00	70.00
1977	17.08	23.95	32.71	40.99	52.13	58.59	65.21	75.88	73.10	81.07	78.92	82.98	92.11		114.67
1978	15.92	26.60	33.52	42.91	50.20	59.22	62.19	70.12	80.10	84.63	93.32	92.76		87.74	98.84
1979	15.21	24.76	31.85	41.11	47.77	54.09	60.39	65.24	70.82	86.11	87.32	83.39	101.68	73.98	105.13
1980	14.47	22.91	33.53	40.37	46.63	50.96	55.57	67.90	73.02	77.78	81.57	88.01	99.52	102.41	94.00
1981	15.24	19.74	31.68	41.41	45.61	50.50	53.62	57.53	68.77	74.31	77.06	93.59	108.04	100.83	108.78
1982	18.12	26.08	30.97	39.80	46.43	49.25	53.23	55.79	60.68	73.81	84.51	101.64	92.29	112.00	
1983	16.77	25.45	31.91	37.01	44.33	51.30	52.53	55.88	59.42	59.40	71.86	82.86	105.09	76.00	100.00
1984	20.64	25.06	31.76	36.75	41.09	48.16	53.12	53.89	58.93	60.78	69.19	104.41	91.00	104.41	91.00
1985	15.61	24.51	33.18	38.23	42.32	45.11	49.57	56.08	56.23	58.43	63.23	83.60	107.81		
1986	17.17	24.71	30.37	37.85	40.91	44.04	47.54	51.00	59.83	56.05	63.08	68.70	83.12	102.71	
1987	19.28	24.91	31.07	36.81	42.19	44.88	47.27	49.91	53.57	56.88	59.75	59.13	70.66	79.83	115.08
1988	17.87	26.03	32.00	37.09	41.62	45.22	46.73	48.50	51.15	59.88	63.10	65.74	69.50	110.78	114.80
1989	18.03	24.23	31.17	37.59	42.22	45.72	48.31	49.05	49.93	51.56	57.59	65.47	76.07	81.76	82.75
1990	16.86	26.85	32.89	38.49	43.16	46.56	49.10	50.45	51.12	51.92	52.87	59.62	83.32	88.53	79.22
1991	17.34	25.14	30.58	37.36	42.06	46.42	48.64	50.72	52.50	52.03	52.28	55.16	68.82	91.40	124.18
1992	16.52	26.56	31.95	35.83	42.61	46.45	48.97	50.92	53.75	56.11	58.08	53.11	53.64	56.00	
1993	16.80	24.87	31.96	36.87	41.35	46.33	48.63	51.35	52.46	59.54	54.07	61.44	54.97	77.56	94.00
1994	15.81	24.45	32.54	36.60	41.38	44.62	49.14	52.04	53.60	54.36	60.88	66.03	59.51	58.08	
1995	18.57	24.88	29.93	37.99	41.88	44.94	47.89	50.97	54.46	60.72	62.10	68.05	70.55	85.76	95.78
1996	15.41	27.82	33.39	36.50	43.54	46.26	48.68	50.93	54.22	60.13	62.68	72.78	67.86	57.00	75.00
1997	14.47	24.54	29.14	39.42	43.73	48.83	51.09	53.72	54.64	57.64	59.69	60.69	67.35	67.48	
1998	15.93	24.23	31.83	36.41	44.08	48.04	52.28	53.63	55.97	56.82	61.55	62.14	66.70	67.80	72.00

Table 15: 4TVn (Nov.-Apr.) cod biomass per stratum from research vessel surveys, 1971 to 1998.

	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	431	432	433	434	435	436	437	438	439	Total
1971	1485	12582	5416	4922	5870	3205	1910	13293	16199	1837	796	733	6642	20	2778	5235	365	247	231	694	1591	40	793	0	86884
1972	2190	9391	5071	3096	3191	2927	5028	30865	7672	4559	44	2778	1576	1254	3830	766	6027	687	5953	576	581	592	1444	752	100851
1973	247	13777	5170	4874	2733	10278	831	17603	14048	1179	0	891	336	341	12002	2073	118	81	133	802	314	232	223	424	88710
1974	1364	15904	2936	1680	11142	10020	512	7414	6014	2874	364	2278	2856	159	10734	5927	0	3001	249	549	756	21	809	829	88395
1975	0	3194	3215	2698	573	1408	1490	18989	1499	3908	1428	146	0	753	9705	4266	215	3814	538	2743	116	1845	0	131	62675
1976	0	2152	5972	2225	5938	8497	38	23504	11181	1950	87	398	142	1358	2600	3562	0	974	441	4901	555	1432	554	0	78460
1977	1617	8220	8163	2954	4575	3653	1844	19898	7907	3995	216	531	3061	300	10563	8535	0	20624	508	1042	219	945	376	956	110702
1978	0	10611	10109	5492	12140	18690	4712	43396	54547	0	0	1767	3056	0	5342	7393	110	2176	927	974	609	866	978	4717	188611
1979	137	23262	7903	5918	12328	14531	6420	44821	42017	22457	0	7095	4811	7872	17156	15096	59	6846	5910	1091	2618	2271	2561	836	254015
1980	412	27989	19294	2869	7477	3046	622	29970	62553	18663	1224	4629	5981	1212	15665	19115	81	212	6825	10125	4929	4449	3577	0	250920
1981	949	22106	55027	8551	7533	5454	9195	49835	98889	47175	115	16417	4530	8003	33377	14694	0	11502	8423	2611	7684	3579	3311	4178	423138
1982	155	18928	7878	5850	3513	1486	1720	11916	38141	11874 6	0	9020	43582	3847	21490	27513	15	1732	5943	657	7580	10890	1460	289	342348
1983	1260	34296	16829	7068	17696	16859	0	14928	36902	9197	0	12579	12122	4392	16798	18667	0	843	21343	5582	3165	3755	3281	969	258530
1984	745	25236	25074	3785	2430	4989	1479	15789	19100	11674	0	7455	1092	5925	19251	11623	79	5170	12155	12415	15999	4656	1723	271	208113
1985	284	43299	22695	8628	4970	7615	1823	25086	32381	91288	22	9353	3791	3724	23900	17292	3	6080	9319	19053	19424	1520	565	453	352568
1986	240	30105	22332	3958	7986	7524	1356	33443	42673	11360	84	8726	5093	2203	26259	18052	22	5877	16984	11286	10030	3729	11939	142	281404
1987	93	22164	11912	6287	2907	5856	1468	32762	31423	10693	0	16452	4329	2713	11894	10962	16	5295	12121	8922	8887	1384	1389	137	210065
1988	174	26058	11417	3893	4230	2507	0	77291	60108	8068	17	12189	9339	7744	40012	34784	57	4073	11774	4138	21097	1858	1751	476	343056
1989	1	10277	26456	2956	3196	11826	2352	33697	36127	12738	0	8261	1631	11241	30434	20416	0	3974	21634	8984	4251	1707	619	16	252792
1990	5	12313	3487	5891	2352	5736	1483	22384	46928	5715	0	1529	1527	877	13055	15756	48	1533	7720	3862	3107	2818	766	946	159841
1991	288	3249	1900	1275	2614	837	782	19161	31687	2298	3	1831	1403	903	16500	21585	38	6269	4517	2575	2567	712	521	267	123781
1992	13	8470	6570	741	1457	1324	383	6719	9452	1498	423	791	1173	1493	4302	6135	1	568	2463	2707	1104	1547	303	221	59858
1993	340	4962	1816	505	3646	1465	157	14567	8982	1970	22	2377	1407	779	6983	5720	26	545	3840	1384	5907	1595	3773	49	72819
1994	291	2139	3276	520	2154	4789	479	9619	5770	989	18	3741	2277	3413	5679	5764	4	2546	6727	2831	2125	3052	1520	454	70177
1995	514	4053	517	4407	1860	6038	543	13358	9287	1660	0	2955	355	1260	6799	5097	4	1476	5769	3619	5534	856	1390	223	77574
1996	1849	226	300	3879	2027	7169	1003	14445	9684	719	397	7668	866	420	7346	5161	3	1272	4154	5364	13324	6295	4498	563	98632
1997	0	1642	837	2897	2066	2457	3358	9300	6373	1806	13651	438	933	192	6244	11325	2	1299	2349	2977	2216	971	1791	416	75540
1998	228	623	246	479	623	1023	4622	9090	6451	605	20	2017	418	33	15574	10957	0	1419	6526	9947	2444	1307	1599	41	76292

Table 16: Sentinel survey indices for southern Gulf of St. Lawrence cod (see Chouinard et al. 1999).

a) Longline (numbers per 1000 hooks)

	AGE								
YEAR	3	4	5	6	7	8	9	10	11
1995	0.8	5.8	14.0	20.6	51.6	36.9	20.8	7.8	4.4
1996	1.5	6.8	26.8	39.4	32.8	56.6	40.5	16.1	7.7
1997	0.7	8.6	25.9	42.6	58.5	57.9	75.5	40.3	12.9
1998	1.2	4.9	14.5	25.5	26.0	23.1	19.7	20.8	11.8

b) Seines – Lined (number/10 per set)

	AGE								
YEAR	2	3	4	5	6	7	8	9	10
1995	12.8	20.2	31.7	30.2	21.0	29.5	13.5	4.3	1.4
1996	7.3	23.1	33.5	21.4	25.2	16.0	13.9	5.6	1.1
1997	14.9	19.5	19.1	26.1	15.3	10.3	6.7	7.1	2.7
1998	25.2	40.1	31.3	23.8	25.8	15.6	9.0	7.0	5.8

c) Seines – Unlined (number per set)

	AGE						
YEAR	5	6	7	8	9	10	11
1996	53.2	90.6	75.3	84.8	44.1	9.3	1.8
1997	32.4	63.1	49.1	43.1	42.8	19.9	6.2
1998	66.9	110.9	139.5	63.7	45.0	38.0	19.4

d) Otter trawl – Lined (number per hour)

	AGE								
YEAR	2	3	4	5	6	7	8	9	10
1995	2.02	4.6	11.4	11.6	8.8	12.2	5.8	2.3	0.8
1996	0.04	5.4	15.4	27.3	18.9	17.4	20.9	8.9	4.1
1997	1.21	3.4	10.4	19.7	14.1	10.0	6.8	7.5	3.0
1998	2.02	9.1	13.1	16.5	20.3	13.7	8.0	6.5	5.5

e) Otter trawl – Unlined (number per hour)

	AGE					
YEAR	5	6	7	8	9	10
1995	2.49	3.17	6.30	3.89	1.81	0.58
1996	2.09	2.49	5.50	7.46	3.36	2.19
1997	5.74	16.23	13.64	13.84	15.43	7.03
1998	3.98	8.67	14.11	6.97	6.37	5.82

Table 17: Summary statistics from two multiplicative analyses of research vessel and sentinel survey catches at age of southern Gulf of St. Lawrence cod, 1971-97. Source indicates the type of survey (research or sentinel).

Analysis	N	R^2	Effect	DF	F-ratio	P
Age 2-3, set 127 in 1995 excluded, RV survey, seine lined and otter trawl lined	72	0.93	age	1	45.7	<.0001
			year-class	28	5.6	<.0001
			source	2	169.6	<.0001
			source*age	2	7.7	0.0016
Age 4-6, set 127 in 1995 excluded, RV survey and all 5 sentinel indices	141	0.93	age	2	24.3	<.0001
			year-class	29	9.8	<.0001
			source	5	170.9	<.0001
			source*age	10	13.3	<.0001

Table 18: Summary of total mortality estimates from 5 sentinel surveys and the annual research vessel survey, southern Gulf cod. Upper and lower indicate the bounds of the 95% confidence interval.

Source	Years	Ages	Year-classes	N	Z	Upper	Lower
Seine Lined	1995-98	5-12	1984-92	30	0.59	0.74	0.44
Seine Unlined	1996-98	7-12	1985-90	16	0.34	0.52	0.16
Otter Trawl Lined	1995-98	5-12	1984-92	30	0.37	0.55	0.19
Otter Trawl Unlined	1995-98	8-13	1983-89	22	0.32	0.63	0.03
Longline	1995-98	9-13	1983-88	18	0.57	0.81	0.34
RV Survey	1995-98	5-12	1984-92	30	0.57	0.69	0.46

Table 19: Relative spawning stock biomass at age (kg/tow) calculated from research vessel data for southern Gulf cod, 1971 - 1998.

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1971	0.4	2.4	6.6	7.8	7.8	3.8	1.5	1.9	1.6	0.5	0.1	0.5	0.9	35.6
1972	0.4	4.8	6.0	8.1	7.5	6.5	1.9	1.8	2.6	0.9	0.3	0.5	0.3	41.8
1973	0.5	1.6	7.9	6.1	5.8	5.4	4.1	1.9	0.6	2.4	0.1	0.2	0.1	36.6
1974	0.8	3.0	4.1	8.6	4.4	3.3	3.5	1.7	0.8	0.6	2.6	0.0	0.2	33.7
1975	0.2	2.5	6.3	4.0	4.0	3.3	1.6	1.5	2.1	0.7	0.5	0.1	0.1	26.9
1976	1.2	2.7	7.1	5.7	2.2	1.9	1.0	1.3	1.4	0.4	0.3	0.1	0.1	25.5
1977	1.1	4.6	6.9	6.5	5.0	3.9	2.5	2.2	1.7	1.9	2.8	0.0	0.9	40.1
1978	2.2	11.1	17.3	10.3	7.8	3.7	2.3	3.5	6.1	1.0	0.0	1.1	0.5	67.0
1979	1.0	14.1	27.4	21.4	8.8	4.8	3.0	1.8	1.9	1.3	0.8	0.3	0.5	87.2
1980	1.7	6.8	36.3	29.6	15.2	5.0	3.0	1.6	0.6	0.3	0.3	0.5	0.2	101.1
1981	0.8	16.1	35.5	59.3	32.4	22.6	5.5	2.9	1.6	1.1	0.7	0.6	1.2	180.2
1982	0.8	6.1	21.6	52.0	36.9	21.4	8.8	1.9	1.2	1.3	0.5	0.3	0.0	152.8
1983	1.7	7.6	13.9	19.7	20.1	16.4	9.9	6.5	3.8	1.0	5.3	0.2	0.7	106.7
1984	0.5	5.7	21.3	15.9	13.2	15.0	9.0	4.6	2.7	0.8	0.3	0.8	0.1	90.1
1985	1.5	7.7	33.8	52.8	17.3	11.2	7.6	4.0	4.0	2.3	2.2	0.0	0.0	144.3
1986	1.2	6.9	17.4	32.5	32.5	12.6	4.6	4.9	3.0	2.7	1.4	1.5	0.0	121.1
1987	0.8	3.6	14.9	17.1	28.1	12.6	3.7	3.2	1.6	1.2	1.0	0.7	0.5	88.8
1988	2.5	11.2	24.4	27.6	17.7	22.2	15.5	5.7	1.3	1.2	1.1	1.4	1.7	133.4
1989	1.2	5.9	14.9	24.9	17.5	12.0	12.4	9.0	2.7	1.5	1.2	1.2	0.4	104.9
1990	1.4	5.2	10.6	11.9	10.4	6.6	4.0	4.9	2.4	0.8	0.4	0.8	0.1	59.5
1991	0.5	5.9	13.1	8.6	6.2	4.9	2.3	1.4	1.5	1.1	0.3	0.2	0.2	46.1
1992	0.4	2.2	6.4	5.5	2.7	1.5	1.1	0.6	0.4	0.1	0.1	0.0	0.0	21.0
1993	0.3	2.3	7.6	8.9	5.1	2.0	0.9	0.8	0.2	0.1	0.2	0.1	0.2	28.8
1994	0.3	1.5	4.6	9.0	8.5	3.7	1.7	0.6	0.7	0.2	0.1	0.0	0.0	31.1
1995	0.2	1.9	4.9	6.1	10.4	6.0	2.9	1.3	0.8	0.4	0.1	0.2	0.2	35.4
1996	0.6	1.8	5.6	6.7	11.1	6.0	2.8	1.3	0.8	0.5	0.1	0.1	0.1	37.4
1997	0.2	2.6	6.1	9.6	9.3	12.5	6.2	2.2	0.9	0.3	0.3	0.0	0.0	50.0
1998	0.2	1.0	5.9	6.7	6.7	5.0	6.8	2.6	0.9	0.1	0.1	0.0	0.0	36.0

Table 20: Parameter estimates from an ADAPT fitting 5 year/age periods of natural mortality (M). Codes: (pop = population estimates at the beginning of the year 1999; 82-87, etc = natural mortality estimates; rv = research vessel index; l = longline sentinel survey index; s1 = seine (lined) sentinel survey index; s0 = seine (unlined) sentinel survey index; o1 = otter trawl (lined) sentinel survey index; o0 = otter trawl (unlined) sentinel survey index; rec = age 3 index derived from multiplicative analysis of rv and sentinel surveys; cpue = otter trawl catch rate index)

Parameter	Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
pop	3	101000	40700	0.402	8170	0.081
pop	4	48800	10100	0.207	1050	0.022
pop	5	21500	3470	0.161	287	0.013
pop	6	22900	3220	0.141	239	0.01
pop	7	20900	3050	0.146	237	0.011
pop	8	11700	1560	0.134	109	0.009
pop	9	5470	715	0.131	47.4	0.009
pop	10	3030	433	0.143	30.5	0.01
pop	11	2370	373	0.158	27.7	0.012
pop	12	966	163	0.168	12.1	0.013
82-87	M	0.316	0.0268	0.085	-0.00037	-0.001
88-93, 3-6	M	0.593	0.0459	0.077	-0.00036	-0.001
88-93, 7-15	M	0.361	0.052	0.144	-0.00094	-0.003
94-98, 3-6	M	0.149	0.0514	0.345	-0.00023	-0.002
94-98,7-15	M	0.572	0.0326	0.057	0.000163	0
rv	3	0.000203	0.0000198	0.097	9.34E-07	0.005
rv	4	0.000324	0.0000284	0.088	1.15E-06	0.004
rv	5	0.000435	0.0000357	0.082	1.31E-06	0.003
rv	6	0.000515	0.000042	0.082	1.53E-06	0.003
rv	7	0.000563	0.0000454	0.081	1.68E-06	0.003
rv	8	0.000625	0.0000495	0.079	1.84E-06	0.003
rv	9	0.00065	0.0000509	0.078	1.9E-06	0.003
rv	10	0.000808	0.000063	0.078	2.39E-06	0.003
l	3	0.0000287	0.00000662	0.231	7.61E-07	0.026
l	4	0.000234	0.0000507	0.217	5.42E-06	0.023
l	5	0.000801	0.00017	0.212	1.76E-05	0.022
l	6	0.00151	0.000324	0.214	3.36E-05	0.022
l	7	0.00301	0.000639	0.212	6.58E-05	0.022
l	8	0.00566	0.0012	0.212	0.000126	0.022
l	9	0.00925	0.00199	0.215	0.000216	0.023
l	10	0.0116	0.00252	0.216	0.00028	0.024
l	11	0.019	0.00406	0.214	0.000455	0.024
s1	3	0.000704	0.000162	0.231	1.87E-05	0.026
s1	4	0.00103	0.000224	0.217	0.000024	0.023
s1	5	0.00104	0.000221	0.212	2.28E-05	0.022
s1	6	0.00105	0.000226	0.214	2.34E-05	0.022
s1	7	0.00125	0.000265	0.212	2.73E-05	0.022

Table 20 (continued)

s1	8	0.00143	0.000303	0.212	3.17E-05	0.022
s1	9	0.00163	0.00035	0.215	3.79E-05	0.023
s1	10	0.00143	0.000309	0.216	3.45E-05	0.024
s0	5	0.00195	0.000473	0.243	5.66E-05	0.029
s0	6	0.00414	0.00102	0.247	0.000123	0.03
s0	7	0.00653	0.00159	0.244	0.00019	0.029
s0	8	0.00842	0.00204	0.243	0.000245	0.029
s0	9	0.0106	0.00263	0.247	0.000326	0.031
s0	10	0.00966	0.00241	0.249	0.000306	0.032
s0	11	0.00866	0.00214	0.248	0.000276	0.032
o1	3	0.000151	0.0000348	0.231	0.000004	0.026
o1	4	0.000456	0.0000988	0.217	1.06E-05	0.023
o1	5	0.000741	0.000157	0.212	1.62E-05	0.022
o1	6	0.000728	0.000156	0.214	1.62E-05	0.022
o1	7	0.000982	0.000208	0.212	2.15E-05	0.022
o1	8	0.00125	0.000264	0.212	2.77E-05	0.022
o1	9	0.00155	0.000334	0.215	3.63E-05	0.023
o1	10	0.00175	0.000379	0.216	4.22E-05	0.024
o0	5	0.000137	0.0000289	0.212	0.000003	0.022
o0	6	0.000284	0.000061	0.214	6.33E-06	0.022
o0	7	0.00068	0.000144	0.212	1.48E-05	0.022
o0	8	0.00101	0.000213	0.212	2.23E-05	0.022
o0	9	0.00137	0.000294	0.215	3.19E-05	0.023
o0	10	0.00173	0.000375	0.216	4.18E-05	0.024
rec	3	0.000266	0.0000279	0.105	1.47E-06	0.006
cpue	5	0.000682	0.000154	0.226	1.72E-05	0.025
cpue		1.1	0.037	0.034	0.000585	0.001
cpue	6	0.00175	0.000389	0.222	4.26E-05	0.024
cpue		1.11	0.0374	0.034	0.000612	0.001
cpue	7	0.00269	0.000587	0.219	6.34E-05	0.024
cpue		1.13	0.038	0.034	0.000662	0.001
cpue	8	0.00295	0.000641	0.217	6.89E-05	0.023
cpue		1.15	0.0384	0.033	0.000654	0.001
cpue	9	0.00291	0.00063	0.216	6.73E-05	0.023
cpue		1.19	0.0395	0.033	0.000653	0.001
cpue	10	0.00448	0.000972	0.217	0.000104	0.023
cpue		1.16	0.0385	0.033	0.000664	0.001
cpue	11	0.00311	0.000672	0.216	7.11E-05	0.023
cpue		1.17	0.039	0.033	0.000713	0.001
cpue	12	0.00334	0.000726	0.217	7.72E-05	0.023
cpue		1.25	0.0411	0.033	0.000714	0.001

Table 21: Parameter estimates from the ADAPT formulation using all indices and two series of natural mortality (M=0.2 from 1971 to 1985; M=0.4 from 1986 to 1998. Codes: (pop99 = population estimates at the beginning of the year 1999; RV = research vessel index; Longline = longline sentinel survey index; SNU_1 = seine (lined) sentinel survey index; SNU_0 = seine (unlined) sentinel survey index; OTB_1 = otter trawl (lined) sentinel survey index; OTB_0 = otter trawl (unlined) sentinel survey index; CPUE = otter trawl catch rate index)

Approximate statistics assuming linearity near solution
Orthogonality offset = 0.004914
Mean Square Residual = 0.184771
Parameters in linear scale

Parameter	Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
Pop 99	3	107000	30700	0.286	4400	0.041
Pop 99	4	47500	9340	0.197	929	0.02
Pop 99	5	13900	2250	0.162	185	0.013
Pop 99	6	16800	2290	0.137	159	0.009
Pop 99	7	11700	1460	0.125	92.1	0.008
Pop 99	8	8720	1020	0.117	59.9	0.007
Pop 99	9	5320	598	0.113	33.2	0.006
Pop 99	10	4500	459	0.102	24.3	0.005
Pop 99	11	4270	445	0.104	22.8	0.005
Pop 99	12	1910	222	0.116	11.2	0.006
RV	2	7.81E-05	6.68E-06	0.086	2.72E-07	0.003
RV	3	2.25E-04	1.90E-05	0.084	7.64E-07	0.003
RV	4	3.58E-04	2.99E-05	0.084	1.20E-06	0.003
RV	5	4.75E-04	3.94E-05	0.083	1.59E-06	0.003
RV	6	5.61E-04	4.65E-05	0.083	1.90E-06	0.003
RV	7	5.93E-04	4.91E-05	0.083	2.04E-06	0.003
RV	8	6.34E-04	5.26E-05	0.083	2.21E-06	0.003
RV	9	6.29E-04	5.22E-05	0.083	2.23E-06	0.004
RV	10	7.50E-04	6.23E-05	0.083	2.73E-06	0.004
Longline	3	2.59E-05	6.21E-06	0.24	7.39E-07	0.029
Longline	4	2.50E-04	5.84E-05	0.234	6.78E-06	0.027
Longline	5	9.52E-04	2.20E-04	0.231	2.51E-05	0.026
Longline	6	2.08E-03	4.74E-04	0.228	5.35E-05	0.026
Longline	7	3.48E-03	7.88E-04	0.226	8.83E-05	0.025
Longline	8	5.18E-03	1.17E-03	0.227	1.32E-04	0.026
Longline	9	7.44E-03	1.70E-03	0.228	1.96E-04	0.026
Longline	10	9.11E-03	2.08E-03	0.228	2.45E-04	0.027
Longline	11	1.52E-02	3.45E-03	0.227	4.10E-04	0.027
SNU_1	2	2.05E-04	5.15E-05	0.252	6.44E-06	0.031
SNU_1	3	6.35E-04	1.52E-04	0.24	1.81E-05	0.029
SNU_1	4	1.10E-03	2.58E-04	0.234	3.00E-05	0.027
SNU_1	5	1.24E-03	2.85E-04	0.231	3.26E-05	0.026
SNU_1	6	1.45E-03	3.31E-04	0.228	3.73E-05	0.026
SNU_1	7	1.44E-03	3.26E-04	0.226	3.66E-05	0.025

SNU_1	8	1.31E-03	2.96E-04	0.227	3.34E-05	0.026
SNU_1	9	1.31E-03	2.98E-04	0.228	3.44E-05	0.026
SNU_1	10	1.12E-03	2.56E-04	0.228	3.02E-05	0.027
SNU_0	5	2.41E-03	6.39E-04	0.265	8.41E-05	0.035
SNU_0	6	6.18E-03	1.62E-03	0.263	2.12E-04	0.034
SNU_0	7	7.92E-03	2.06E-03	0.26	2.67E-04	0.034
SNU_0	8	7.69E-03	1.99E-03	0.259	2.57E-04	0.033
SNU_0	9	7.73E-03	2.01E-03	0.26	2.61E-04	0.034
SNU_0	10	6.77E-03	1.77E-03	0.261	2.35E-04	0.035
SNU_0	11	6.25E-03	1.62E-03	0.26	2.19E-04	0.035
OTB_1	2	9.98E-06	2.51E-06	0.252	3.13E-07	0.031
OTB_1	3	1.36E-04	3.27E-05	0.24	3.88E-06	0.029
OTB_1	4	4.86E-04	1.14E-04	0.234	1.32E-05	0.027
OTB_1	5	8.80E-04	2.03E-04	0.231	2.32E-05	0.026
OTB_1	6	1.00E-03	2.28E-04	0.228	2.58E-05	0.026
OTB_1	7	1.13E-03	2.57E-04	0.226	2.88E-05	0.025
OTB_1	8	1.14E-03	2.59E-04	0.227	2.92E-05	0.026
OTB_1	9	1.25E-03	2.85E-04	0.228	3.29E-05	0.026
OTB_1	10	1.37E-03	3.13E-04	0.228	3.69E-05	0.027
OTB_0	5	1.62E-04	3.74E-05	0.231	4.28E-06	0.026
OTB_0	6	3.91E-04	8.93E-05	0.228	1.01E-05	0.026
OTB_0	7	7.85E-04	1.78E-04	0.226	1.99E-05	0.025
OTB_0	8	9.21E-04	2.09E-04	0.227	2.36E-05	0.026
OTB_0	9	1.10E-03	2.51E-04	0.228	2.89E-05	0.026
OTB_0	10	1.36E-03	3.10E-04	0.228	3.65E-05	0.027
CPUE	5	6.98E-04	1.63E-04	0.234	1.92E-05	0.027
CPUE	5	1.12	4.09E-02	0.036	7.00E-04	0.001
CPUE	6	1.71E-03	4.01E-04	0.234	4.68E-05	0.027
CPUE	6	1.13	4.11E-02	0.036	7.51E-04	0.001
CPUE	7	2.65E-03	6.20E-04	0.234	7.21E-05	0.027
CPUE	7	1.13	4.10E-02	0.036	7.80E-04	0.001
CPUE	8	2.98E-03	6.97E-04	0.234	8.12E-05	0.027
CPUE	8	1.15	4.15E-02	0.036	7.70E-04	0.001
CPUE	9	3.14E-03	7.33E-04	0.234	8.55E-05	0.027
CPUE	9	1.16	4.20E-02	0.036	7.62E-04	0.001
CPUE	10	5.62E-03	1.31E-03	0.234	1.53E-04	0.027
CPUE	10	1.09	3.94E-02	0.036	7.46E-04	0.001
CPUE	11	3.38E-03	7.90E-04	0.234	9.19E-05	0.027
CPUE	11	1.15	4.14E-02	0.036	7.85E-04	0.001
CPUE	12	4.43E-03	1.04E-03	0.234	1.21E-04	0.027
CPUE	12	1.14	4.13E-02	0.036	7.67E-04	0.001

Table 22: Beginning of the year population numbers ('000) for southern Gulf of St. Lawrence cod from the final ADAPT calibration (1971-1999).

	AGE												
YEAR	3	4	5	6	7	8	9	10	11	12	13	14	15
1971	88983	39530	31415	31371	18839	6000	3266	1656	500	551	148	298	441
1972	35225	72848	30470	19184	17371	10117	2826	1554	890	293	137	55	136
1973	48616	25974	39682	14192	9732	7465	5101	1460	782	396	132	67	32
1974	56532	38563	14980	19502	6851	4638	3604	2509	697	338	234	47	13
1975	47359	43583	26708	7752	7325	2838	2138	1370	1112	338	101	119	13
1976	123820	37359	27668	15639	4069	3052	1146	753	410	307	142	36	30
1977	171161	100916	26898	13698	6572	1804	1374	511	362	203	122	74	14
1978	167939	139539	78147	16718	8231	3788	1118	870	255	194	121	52	51
1979	122289	137002	105191	54165	9560	4335	2107	696	490	110	94	60	38
1980	127595	99988	107530	71792	34227	4684	2006	952	306	175	32	48	34
1981	106071	104200	80130	74818	46055	19235	2470	920	418	123	117	10	32
1982	225461	86755	81855	58950	44057	25932	10188	1205	340	161	37	17	6
1983	321898	184124	69565	57403	40428	24814	14354	6065	589	152	64	26	12
1984	200989	263510	149712	51264	36093	22387	13456	6935	2581	357	78	36	12
1985	215520	164528	214552	118773	35297	21388	12095	6386	3052	1270	157	18	23
1986	204582	176295	133295	166358	81783	21401	12040	6338	3188	1628	723	105	9
1987	147714	137025	115292	82621	92402	46941	11064	5627	2357	1182	456	356	55
1988	112681	98951	91014	71280	46608	46684	25801	5604	2422	1019	459	200	149
1989	112731	75442	64927	56756	38688	23929	21532	11823	2301	851	313	148	93
1990	126188	75508	49223	38609	28063	17335	10179	8341	3819	756	205	89	60
1991	123202	84148	48200	26930	17362	10663	6060	3275	1941	934	203	42	30
1992	80415	82352	52205	23958	10396	4980	3390	1561	814	546	168	64	8
1993	62552	53508	52412	24933	8175	2792	668	662	333	148	76	26	33
1994	67341	41887	35654	34398	15760	4714	1469	270	335	164	70	26	12
1995	59565	45119	28034	23820	22886	10336	3033	927	158	209	103	44	16
1996	55833	39871	30136	18674	15861	15160	6819	1984	602	95	136	68	29
1997	30706	37395	26661	20096	12399	10529	10020	4496	1303	395	58	89	44
1998	69532	20561	25023	17774	13323	8170	6911	6548	2925	842	256	37	58
1999	102888	46550	13715	16601	11650	8665	5282	4472	4251	1903	546	166	24

Table 23: Beginning of the year population biomass ('000) for southern Gulf of St. Lawrence cod from the final ADAPT calibration (1971-1999).

	AGE												
YEAR	3	4	5	6	7	8	9	10	11	12	13	14	15
1971	27800	22186	29137	41305	34999	16489	12712	8174	2744	2232	576	1414	2524
1972	9925	39965	29146	25538	28886	23585	9748	7151	5107	1848	650	341	695
1973	11239	14094	36769	19566	16836	16102	14175	6447	3862	2875	627	260	232
1974	20262	19398	14210	27388	12480	9813	8660	7910	3257	1849	2302	238	47
1975	9193	25396	25212	11382	14622	7013	5829	4408	4567	1734	761	1331	130
1976	20737	17553	27442	23431	8640	8217	3397	2723	1957	1415	918	252	186
1977	38952	41997	26760	22010	14750	5932	4716	2075	1619	1134	758	484	120
1978	42121	69636	69911	27914	18126	11853	5405	4390	1819	1293	944	418	409
1979	20655	60571	89107	72808	20231	11466	7671	4262	3408	856	978	425	376
1980	32145	39711	79705	78713	53326	12064	6548	3903	1831	1207	248	531	208
1981	22183	49230	58158	78496	61149	32891	7578	3531	1921	773	1007	94	349
1982	52281	36592	64039	58152	57153	40002	20073	4247	1609	1086	282	208	60
1983	66770	64043	46346	60314	48740	36824	26063	12573	2622	905	717	142	133
1984	39940	87204	75690	44107	45570	30620	23028	14465	6740	2700	528	437	65
1985	55806	60805	114890	84119	37849	32917	19423	12589	7455	5809	1905	167	267
1986	44816	71915	76410	123931	76258	26489	24180	11439	7797	5146	4711	1266	104
1987	26317	46619	66306	59184	80149	50887	15628	11530	4922	3011	1885	2446	738
1988	26292	33610	48146	52850	40024	46198	30823	10629	5122	2972	1380	1605	1516
1989	22205	28906	37281	43499	36797	24371	23940	15120	5083	2573	1348	793	982
1990	34564	28990	29970	31718	28242	19878	12074	10489	5208	1648	1001	600	379
1991	26189	33456	29249	22566	17679	12677	7989	4312	2635	1453	610	300	383
1992	19501	27826	30573	19201	10505	5784	4615	2542	1339	759	261	160	83
1993	15178	19594	27281	20059	8154	3289	887	1198	559	327	112	71	124
1994	16438	15560	19431	25070	15911	5618	2013	403	775	337	154	44	80
1995	11099	17763	15563	17736	21161	12230	4441	1727	317	596	329	159	64
1996	14792	13373	18699	14741	15316	17475	9583	3855	1479	315	469	173	153
1997	4723	16317	15694	18411	13528	13811	14530	7932	3003	972	210	289	119
1998	13731	6469	16644	15982	16221	11283	11415	11309	6253	1953	688	120	188
1999	20319	21214	8827	15577	14284	13163	8491	8387	8243	4791	1345	589	89

Table 24: Fishing mortality for southern Gulf of St. Lawrence cod from the final ADAPT calibration (1971-1998).

	AGE												
YEAR	3	4	5	6	7	8	9	10	11	12	13	14	15
1971	0.00	0.06	0.29	0.39	0.42	0.55	0.54	0.42	0.34	1.19	0.80	0.58	0.48
1972	0.11	0.41	0.56	0.48	0.65	0.49	0.46	0.49	0.61	0.59	0.52	0.33	0.47
1973	0.03	0.35	0.51	0.53	0.54	0.53	0.51	0.54	0.64	0.33	0.84	1.43	0.53
1974	0.06	0.17	0.46	0.78	0.68	0.57	0.77	0.61	0.52	1.01	0.48	1.11	0.69
1975	0.04	0.25	0.34	0.45	0.68	0.71	0.84	1.01	1.09	0.67	0.84	1.17	0.93
1976	0.01	0.13	0.50	0.67	0.61	0.60	0.61	0.53	0.50	0.72	0.45	0.73	0.57
1977	0.00	0.06	0.28	0.31	0.35	0.28	0.26	0.49	0.42	0.32	0.65	0.16	0.38
1978	0.00	0.08	0.17	0.36	0.44	0.39	0.27	0.38	0.64	0.52	0.51	0.11	0.33
1979	0.00	0.04	0.18	0.26	0.51	0.57	0.60	0.62	0.83	1.05	0.48	0.37	0.61
1980	0.00	0.02	0.16	0.24	0.38	0.44	0.58	0.62	0.71	0.21	0.95	0.20	0.60
1981	0.00	0.04	0.11	0.33	0.37	0.44	0.52	0.79	0.75	0.99	1.72	0.25	0.66
1982	0.00	0.02	0.16	0.18	0.37	0.39	0.32	0.52	0.61	0.72	0.16	0.14	0.42
1983	0.00	0.01	0.11	0.26	0.39	0.41	0.53	0.65	0.30	0.46	0.37	0.55	0.59
1984	0.00	0.01	0.03	0.17	0.32	0.42	0.55	0.62	0.51	0.62	1.26	0.24	0.58
1985	0.00	0.01	0.05	0.17	0.30	0.38	0.45	0.50	0.43	0.36	0.20	0.45	0.47
1986	0.00	0.03	0.08	0.19	0.16	0.26	0.36	0.59	0.59	0.87	0.31	0.25	0.48
1987	0.00	0.01	0.08	0.17	0.28	0.20	0.28	0.44	0.44	0.55	0.43	0.47	0.36
1988	0.00	0.02	0.07	0.21	0.27	0.37	0.38	0.49	0.65	0.78	0.74	0.37	0.44
1989	0.00	0.03	0.12	0.30	0.40	0.46	0.55	0.73	0.71	1.03	0.86	0.50	0.64
1990	0.01	0.05	0.20	0.40	0.57	0.65	0.73	1.06	1.01	0.92	1.19	0.68	0.90
1991	0.00	0.08	0.30	0.55	0.85	0.75	0.96	0.99	0.87	1.32	0.76	1.20	0.97
1992	0.01	0.05	0.34	0.68	0.92	1.61	1.23	1.15	1.31	1.58	1.48	0.26	1.19
1993	0.00	0.01	0.02	0.06	0.15	0.24	0.51	0.28	0.31	0.35	0.67	0.39	0.39
1994	0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.13	0.07	0.06	0.07	0.10	0.00
1995	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.11	0.03	0.02	0.03	0.00
1996	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.09	0.03	0.02	0.00
1997	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.03	0.06	0.03	0.03
1998	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.00

Table 25: Input parameters for catch projections for southern Gulf of St. Lawrence cod. Beginning of year weights (calculated from the research survey), catch weights and fishing mortality at age are the average for the period 1996-1998. Maturity was derived from 1990-1995 surveys conducted at the end of the spawning season.

Age	Weight at age		Maturity	Partial recruitment	Population numbers in 1999 ('000')
	Beginning of year	Catch			
3	0.197	0.298	0.121	0.033	102888
4	0.456	0.513	0.368	0.099	46550
5	0.644	0.856	0.721	0.219	13715
6	0.938	1.111	0.905	0.461	16601
7	1.226	1.432	0.974	0.625	11650
8	1.519	1.759	1.000	0.779	8665
9	1.608	2.011	1.000	0.834	5282
10	1.875	2.350	1.000	0.911	4472
11	1.939	2.749	1.000	1.000	4251
12	2.518	2.917	1.000	1.000	1903
13	2.463	3.072	1.000	1.000	546
14	3.551	3.958	1.000	1.000	166
15	3.720	4.065	1.000	1.000	24

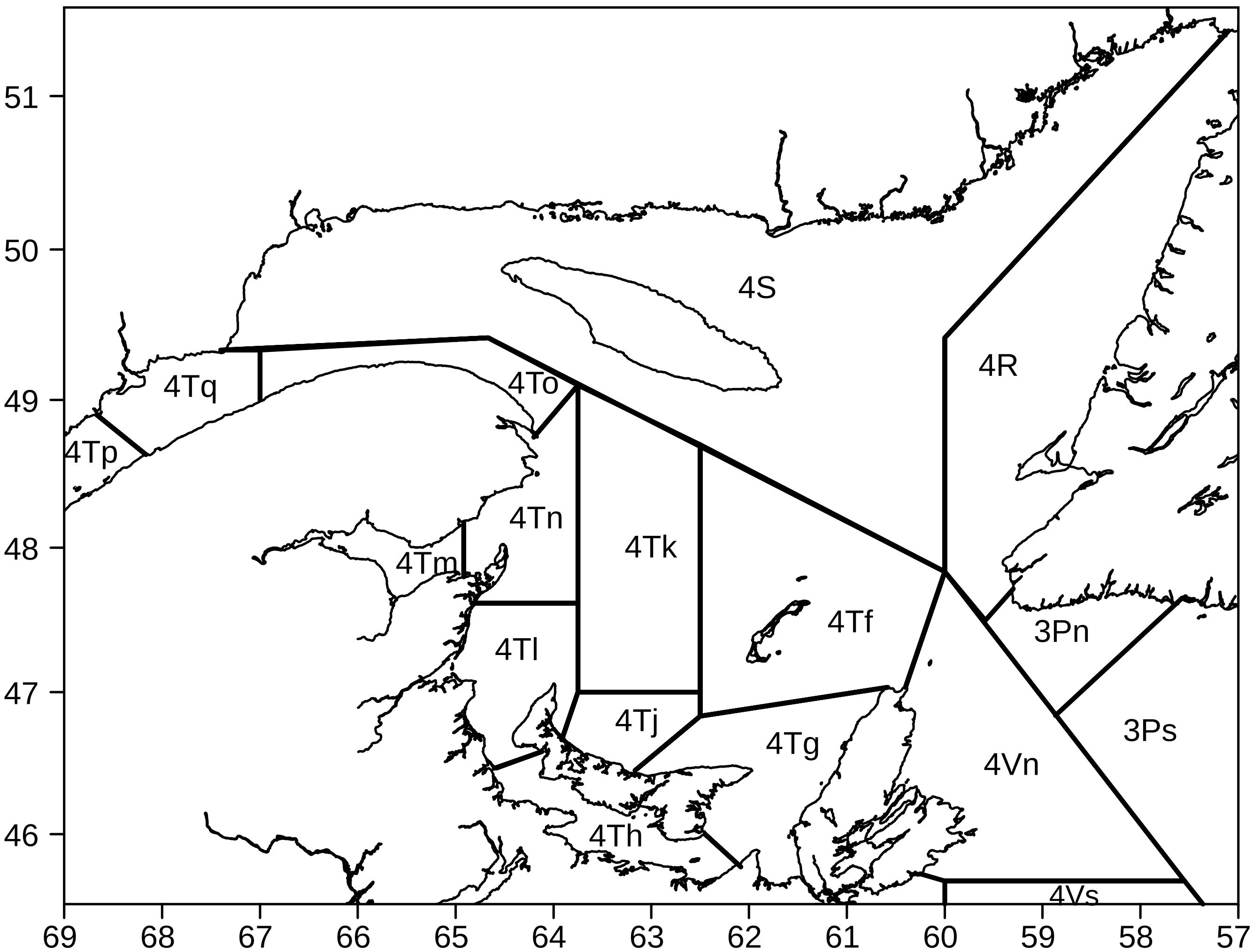


Figure 1: NAFO Divisions in the area of the Gulf of St. Lawrence. Unit areas are indicated for Division 4T.

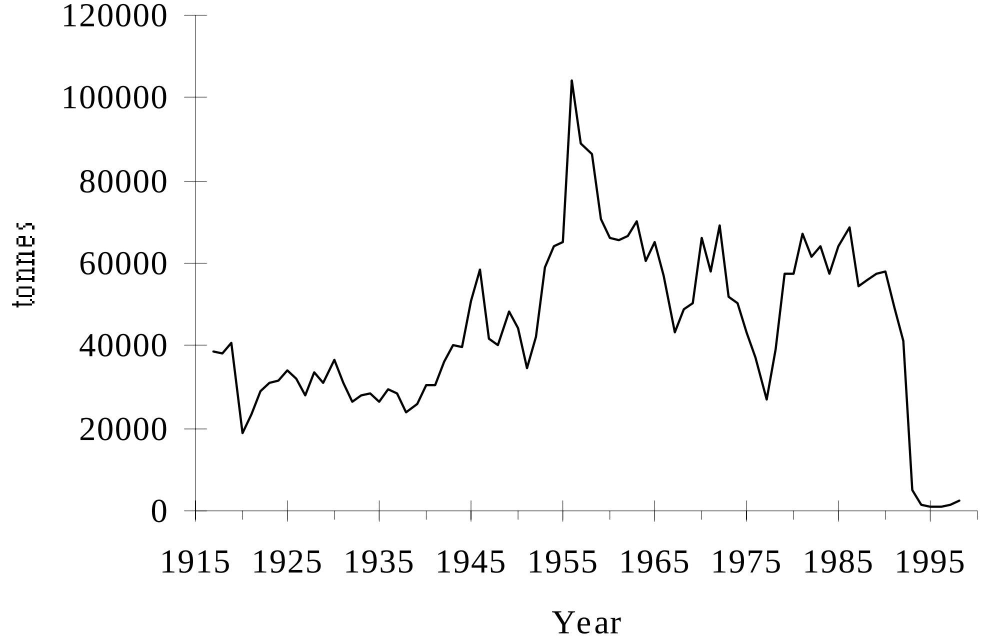
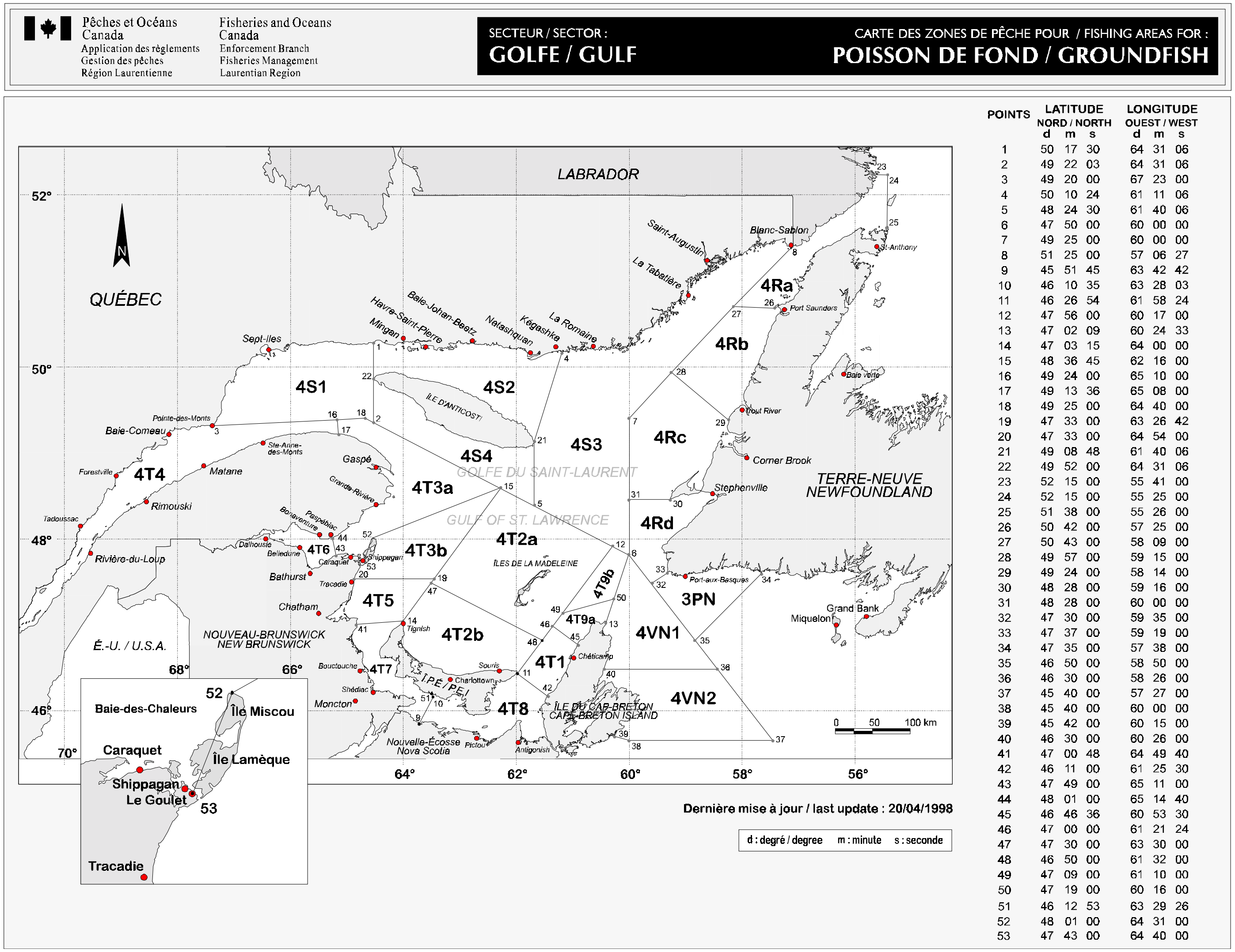


Figure 2: Landings of southern Gulf of St. Lawrence (4T-Vn(N-A)) cod, 1917 - 1998.



POINTS	LATITUDE NORD / NORTH d	m	s	LONGITUDE OUEST / WEST d	m	s
1	50	17	30	64	31	06
2	49	22	03	64	31	06
3	49	20	00	67	23	00
4	50	10	24	61	11	06
5	48	24	30	61	40	06
6	47	50	00	60	00	00
7	49	25	00	60	00	00
8	51	25	00	57	06	27
9	45	51	45	63	42	42
10	46	10	35	63	28	03
11	46	26	54	61	58	24
12	47	56	00	60	17	00
13	47	02	09	60	24	33
14	47	03	15	64	00	00
15	48	36	45	62	16	00
16	49	24	00	65	10	00
17	49	13	36	65	08	00
18	49	25	00	64	40	00
19	47	33	00	63	26	42
20	47	33	00	64	54	00
21	49	08	48	61	40	06
22	49	52	00	64	31	06
23	52	15	00	55	41	00
24	52	15	00	55	25	00
25	51	38	00	55	26	00
26	50	42	00	57	25	00
27	50	43	00	58	09	00
28	49	57	00	59	15	00
29	49	24	00	58	14	00
30	48	28	00	59	16	00
31	48	28	00	60	00	00
32	47	30	00	59	35	00
33	47	37	00	59	19	00
34	47	35	00	57	38	00
35	46	50	00	58	50	00
36	46	30	00	58	26	00
37	45	40	00	57	27	00
38	45	40	00	60	00	00
39	45	42	00	60	15	00
40	46	30	00	60	26	00
41	47	00	48	64	49	40
42	46	11	00	61	25	30
43	47	49	00	65	11	00
44	48	01	00	65	14	40
45	46	46	36	60	53	30
46	47	00	00	61	21	24
47	47	30	00	63	30	00
48	46	50	00	61	32	00
49	47	09	00	61	10	00
50	47	19	00	60	16	00
51	46	12	53	63	29	26
52	48	01	00	64	31	00
53	47	43	00	64	40	00

Figure 3: Groundfish fishing management zones in NAFO Division 4T.

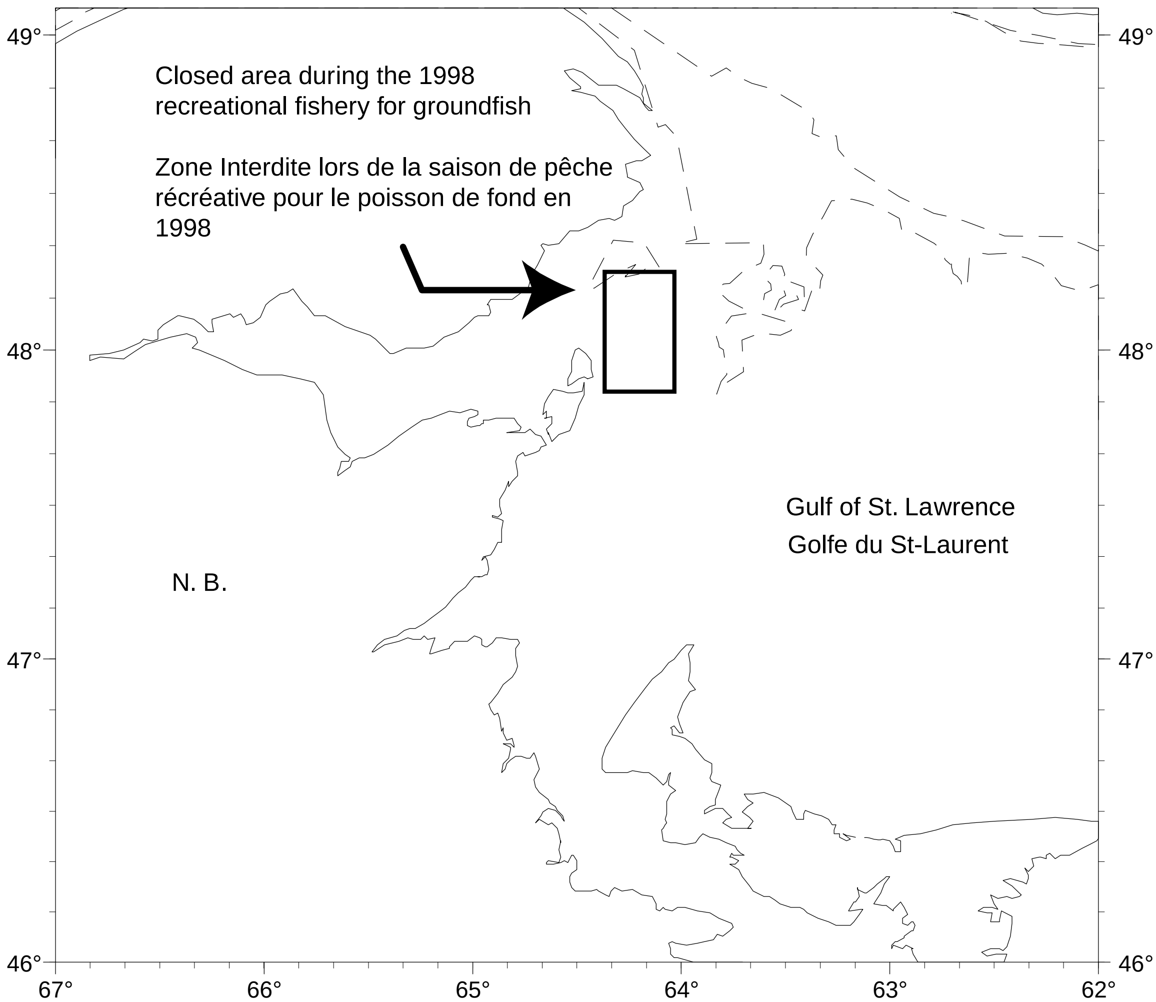


Figure 4 : Closed area for the recreational fishery in the southern Gulf of St. Lawrence in 1998.

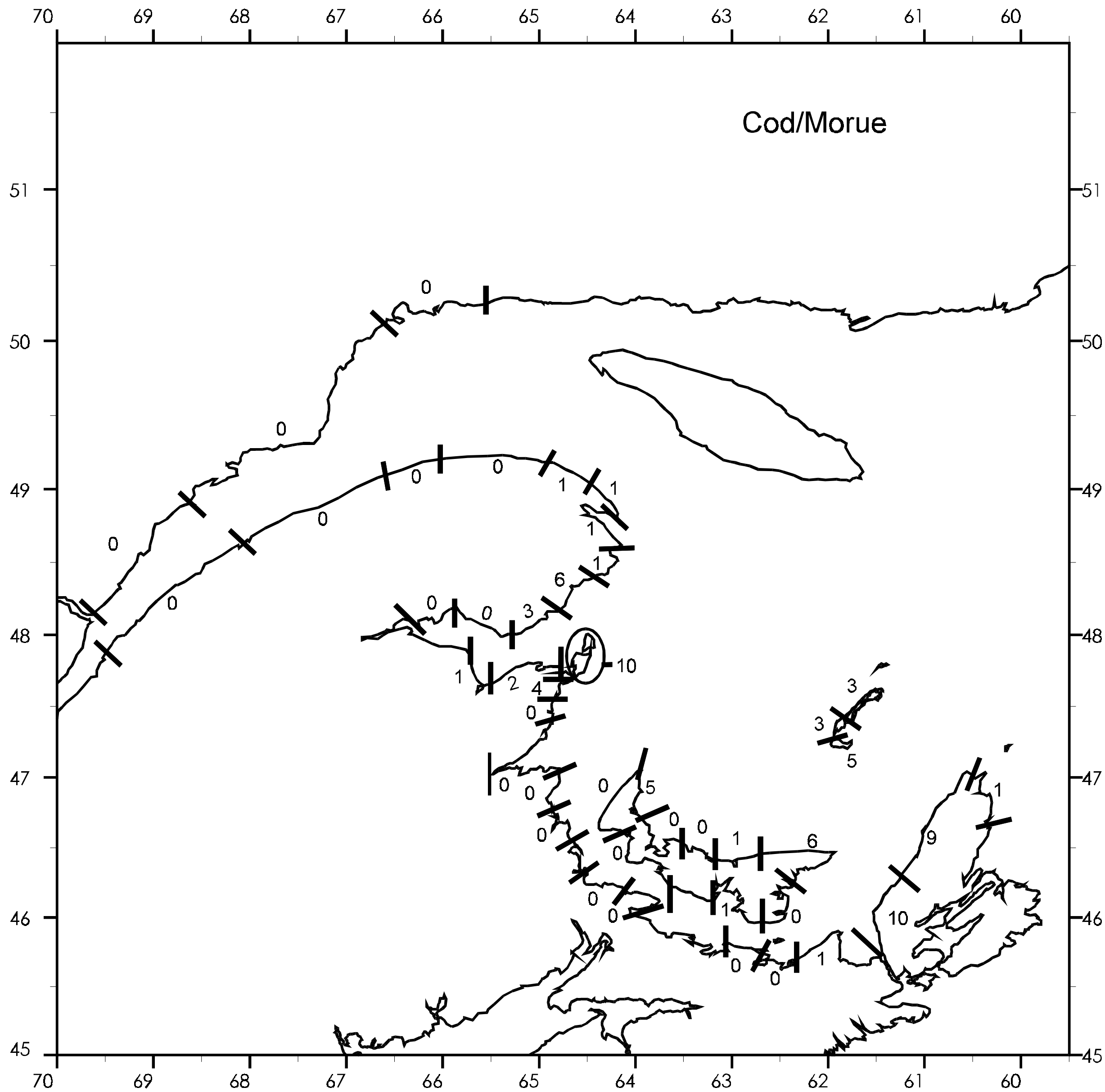


Figure 5: The distribution of respondents that fished for cod 'most of the time' in 1998 by statistical district (Cod was either their first, second or third priority).

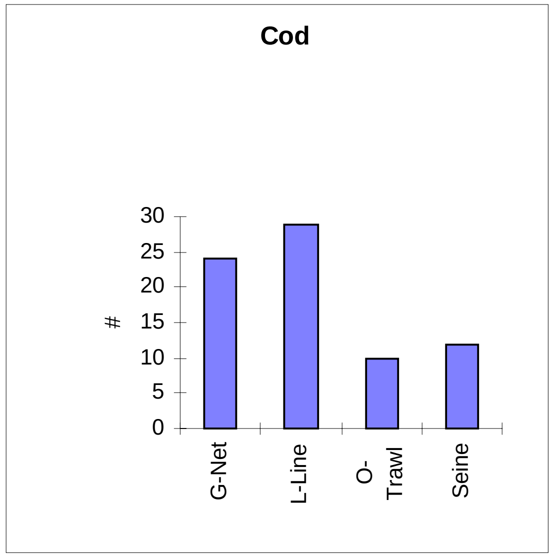


Figure 6: The fishing gear that was used 'most of the time' by respondents that directed for cod in 1998 (cod was either their first, second or third priority).

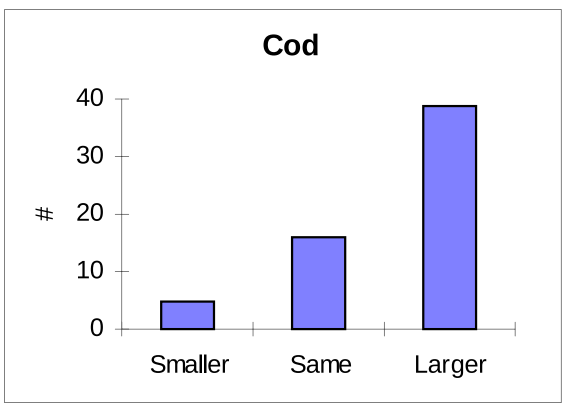


Figure 7: Comparison to previous years of the average size of cod in 1998 (cod was their 'first priority').

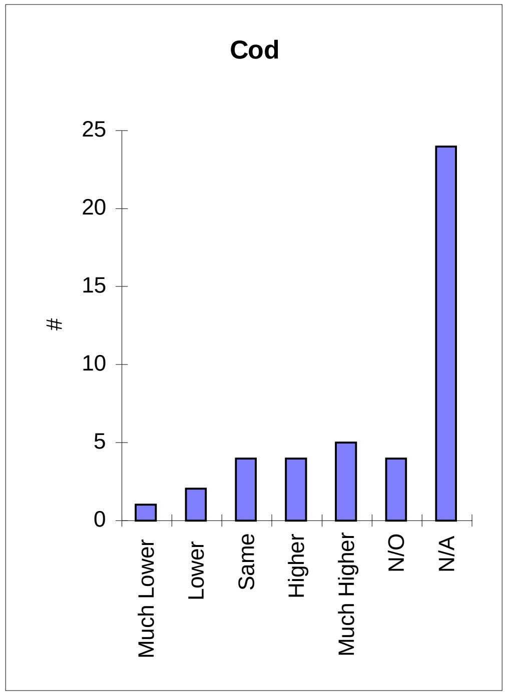


Figure 8: Opinions of respondents asked to compare the abundance of cod in 1998 with its abundance in 1997 (cod was their 'first priority') (Note: N/O = No Opinion and N/A = Not Applicable (these fishers had no activity in 1997)).

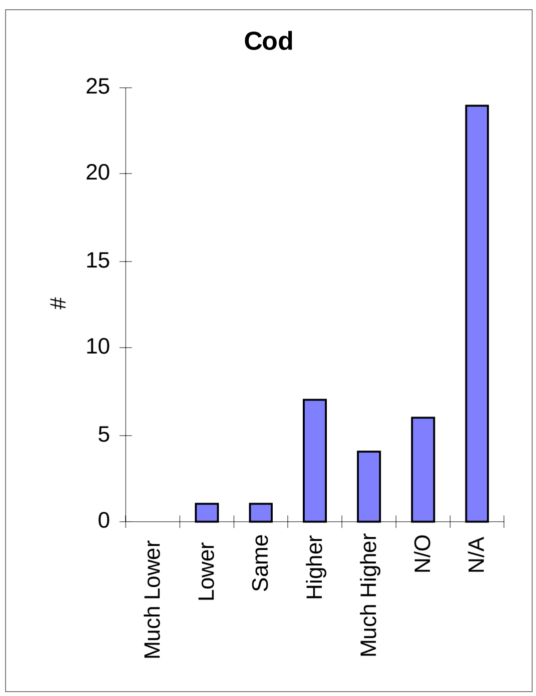


Figure 9 Opinions of respondents asked to compare the abundance of cod in 1998 with its abundance from 1993 to 1997 (cod was their 'first priority')(Note: N/O = No Opinion and N/A = Not Applicable (these fishers had no activity in 1997)).

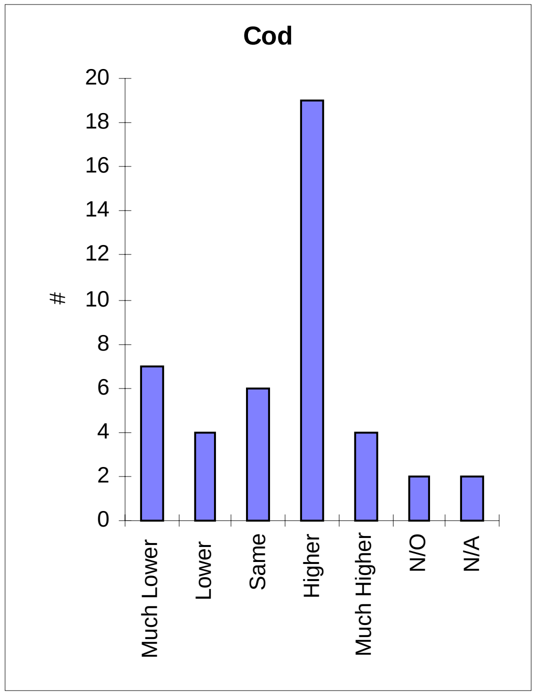


Figure 10: Opinions of respondents asked to compare the abundance of cod in 1998 with its abundance during all of the years that they fished for this species (cod was their 'first priority')(Note: N/O = No Opinion and N/A = Not Applicable).

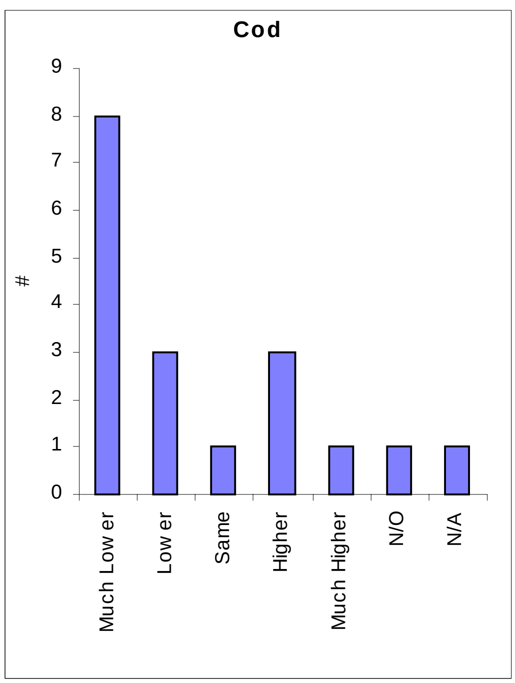


Figure 11: Opinions of sentinel fishery respondents asked to compare the abundance of cod in 1998 with its abundance during all of the years that

they fished for this species (cod was their ‘first priority’)(Note: N/O = No Opinion and N/A = Not Applicable).

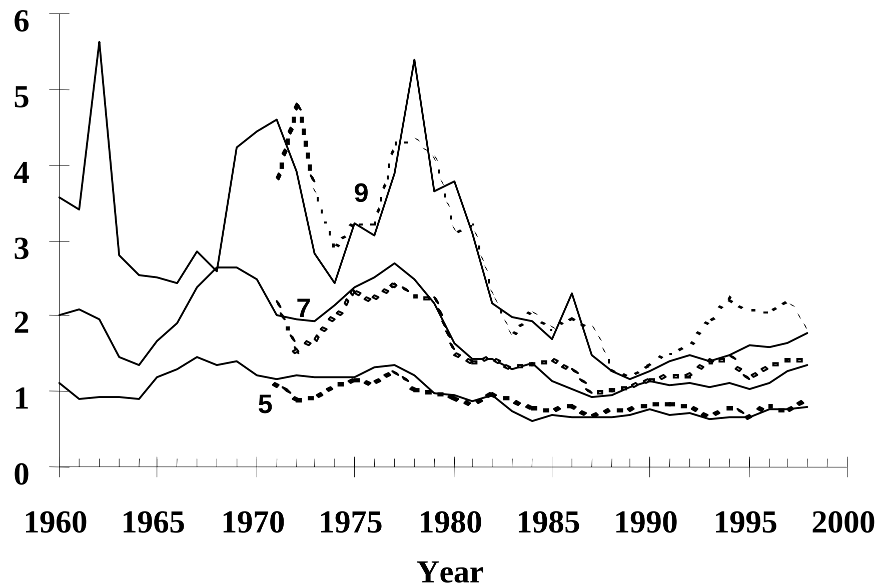


Figure 12: Trends in mean weights (kg) at ages 5, 7, and 9 of southern Gulf cod from the commercial fishery (dashed lines) and the research vessel surveys (solid lines), 1960 to 1998.

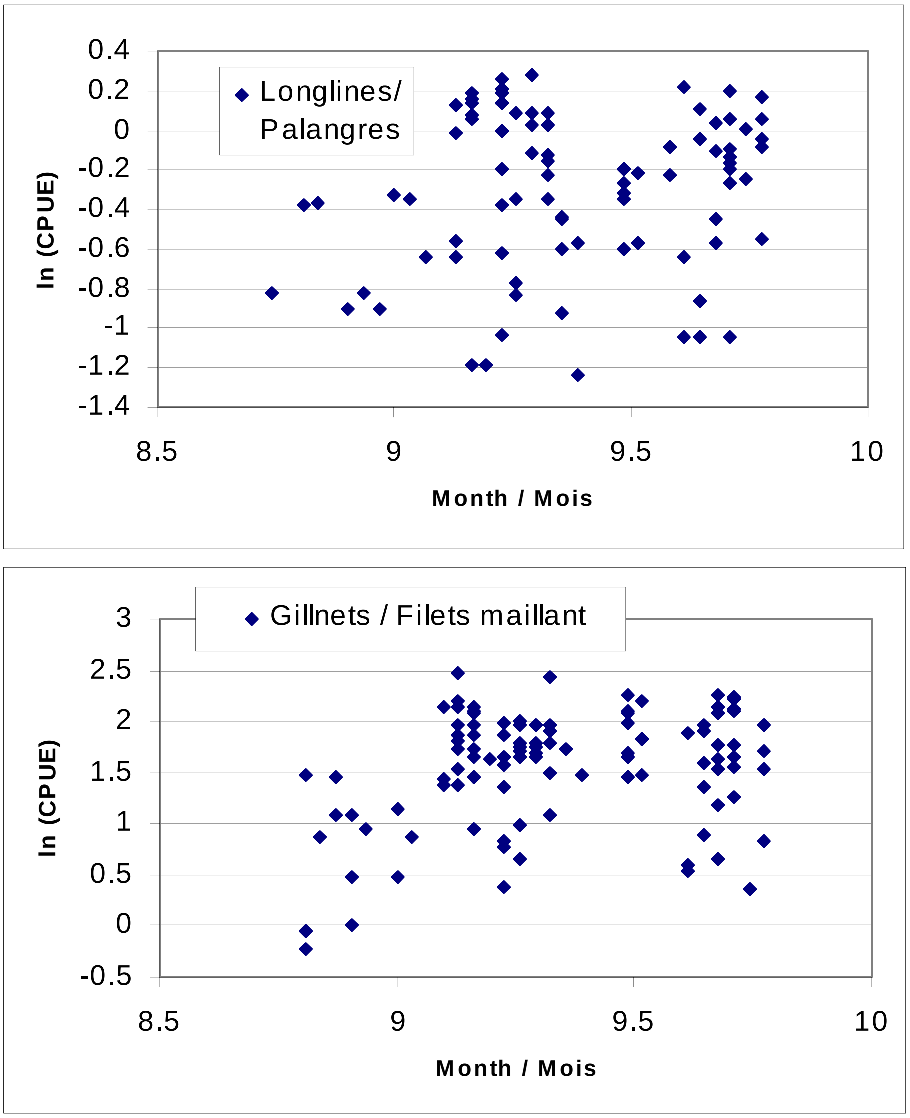


Figure 13 : Log CPUE by month for the 1998 fixed gear (longlines and gillnets) index fishery in the southern Gulf of St. Lawrence. CPUE for longlines are kg/ 1000hooks and kg/net for gillnets.

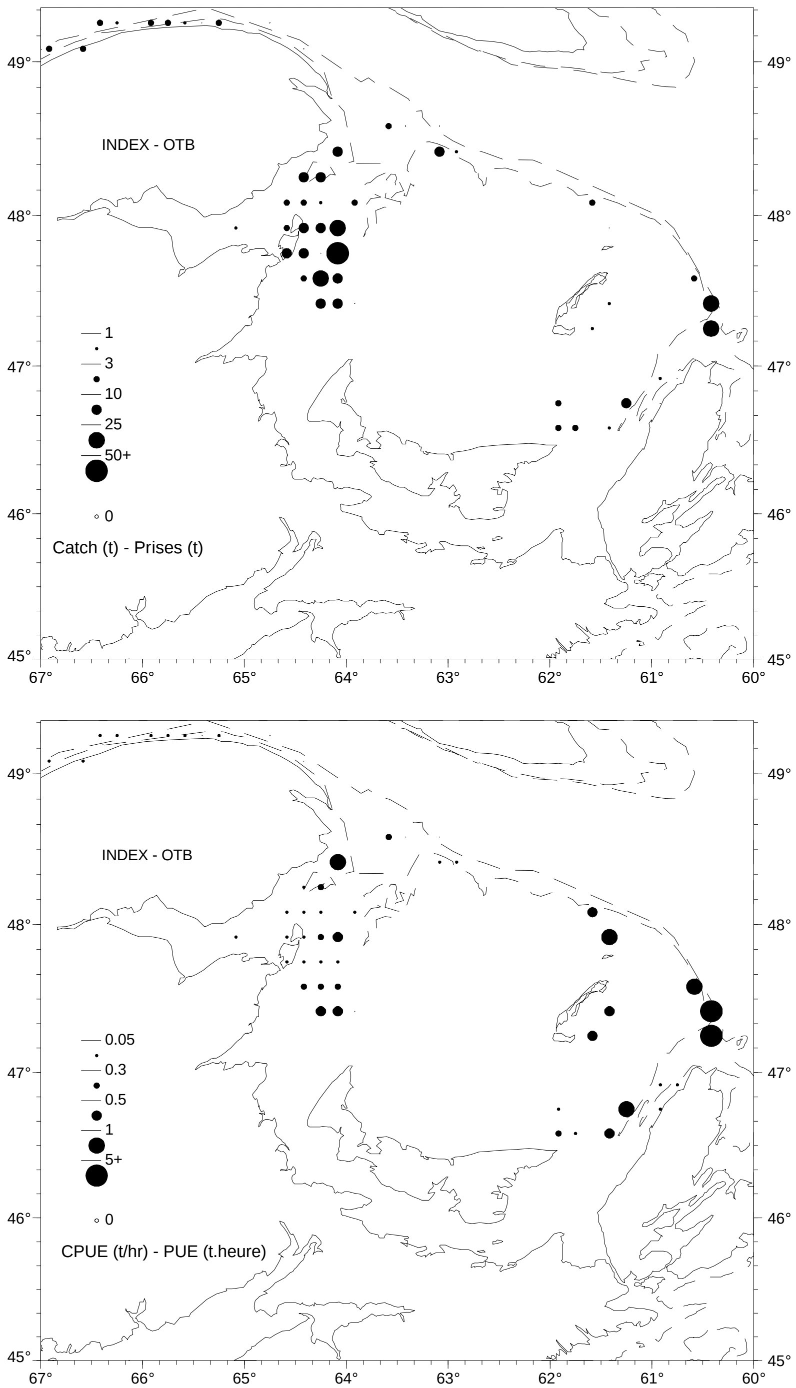
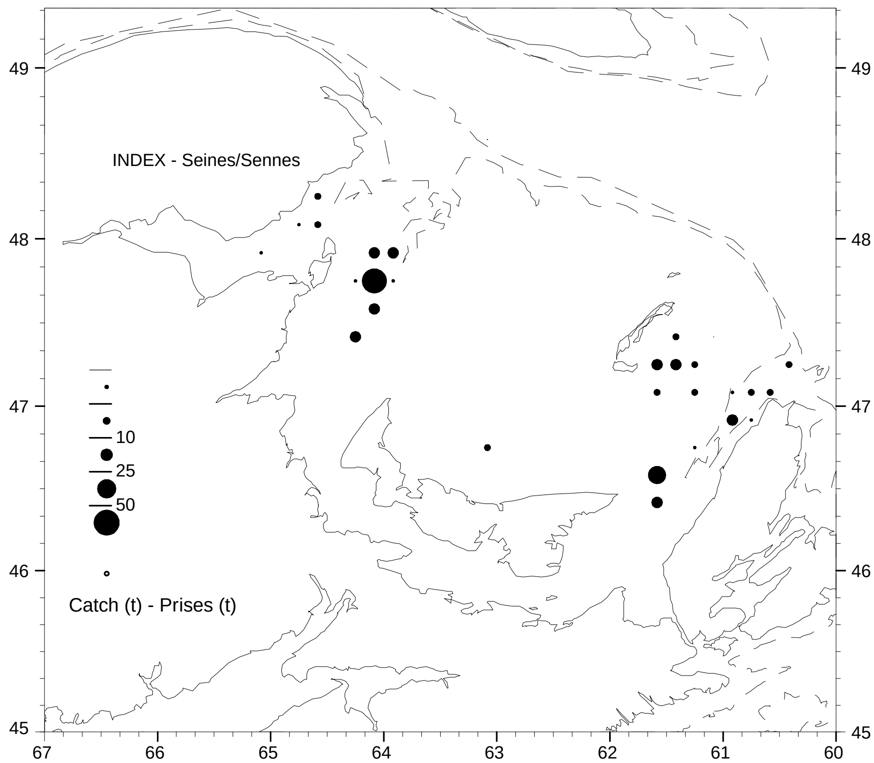


Figure 14: Distribution of catch and catch rates in the 1998 otter trawl index fishery in the 1998 southern Gulf of St. Lawrence aggregated by 10 minute squares.



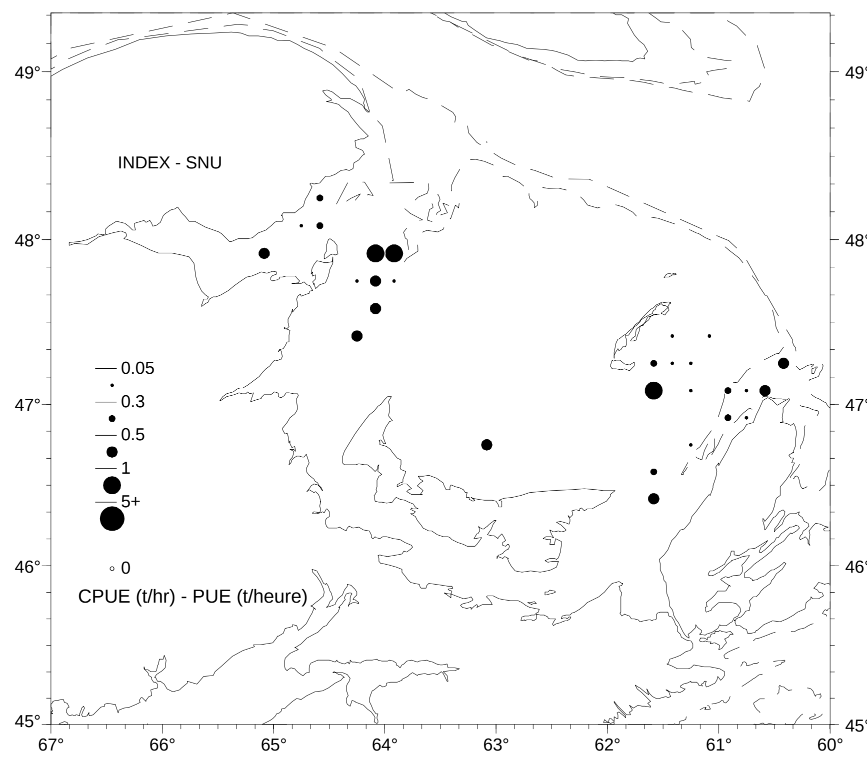


Figure 15: Distribution of catch and catch rates in the 1998 seines index fishery in the 1998 southern Gulf of St. Lawrence aggregated by 10 minute squares.

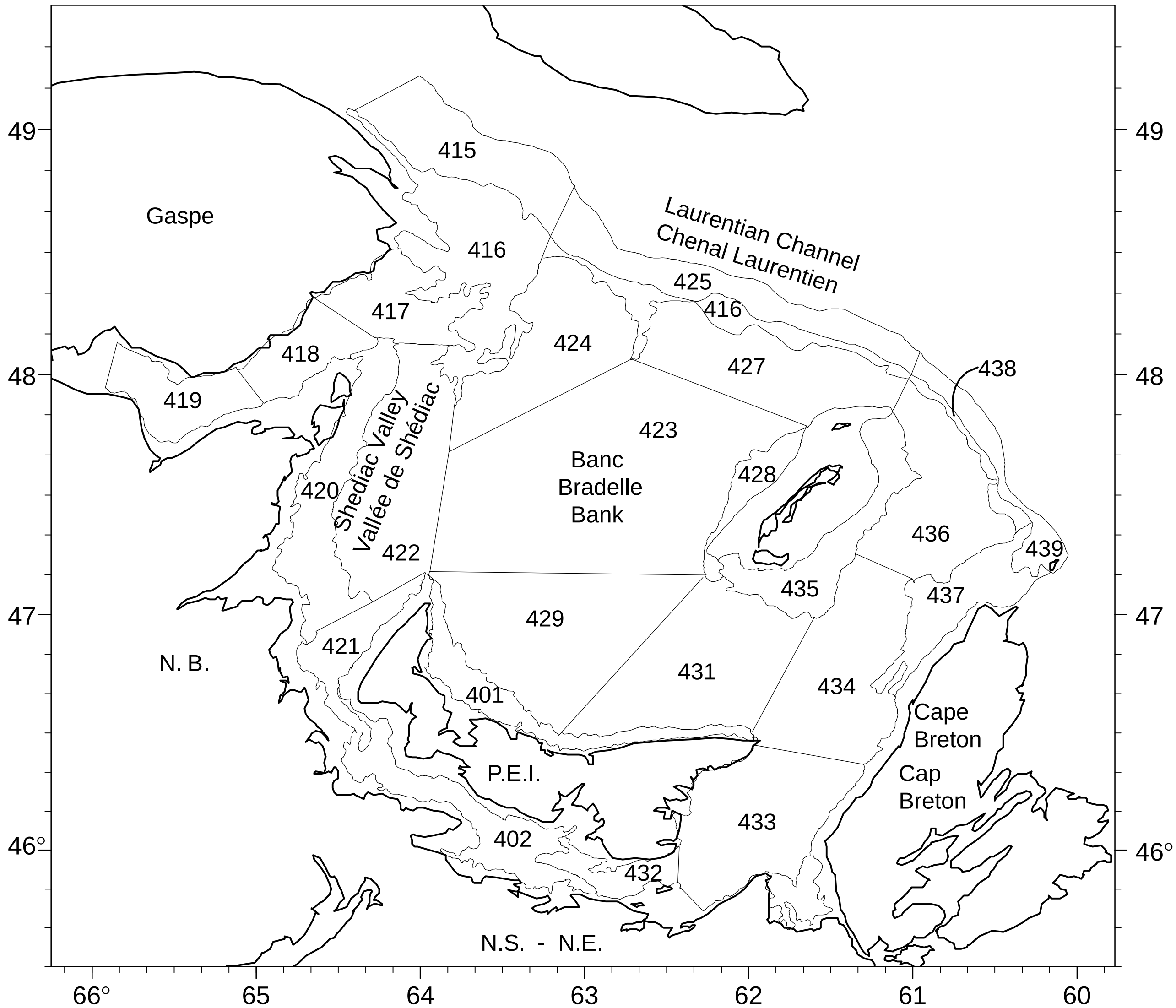


Figure 16: Stratification scheme for the southern Gulf of St. Lawrence groundfish survey and place names cited in the text. Strata depths are as follows: < 50 fathoms: 401-403, 417-424, 427-436; 51-100 fathoms: 416, 426, 437-438; >100 fathoms: 415, 425,439.

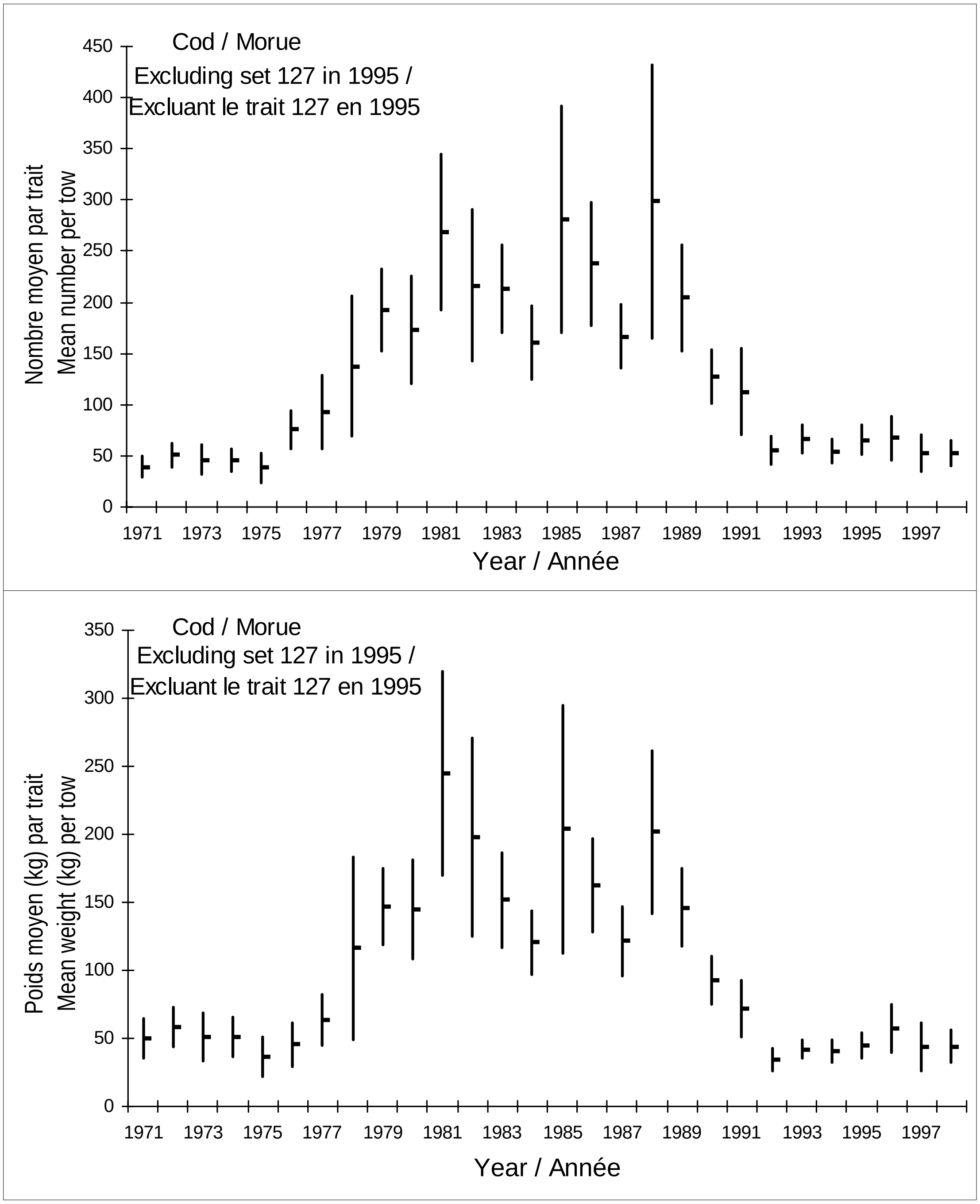


Figure 17: Mean number per tow (top) and mean weight per tow in kg (bottom) for ages 0+ cod in the southern Gulf of St. Lawrence September groundfish surveys. Error bars indicate approximate 95% confidence intervals.

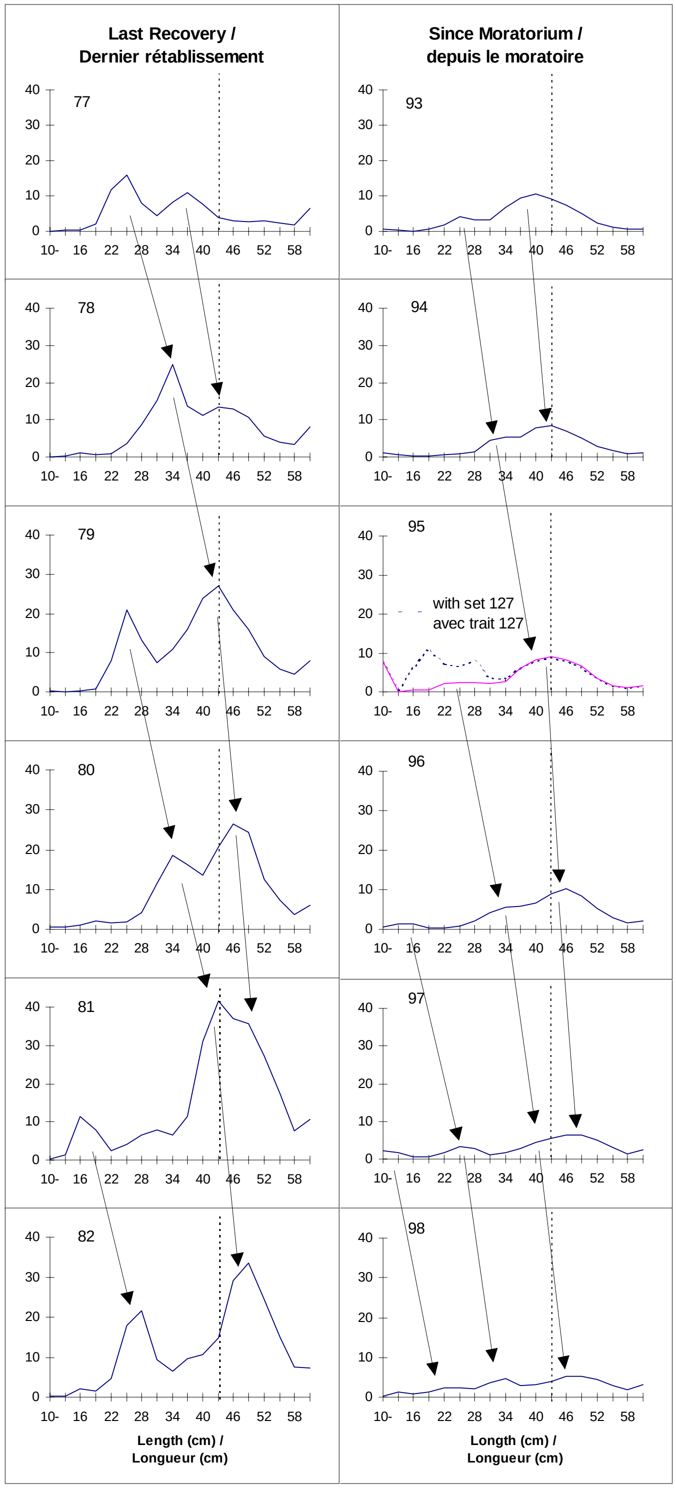


Figure 18: Comparison of survey length composition (numbers per tow) for 4T-Vn (N-A) cod during the period of the last recovery (1977-1982) and since the moratorium (1993-1998). Arrows indicate approximate progression of cohorts in the population.

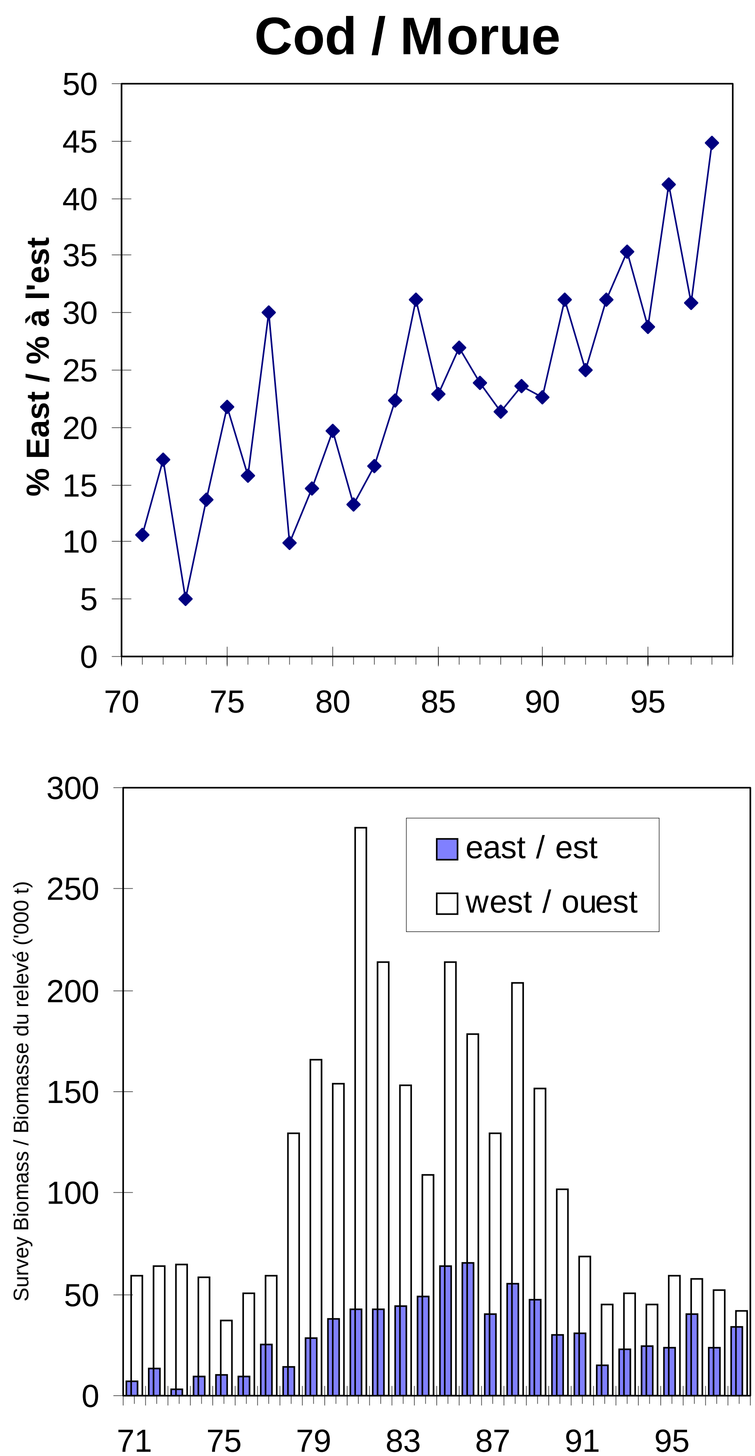


Figure 19: Distribution of cod survey biomass between eastern (strata 431-439) and western (strata 415-429) regions of the southern Gulf of St. Lawrence.

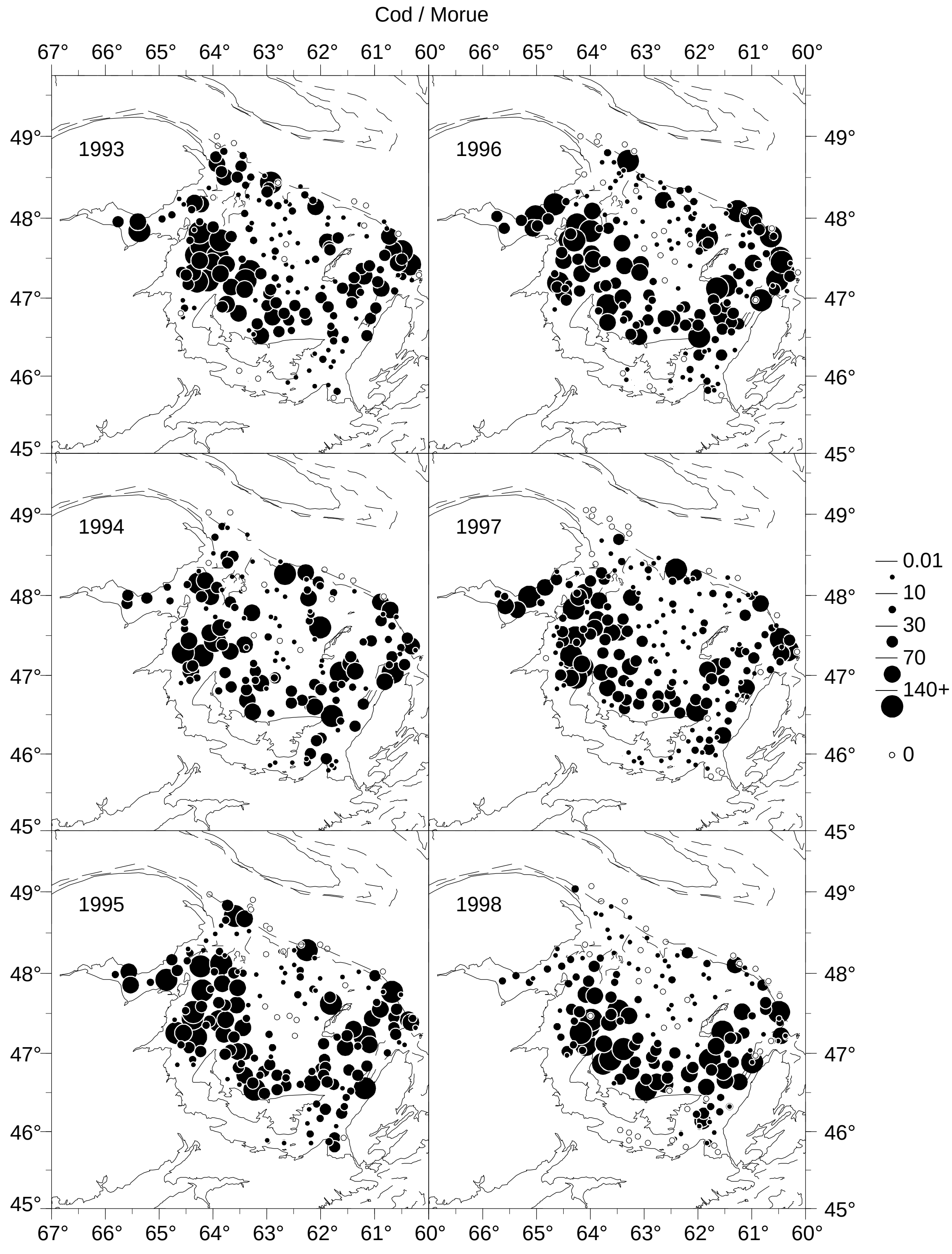


Figure 20: Cod catches (kg) in the southern Gulf of St. Lawrence September groundfish survey from 1993 to 1998.

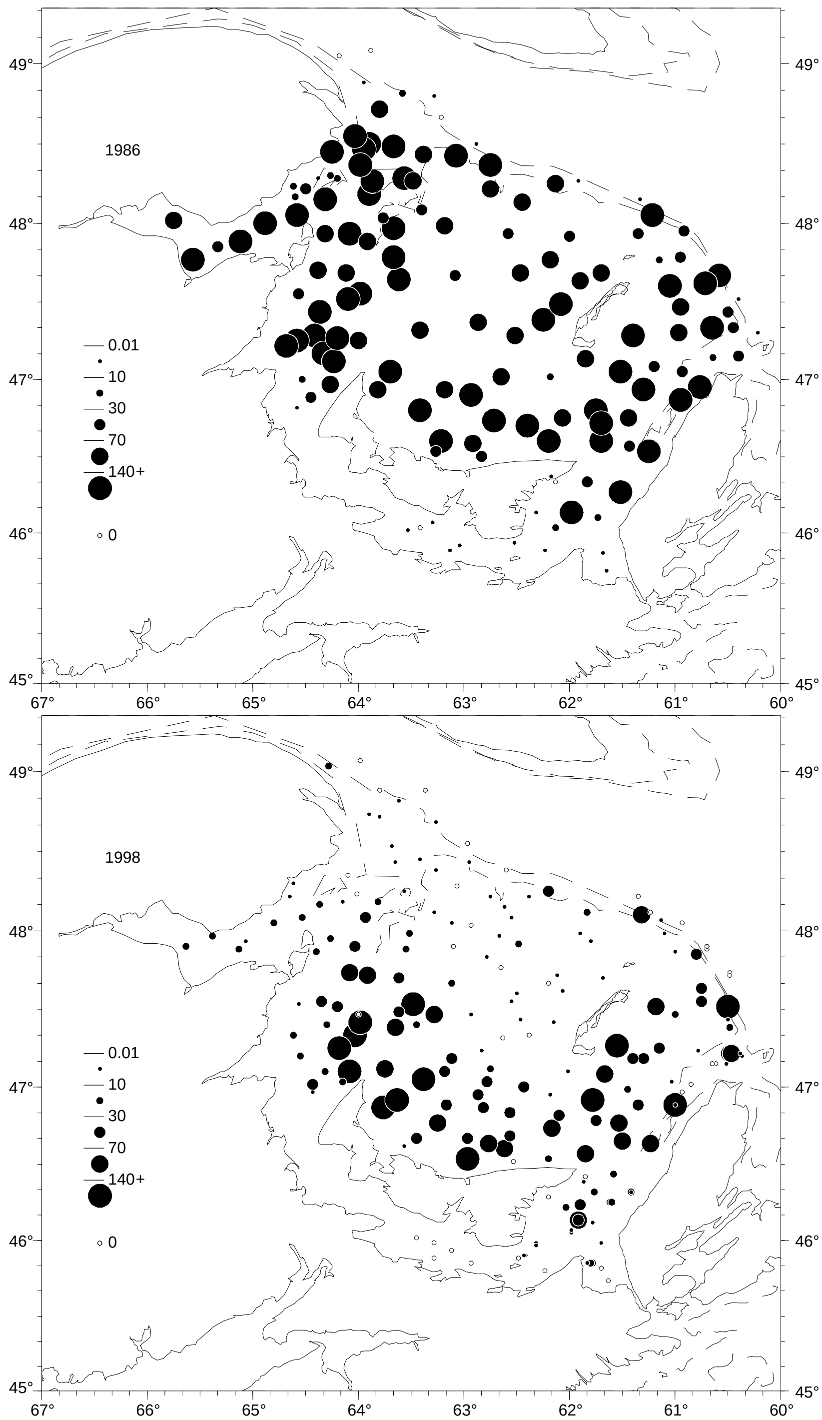


Figure 21: Cod catches (kg) in the southern Gulf of St. Lawrence groundfish survey during the period of high abundance (1986) and the most recent survey during a period of low abundance.

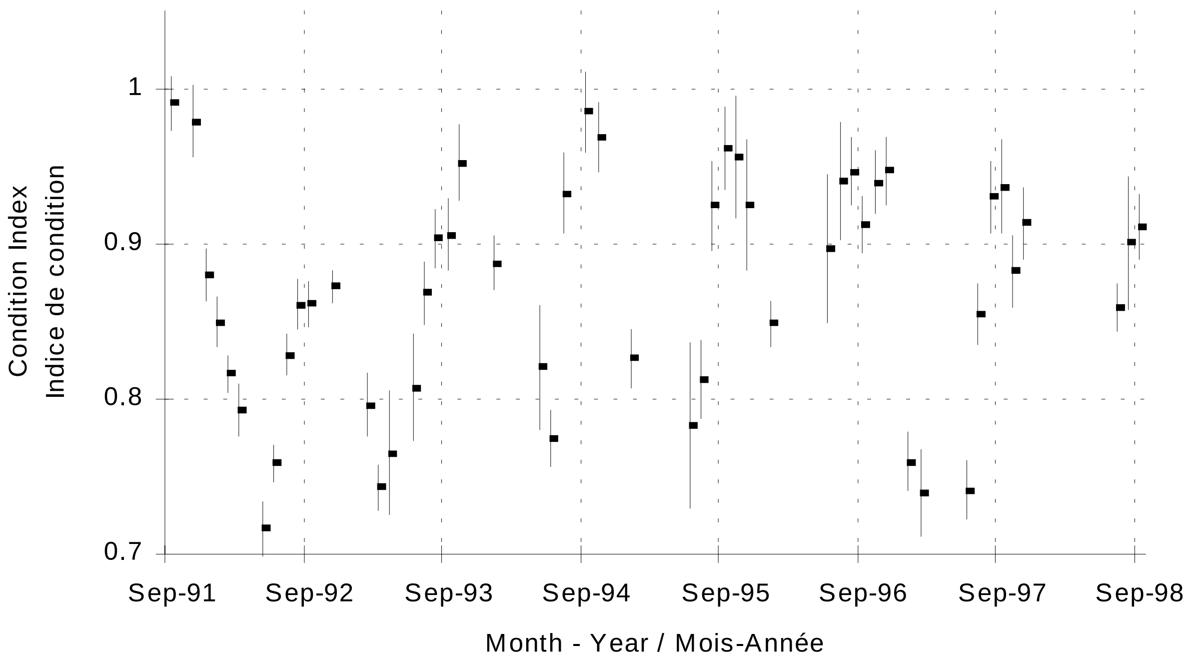
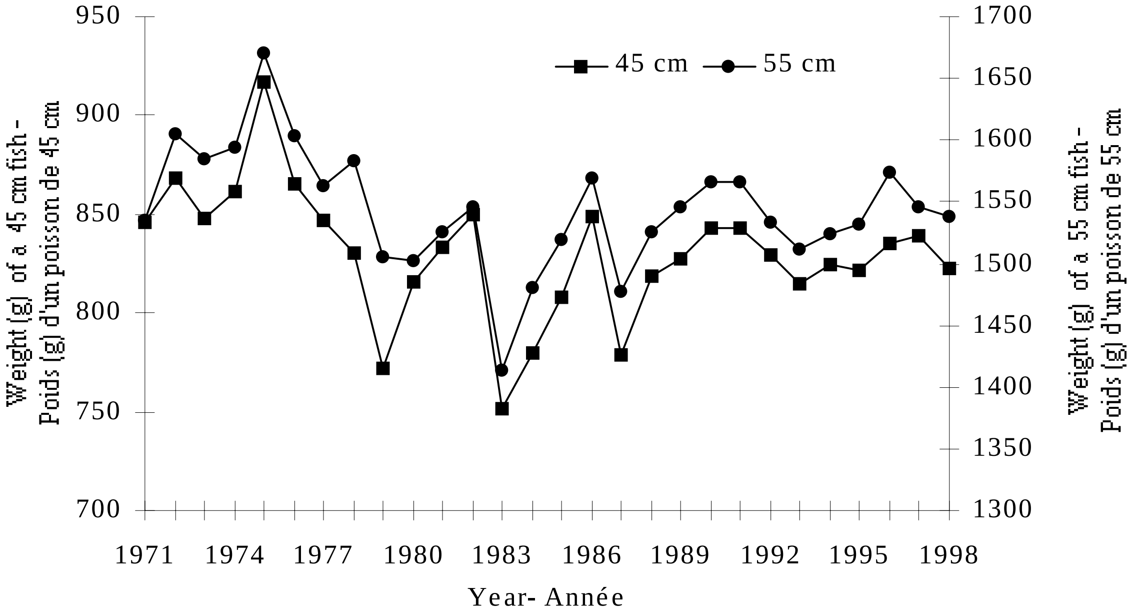


Figure 22: Seasonal change in condition index (carcass weight/length^3) +/ - 2 standard errors for southern Gulf of St. Lawrence cod of 40-50 cm length between September 1991 and September 1998.



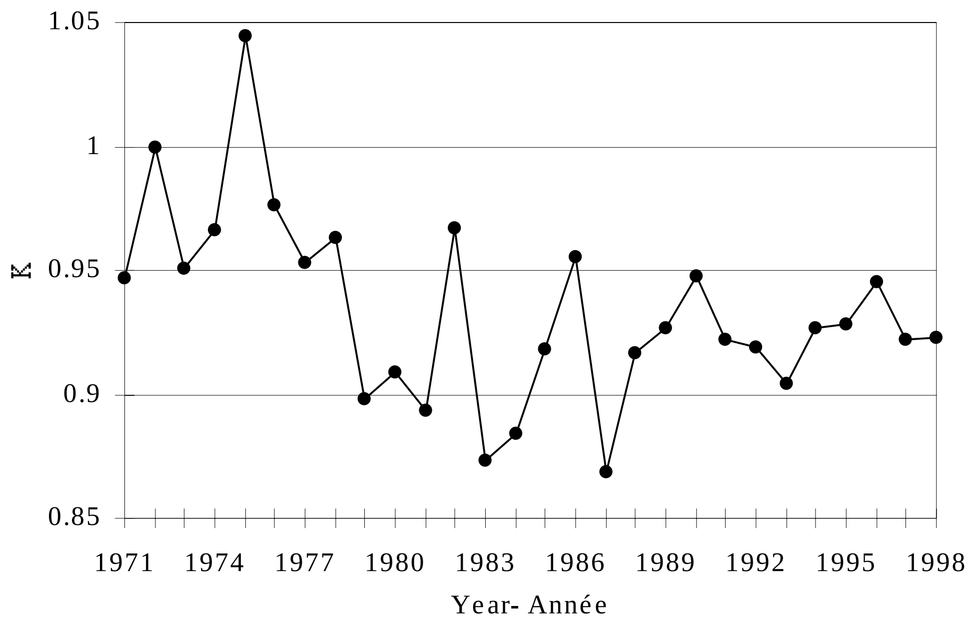


Figure 23: Condition indices derived from length and weight data collected during the annual groundfish surveys in the southern Gulf of St. Lawrence. The top graph shows the predicted weight for a 45 and a 55 cm cod from the length-weight relationship. The bottom graph shows the condition factor calculated for fish ranging from 40 to 50 cm.

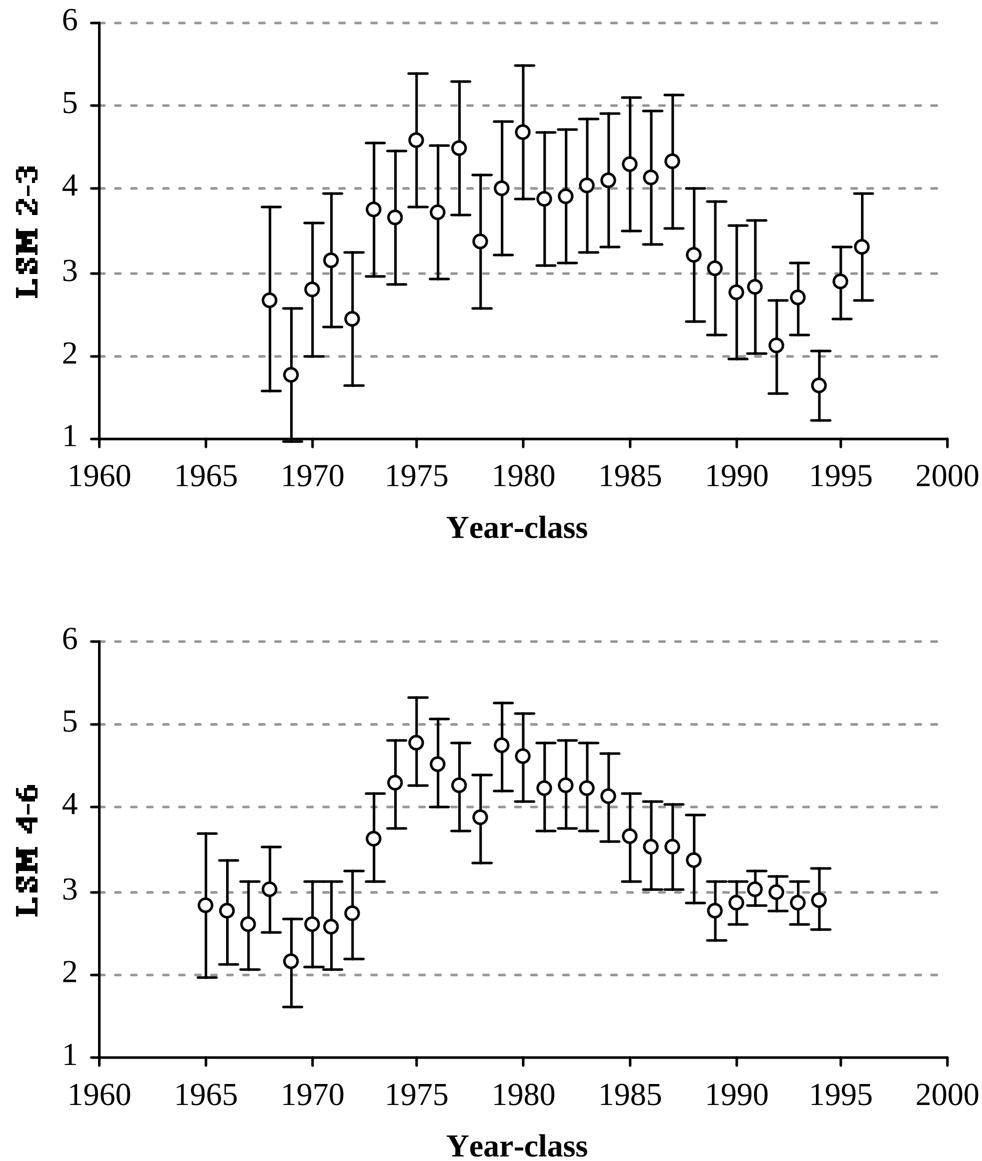


Figure 24: Relative year-class abundance estimated from research vessel and sentinel survey results for southern Gulf cod. The upper panel is for ages 2-3 and the lower is for ages 4-6. Error bars give 2 standard errors. The estimates are in the ln scale.

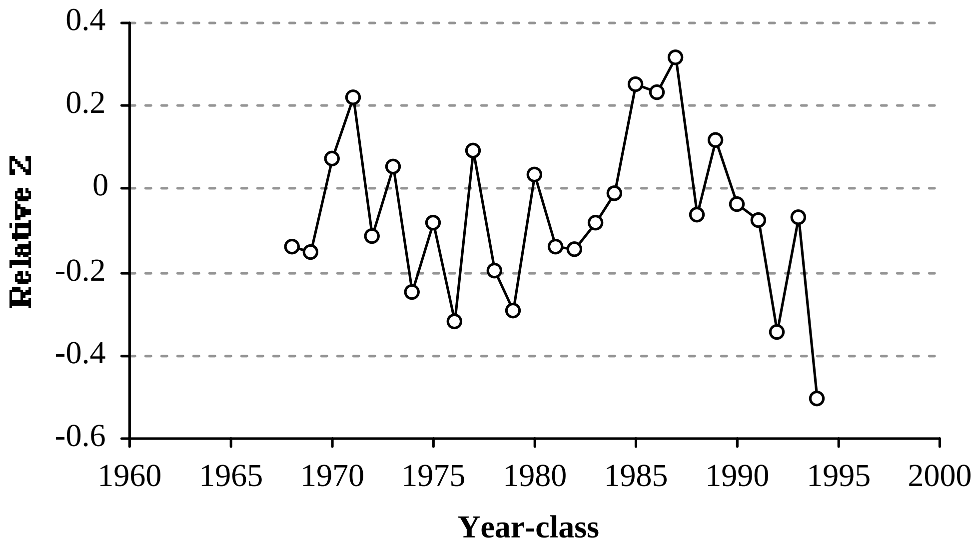


Figure 25: Trend in relative total mortality between ages 2-3 and 4-6 for southern Gulf cod, estimated from multiplicative analyses of research vessel and sentinel survey results.

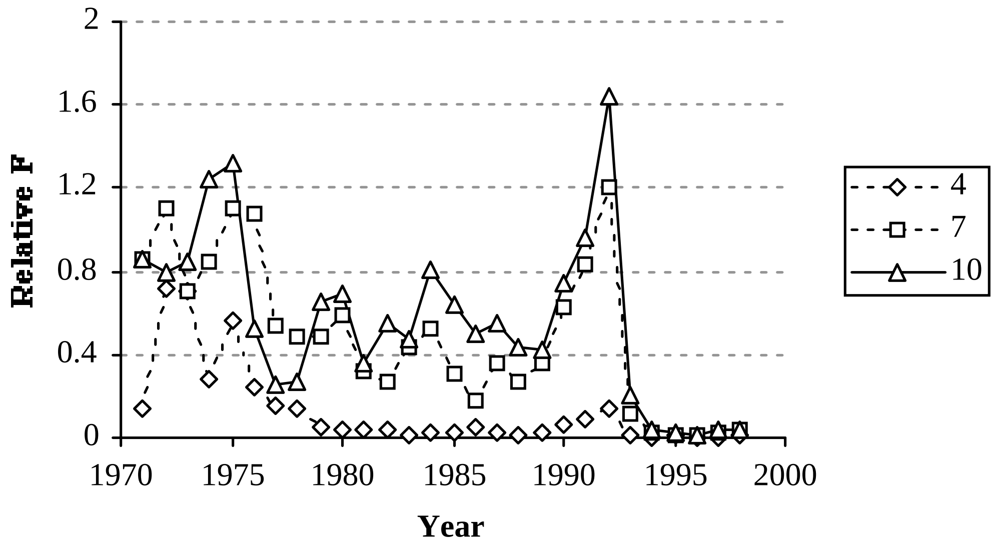


Figure 26: Trend in relative fishing mortality estimated as the ratio of catch at age divided by RV population estimates at age for southern Gulf cod. Separate estimates are presented for ages 4, 7 and 10.

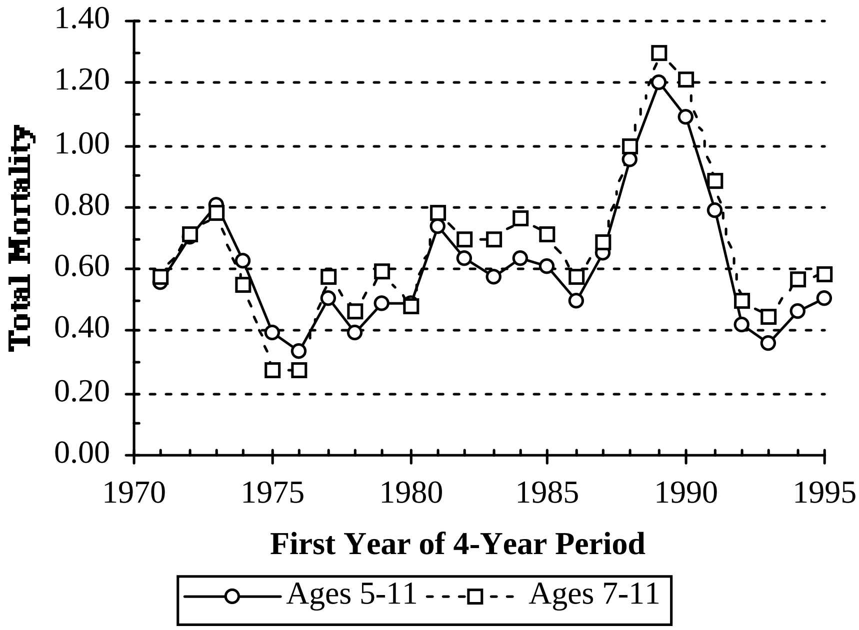


Figure 27: Total mortality of southern Gulf of St. Lawrence cod estimated by a modified catch curve analysis of RV results in 4-year moving windows. Two series are presented, one with ages 7-11 and the other with ages 5-11.

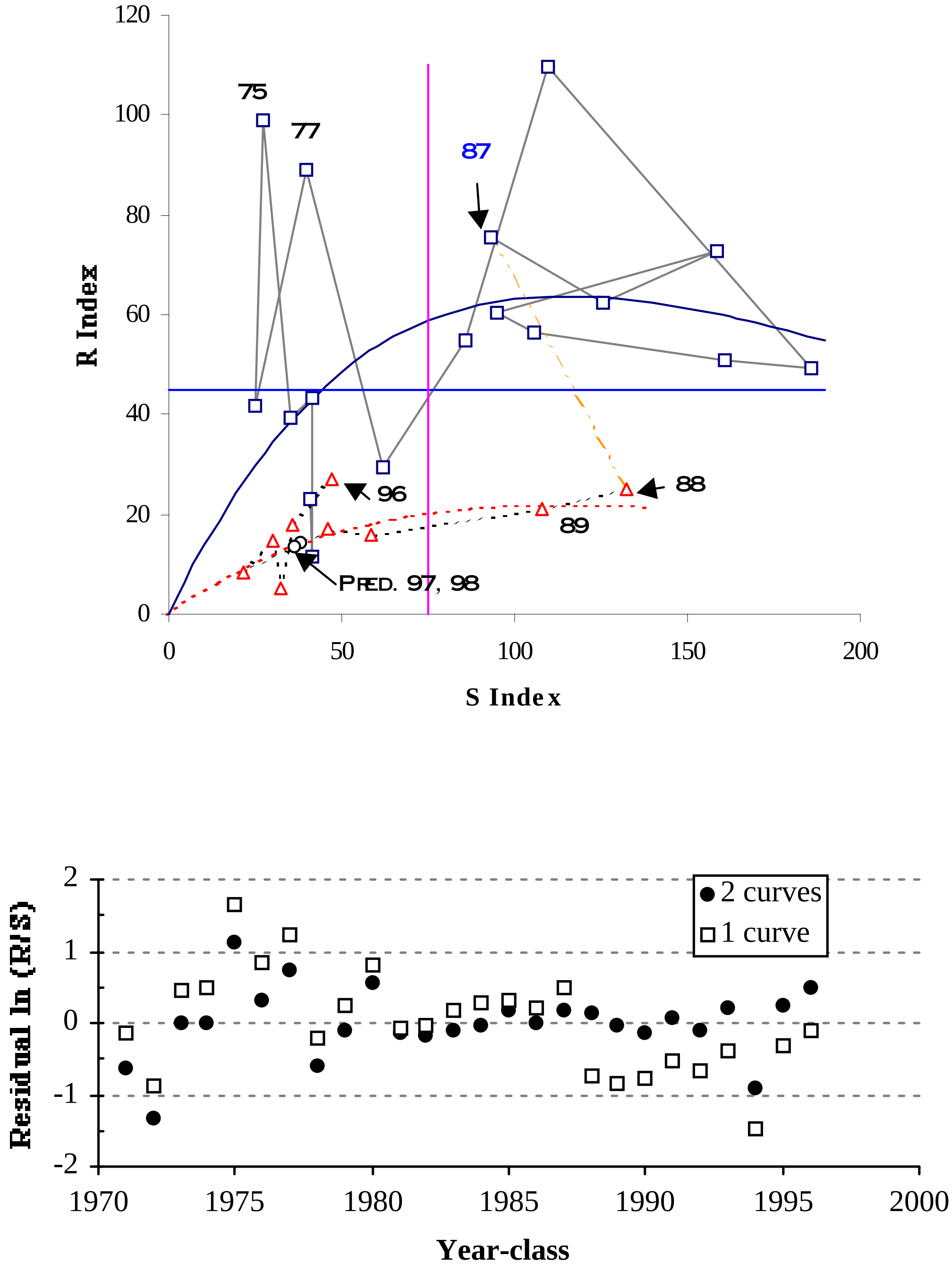


Figure 28: Stock and recruitment estimates for southern Gulf cod obtained from RV and sentinel survey results. The upper panel plots spawning stock biomass and recruitment. The points are connected in temporal sequence and key year-classes are labelled. It includes lines separating the plot in quadrants of high and low recruitment and biomass index above and below 75 kg per tow. It also includes two fitted Ricker stock recruitment relationships. The lower panel shows residuals from fitting one curve (open square) and two curves (closed circle.

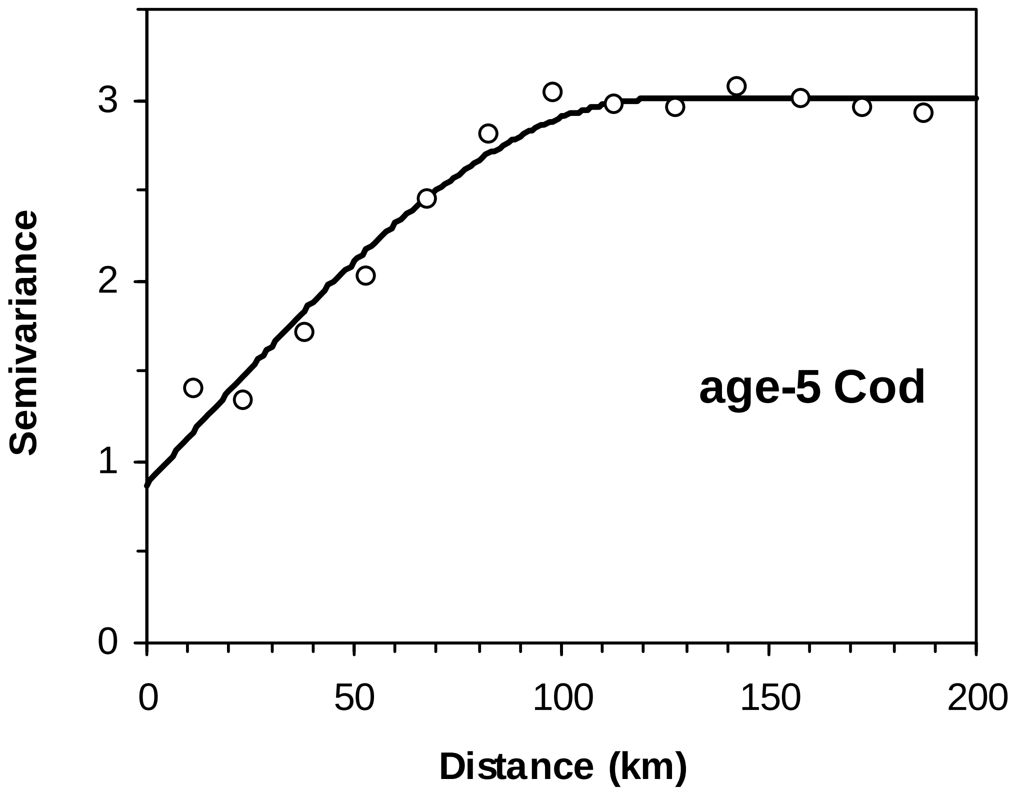


Figure 29: Variogram for the ln-transformed catch rates of 5-yr old cod in the September 1998 trawl survey of the southern Gulf of St. Lawrence.

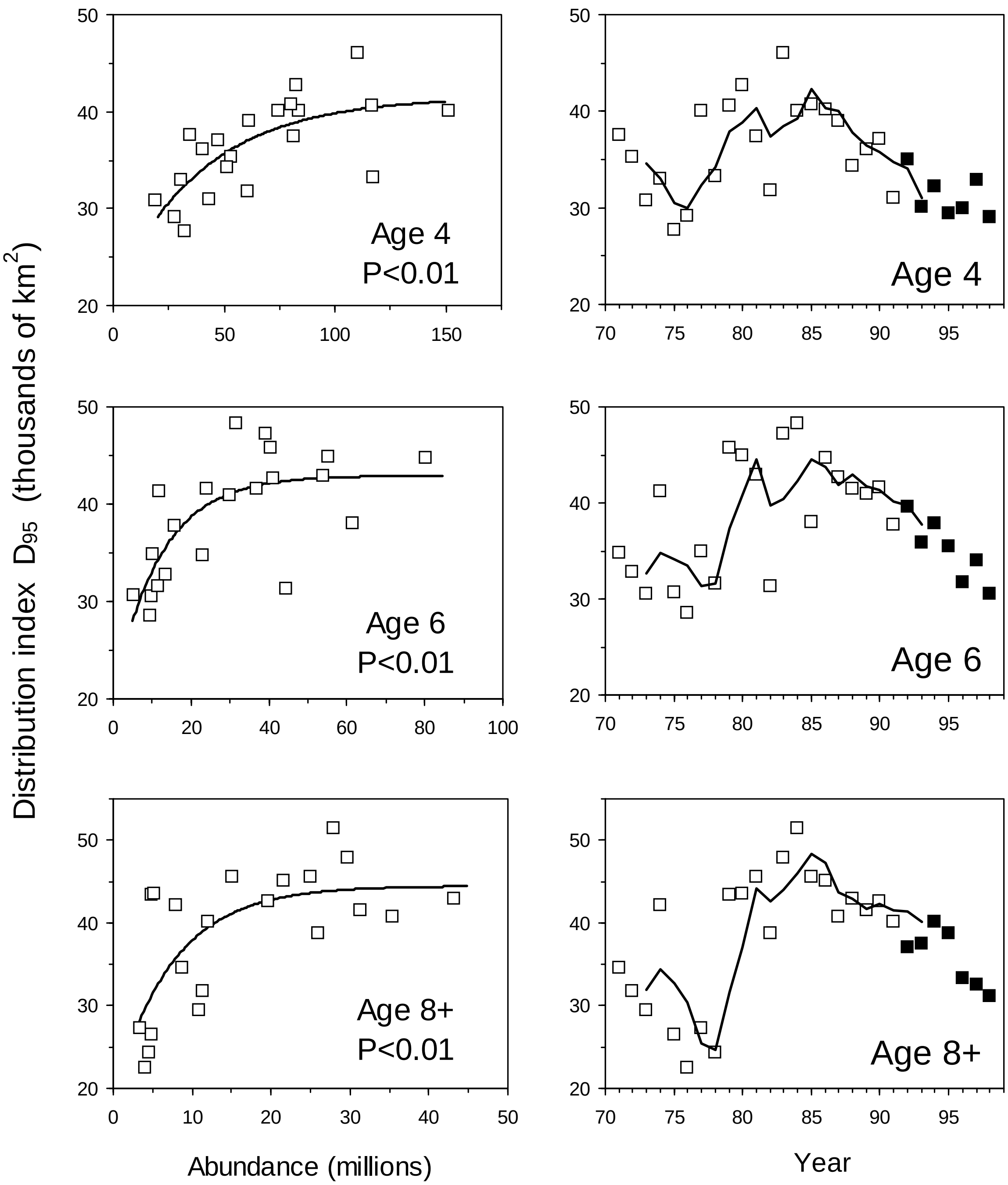


Figure 30: D95, the minimum area containing 95% of cod aged 4, 6 or 8+ years. Panels on the left show the relationship between D95 and abundance for 1971-1991 from Swain & Sinclair (1994). Panels on the right show interannual variation in D95. Open squares are the 1971-1991 values from Swain & Sinclair (1994), closed squares show the 1992-1998 values. Line in right panels is a 3-yr moving average for the 1971-1991 data.

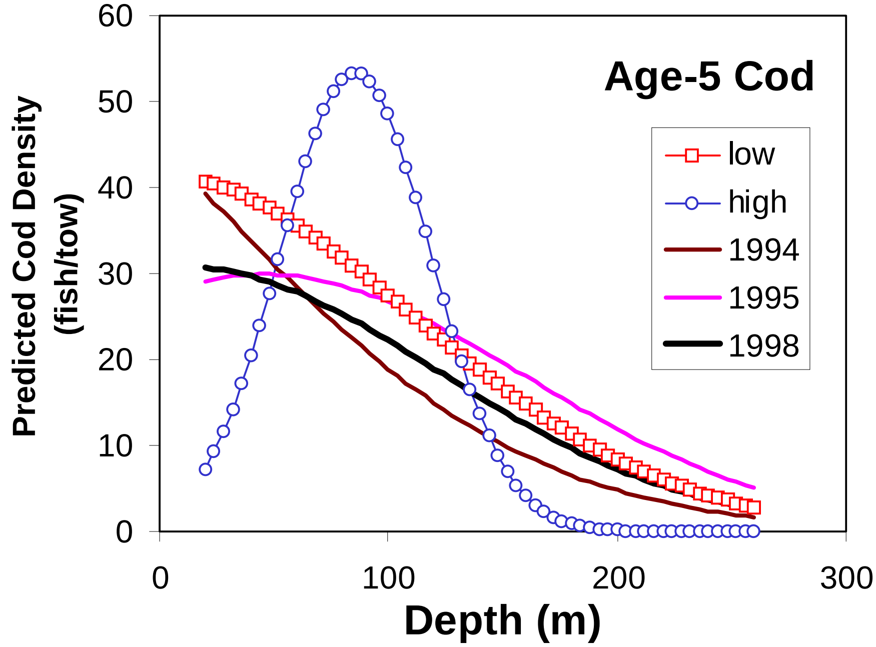


Figure 31: Poisson regression lines predicting the density (fish/tow) of age-5 cod (adjusted to an average value of 25 fish/tow in each year) from depth, for five years of low abundance in the mid 1970s, five years of high abundance in the early to mid 1980s, and for recent (1994, 1995, 1998) years.

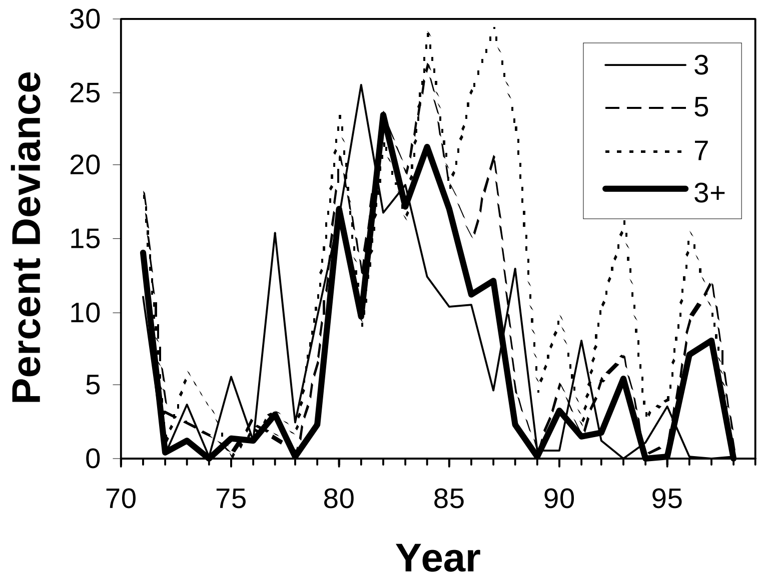


Figure 32: Percent of the deviance (D_Q) in cod catch rates explained by the quadratic term in Poisson regression models relating cod density (ages 3, 5, 7, or 3+ yr) to depth.

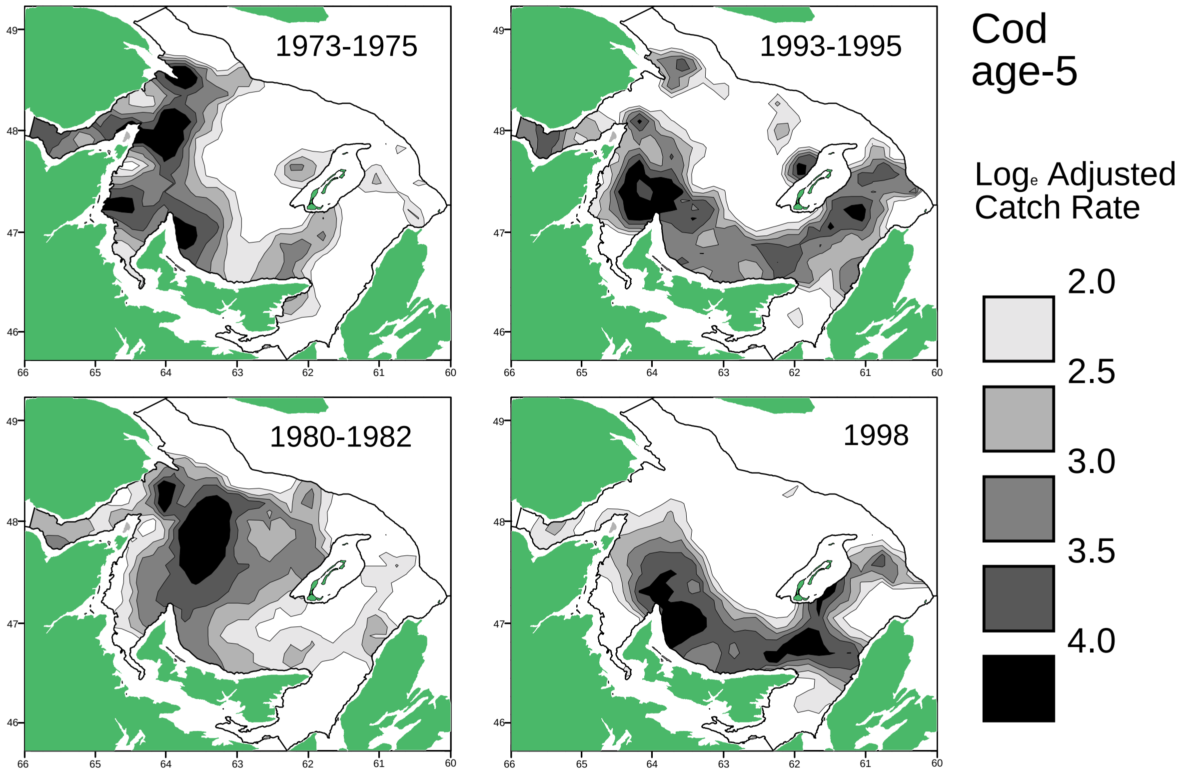


Figure 33: Distribution of 5-yr old cod in September in the southern Gulf of St. Lawrence in 1998 and in three earlier periods. Cod abundance was high in the 1980-1982 period and relatively low in the other periods. Cod density has been adjusted to the same average level (25 fish/tow) in all periods to emphasise changes in distribution rather than changes in overall abundance.

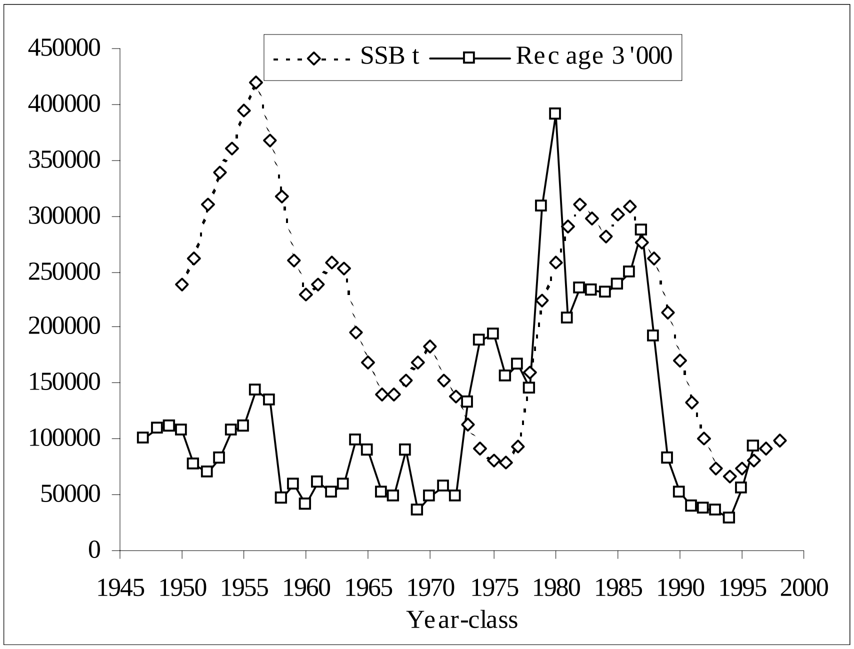


Figure 34: Trends in spawning stock biomass (SSB in tonnes) and recruitment (Age 3) for southern Gulf cod, estimated with an SPA which estimated M in 5 time/age periods.

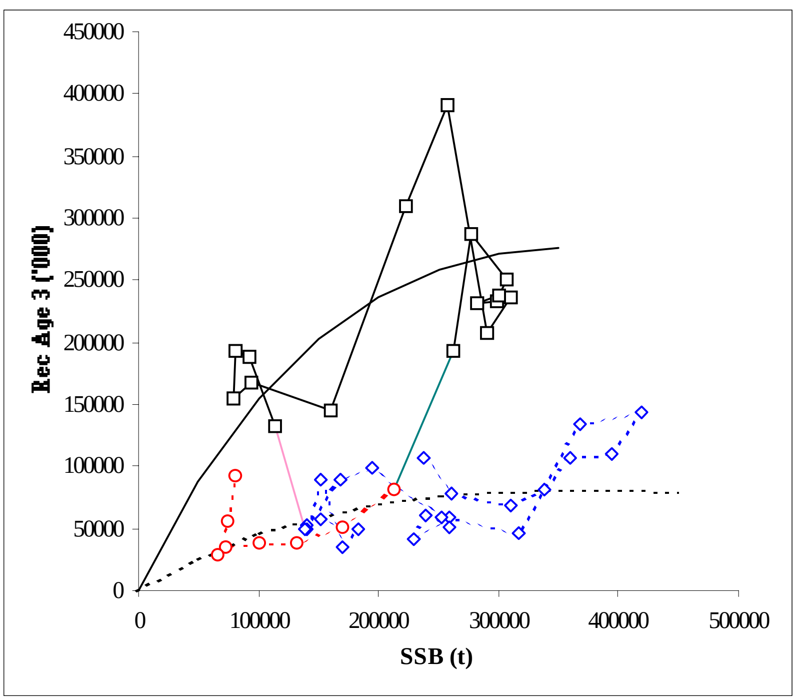


Figure 35: Stock recruitment plot for southern Gulf cod, estimated with an SPA which estimated M in 5 time/age periods. A Ricker relationship was fit to the data in time periods of low production (1950-71, 1989-96) and high production (1972-88).

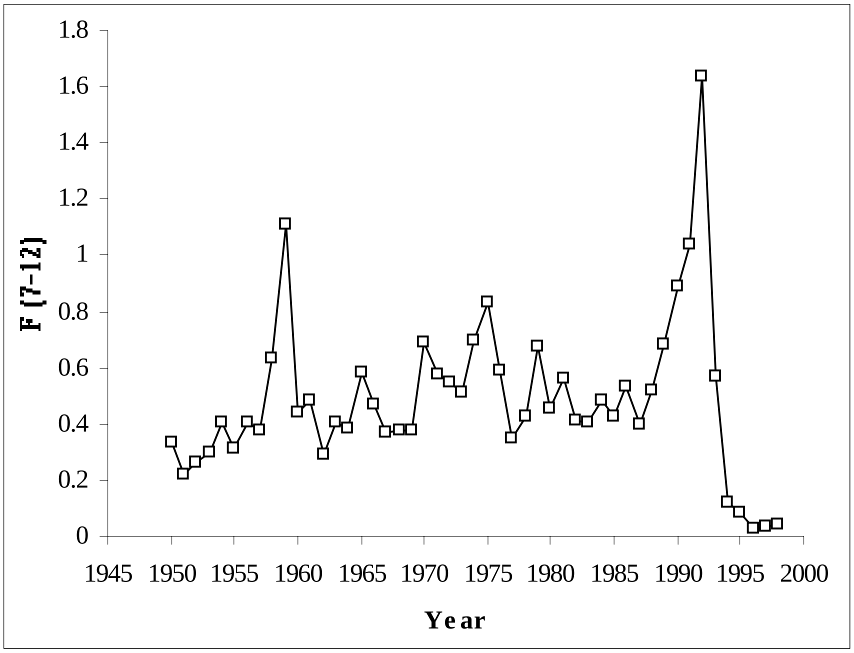


Figure 36 :Trends in fishing mortality for southern Gulf cod, estimated with an SPA which estimated M in 5 time/age periods.

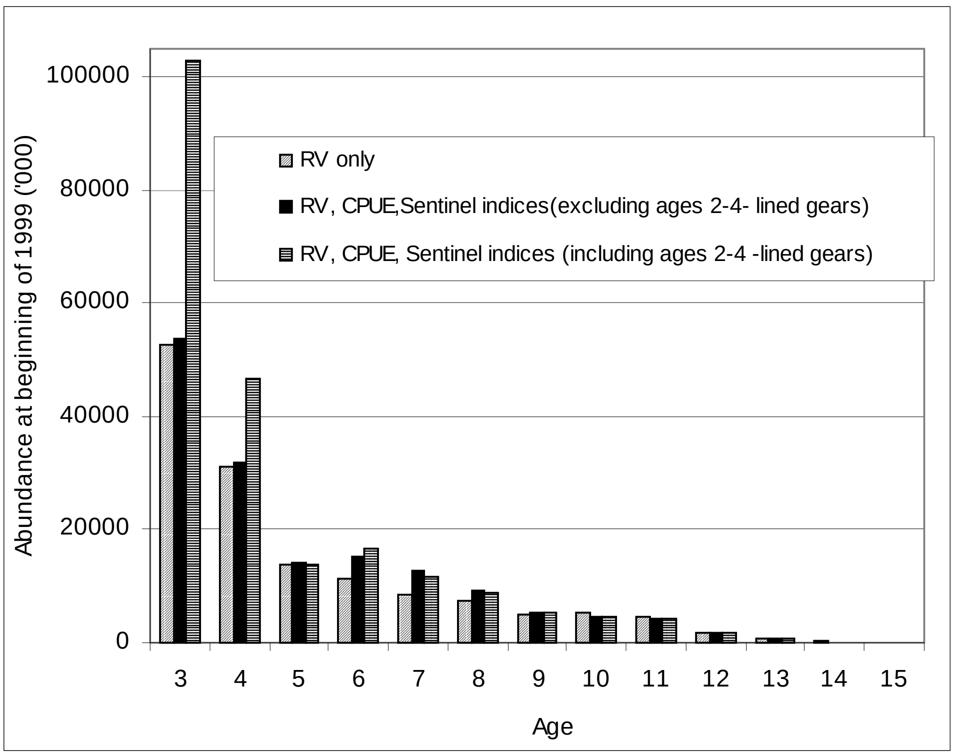


Figure 37: Population estimates in 1999 for various calibrations of SPA for southern Gulf of St. Lawrence cod (see text for details).

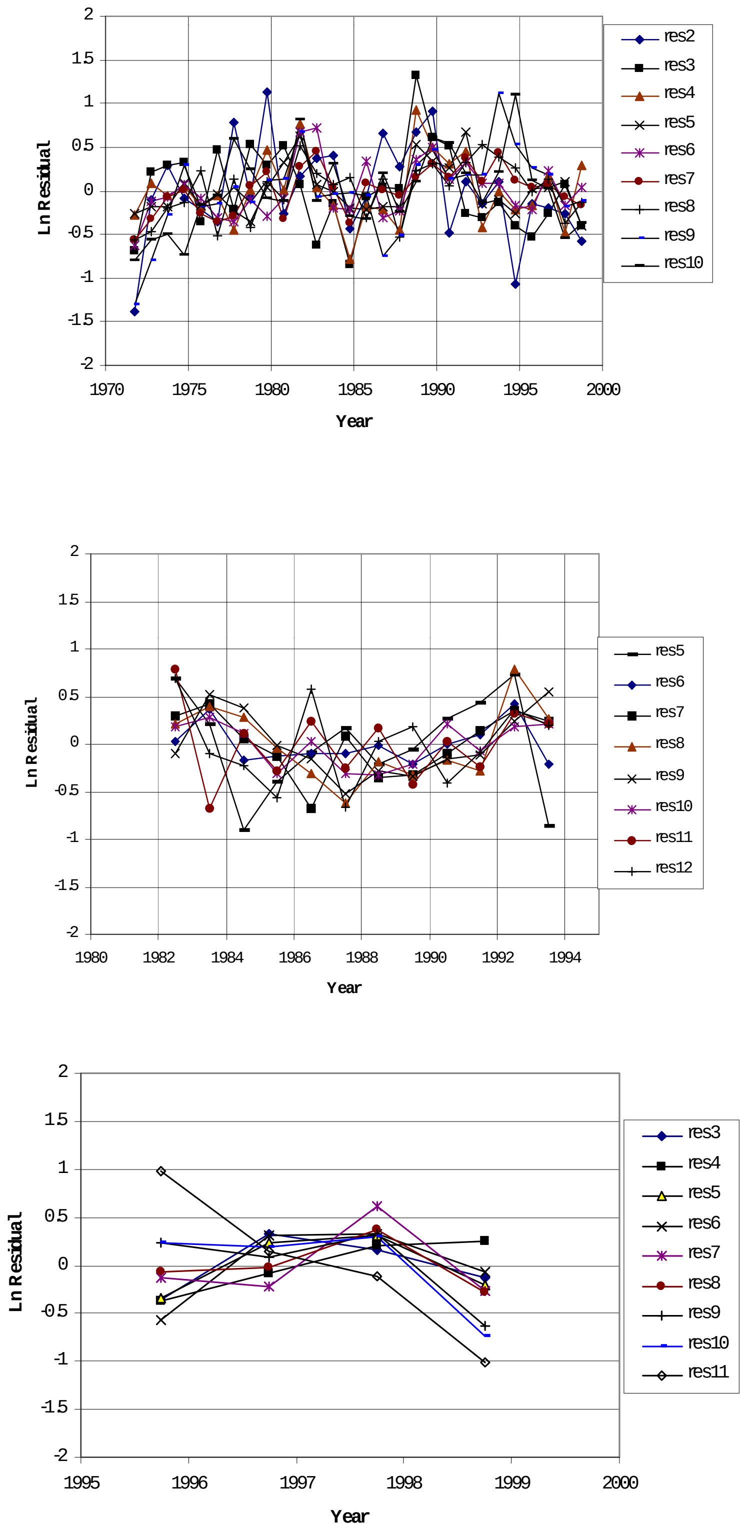
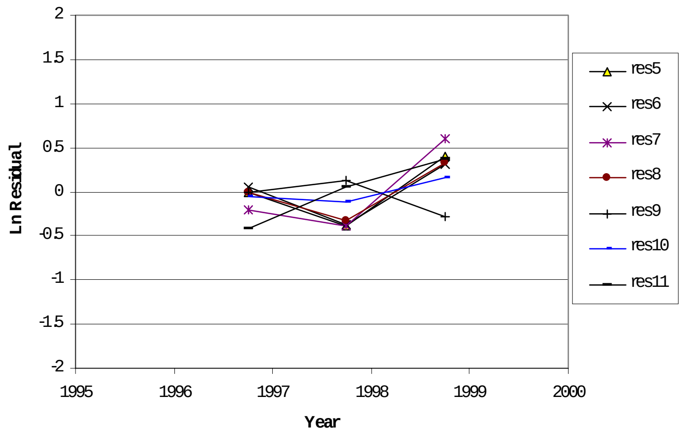
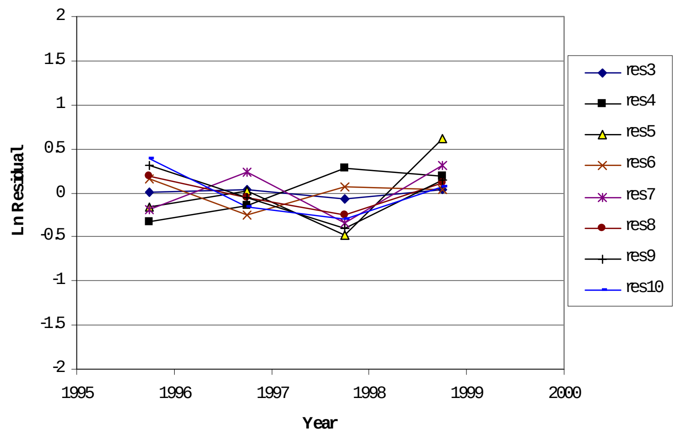


Figure 38: Residual patterns for the RV (top), CPUE (middle) and sentinel longline (bottom) indices of abundance for the ADAPT calibration.





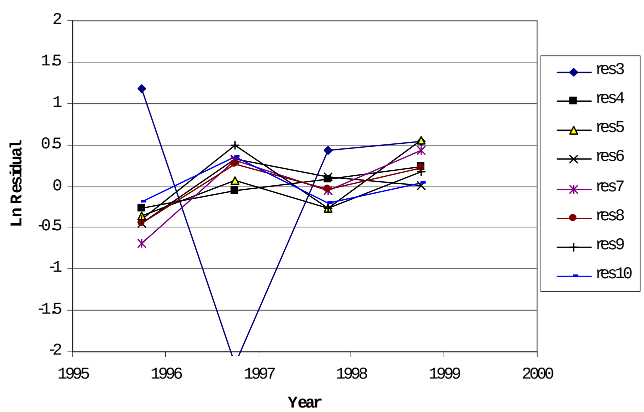


Figure 39: Residual patterns for the sentinel SNU_1 (top), SNU_0 (middle) and OTB_1 (bottom) indices of abundance for the ADAPT calibration.

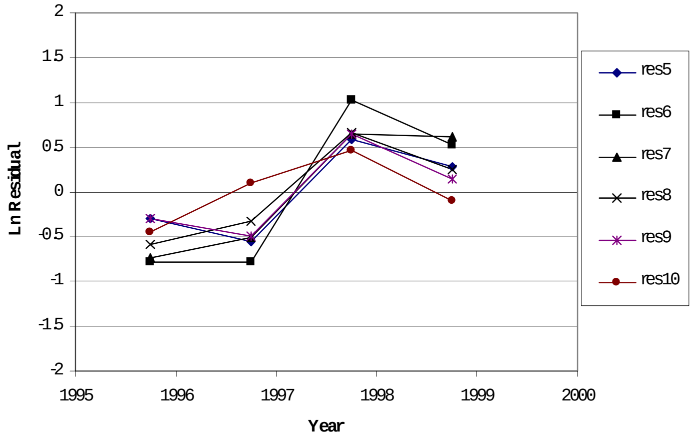


Figure 40: Residual patterns for the sentinel OTB_0 index of abundance for the ADAPT calibration.

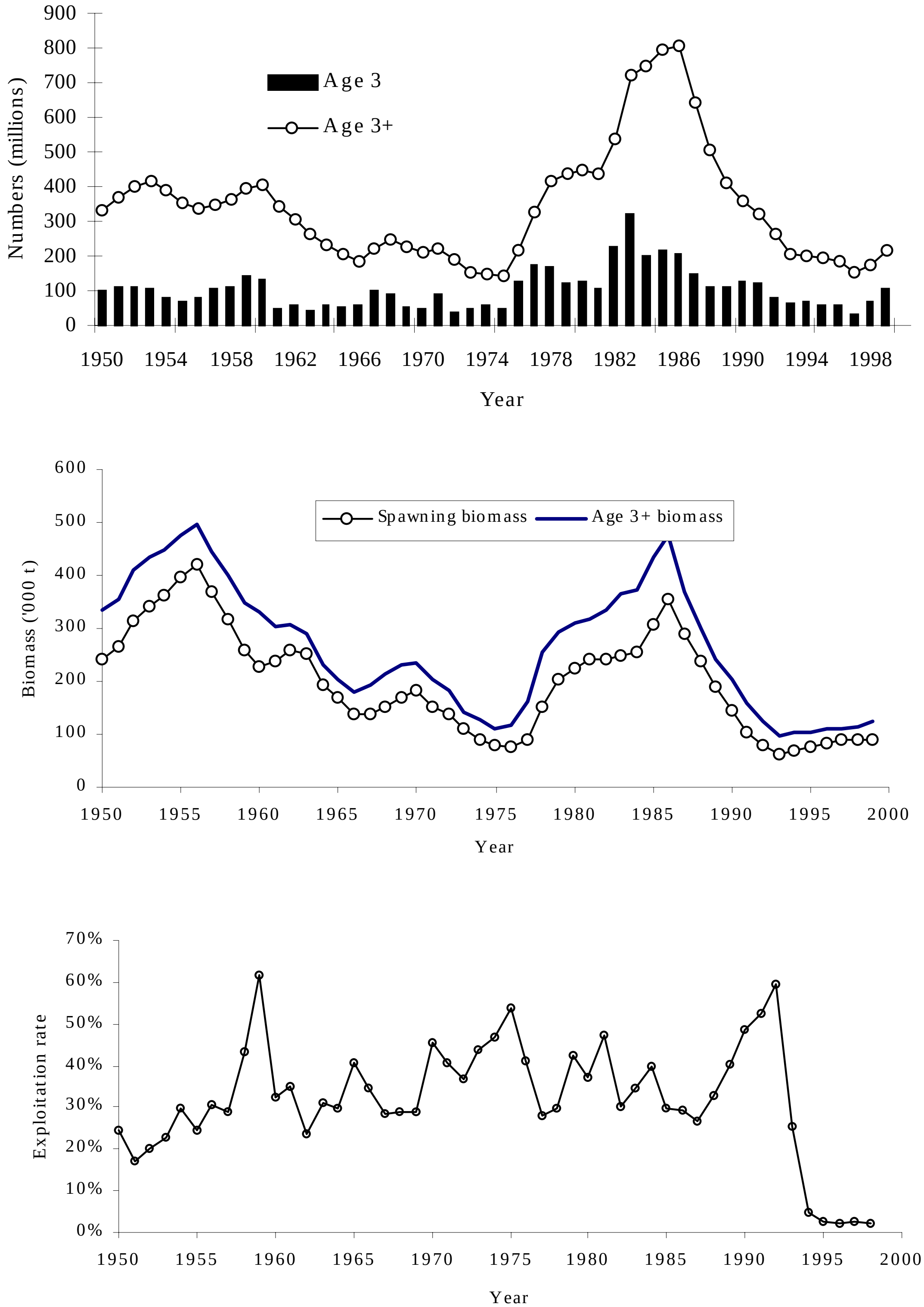


Figure 41: Recruitment, population and spawning biomass and exploitation rate trends for southern Gulf of St. Lawrence cod from the calibration using the RV, Sentinel (5), and CPUE abundance estimates with assumptions of M of 0.2 from 1971-1985 and 0.4 from 1986-1998.

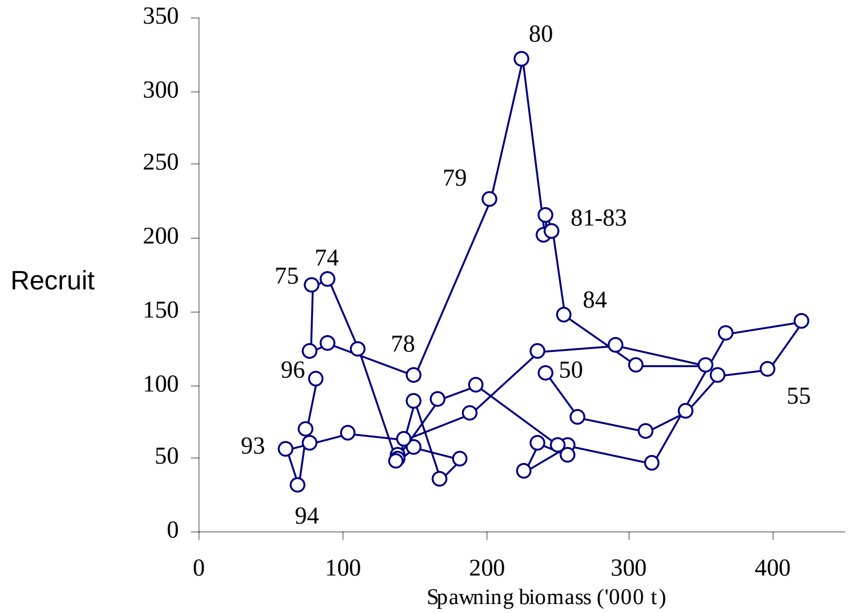


Figure 42: Spawning biomass and recruit plot for cod in the southern Gulf of St. Lawrence.

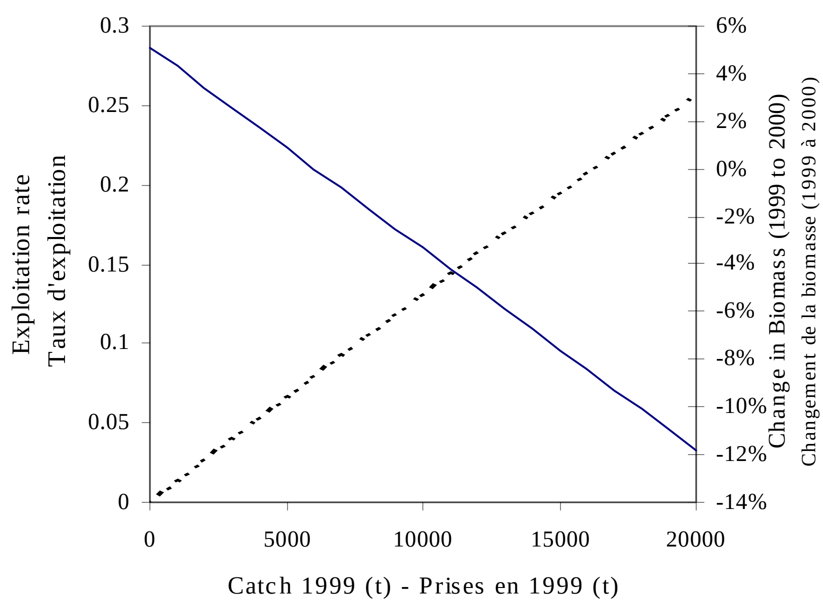


Figure 43: Deterministic catch projection for cod in the southern Gulf of St. Lawrence for various levels of catch in 1999. Dotted line represents the exploitation rate and the solid line is the change in biomass.

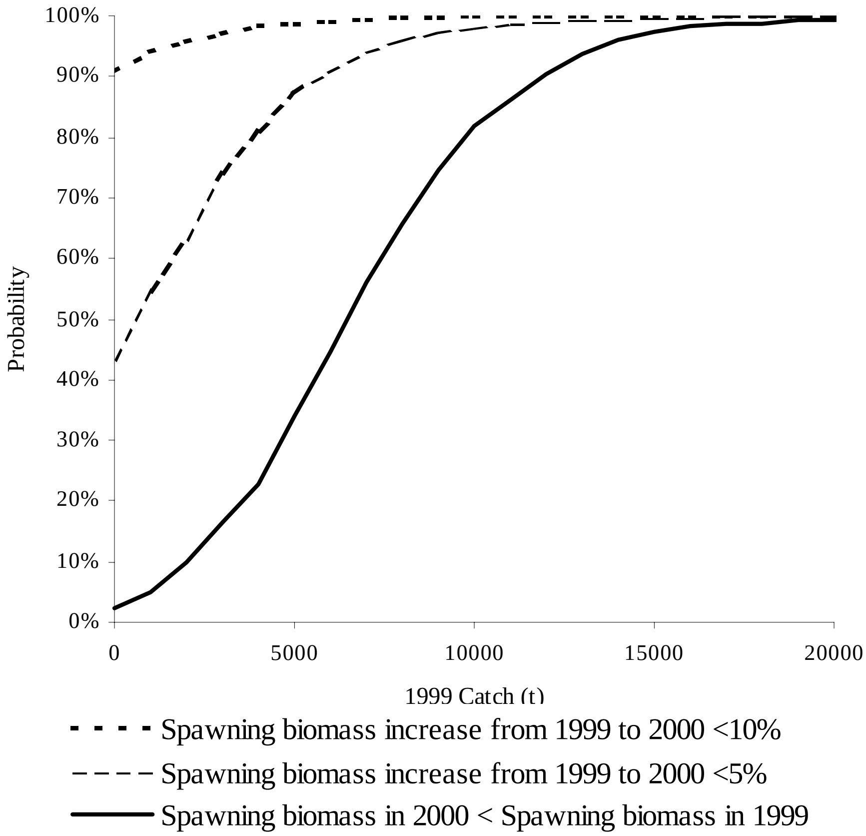


Figure 44: Risk analysis of spawning biomass changes for southern Gulf cod given a range of catch levels in 1999.

Appendix I: Landings (numbers) at age by gear and time period, 1997, updated with final ZIF catches.

KEY	1	2	3	4	5	6	7	8	9	10	11	
GEAR	OTB	OTB	SNU	SNU	GNS	LLS	LLS	LHP	Mobile	Fixed	Unsamp.	TOTAL
QUARTER	2	3	2	3	3	2	3	3				
Age												
0									164		7	171
1									4336		178	4513
2				74					17018		700	17793
3		465		1446	28				23693	194	1058	26883
4		3962	142	12807	381		16	150	31206	2280	2087	53031
5	4	13259	901	33865	1178	177	397	3389	54730	7207	4716	119822
6	15	32140	2088	55687	4017	480	1731	10495	55067	13195	7167	182082
7	29	28311	3724	42204	9384	1378	4030	17395	41128	19800	6858	174243
8	64	28375	8808	37780	15464	1580	6078	19300	33484	21599	7069	179601
9	63	30800	9622	38887	21677	1736	8443	24763	35243	28586	8187	208007
10	33	15346	4756	17707	14036	2234	5123	13997	15332	16149	4291	109005
11	13	4596	2825	5511	5625	954	1940	4524	4598	5440	1476	37502
12	3	771	495	1168	1869	269	706	1512	819	1734	383	9729
13	1	406	156	443	384	419	153	298	323	371	121	3074
14	1	107	313	259	454	182	165	258	180	354	93	2365
15					247	16	78	239		274	35	889
16+	0		69		47		23	19	6	31	8	203
Total 3+	224	158537	33898	247762	74791	9425	28882	96339	295810	117215	43551	1106436
All	224	158537	33898	247837	74791	9425	28882	96339	317328	117215	44436	1128913

Appendix I (continued) : Weights (kg) at age by gear and time period, 1997, updated with final ZIF catches.

KEY	1	2	3	4	5	6	7	8	9	10	
GEAR	OTB	OTB	SNU	SNU	GNS	LLS	LLS	LHP	Mobile	Fixed	AVERAGE
QUARTER	2	3	2	3	3	2	3	3			
Age											
0									0.013		0.013
1									0.041		0.041
2				0.159					0.129		0.129
3		0.372		0.375	0.514				0.231	0.379	0.243
4		0.616	0.401	0.582	0.650		0.750	0.739	0.544	0.639	0.565
5	0.979	0.826	0.796	0.764	1.183	0.847	1.403	1.259	0.749	0.988	0.800
6	1.270	1.138	1.254	1.032	1.900	2.002	1.761	1.522	1.051	1.423	1.149
7	1.643	1.263	1.695	1.174	2.204	2.330	2.145	1.763	1.191	1.744	1.424
8	2.256	1.484	2.661	1.460	2.702	2.876	2.594	2.118	1.427	2.221	1.852
9	2.463	1.614	2.951	1.669	2.786	2.485	2.717	2.165	1.593	2.308	2.034
10	3.147	1.782	3.574	1.865	2.878	2.810	2.896	2.296	1.812	2.496	2.284
11	3.363	1.726	4.014	2.004	3.224	2.856	2.937	2.441	1.850	2.891	2.559
12	2.400	2.381	3.084	2.581	3.174	3.874	3.161	2.738	2.505	3.027	2.892
13	3.489	1.981	5.424	2.278	3.094	2.702	3.285	2.641	2.238	3.230	2.774
14	2.222	2.624	3.849	3.073	3.592	2.960	3.543	2.961	3.300	3.486	3.357
15					2.119	6.242	2.119	2.119		2.160	2.208
16+	3.509		4.930		4.477		4.477	4.477	4.516	4.710	4.675
3+	2.354	1.362	2.767	1.250	2.676	2.652	2.600	2.024	1.061	2.051	1.571
All	2.354	1.362	2.767	1.250	2.676	2.652	2.600	2.024	0.997	2.051	1.542

Appendix I (continued): Lengths (cm) at age by gear and time period, 1997, updated with final ZIF catches.

KEY	1	2	3	4	5	6	7	8	9	10	
GEAR	OTB	OTB	SNU	SNU	GNS	LLS	LLS	LHP	Mobile	Fixed	AVERAGE
QUARTER	2	3	2	3	3	2	3	3			
0									11.79		11.79
1									17.30		17.30
2				26.01					24.73		24.74
3		34.19		34.20	38.26				29.52	35.25	29.92
4		40.03	34.78	39.46	41.20		43.28	43.07	39.04	41.39	39.35
5	47.13	44.40	43.75	43.28	49.20	45.07	52.88	51.10	43.31	47.08	43.99
6	51.12	49.35	51.00	47.76	58.35	59.51	56.97	54.30	48.21	52.93	49.38
7	55.43	50.96	55.77	49.56	61.29	61.80	60.61	56.81	50.00	56.24	52.61
8	61.21	53.60	64.30	52.99	65.18	66.28	64.34	60.22	52.68	60.50	56.97
9	62.74	55.07	66.26	55.24	65.84	62.84	65.34	60.59	54.46	61.07	58.75
10	67.67	56.88	70.47	57.24	66.44	65.83	66.48	61.96	56.64	62.82	61.06
11	68.89	56.17	73.24	58.00	68.73	66.23	66.96	63.35	56.67	65.62	62.99
12	63.18	63.22	67.58	64.78	69.03	73.01	68.84	66.00	63.43	67.19	66.72
13	70.84	59.52	79.12	61.91	68.29	64.64	69.35	65.45	61.12	68.28	65.17
14	61.55	65.44	73.26	67.80	71.99	66.73	71.64	67.93	68.42	70.44	69.95
15					61.00	87.00	61.00	61.00		61.00	61.48
16+	72.00		79.12		78.00		78.00	78.00	77.00	78.00	78.36
3+	61.49	51.85	64.27	49.95	64.79	64.30	64.24	59.24	46.98	58.55	53.21
All	61.49	51.85	64.27	49.94	64.79	64.30	64.24	59.24	45.36	58.55	52.62