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Status of American plaice in NAFO Division 4T, 1995

by

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Abstract

Provisional landings of American plaice in NAFO Division 4T totalled 2311 t in 1995, considerably lower than the average of 7647 t since 1960. Landings reached their lowest level in 1993 (1403 t), the year that the Atlantic cod fishery was closed in 4T. The increase in landings since 1993 was attributed to fewer closures in the commercial fishery and increased effort by mobile gear. The annual total allowable catch (TAC) of 4T plaice was maintained at 10000 t from 1977 to 1992; since 1993, it has been set at 5000 t. All fleet sectors reported landings below their allocated quotas in 1995, with the exception of the competitive mobile fleet of vessels less than 45 feet. Seines contributed about 75% of the landed catch (1731 t in 1995). Commercial plaice catches have increasingly concentrated in the eastern part of 4T since 1993, in unit areas 4Tf and 4Tg. The 1995 research survey of 4T resulted in an average catch of 176 plaice per tow, the lowest catch rate on record for this survey. Since 1971, plaice catches have averaged 395 per tow with the highest average catch in 1977 (1127 per tow) Survey data indicate that the stock declined in abundance in the late 1970s and has fluctuated at a low level since 1982. Multiplicative analyses of mean catch-at-age data from research data indicated that total mortality from 1994 to 1995, between ages 5 and 13 years, standardized for year-class abundance, was approximately 0.36 for both males and females. Similar analyses indicate that year-classes of the early 1970s were abundant, but have been relatively weak in abundance over the past 20 years. A length-based index of fishing mortality (F), calculated from the ratio of commercial to research catches, indicated an increasing trend in F from the mid-1980s to 1993. Predicting the abundance of research catch-at-age for 1996, commercial removals in the order of 1000 t would be required for 1996 to lower F to levels recorded during the 1970s.

Résumé

Les débarquements provisoires de la plie canadienne dans la division 4T de l'OPANO ont atteint 2311 t en 1995, soit un niveau considérablement inférieur à la moyenne de 7647 t enregistré depuis 1960. Les débarquements ont atteint leur plus bas niveau en 1993 (1403 t), l'année de la fermeture de la pêche de la morue Atlantique dans la division 4T. L'augmentation dans les débarquements depuis 1993 serait dûe au plus faible nombre de fermetures dans la pêcherie, ainsi qu'un effort accru de pêche par les engins mobiles. Le total des prises admissibles (TPA) pour la plie canadienne de 4T a été maintenu à 10000 t de 1977 jusqu'à 1992, alors que depuis 1993, le TPA annuel est de 5000 t. Tous les secteurs de pêche ont rapporté des débarquements de plie inférieurs à leur contingent alloué, à l'exception du secteur compétitif des bateaux inférieurs à 45 pieds. Les sennes ont contribué à environ 75% des débarquements (1731 t en 1995). Les prises commerciales de plie canadienne proviennent surtout de l'est de 4T depuis 1993, dans les secteurs de 4Tf et 4Tg. Le relevé scientifique de 4T a enregistré une moyenne des prises de 176 plies canadiennes par trait en 1995, soit le plus bas niveau enregistré pour ce relevé. Depuis 1971, les prises de la plie canadienne ont été en moyenne de 395 par trait, atteignant un maximum en 1977 à 1 127 plies par trait. Les données des relevés indiquent que le stock a décliné en abondance vers la fin des années 1970 et a fluctué autour des bas niveaux depuis 1982. Des analyses multiplicatives des prises moyennes à l'âge dans les relevés scientifiques indiquent que la mortalité totale de 1994 à 1995, pour les plies dont l'âge est de 5 à 13 ans, standardisée pour l'effet des classes d'âge, a été approximativement de 0.36 pour les mâles et les femelles. Des analyses semblables indiquent que les classes d'âge du début des années 1970 étaient abondantes, alors que les classes d'âges depuis les derniers 20 ans sont relativement peu abondante. Un indice à la mortalité de pêche (F), basé sur la longueur et calculé à partir du rapport des prises de la pêche commerciale et des relevés scientifiques, indique une tendance pour F d'augmenter depuis le mileu des années 1980 jusqu'à 1993. En faisant la prévision des prises à l'âge du relevé scientifique de 1996, une pêche de 1000 t serait nécessaire en 1996 pour permettre une réduction de F aux niveaux enregistrés durant les années 1970.

Introduction

American plaice *Hippoglossoides platessoides* is a coldwater flatfish, widely distributed throughout the northwest Atlantic from the Gulf of Maine to western Greenland (Scott and Scott 1988). In most parts of their range they are an important commercial groundfish. In the southern Gulf of St. Lawrence (NAFO Division 4T, Figure 1), plaice dominate benthic fish communities and are the most abundant species in research surveys (Clay 1991). American plaice have been an important resource for many years in 4T, where they were second in groundfish landings to Atlantic cod, until the cod fishery was closed in 1993. Southern Gulf plaice are exploited by a diverse fleet originating from five provinces, with landings from ports of New Brunswick, Nova Scotia and Prince Edward Island valued at $2.1M in 1994 (Anon. 1996).

This document updates landing statistics and abundance indices for 4T American plaice. The last assessment for this stock raised questions concerning changes in growth and mortality of male and female plaice (Science Branch 1995). These issues are addressed through analyses of the growth and abundance of year-classes and analyses of total mortality and fishing mortality. An emphasis is placed on separating males and females, in view of their natural dimorphism and the differential effects of exploitation on the two sexes. This assessment also reports on problems in the reporting of flatfish landing statistics and biological sampling.

Description of the fishery

Landings

The landings of 4T American plaice totalled 2311 t in 1995, an equivalent level to 1994 (Table 1). Plaice landings reached their lowest point in 1993 (1403 t) when the 4T cod moratorium and numerous groundfish closures contributed to reducing fishing effort. Although on average 7647 t have been landed annually since 1965, this level was last exceeded in 1987. Maximum landings were reported in 1976 (Table 1). The 1993 plaice landings were updated to account for misreporting (see section on uncertainties in landing statistics, subsection on Supplementary "B" landings). The quota for plaice in 4T was 5000 t in 1995.

Seines have been the dominant gear for 4T plaice, surpassing otter trawls in most years since 1981. In 1995, seines landed 1731 t of plaice, roughly 75% of the total landed catch. Gillnets declined for the third consecutive year, following a four-year period (1989-1992) when plaice landings by gillnets ranged between 474 and 537 t. Bottom pair trawls have contributed over 60 t annually since 1985 (111 t in 1995, Table 2). The fishery was conducted mainly between the months of May and October (Table 2).

The plaice fishery was concentrated in the eastern part of 4T, in unit areas 4Tf and 4Tg (Figures 1 and 2). Although these sectors have been the main concentration of landings for several years, landings in western unit areas (4Tl, 4Tm, 4Tn, 4To) have declined sharply since 1992 (Figure 2). This pattern is revealed in further detail by mapping the geographic distribution of 4T plaice catches. Figure 3, showing total catches in 10' by 10' coordinates, illustrates the declining activity and catches of vessels off the Gaspé coast, in the Baie des Chaleurs and in the Shediac Valley.

The mobile gear fleet sector of vessels <45', particularly those fishing competitively, reported strong catches in 1995. DFO approved a transfer of 130 t of plaice to allow the fleet to continue fishing. The system of allocations by fleet sector is outlined in Table 3. Mobile gear vessels <45' landed 1627 t in 1995 (unofficial statistics), roughly 250 t more than in 1994. All other fleet sectors landed less than their allocation. There were 14 closures affecting vessels <66 feet in the 4T plaice fishery during 1995.

Mesh sizes have increased considerably in the plaice fishery over the past 30-40 years. In the 1950s, codend mesh sizes increased from 76 mm to 114 mm. In 1977, it was increased to 120 mm and in 1981 it became 130 mm diamond mesh. In 1993, the minimum mesh size for mobile gear directing for plaice became 145-mm square mesh in codends and lengthening pieces (minimum 130-mm diamond mesh in other gear parts). Mobile gear directing for winter flounder were allowed a minimum mesh size of 130 mm square in Northumberland Strait and 135 mm square in Chaleur Bay and Miscou. These regulations remained in effect in

1995. Most plaice catches (94%) were made by a directed plaice fishery in 1995 and winter flounder-directed fishing accounted for only 1% of the annual plaice landings. Many fishers reported using 160 and 165-mm meshes in 1995. The minimum mesh size for gill nets was 140 mm (stretched measure, diamond). Other regulations in effect remained the same, including plaice minimum size of 30 cm. Fishery closure was imposed when undersized plaice exceeded 20%, by number, of the total catch.

In 1995, special licences for bait were eliminated in the southern Gulf in order to substantially reduce catches of juvenile flatfish species. Dockside monitors were requested to measure the lengths of plaice sampled from landed catches. This measure resulted in two closures of the plaice fishery.

Nominal effort

The 4T plaice fishery has been largely a bycatch of the cod fishery, with a significant fleet directing for plaice. Since the closure of the 4T cod fishery, plaice has become an almost entirely directed fishery. From 1985 to 1992, the directed plaice fishery landed 46-64% of the annual plaice landings. In 1993, the year the cod fishery was closed, 83% of plaice landings were from directed fishing effort. In 1994 and 1995, directed effort accounted for 92 and 94% of plaice landings in the respective years. We have focussed our attention on nominal effort in the directed fishery to assess changes in fishing pressure since closure of the cod fishery.

The number of vessels directing for 4T plaice increased in 1995 (Figure 4). Fifty-three seiners reported directed plaice catches in 1995, a small increase from 49 vessels in 1994. The number of trawling vessels with directed plaice catches rose to 41 in 1995 from 23 vessels in 1994. The number of trawlers registering directed effort at plaice in 1995 was similar to the number of vessels in the 1992 fishery.

Nominal effort, recorded on vessel logbooks as the number of days of fishing, indicated a similar level of fishing effort to that of 1994 (Figure 4). The level of reporting was very high in 1995 logbooks: >98% of the directed plaice landings by trawls and seines indicated the effort in their logbooks. Seines fished a total of 1007 days in 1995, virtually the same as in 1994 (1008 days). Trawls directing for plaice fished a total of 347 days in 1995, an increase from their level in 1994 (304 days). Both gears recorded their lowest level of directed effort in 1993 (seines: 563 days; trawls: 116 days).

Discarding

The capture and discarding of commercially undersized plaice have been a longstanding problem in the 4T plaice fishery. Several measures have been imposed in recent years to eliminate the problem, including mesh size increases, mandatory landing of all fish caught, dockside monitoring and limits set on acceptable catches of small fish. In assessments since 1994 we have evaluated the effectiveness of these measures by comparing the size composition of plaice measured at sea by observers aboard fishing vessels with the size composition of landed plaice catches. For the landed catches, our observations were taken from port samples used in the catch-at-age analysis. The samples taken at sea were weighted by the set catch and pooled by gear (trawls or seines) and quarter.

Validation of this procedure is made when observers at sea and port samplers measure the same catch. In 1994, this occurred twice and indicated highly similar size composition (Figure 9 in Morin et al. 1995a). Three cases of the same catch measured at sea and at port occurred in 1995 (Figure 5). Of the three comparisons, one catch dated October 14 was reported by observers to have been partly discarded at sea following sampling. The length composition of this port sample (upper panel, Figure 5) was truncated at 33 cm, typical of discarded plaice catches.

Most comparisons of observed and landed (port sampled) catches in 1995 indicated similar size composition (Figure 6). However, two of the seven comparisons (seines in 4Tg, third quarter and 4Tf, fourth quarter) indicated a strong shift in the modal size of landed catches, suggesting that discarding occurred at sea. Seine catches in 4Tg in the fourth quarter also indicated a less pronounced shift to larger size >30 cm in the landed catch.

Views of the fishing industry

Several consultations were made with the fishing industry, between July and December of 1995, concerning the status of 4T groundfish stocks. Assemblies were held in fishing communities throughout the southern Gulf (Gaspé, Grande Rivière and Cap-aux-Meules (Magdalen Islands), Québec; Caraquet, New Brunswick; Charletown, PEI; Port Hawkesbury, Nova Scotia). The meetings were conducted with brief presentations by DFO personnel on recent trends in the fishery and preliminary results of the latest research survey data, followed by general discussions on each stock. The consultations were undertaken to obtain the views of the fishing industry concerning the state of groundfish stocks and to identify analyses that the industry would recommend in assessing particular stocks.

The meetings with industry participants received diverse views on the state of American plaice in 4T and some divergence appeared to be based on regions of the southern Gulf. A fisherman in Grande Rivière expressed the view that the plaice stock in that sector is weak in spite of a low level of exploitation, and the fishery should be closed. This view was not shared by participants in meetings at Port Hawkesbury and Cap-aux-Meules who maintained that catch rates in the plaice fishery were better in 1995 than in 1994 or in some previous years. In Port Hawkesbury, many shared the view that the plaice stock in the western part of the southern Gulf is in worse condition than in the southeastern Gulf. Fishermen at Cap-aux-Meules indicated that plaice are more abundant and of larger size in the region southeast of the Magdalen Islands, but scarcer to the northwest. In Caraquet, a fisherman noted that plaice abundance was weak in 1995, but comparable to the level of recent years. Participants in Caraquet and Port Hawkesbury commented on fishing effort in the plaice fishery and at both assemblies it was felt that effort had increased in 1995. At Port Hawkesbury it was suggested that the number of vessels had not increased in 1995, but the vessels had fished longer.

Similar views were expressed during industry consultations in 1994, concerning the distribution of plaice in the southern Gulf and trends in abundance (Science Branch 1995). In Charlettown and Cheticamp in November 1994, fishermen indicated that plaice were found mostly in the eastern part of 4T. Most vessels fishing off Cape Breton reported good catches of plaice in 1994.

Telephone questionnaire

A telephone survey was conducted of fishers who were active in the Gulf of St. Lawrence during 1995. In October 1995, a list of 232 vessels was drawn from CFV numbers identified on purchase slips up to that time. From December 12, 1995 to January 9, 1996, 138 participants were interviewed for their views on the groundfish fishery. The respondents were distributed throughout the southern Gulf, from New Brunswick, Prince Edward Island and Nova Scotia (Figure 7). The questionnaire included 25 questions on diverse topics. The duration of the interviews averaged 16 minutes (ranged 8 to 30 minutes) and was conducted in English or French. Of the vessels that were identified and whose owners did not participate in the survey, five refused to participate, 28 did not fish groundfish in 1995, and the remainder could not be reached by telephone.

Of the 138 respondents in the survey, 60 directed their fishing effort on American plaice during 1995 and, of these, 42 respondents identified plaice as their primary choice of directed species. The main group of vessels comprised the following gear categories: 26 seiners, 21 otter trawls, 9 gillnetters, 2 longliners, and 2 with unspecified gear. Purchase slip data for mobile gear vessels that participated in the survey totalled 1051 t of 4T plaice, roughly 50% of landings by mobile gear in 1995. We present prelimary results on the views of respondents who directed for plaice in 1995.

Most respondents reported the same or less fishing effort in 1995 compared to 1994. Of the 60 vessels directing for plaice, 44 deployed the same effort in 1995 as in previous years, 12 deployed less effort, and only 3 reported more effort (one expressed no opinion). Compared to 1994, 31 respondents fished fewer days, 21 fished the same, and 5 reported more days of fishing (3 expressed no opinion).

Nineteen fishermen were able to provide the exact number of fishing days, averaging 26 days in 1995 (range 3 to 65 days). When asked to estimate the number of fishing days, 51 fishermen responded. Their estimated fishing days spanned a mode of 10 to 29 days (Figure 8). The most common reason cited for changing fishing effort was fishery management regulations. Although the respondents did not specify which regulations caused them to alter their fishing activity, several expressed disagreement with the recent reduction of the American plaice quota.

When asked to judge the abundance of plaice in 4T on the basis of their experience, 21 of the 60 fishermen who directed for plaice considered the resource to be at its average level. However, more respondents considered plaice to be better than average (25) than below average (14, Figure 8). Figure 8 illustrates how fishermen who directed for plaice related the state of the 1995 fishery to the past year, the past five years, and to all of their years of fishing experience. Most of the respondents considered the fishery to be the same or better than in 1994. Only 8 respondents considered the fishery to be worse, whereas 31 considered it to be better or much better. When judged on the basis of their longer term experience, the 1995 fishery was not considered as favorably. Compared to the fishery during 1990 to 1994, 20 respondents considered it to be better or much better and 18 considered it to be worse or much worse. When judged on the basis of all of their years of experience, 18 felt that the 1995 fishery was better or much better and 17 considered it to be worse or much worse.

Fishery Data

Commercial catch statistics for 4T plaice are based on combined data from the Maritime, Laurentian and Newfoundland regions of DFO. Information on the commercial fisheries originate from sources such as vessel logbooks, purchase records, observers onboard fishing vessels and port samplers. Logbooks became a condition for all mobile gear permits in 1991.

Unreported catches that are destined for bait fisheries or personal consumption, or landings without purchase slips, are estimated periodically by fishery officers through dockside interviews. These estimates, referred to as Supplementary "B" landings, are reviewed in another section. Supplementary "B" landings usually contribute a small portion of the annual landings of 4T plaice. In 1995, they were estimated at 38 t, 2% of the total landed catch.

The commercial catches of plaice were sampled at landing ports throughout the active months of fishing (Table 4). In total, 44 samples were obtained from the commercial fishery, most from seines. Fixed gear were not sampled in 1995 and trawls were not sampled before August. Commercial port sampling is based on sexed length frequencies and otoliths removed on a sex and length-stratified basis of one sample per sex, per cm length. Port samplers recorded the location and weight of each catch, and corrected for grading of the catch by size. Age-length keys for 1995 were constructed for each sex and for two periods: before and after July 31, but grouped all gear. Age-length relations established from research survey data were used to convert number-at-length of male and female plaice to estimates of total catch weight.

The current level of commercial sampling is intermediate to the numbers of samples obtained yearly since 1976 (Figure 9). The current level of sampling, given the low level of landings in recent years, compares favorably with the late 1970s and 1980s when landings were several times their current level. However, since 1993, port samplers have found it difficult to obtain samples from ports where the fishing fleet is small and landings are infrequent. In order to sample plaice in all gear types, sectors and months, further analyses will be required to incorporate alternate sources of catch data.

The landings at age for male, female and juvenile plaice were combined for total landings at age and compared with data since 1976 (Table 5). The total estimated catch of plaice in 1995 was similar to the estimate for 1994 and considerably greater than catches in 1993, the lowest year in the data series. In the last assessment, the increased abundance of plaice <9 years of age in the 1994 catch-at-age was seen as a possible indication of the effect of the mandatory landings regulation (Morin et al. 1995a). In the 1995 catch-at-age, the numbers of plaice <8 years of age declined from their level in 1994 (Table 5). The 1987 year-class, age-8 in 1995, has appeared as a strong mode in the catch-at-age for 1994 and 1995.

Uncertainties in landing statistics

Recent flatfish assessments, regional reviews and client consultations have underlined problems in the reporting of commercial catch statistics for flatfish in the southern Gulf of St. Lawrence. In this section, we examine three issues:

1) Unspecified flounder catches (species unknown) were a problem in landing statistics until the mid 1970s. How was this problem addressed by CAFSAC and by Statistics Branch?

2) What is the extent of current misreporting of flatfish catches?

3) How effective are fishery officer surveys (Supplementary B forms) in estimating flatfish catches in bait fisheries and other unreported catches?

Unspecified flounder

In 1973, the International Commission on North Atlantic Fisheries (ICNAF) requested advice from participating countries on allocating the annual landings of unspecified flounders to their respective species (ICNAF 1974). The response for 4T was that American plaice contribute 90% of the landings of unspecified flounder. We were unable to find any studies by CAFSAC or ICNAF that may have led to the 90% criterion, nor how the remaining 10% of unspecified flounder were allocated. Powles (1969) reported that 90% of flatfish catches in research surveys of the northern Magdalen Shallows were plaice and that plaice constituted 80% of flatfish in surveys of the southern half of the Magdalen Shallows. We were unable to locate any studies relating the composition of research and commercial catches, nor any study of the flatfish species composition in commercial catches. In the absence of any other documented sources of information, we feel that the study by Powles (1969) is the most likely origin for the 90% criterion.

ICNAF reports of 4T landing statistics from 1964 to 1971 included 90% of the unspecified flounder landings in the yearly totals of plaice landings (Schweigert 1978). Although unspecified flounder continued to be reported annually until 1985, 4T plaice landings were not adjusted to include unspecified flounder after 1971. Our most recent research documents (e.g. Morin et al. 1995a) continue to report plaice landings + 90% unspecified flounder landings up to 1971 and plaice landings without any correction since 1972.

The broad application of the 90% criterion for identifying plaice landed as unspecified flounder is clearly questionable. A more rigorous examination of the location of unspecified flounder catches and their gear sector might reveal inshore fishing activity or bait fisheries where winter flounder is the predominant flatfish caught. Notwithstanding, the failure to break down unspecified flounder by species from 1972-1984 probably underestimated plaice landings significantly in several years. The following table, based on NAFO Table 5 data, indicates the effect of including 90% of unspecified flounder landings.

Year	Plaice landed (t)	Unspecified flounder (t)	Plaice + 90% unspecified
1972	8294	1201	9375
1973	6905	1388	8154
1974	8485	602	9027
1975	8443	2464	10661
1976	11193	668	11794
1977	9230	1163	10277
1978	9031	764	9719
1979	9996	841	10753
1980	8292	759	8975
1981	7834	118	7940
1982	6542	344	6852
1983	6094	792	6807
1984	9599	46	9640
1985	9490	3	9493

From 1972 to 1979, gillnets contributed 17-87% of the annual landings of unspecified flounder, over 50% in five of the eight years. From 1980 to 1983, most landings of unspecified flounder were attributed to unknown gear, whereas gillnets did not appear.

Current misreporting

The problem of unidentified flatfish catches did not end in 1985. The fixed gear fishery has continued to operate without logbooks. Purchase slips from fixed gear have frequently been filled out with the specification "flounder". This problem is mainly restricted to flatfish species used in bait fisheries or species with the same market price: plaice, winter flounder, and possibly yellowtail flounder. Without adequate advice to the contrary, Statistics Branch has coded these unspecified flounder catches as plaice.

It is difficult to assess the magnitude of unreported catches that become bartered or sold among fishers or in local markets. Of the 2420 t of plaice landed in 4T during 1994, 248 t of plaice were landed by gillnets, with an additional 140 t by other fixed gear. We undertook a small telephone survey to validate reported landings of plaice from a portion of the fixed gear landing 4T plaice.

We examined the Gulf Region purchase-slip data for all fixed gear reporting catches of plaice and winter flounder in 1994. During 1994, 101 identified vessels operating fixed gear (gillnets and traps) landed 4T plaice in southern Gulf ports. Of these, only 17 vessels landed more than 2 t of plaice in 1994. We were able to contact 16 of these fishers by telephone, whose combined plaice landings in 1994 were 92 t. Total 1994 plaice landings by gillnets and trap nets in the Gulf Region were 197 t, of which unidentified vessels (CFV unknown) accounted for 85 t.

Our telephone survey revealed widespread misreporting among fixed gear landing plaice. Thirteen of the 16 fishers stated that their reported landings of plaice were erroneous and that these should have been coded as winter flounder. The misreporting of winter flounder catches as plaice occurred at three landing ports in northern New Brunswick: Pointe Sapin, Escuminac and Le Goulet (7 vessels). Similar misreporting occurred in three PEI ports: Egmont Bay, Miminegash and Malpeque (6 vessels). One New Brunswick fisher from Baie Ste. Anne and two fishers from PEI (Miminegash and Beach Point) confirmed that their reported landings of plaice were correct.

Supplementary "B" landings

Supplementary "B" forms are completed by fishery officers who conduct dockside surveys to estimate catches that are used for bait or become marketed through personal sales. Typically, such catches are not marketed through fish buyers and, therefore, are not recorded on purchase slips. Estimates of plaice landings by supplementary "B" forms usually total less than 10% yearly, with the notable exception of 1993 when they contributed 24% of the plaice landings. Supplementary "B" estimates contribute a smaller portion of the annual landings of winter flounder, usually less than 3%.

Current procedures for filling Supplementary "B" forms have been criticized for a lack of clear methods and scientific basis (Robitaille 1994). Morin et al. (1995b) reported that Supplementary "B" estimates in 4T tend to indicate more null catches of winter flounder than plaice and that the ratio of plaice to winter flounder catches is stronger among Supplementary "B" estimates than among reported landings by vessels <45 ft. This suggests that Supplementary "B" forms may identify winter flounder catches as plaice. In fact, the forms provided to fishery officers for this purpose do not indicate separate categories for the different flatfish species. It has therefore been the responsibility of the officers to correctly identify the composition of flatfish catches.

We restricted our analysis of Supplementary "B" estimates to the abnormally high estimate (445 tons) that was made for plaice in 1993. Most of these landings originated from three statistical districts: district 65 located on the south shore of Chaleur Bay in northern New Brunswick and districts 82 and 92 located at the western end of PEI. Supplementary "B" landings of plaice over the past five years illustrate the unusual estimate that was made in 1993:

	Statistical District		
Year	65	82	92
1990	95.5	0	0
1991	72.0	5.1	3.5
1992	92.0	0	0
1993	75.9	161.0	145.2
1994	23.2	0	0

The fishery officer responsible for districts 82 and 92 confirmed the amount of flatfish estimated in 1993 and maintained that this was representative of the level of bait fishing that occurs yearly in those sectors. However, he stated that his estimates were miscoded as American plaice; in his words, flatfish catches in those sectors would be "at least 90% winter flounder". The error was caused when "flounder" was indicated on the Supplementary "B" forms and was later coded as plaice. The fishery officer was instructed in 1993 to obtain estimates at all landing wharves. He confirmed that Supplementary "B" forms were not filled out the following year, in 1994.

Summary

1- From 1965-1971, annual landings of 4T plaice were corrected by adding 90% of the reported landings of unspecified flounder. The 90% criterion, based on research survey data, probably overestimates the contribution of plaice to unspecified flounder at the expense of winter flounder.

2- From 1972-1985, unspecified flounder continued to appear in landing statistics, but were no longer apportioned by species. The landings of plaice and winter flounder tended to be underestimated over this period.

3- Fixed gear in 4T yearly report landings of hundreds of tons of plaice. Telephone interviews with fixed gear fishers indicate that a significant portion of these landings are misreported catches of winter flounder.

4- Fishery officers in 1993 reported unusually high estimates of unreported catches of plaice. It was confirmed that most of these estimates were misidentified winter flounder catches. This incident highlights difficulties in estimating unreported catches in bait fisheries. Supplementary "B" forms are frequently completed without regard to accurate identification of the species caught, nor consistent coverage from year to year.

Research Data

Groundfish stocks in 4T have been surveyed every September since 1971. Three research vessels and two trawling gears have been used. The *E.E. Prince* was used with a Yankee 36 trawl from 1971 to 1985. The *Lady Hammond* fishing a Western IIA trawl was used until 1991, followed by the *Alfred Needler* and the Western IIA trawl. In 1985 and 1992 with the respective vessels fished alongside to evaluated their relative fishing efficiencies. The results of these surveys, summarized by Nielsen (1994), established a conversion factor for plaice to equate *Prince* catches to *Hammond* catches. No significant difference was found between the *Hammond* and *Needler* catches of plaice by number and weight. All measures of plaice abundance from *Prince* surveys were adjusted for equivalence with *Hammond/Needler* abundance and a standard distance towed of 1.75 NM.

Research surveys of 4T have been based on a stratified random design with depth as the main criterion for stratification. From 1971 to 1983, a stratified random design was used in addition to 13 fixed stations that were selected from previous exploratory surveys (Halliday and Koeller 1981). From 1984 to 1987, a fixed station survey design was adopted with some stations selected from previous surveys and other stations selected in 1984. In some years, stations were sampled more than once; for example, in 1988 stations were sampled repeatedly to evaluate day-night effects in catchability. Research surveys of 4T reverted to a completely random stratified design in 1988.

Most sampling procedures in the 4T research surveys have remained constant since 1971 (Hurlbut and Clay 1990). The length frequencies of plaice have been sex-based, with the exception of the years 1984 to 1986, when sexes were combined. The length frequency in large catches is based on a minimum sample of 200 plaice, selected randomly from the catch. Biological sampling of plaice, including length, weight, sex, maturity and otolith collection, has been conducted at a rate of one specimen per centimetre, sex and set. The 1995 age-length keys was based on 1969 male and 2715 female plaice.

Research survey analyses, including age-length keys, catch-at-age, and biomass were generated by the program RVAN, programmed in SAS IML (SAS Institute 1989) by G. Nielsen, based on the RVAN version documented by Clay (1989). Fixed and repeat-set stations were incorportated into the research abundance index by treating fixed stations as random and averaging all repeat sets before including them in the stratum averages (Morin et al. 1995a).

Plaice abundance

The mean stratified catch of 4T plaice in 1995 was 176 plaice per tow, the lowest level recorded in the data series (Figure 10). The highest abundance of plaice was reached in 1977 when a stratified mean of 1127 plaice per tow was recorded. Since 1971, the average of the yearly estimates has been 395 plaice per tow. It appears that the stock declined in the late 1970s and, since 1982, has fluctuated at a level that is below the longterm average. Error bars on the estimates of the stratified mean catches in Figure 10 illustrate the variability that is associated with our survey estimates. Part of this variability is due to the inherent relation between the average and the variance in such data. Sampling intensity has also increased from 70 valid sets or less before 1984 to 141 sets or more since 1984, contributing to reducing the variance in estimates from recent years. In the 1995 survey, 175 valid sets were made in 4T.

The biomass trend since 1986 is similar to that of catch numbers (Figure 11). The biomass was estimated to be 45045 t in 1995, the lowest estimate in the data series. Since the catchability of research gear has not been determined for 4T plaice, the biomass estimate should be regarded as an index of biomass. Plaice of commercial size (>30 cm) have contributed a constant proportion of the total estimated biomass since 1990 (34-36%).

The strongest age groups in survey catches of 1995, 4-7 years of age, had mean catches ranging between 23 and 32 plaice per tow (Table 6). These age classes were frequently caught with catch rates >100 plaice per tow from the mid 1970s until 1981. The 1985 catch at age was removed from the data series because of uncertainty with the age determination (see section on growth). The coefficients of variation for catch-at-age data (Table 7) have declined to values <10% over several age classes since 1989, as sampling increased. In general, coefficients of variation for plaice are low when compared to other groundfish in the survey, such as Atlantic cod (Table 16 in Sinclair et al. 1995).

The mean numbers at age of male and female plaice (Tables 8 and 9) indicate the shorter life span of males. Few plaice aged >10 years of either sex appear in survey data. The maximum age of males has been 19 years in surveys since 1971 and in 1995 all age classes appeared up to 16 years of age. Older age classes of female plaice appear to have declined in recent surveys. In 1995, the oldest female was aged 16 years, whereas the maximum age of female plaice since 1971 has been 29 years. The mean catch of all age classes of males and females is presently at a low level, particularly in comparison to the levels attained in the mid 1970s.

The ratio of male to female abundance reflects a dominance of male plaice of ages 3-10 years (Figure 12). At ages 10-12 years, a shift has occurred in the relative abundance of the two sexes, with males becoming more abundant than females since the late 1980s. This increase in the abundance of males relative to females corresponds to a decline in male total mortality (see following section on stock parameters). By 13 years of age, female plaice become more abundant than males for most years (Tables 8 and 9). The research survey in 1978 produced an abnormally high proportion of males between the ages of 3 and 7 years (Figure 12). This was caused by several catches that were male-dominated; in fact, of nine catches >100 kg of plaice, six were strongly male-dominated (ratios ranging 1.6:1 to 12.1:1).

An important application of catch-at-age data is in identifying strong year-classes. To evaluate the consistency of our catch-at-age data, we correlated the abundance of plaice of the same year-class across ages. For example, the abundance of 3-year-old plaice was correlated with the abundance of 4-year-olds of the same year-class, followed by 5-year-olds, 6-year-olds and older. Female plaice were tested across seven ages; male plaice were tested across six ages. Spearman rank correlations were used. Figure 13 indicates the significance level of each correlation on a grey scale, with the white end of the scale indicating highly significant correlation (P =0.0) and the black representing non-significant correlation (P =1.0). The superimposed line is the 0.05 probability level contour. This analysis shows that female catch at age correlates over a larger range of age classes than male plaice. Seven- and 8-year-old male plaice correlated with the abundance or male plaice up to four years older. Males younger than 5 years and older than 9 years failed to correlate significantly with any older age classes (P >0.05). Female plaice aged 4-15 years correlated with lags of 1-5 years (P<0.05, Figure 13).

Growth

The size and growth rate of fish are important to the interpretation of population changes. Numerous examples of the negative relation between growth and stock density may be found for marine and freshwater fish populations (e.g. Backiel and LeCren 1967, Ross and Almeida 1986). Other factors intervene in the dynamics of exploited populations, including size-selective fishing and environmental conditions, so that some of the mechanisms involved in the growth-density relation remain unclear (Walters and Post 1993). We examine the size and growth rate of 4T plaice in relation to population density and year-class strength.

The length-weight relation relates to the condition of fish and is, in turn, subject to density effects. We analyzed biological data on male and female plaice from research surveys since 1971. Lengths and weights were log-transformed and the data were submitted to an analysis of covariance with year and length as main effects and with a year/length interraction. The models were highly significant for both sexes and resulted in significant year/length interractions (Tables 10 and 11). The slopes of the length-weight relations varied widely between years and without a consistant pattern (Figure 14). Hand-held spring scales were used on research vessels to weigh fish until 1990 and from 1973-1983 the minimum weight measurement was 50 g. The maximum weight of male and female plaice has varied widely over time, so we reanalyzed the data, restricting the input to a range of fish weights that was common over all years (males: 60-900 g; females: 60-2500 g). This analysis was also highly significant and produced a significant year/length interaction (Tables 10 and 11). The amplitude of variation in the slopes of the length-weight relations was somewhat reduced, particularly for male plaice; however, the pattern continued to be highly variable over time.

The use of electronic balances since 1990 appears to have improved the precision of fish weights considerably. Fish are weighed to a gram, with a minimum weight of 5 g. The slopes of length-weight relations follow a regular pattern since 1990 for both sexes and the variance about the estimates has been reduced. For these reasons, we have chosen to base our analyses of growth on the length-age relation rather than weight at age.

The stratified mean length at age of male and female plaice was calculated and for the years 1984-1986 when the length frequencies were not sexed, the means of biological samples were used. Biological sampling was normally size-stratified by sex (one fish sampled per centimeter length, per sex, per set). Mean length at age from biological samples usually approximated the stratified mean length at age. Compared over the years 1971-1994, mean lengths from the two groups were not significantly different over most age classes (paired t-tests, $P > 0.05$). Sample means of male plaice aged 3 and 4 years were on average less than 1 cm of the stratified mean length and in given years, the difference could range between 0.6 and 1.7 cm. Sample means of male plaice aged 7-ll years were significantly greater in length than stratified means and the difference appeared in almost all years. Only ages 3, 6 and 9 of females recorded significant differences in the mean lengths between sample and stratified mean estimates. In presenting mean length at age of plaice we included sample means for the years 1984-1986. We corrected the sample mean estimates for the age classes that differed significantly by the proportion of the two estimates over the observed 21 years.

Length data from 1985 presented an anomolous pattern. Tallman and Sinclair (1988) reported bias in age determinations of 1985, causing them to reread a portion of the 1985 ages. Their readings produced a highly dispersed age-length key for males and mean lengths for male plaice aged 7-11 years that converged within a range of 1.6 cm. A sample of 120 otoliths from the 1985 collection were read by the current reader (I. Forest-Gallant) and compared with the two previous readings. On the basis of the results of that comparison, we restored the original age determinations and recalculated the mean lengths at age. Mean length at age for both sexes and all ages in 1985 were anomalous in the data series, with significantly greater values than adjoining years. We have suspended use of the 1985 age data and will reread the collection.

The mean length at age of both sexes aged 2-6 years has remained relatively constant since 1971 (Figure 15). Most of the older age classes (>6 years of age) indicate that sizes declined during the 1970s and early 1980s, but have remained at a stable level since 1986.

We compared the growth rates of plaice cohorts, basing the analyses on age classes 2-8. By restricting the analysis to younger age classes, we examined ages for which growth is rapid and for which variability in age determination within and among readers is minimal. The data were taken from research survey biological data files, excluding data from 1985. Two models were examined: length was cast as a linear function of age and as a function of ln(age). Both models gave similar results with respect to R^2. Although the two models predicted similar lengths for most ages and year-classes, the linear model estimated the length at age-2 closer to observed values than the semi-log model.

Growth rates of year-classes, determined by the slopes of the linear growth model, followed a regular trend over time for both sexes (Figure 16). Maximum growth rates for males and females were attained by the 1970 year-class. The growth rates of more recent year-classes declined to their lowest values in 1975 year-class for females and 1976 year-class for males. This pattern does not support the prediction based on density-dependent growth since the abundance of year-classes from 1970 to 1976 declined (see following section). Growth rates of males and females rose to an intermediate level in the late 1970s, then dropped to lows in 1981 and 1982 (Figure 16).

Although this analysis shows a compelling pattern of growth rates among successive cohorts, it does not clearly indicate that density-dependence has been a determining factor for growth between 2 and 8 years of age. Size-at-age data (Figure 15) also indicate that mean lengths have shown the strongest trend over time among older age classes. Work is underway to model the growth of plaice taking into account other processes affecting growth.

Estimation of stock parameters

Total mortality at age (Z) was calculated for male and female plaice by subtracting the natural logarithm of the mean catch at age between consecutive ages of a cohort (Tables 12 and 13). Mortality since 1991 (with the exception of 1993 when Z declined in males) exceeded the longterm averages of Z for most age classes in both sexes. Average Z values for male plaice were greater than corresponding values for females, although when paired t-tests were performed on age classes 4-15, only four of the 12 comparisons were significantly different. Male Z was significantly greater than female Z for age classes 7, 11, 12 and 15 (P=0.03-0.04).

Multiplicative models were performed on stratified mean catch-at-age data for male, females and combined data with age and year-class effects. The procedure was the same as in the last assessment (Morin et al. 1995a) and Sinclair et al. (1994). The analyses were performed over successive 3-year periods; e.g., first analysis: years 1971-1973; second analysis: years 1972-1974. Each analysis provided the estimated ln catch for plaice of four years of age and least-square means of the year-class effect. Z was estimated from the slope of least-square estimates of the age effects over the range of ages 5-13 years. Year-class estimates at age-4 were obtained from each analysis, then averaged across estimates. For example, the 1970 year-class was averaged over three analyses: 1972-1974, 1973-1975, 1974-1976. The year-class estimates were back-transformed from logarithms with the bias correction formulated by Bradu and Mundlak (1970).

Multiplicative analyses of catch-at-age data including year-class effects indicate that mortality on males was higher than females from 1972 to 1982 (Figure 17). Male and female mortalities from ages 5-13 years have converged since 1988 with female Z slightly greater than male Z in 1990 and 1991. Estimates of Z have fluctuated widely over the years covered by the survey. Mortality appears to have declined since 1992 and for male plaice, Z in 1994 (0.36) is at the lower range of estimates before 1990. Mortality on females in 1994 was within the mid to upper range of previous estimates (Figure 17). Missing estimates of Z in Figure 17 were caused by non-significant regression models for 1973 and 1974. The remaining missing values were caused by the absence of sexed length frequencies in surveys conducted from 1984-1986 and the removal of 1985 catch-at-age data due to questionable age determinations.

In the last assessment, we reported a significant interaction of sex and year-class in a multiplicative analysis of catch-at-age data (Morin et al. 1995a). Figure 18 shows estimates of catch by year-class based on separate analyses conducted on male, female and combined sexes. Each analysis, which included age and year-class effects, was highly significant and accounted for over 85% of the variation in abundance (Table 14). The estimated catches show that the abundance of year-classes has not always varied similarly for males and females (Figure 18). In general, however, year-classes of the early 1970s were strong, but declined to a low level by 1976 and have remained stable since then. Our estimates were based on age-4 plaice, but since age was not included as an interaction term in the model, any other age selected would only increase or decrease the estimates proportionately.

We evaluated trends in fishing mortality (F) by combining estimates from commercial catches and research surveys. Relative F is the ratio of commercial catch to research survey catch. In the last assessment, this analysis was conducted on catch-at-age data (Morin et al. 1995a). Since discarded plaice in the fishery span several age classes, the analysis was sensitive to the age classes that were included in the model. For this assessment, we have based the analysis on length-frequency data, using the procedure of Sinclair et al. (1993) and including only commercial sizes (>30 cm). This method assumes that commercial length frequencies and research survey length frequencies are consistent indices of the size composition of the exploited stock and the population. Absolute fishing mortality cannot be determined for plaice by this method because catchability remains unknown for research surveys of 4T plaice.

A multiplicative model of the log ratio of males and females was cast with terms shown in Table 15. The same analysis was conducted with sexes combined. Commercial data for these analyses grouped all gear and estimated the total catch by centimetre of plaice >30 cm from 1976 to 1995. Lengths for which commercial catch and population (survey estimate) were zero, or for which population was zero, were excluded. The model included a quadratic term for length. A cubic term was included and, although significant, contributed only slightly to improving the model. Tables 15 and 16 show the analyses of variance resulting from the two analyses. Both models were highly significant (P=0.0001) and accounted for 60-69% of the variation in relative F.

Relative fishing mortality was at its lowest level over the time period studied during the 1970s and early 1980s (Figure 19). This period includes the years when the plaice population was abundant (Figure 10). Relative F increased sharply in 1984 and continued to rise and then fall in more recent years. Comparing Z and relative F (Figures 17 and 19), it is not obvious that the same trends were followed over time. However, Z was based on an analysis of ages that included plaice <30 cm. In this respect, the elevated Z that we noted in the 1970s, particularly for male plaice, is evidence of the high level of discarding that occurred when the minimum mesh size was 130 mm. We noted a sharp increase in Z in 1991 and 1992, with mortality on females equal or greater than male Z (Figure 17). This coincided with an increase in relative F, particularly for female plaice (Figure 19). Both Z and relative F declined sharply in 1993, a pattern that was also noted in age-based analyses conducted in the last assessment. Although Z was lower in 1994, relative F has tended to increase since 1993.

Estimates of relative F from the multiplicative analysis were solved for lengths in years of low and high fishing mortality, 1982 and 1992. In both years, the predicted values of relative F failed to accurately fit the observed values of relative F at lengths <35-45 cm (Figure 19). Observed values of relative F were low at the minimum length of 31 cm, but increased to approximately 35 cm for male and 40 cm for females.

Projection

Analyses of commercial and research survey catches (relative F) may be used to assess future management measures. If research survey data can be used as an index of future stock abundance, then the fishing mortality, measured as relative F, resulting from proposed levels of commercial removals could be estimated. Since research surveys for 4T plaice only provide an index of abundance (catchability undetermined), the projected relative F would not correspond to a specific target such as $F_{0.1}$. However, comparing the projected relative F to previous levels of relative F for the stock could provide insight into whether a given TAC would increase or decrease exploitation.

We illustrate this application first by assessing three approaches to projecting research survey catch at age. We used catch-at-age research data for 4T plaice, sexes combined, since 1987. We projected the abundance of plaice at ages 6-13 by first averaging all age-classes over the preceding three years (Method 1).

$$\hat{A}_4 = \frac{\sum_{y=1}^{3} \sum_{a=5}^{13} A_{ya}}{27}$$

where $\hat{A}_4$ is the number of plaice of each age-class predicted for the fourth year and A_{ya} is the number of plaice of age a caught in the previous three research surveys. The second method (Method 2) averaged the abundance of each age-class separately over the preceding three years.

$$\hat{A}_{4a} = \frac{\sum_{y=1}^{3} A_{ya}}{3}$$

where $\hat{A}_{4a}$ is the number of plaice of age-class a predicted for year 4.

Our third method was similar to the approach of Shepherd and Nicholson (1991) where a multiplicative model was used to project catch-at-age. The model

$$\ln A_{Za} = \beta_0 + \beta_1 Z + \beta_2 A + e$$

was used to estimate projection parameters. A_{Za} are the research survey catches of year-class Z at age a. Z and A are matrices of 0 and 1 denoting the year-class and age of the observations. The parameters β_0, β_1 and β_2 are vectors. The survey catches in year 4 were predicted as

$$\hat{A}_{Za} = e^{(\beta_0 + \beta_1 Z + \beta_2 A)}$$

for all estimable cases where $Z - a = 4$.

The three methods were evaluated by comparing their predicted catches-at-age with the observed catch-at-age over the years 1990-1995. We compared the average squared deviance of observed and predicted catch-at-age ($(\text{obs} - \text{pred})^2/48$). We also regressed predicted catch-at-age on observed values (data log-transformed) for each method.

The second method of survey catch projection provided the closest estimates of catch-at-age relative to observed values over the years 1990 to 1995. The average squared deviance of the estimates was 2318 for Method 2, 4715 for Method 3 and 11805 for Method 1. The regression of estimated values on observed values for the first method was not significant (P=0.96), whereas the remaining methods produced highly significant regressions (P<0.0001). The regression of values estimated by Method 2 accounted for 93% of the total variation, compared to 80% for Method 3. Of the seven multiplicative analyses that were conducted to project catch-at-age, the year-class term was not significant in three cases (P>0.05). Given the relative stability of year-class strength over the data series analyzed (Figure 18), the year-class effect contributed little to the total variance in abundance-at-age.

We calculated relative F for plaice aged 5 to 13 years of age based on four levels of harvest in 1996: 2000 t (little change from 1995), 1500 t, 1000 t and 500 t. Values were initially set to observed levels in 1995: relative F was set to 0.38; catch-at-age (survey data); mean weight-at-age (commercial data with gear and sexes combined). A factor was calculated to expand the numbers- and weight-at-age of plaice to a total landed catch of 2310 t in 1995. Relative F was then calculated for the projected numbers-at-age at the four proposed levels of harvest, assuming the same weight-at-age as in 1995 and using the same expansion factor.

A relative F of 0.33 was predicted based on the projected catch-at-age for 1996 by Method 2 and a harvest of 2000 t. At a harvest of 1500 t, relative F was 0.24, a value that is within the mid-range for estimates since 1976 (Figure 19, upper panel). At harvests of 1000 t and 500 t, relative F was estimated at 0.16 and 0.08, respectively, producing levels of fishing mortality that were similar or lower than during the period of 1976 to 1983.

The procedure outlined in this section is a useful application of methods for projecting stock abundance and fishing mortality. In this simple application we evaluated the effectiveness of reducing harvests of 4T plaice during 1996 in lowering fishing mortality to levels that have been observed in the past. The procedure could be used to assess other management measures, including changes in gear selectivity or minimum size. The procedure can also be modified to estimate relative F on the non-discarded portion of the catch. Our application was age-based, unlike relative-F calculations in the previous section (Figure 19) that were based on lengths >30 cm. Our projection was based on ages 6-13. Age-6 plaice were fully recruited to the survey gear and in 1995 they averaged roughly 30 cm in commercial catches (males: 28 cm; females: 32 cm). In spite of this, discarding remains an important consideration in projecting relative F under different management policies, particularly since restrictive quotas may induce more high-grading of plaice catches, effectively increasing the rate of discarding.

Assessment results

Landings of 4T plaice since 1993 are near their lowest level recorded since 1965. The landed catch of plaice in 1995 (2311 t) is similar to the 1994 landings. Catch-at-age data suggest a moderately strong 1987 year-class for the second consecutive year. Seine landings were similar in 1994 and 1995, and reported the same nominal effort. The number of trawls and nominal effort of trawls increased in 1995, but lower landings were reported. Fishing activity was concentrated in the eastern part of 4T for the third consecutive year. Since the closure of the cod fishery, plaice are fished almost entirely by directed fishing effort. In consultations with the fishing industry through assemblies and telephone surveys, most participants indicated that plaice abundance is at its average level and that the 1995 fishery was better than in 1994.

Several management measures have come into effect in the past three years that should contribute to reducing discarding and improving the precision of landing statistics. Industry continues to adopt larger mesh sizes. Dockside monitoring came into effect and the size composition of plaice catches was measured at sea and at port. In spite of these measures, discarding persists in the fishery. Further improvements are also required to landing statistics to reduce the reporting of unspecified flounder species and to gain better estimates of unreported catches that are used for bait, personal consumption or private sale.

Research survey data indicate that 4T plaice abundance has fluctuated at a low level since the early 1980s. Year-classes from the early 1970s were abundant, but since 1976 year-classes have been relatively weak and stable. Total mortality reached a recent maximum in 1992 and has since declined to a level that is intermediate to levels observed since 1971. Fishing mortality on commercially-sized plaice (length >30 cm) was relatively low in the 1970s, but increased sharply in 1984 and has fluctuated yearly since then. On the basis of a model predicting research survey catch-at-age in 1996, it is predicted that commercial removals in the order of 1000 t would be required to reduce fishing mortality to a level comparable to that observed in the 1970s.

Ecological considerations

Geographic Distribution

Review of recent research

Optimal foraging theory predicts that population range should expand as population size increases (MacCall 1990). This range expansion is expected when individuals begin to occupy poorer habitats as abundance and competition increase in the better habitats. This prediction has important implications for stock assessment because catchability to commercial fisheries (the proportion of a population captured by a unit of effort) is expected to be inversely proportional to stock area (Paloheimo and Dickie 1964). Thus, if geographic range is density-dependent, catchability will increase as abundance decreases. Recent studies have demonstrated density-dependent geographic range for cod in the southern Gulf of St. Lawrence (Swain and Sinclair 1994) and for juvenile haddock on the southwestern Scotian Shelf (Marshall and Frank 1994). In addition to range expansion and contraction, cod in the southern Gulf have shown density-dependent shifts in distribution (Swain and Wade 1993, Swain 1993, Swain and Kramer 1995) that may contribute to density-dependent catchability of cod to the September bottom-trawl survey (Swain et al. 1994).

Swain and Morin (1996) examined relationships between geographic distribution and abundance of plaice in the southern Gulf over the 1971-1992 period using data from the September bottom trawl surveys. The September distribution of plaice was remarkably stable throughout this period and was unrelated to population size. Plaice were most concentrated in the same three general areas during periods of both low and high abundance: 1) Chaleur Bay, 2) the Shediac Valley and central Magdalen Shallows, and 3) the area between Prince Edward and Cape Breton Islands (Figure 20). Plaice geographic range (the area containing 95% of the population) showed no tendency to expand as population size increased. The area of highest density (the area containing 50% of the population) did show a slight tendency to expand with population size. However, contrary to predictions given density-dependent habitat selection, there was no tendency for changes in local plaice density to be greatest in marginal areas as population size changed. Average catch rates were highest in the same areas in both low and high abundance periods, and no substantial shifts in distribution occurred between the two periods. Thus, catchability of plaice in September is not expected to be density-dependent to either commercial fisheries or the annual bottom trawl survey.

The geographic distribution of plaice below and above the commercial size limit (12 inches) was described for September 1994 in the previous assessment of this stock (Morin et al. 1995a). The distribution of larger plaice (≥31 cm total length) showed a striking shift toward eastern regions of the southern Gulf compared to the distributions in earlier years.

Distribution in September 1995 and in January 1996

We mapped spatial variation in plaice density in September 1995 using the geostatistical methods described in Morin et al. (1995a). As in the previous assessment, distribution was mapped separately for plaice ≤30 cm versus ≥31 cm total length. Geographic distribution in 1995 again showed a striking shift toward eastern regions (Figure 21) compared to distribution in the 1971-1993 period. This shift toward the east was again more striking for the larger plaice and is consistent with recent shifts in the distribution of fishing catch (Figure 3). Figure 22 shows the distribution of sampling and of plaice catches in the September surveys since 1990. This figure also illustrates the decline in abundance of plaice in Chaleur Bay and the Magdalen Shallows. Swain (1996) analyzed trends in plaice biomass for southern Gulf surveys, showing that biomass has varied more widely over time in western strata than in eastern strata and is currently low in the west.

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

The survey design followed a grid pattern covering areas with depth >50 m, but with higher sampling intensity at depths of 200-400 m. The survey extended from about 45° 15' to 48° North and from about 58° to 61° West. The survey proceeded in a north-south direction to minimize encounters with ice. At each location, a standard 15-minute tow was made with a Campelen 1800 trawl fitted with a 19 mm liner in the lengthening piece and codend. Depth profiles of conductivity, temperature and oxygen concentrations were also conducted. A total of 139 sets were attempted, of which 138 were successful.

A contoured map of the plaice catches in kg per tow (Figure 23) shows that the largest catches were made at the 4T-4Vn boundary, east of St. Paul's Island, at depths > 300 m. The distribution of catches was relatively similar to that observed in 1994 (Chouinard 1994) and in 1995 (Morin et al. 1995a) both in terms of area and depth.

The length frequency distributions for plaice surveyed in January, 1995 and 1996 indicate a mode between 25 and 30 cm (Figure 24). A higher proportion of fish <15 cm appeared in 1996; however, this may be due to higher catchability for smaller fish with the Campelen 1800 trawl.

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Table 1. Yearly landings of American plaice in NAFO Division 4T by major gear types. Gear codes: OTB=otter trawls (unspecified), OTB1=side otter trawl, OTB2=stern otter trawl, GNS=gillnets, LLS=longlines, LH=handlines.

	GEAR								
YEAR	OTB	OTB1	OTB2	SNU	GNS	LLS	LH	OTHER	TOTAL
1965	7782	0	0	1854	388	212	0	149	10385
1966	0	8066	581	2322	375	2	0	434	11780
1967	0	7237	211	1151	326	117	50	259	9351
1968	0	7900	237	913	298	4	36	180	9568
1969	0	5609	425	1418	421	58	17	244	8192
1970	29	5793	477	2243	439	79	7	134	9201
1971	0	4996	409	2885	876	21	9	317	9513
1972	14	4275	860	2576	286	73	11	199	8294
1973	20	3087	471	2748	241	73	1	264	6905
1974	0	3556	585	3719	250	6	5	364	8485
1975	1	3207	795	3897	217	14	18	294	8443
1976	41	4908	2864	3395	225	2	6	562	11193
1977	35	4261	375	4015	242	16	17	269	9230
1978	58	3651	889	3495	379	42	38	479	9031
1979	83	3415	961	3719	721	9	17	1071	9996
1980	1485	1809	558	3500	717	55	5	163	8292
1981	1022	1311	290	3575	1084	98	2	452	7834
1982	742	580	137	4124	805	94	5	55	6542
1983	821	479	102	4095	494	76	10	17	6094
1984	235	601	2582	3702	1905	386	25	163	9599
1985	165	824	3027	3870	1007	404	29	164	9490
1986	74	768	2125	3289	657	318	44	133	7408
1987	50	1075	2101	3140	831	664	67	136	8064
1988	15	540	2002	2842	957	484	33	116	6989
1989	14	495	1602	2489	501	212	386	18	5717
1990	9	677	1205	2259	474	240	26	17	4907
1991	22	146	1232	3057	525	102	22	116	5222
1992	19	175	1405	2793	537	70	14	185	5198
1993*	0	36	142	844	281	19	3	77	1403
1994*	0	4	272	1763	241	12	1	127	2419
1995*	0	20	238	1731	170	3	0	147	2310
MEAN	411	2565	941	2820	544	128	29	236	7647

* Provisional data

Table 2. Preliminary landings (t) of 4T American plaice in 1995 by gear and month. Asterisks indicate values less than 50 kg. Gear types: OTB1= side otter trawl, OTB2=stern otter trawl, PTB=bottom pair trawl, PTM=midwater pair trawl, TXS=shrimp trawl, SDN=Danish seine, SSC=Scottish seine, GNS=gillnets, BXN=boxnet (eel & smelt), LLS=longline, LHB=baited handlines, FIX=traps, UNK=unkown gear.

	MONTH									
GEAR	JAN	FEB	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	TOTAL
OTB1	0.0	0.0	0.0	0.2	7.4	11.0	0.0	1.4	0.2	20.3
OTB2	0.0	0.0	3.1	0.8	54.4	103.1	55.8	20.4	0.4	238.0
PTB	0.0	0.0	0.0	0.0	32.5	15.5	27.7	35.3	0.0	111.0
PTM	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4
TXS	0.0	0.0	0.0	0.2	1.6	0.7	0.0	0.0	0.0	2.6
SDN	0.0	0.0	326.9	180.5	220.2	150.2	217.1	336.6	1.6	1433.0
SSC	0.0	0.0	43.4	21.4	16.9	35.2	21.8	156.2	3.0	298.0
GNS	0.0	0.0	31.3	35.1	91.6	10.9	1.4	0.2	0.0	170.4
BXN	0.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
LL	0.0	0.0	0.0*	0.0	0.1	1.9	0.1	0.4	0.0*	2.6
LHB	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2
FIX	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6
UNK	0.0	0.0	1.8	5.0	11.7	3.4	2.0	7.2	0.0	31.1
TOTAL	0.5	1.1	406.5	243.8	436.5	332.1	326.3	557.6	5.3	2309.8

Table 3. Resource allocation and management plan for American plaice in 4T (M.G.= mobile gear; F.G.= fixed gear; comp= competitive fleet; itq= individual tranferable quota; s-f= Scotia Fundy).

YEAR	GEAR	FINAL ALLOCATION (t)	CATCH (t)	CLOSURES
1990	M.G. (65-100)	500	368	none
	M.G.(50-64)	2990	1199	none
	M.G.(45-49)	810	271	none
	M.G. (<45)	4200	1829	none
	F.G. (<65)	1500	752	none
1991	M.G. (65-100)	500	347	none
	M.G.(50-64)	2480	992	none
	M.G.(45-49)	810	271	none
	M.G. (<45)	4200	1799	none
	F.G. (<65)	1480	730	none
1992	M.G. (65-100)	500	344	none
	M.G.(50-64)	2990	1058	none
	M.G.(45-49)	830	359	none
	M.G. (<45)	4200	2494	none
	F.G. (<65)	1480	624	none
1993	M.G. (65-100)	250	144	3
	M.G.(45-64)	1655	103	14
	M.G.(50-64)	75	1	14
	M.G.(50-64)	180	0	14
	M.G.(<45)	2100	970	14
	F.G. (<65)	740	287	4
1994	M.G. (65-100)	250	25	none
	M.G. (45-64)	1655	97	4
	M.G. (50-64 shrimp)	75	0	none
	M.G. (50-64 crab)	180	0	none
	M.G. <45 comp	1442	1373	none
	itq	639	556	none
	s-f	19	30	none
	F.G. <65	740	273	2
	Sentinel Fishery	0	2	none
1995	M.G. (65-100)	250	41	
	M.G. (45-64 itq)	1645	37	
	M.G. (45-64 lobster)	10	0	
	M.G. (50-64 shrimp)	75	0	
	M.G. (50-64 crab)	30	0	
	M. G. <45 comp	1592	1627	
	itq	639	346	
	s-f	19	21	
	F.G. (<65)	740	220	
	Sentinel Fishery	0	8	

Table 4. Number of American plaice sampled for length-frequency (measured) and age determination (aged), by month, from the 4T commercial fishery in 1995, with the number of monthly samples. "-"indicates no sampling.

GEAR		MAY	JUNE	JULY	AUG	SEPT	OCT	TOTAL
Seines	Measured	431	881	1697	996	723	3127	7855
	Aged	63	122	239	143	85	409	1061
Trawls	Measured	-	-	-	723	200	328	1251
	Aged	-	-	-	104	21	39	164
Samples		2	4	8	9	4	17	44

Table 5. Estimated annual landings at age (thousands of fish) of 4T American plaice up to age 26. Indicated totals are for all landings, including plaice > 26 years of age. Data for 1993-1995 are based on provisional landing statistics.

AGE	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
4	0	3	9	2	0	8	0	3	51	18	0	1	24	12	313	7	16	10	4	3
5	38	99	242	0	0	27	0	61	122	85	21	71	62	111	138	83	54	95	238	50
6	458	601	776	482	47	59	25	123	604	99	448	173	235	444	397	262	455	174	944	300
7	1381	2101	2000	1237	580	146	48	263	1033	475	784	779	299	1068	674	664	939	374	1201	804
8	2372	2254	3835	4308	1133	420	377	382	847	677	1374	893	491	1300	1458	736	1528	703	1189	1094
9	2143	1884	2671	5472	2628	686	1060	475	670	740	1355	945	779	1769	1246	1619	1294	423	998	941
10	2401	1627	2610	4105	2142	1028	1680	770	1089	1157	1187	1390	751	1175	1298	1046	1958	374	858	940
11	2038	1295	2144	2471	1939	1075	1482	1100	1573	1634	1564	1191	831	952	840	973	1154	467	492	680
12	2820	1706	1471	1675	2362	935	1490	1444	1285	2032	1711	1221	987	766	574	888	836	276	401	435
13	1467	901	1384	1111	1424	750	1030	1494	918	1687	1636	1493	808	665	575	585	374	93	241	380
14	797	595	724	1088	1077	928	735	901	1320	1430	1074	1074	978	509	404	411	383	98	144	147
15	397	289	543	337	898	1088	414	617	923	1050	856	1051	827	446	350	291	275	75	62	114
16	408	233	145	216	623	688	324	470	462	760	608	588	890	401	270	305	244	72	22	50
17	335	201	103	148	243	761	340	451	563	505	342	547	435	277	203	312	114	33	15	32
18	208	238	109	37	82	461	256	298	352	248	193	292	369	226	140	176	146	36	26	27
19	267	157	68	48	73	136	43	337	276	286	172	281	236	97	117	198	98	39	11	32
20	165	172	34	51	33	168	24	116	191	135	152	259	209	99	38	215	112	36	12	10
21	99	45	95	63	32	172	74	75	51	72	122	143	81	63	44	66	66	18	5	9
22	76	20	0	25	21	176	36	105	25	58	31	114	76	34	14	59	19	4	4	13
23	26	10	114	7	45	79	28	17	15	26	23	86	48	20	8	26	6	5	4	7
24	15	18	31	0	0	63	11	4	0	12	16	42	53	7	4	23	4	0	3	2
25	11	0	0	17	0	18	6	16	0	21	6	20	25	7	2	4	9	1	2	3
26	7	15	16	0	0	55	3	3	0	0	6	23	0	3	0	12	4	0	0	0
	17930	14464	19123	22901	15379	9930	9487	9523	12370	13209	13682	12676	9494	10453	9108	8960	10088	3406	6876	6079

Table 6. Mean catch per tow of American plaice in 4T from research surveys. All values have been standardized to the same vessel (Hammond/Needler).

AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1	1.9	1.3	1.0	0.7	0.8	0.0	0.7	0.0	0.1	2.0	3.7	0.4	2.7	0.3		4.1	0.7	0.6	0.7	0.8	1.9	2.2	2.1	1.3	2.7
2	7.0	8.2	6.8	14.6	3.7	1.0	5.8	0.7	1.6	7.1	12.9	8.1	10.8	2.7		7.0	8.0	4.5	4.4	14.5	16.9	7.2	11.0	2.2	5.6
3	21.6	15.4	22.8	50.8	22.1	30.5	77.3	8.2	6.8	34.3	28.7	14.6	27.0	4.8		13.4	15.4	15.9	12.2	34.3	27.8	27.4	12.8	19.2	8.5
4	34.7	34.3	31.0	105.5	79.4	135.5	223.9	78.7	62.1	75.2	66.7	17.9	31.9	19.7		29.9	30.7	26.3	27.5	56.2	52.4	40.1	38.9	25.6	29.2
5	34.8	34.2	35.8	89.9	138.8	236.7	315.5	106.0	165.5	87.2	88.1	35.5	39.2	28.0		29.8	44.0	32.9	38.3	78.3	65.0	46.7	38.7	42.7	23.2
6	38.2	38.7	27.8	73.0	73.5	193.3	198.9	116.4	154.1	109.0	110.1	33.4	38.5	26.3		38.8	36.8	49.8	29.1	59.3	65.6	45.8	35.1	37.9	32.3
7	44.1	44.2	23.3	48.6	60.5	91.3	138.4	117.1	179.4	79.1	116.5	50.6	29.1	24.7		27.6	37.2	33.2	32.0	30.7	46.6	30.3	26.8	30.3	22.8
8	28.9	31.3	27.9	40.1	37.8	42.9	62.3	72.1	137.4	63.7	67.8	67.7	47.1	22.9		12.3	21.6	32.7	21.1	28.9	28.1	21.3	18.9	19.2	19.9
9	9.4	14.3	22.1	47.9	30.5	39.2	25.2	25.1	64.1	33.8	45.3	34.0	45.8	21.2		14.8	17.8	20.3	13.2	16.3	26.7	10.7	10.8	12.5	12.6
10	6.2	8.1	10.1	27.0	19.5	26.5	15.7	17.3	34.0	17.7	23.8	22.1	26.6	25.6		6.0	11.0	10.0	9.1	10.5	13.1	8.6	5.1	8.4	8.7
11	5.6	3.9	5.0	12.7	15.1	18.6	9.7	9.2	19.0	11.3	11.5	8.8	26.3	9.1		7.9	8.1	7.3	4.6	7.4	8.7	4.7	4.9	3.9	4.9
12	3.6	3.9	3.6	4.5	4.1	11.8	6.4	5.1	10.2	6.5	5.3	4.0	13.8	8.2		14.5	6.9	6.1	4.3	3.4	6.1	3.3	2.4	3.7	2.9
13	2.4	2.0	2.7	3.8	2.5	7.0	4.2	5.7	6.5	4.7	3.1	1.9	5.6	3.7		8.7	2.7	5.5	3.2	2.7	2.9	2.0	1.5	1.4	1.6
14	2.1	1.3	3.5	4.1	2.0	3.7	2.1	2.3	6.0	2.4	1.9	2.1	2.7	1.5		8.5	2.8	4.6	2.3	1.2	2.7	1.1	0.5	0.6	0.6
15	1.2	0.6	1.7	3.0	1.1	1.7	1.4	1.5	3.4	1.1	1.4	1.2	2.0	1.4		5.4	1.4	2.4	1.4	1.3	1.9	0.7	0.2	0.3	0.4
16	1.2	0.8	1.4	1.4	1.2	1.4	0.3	0.5	2.4	0.5	1.1	1.2	1.2	0.6		3.5	0.7	1.0	0.8	0.6	1.2	0.6	0.3	0.2	0.1
17	1.0	0.2	1.6	0.6	0.2	1.4	0.7	0.5	0.5	0.5	0.4	0.9	1.1	0.5		1.0	0.6	0.9	0.6	0.2	1.0	0.2	0.2	0.2	0.0
18	0.5	0.2	0.6	0.5	1.1	0.6	0.5	0.5	0.7	0.1	0.2	0.4	0.9	0.5		1.0	0.4	0.3	0.2	0.2	0.5	0.2	0.1	0.1	0.0
19	0.1	0.1	1.6	0.2	0.5	0.3	0.5	0.6	0.4	0.2	0.3	0.4	0.3	0.3		0.6	0.4	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1
20	0.3	0.0	0.5	0.3	0.6	0.1	0.0	0.4	0.4	0.1	0.1	0.1	0.1	0.2		0.5	0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.0	0.0
21	0.0	0.0	0.5	0.0	0.1	0.4	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.2		0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0
22	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.0	0.1		0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
24	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0		0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7. Coefficients of variation (%) for estimates of mean catch per tow in research surveys. - indicates no data.

AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1	44.9	62.5	53.1	73.1	83.0	0.0	41.0	0.0	70.8	35.3	38.7	63.7	45.6	44.3		32.5	31.2	43.4	28.0	30.0	14.1	20.9	14.0	44.5	16.7
2	22.5	21.2	26.9	24.4	26.6	35.7	23.4	49.1	25.1	13.0	26.1	21.6	21.2	19.5		25.8	26.3	23.2	16.7	18.1	9.5	10.8	10.8	25.5	10.5
3	21.5	20.2	21.7	19.1	17.1	20.1	21.0	35.3	13.9	9.9	31.3	21.2	19.1	14.0		17.8	14.6	19.3	9.3	11.1	8.1	8.1	7.3	8.6	6.8
4	22.7	17.5	14.7	13.3	12.7	16.1	23.8	37.3	15.2	9.5	30.2	18.0	14.3	15.7		15.7	12.4	16.8	9.4	11.1	8.4	8.2	8.4	10.3	6.6
5	20.3	22.1	15.1	8.6	11.8	13.1	20.6	35.3	13.5	10.2	23.1	16.6	12.2	16.2		17.6	14.0	15.9	9.5	11.2	9.7	8.4	8.0	10.6	7.8
6	18.6	20.8	15.4	9.0	13.9	9.3	17.1	34.2	11.8	10.8	18.9	17.4	11.0	15.5		20.4	14.9	16.2	9.2	10.0	10.6	7.8	7.8	10.4	7.5
7	18.7	17.5	14.9	9.9	15.1	8.6	14.1	35.1	10.3	11.6	17.4	18.0	10.7	14.3		18.5	14.3	16.9	9.6	9.0	10.6	7.4	7.6	9.9	7.2
8	18.5	19.1	14.8	13.4	13.3	9.2	12.4	27.2	9.9	13.4	16.8	18.0	10.5	13.7		16.7	13.0	17.5	9.9	8.7	10.4	7.4	8.1	9.2	7.7
9	18.6	20.3	12.6	15.5	15.0	11.7	13.1	23.4	10.7	14.4	17.9	18.8	11.2	11.9		15.6	13.6	16.1	9.8	9.3	10.7	7.9	8.4	8.8	8.3
10	18.5	19.2	12.0	16.8	12.7	13.1	11.9	20.8	11.4	14.4	19.6	21.6	12.6	11.4		13.3	9.9	15.5	11.3	8.7	9.9	8.0	8.6	9.3	8.6
11	17.0	18.1	10.9	18.1	12.8	11.1	12.6	18.9	13.3	14.9	21.7	20.9	16.3	10.4		13.1	9.2	14.4	11.4	9.6	9.8	8.3	9.4	8.6	8.8
12	18.1	17.4	11.6	14.7	14.2	11.1	12.9	20.3	14.2	17.7	27.5	26.1	22.4	9.9		13.8	9.1	13.0	12.1	8.0	9.4	7.8	11.0	8.4	9.8
13	18.7	30.3	19.0	19.8	16.4	15.6	14.1	23.0	20.8	19.4	34.1	27.3	35.2	9.8		13.9	9.8	14.9	11.0	8.1	9.5	8.6	10.5	7.8	9.9
14	19.1	39.4	25.9	29.2	20.3	17.8	13.0	31.1	22.4	20.3	32.2	33.7	37.9	12.3		13.3	9.5	14.9	9.4	8.1	10.7	7.2	10.2	8.8	11.2
15	22.4	28.3	34.7	23.2	35.2	20.8	18.1	25.3	27.3	26.1	21.6	30.5	37.7	14.0		11.9	9.4	19.5	9.8	8.8	8.7	8.0	14.0	8.9	11.3
16	22.5	42.6	57.0	20.6	27.9	31.0	26.2	32.3	26.9	22.5	26.5	33.6	34.9	23.4		12.9	12.3	22.7	10.4	15.0	9.2	8.5	17.3	8.3	0.0
17	20.9	56.2	62.3	22.2	34.7	25.5	55.8	39.0	43.4	34.3	28.3	37.3	29.9	24.9		13.6	12.8	31.1	11.0	17.9	7.6	12.3	20.7	10.6	0.0
18	36.1	67.1	60.1	29.9	43.9	39.3	64.0	45.3	28.7	40.9	40.9	38.6	34.6	29.8		18.3	19.5	21.1	19.8	23.0	8.5	12.6	25.2	11.3	0.0
19	26.9	70.7	79.9	39.6	45.5	72.3	36.6	51.1	29.9	36.8	28.1	38.8	28.3	28.8		20.0	17.7	31.6	19.1	16.7	11.2	17.4	37.0	20.7	0.0
20	34.6	59.6	72.5	38.0	48.6	54.7	100.0	42.0	33.2	53.3	45.1	39.7	64.3	36.4		16.7	26.4	31.0	29.2	22.3	19.9	33.8	46.5	48.6	0.0
21	-	-	84.4	49.2	77.4	27.2	100.0	-	48.6	81.8	-	100.0	34.1	35.0		22.2	19.0	30.3	22.1	37.5	25.4	16.8	49.0	35.8	-
22	32.0	-	79.5	100.0	64.8	58.4	-	64.3	48.2	100.0	32.2	44.2	100.0	40.2		36.8	42.7	-	24.7	-	51.2	-	60.0	59.5	0.0
23	-	41.9	53.7	91.2	-	-	57.6	-	46.9	-	-	63.4	-	40.1		0.0	55.5	63.2	63.5	39.3	42.2	-	84.4	76.6	-
24	-	-	84.1	-	-	100.0	-	-	15.5	-	62.0	-	49.6	35.8		35.5	-	-	34.0	-	57.6	100.0	-	-	-
25	-	-	-	-	73.7	-	-	-	-	-	-	100.0	-	-		0.0	-	-	85.8	-	58.0	-	57.8	-	-
26	-	-	-	67.6	-	-	-	-	-	-	-	51.9	-	-		0.0	-	-	-	100.0	-	55.5	-	-	-
27	-	-	-	-	-	-	-	-	-	-	54.9	-	-	-		-	-	-	-	-	-	70.8	63.8	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-

Table 8. Mean catch per tow of male American plaice in 4T research surveys.

Age	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1	0.4	0.1	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.1	1.7	0.0	0.2				0.1	0.1	0.1	0.0	0.2	0.2	0.5	0.0	0.1
2	3.7	2.2	1.9	6.6	1.6	0.3	1.2	0.5	0.3	3.5	5.4	4.1	4.4				2.6	1.7	1.3	2.2	4.2	2.5	2.3	0.6	1.8
3	11.6	7.9	12.1	26.4	13.5	15.3	33.8	7.0	3.6	19.6	19.8	9.6	12.5				7.5	7.9	5.1	12.5	11.5	15.5	6.2	9.0	4.4
4	18.3	19.0	16.7	62.8	43.6	78.1	137.4	67.5	33.2	47.2	45.6	10.3	17.2				18.1	13.9	13.0	27.5	27.8	25.0	25.1	15.1	16.1
5	18.7	23.0	21.2	56.5	77.2	136.7	187.9	86.9	90.8	55.4	60.1	21.0	24.7				29.3	19.6	19.4	40.5	34.8	28.5	22.5	24.2	11.9
6	22.6	25.8	16.2	46.8	47.3	115.2	111.6	92.7	95.1	67.6	81.4	22.0	24.6				23.2	29.0	14.5	28.4	35.6	24.5	18.9	20.4	15.9
7	24.3	25.7	13.2	31.1	41.0	50.2	62.4	90.5	112.4	38.7	71.4	35.0	17.9				23.3	18.1	17.6	15.0	25.0	16.0	13.2	16.1	10.6
8	15.3	14.4	16.6	24.9	22.2	23.5	31.1	38.7	77.9	29.1	34.6	39.0	30.3				13.5	17.2	11.5	14.7	15.5	11.8	10.6	10.1	10.5
9	5.5	5.4	10.2	29.5	21.2	23.5	13.5	13.2	27.0	10.3	16.3	14.2	22.3				12.7	12.2	6.6	9.9	16.1	6.7	6.0	6.7	6.8
10	3.7	5.5	4.8	8.1	10.4	17.6	8.0	8.1	17.2	5.4	9.3	4.6	12.6				5.7	6.5	5.6	5.8	7.7	5.1	2.7	5.3	4.8
11	3.0	2.3	2.6	4.0	7.3	6.7	4.3	4.3	9.0	2.9	4.3	2.2	8.3				4.6	4.4	2.7	4.7	5.0	2.9	2.7	2.5	2.7
12	1.3	1.8	2.0	2.2	1.4	3.3	2.5	1.4	4.3	1.2	1.4	0.2	2.6				2.7	3.0	2.8	1.3	3.5	1.8	1.6	2.2	1.9
13	1.1	0.4	1.5	1.9	1.3	1.0	0.9	0.7	2.0	0.6	0.5	0.2	0.4				0.6	2.5	1.8	1.2	1.7	1.2	0.7	0.8	0.9
14	0.8	0.1	1.1	3.1	1.3	0.6	0.1	0.4	1.3	0.2	0.0	0.0	0.2				0.8	1.8	1.0	0.2	1.7	0.5	0.2	0.3	0.3
15	0.3	0.2	0.5	1.1	0.0	0.8	0.3	0.2	0.4	0.0	0.5	0.0	0.2				0.6	0.6	0.4	0.2	1.0	0.3	0.1	0.2	0.1
16	0.3	0.0	0.2	0.2	0.4	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0				0.1	0.0	0.2	0.0	0.7	0.1	0.1	0.1	0.1
17	0.1	0.0	0.2	0.1	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0				0.2	0.1	0.0	0.0	0.3	0.0	0.0	0.1	0.0
18	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 9. Mean catch per tow of female American plaice in 4T research surveys.

Age	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.2	0.1	0.6				0.2	0.2	0.1	0.0	0.6	0.0	0.2	0.0	0.1
2	3.3	3.3	3.8	6.6	1.5	0.8	2.5	0.0	0.5	2.9	4.5	3.8	2.8				1.6	1.3	0.7	1.6	7.3	2.0	2.0	0.6	1.8
3	10.1	7.5	10.7	23.6	8.6	15.1	33.4	0.6	3.1	14.0	8.9	5.1	10.7				7.8	6.3	4.3	9.8	14.7	10.8	4.7	7.7	3.8
4	16.4	15.3	14.2	42.7	35.8	57.4	83.9	10.5	28.8	28.0	21.1	7.7	12.5				12.6	12.4	13.7	26.7	24.5	15.1	13.6	10.3	13.1
5	16.1	11.3	14.6	33.4	61.6	100.0	127.6	19.0	74.6	31.8	28.0	14.7	13.6				14.7	13.3	18.9	37.7	30.2	18.2	16.2	18.5	11.2
6	15.6	12.9	11.5	26.2	26.2	78.1	87.1	23.7	59.0	41.4	28.6	11.6	13.9				13.6	20.8	14.5	30.9	30.0	21.3	16.2	17.4	16.4
7	19.9	18.5	10.1	17.5	19.5	41.1	75.9	26.5	67.0	40.4	45.1	15.9	11.2				13.9	15.1	14.4	15.7	21.6	14.3	13.5	14.2	12.2
8	13.6	16.9	11.3	15.2	15.6	19.4	31.2	33.5	59.5	34.6	33.2	29.2	16.9				8.2	15.5	9.6	14.2	12.6	9.6	8.4	9.2	9.4
9	4.0	8.9	11.9	18.4	9.3	15.7	11.7	12.0	37.0	23.5	28.9	20.0	23.5				5.1	8.2	6.6	6.4	10.6	4.0	4.9	5.9	5.8
10	2.6	2.6	5.3	18.9	9.2	8.9	7.8	9.2	16.8	12.3	14.5	17.6	14.0				5.3	3.5	3.5	4.8	5.4	3.5	2.3	3.2	3.9
11	2.6	1.6	2.4	8.7	7.7	11.8	5.4	4.8	10.0	8.4	7.1	6.6	18.0				3.5	2.9	1.9	2.6	3.7	1.8	2.1	1.4	2.1
12	2.3	2.1	1.6	2.2	2.7	8.5	3.8	3.7	5.9	5.4	3.8	3.8	11.2				4.2	3.1	1.6	2.1	2.6	1.6	0.8	1.5	1.1
13	1.3	1.5	1.3	1.9	1.2	6.0	3.4	4.9	4.5	4.1	2.6	1.7	5.2				2.1	3.0	1.4	1.5	1.2	0.8	0.7	0.6	0.7
14	1.2	1.2	2.4	1.0	0.7	3.1	2.0	1.9	4.8	2.2	1.9	2.1	2.5				2.0	2.8	1.3	0.9	1.0	0.6	0.3	0.3	0.3
15	1.0	0.4	1.2	1.9	1.1	0.9	1.1	1.3	3.1	1.1	0.9	1.2	1.8				0.7	1.8	1.0	1.1	0.9	0.4	0.1	0.1	0.3
16	0.9	0.8	1.2	1.2	0.9	1.3	0.2	0.4	2.2	0.5	1.1	1.2	1.2				0.5	0.9	0.6	0.6	0.5	0.5	0.2	0.1	0.1
17	0.9	0.2	1.4	0.4	0.2	1.2	0.7	0.5	0.4	0.5	0.4	0.9	1.1				0.4	0.9	0.6	0.2	0.7	0.2	0.1	0.1	0.0
18	0.5	0.2	0.5	0.4	1.0	0.6	0.5	0.5	0.7	0.1	0.2	0.4	0.9				0.4	0.3	0.2	0.2	0.4	0.2	0.1	0.1	0.0
19	0.1	0.1	1.6	0.2	0.5	0.3	0.5	0.6	0.4	0.2	0.3	0.4	0.2				0.4	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.0
20	0.2	0.0	0.5	0.3	0.6	0.1	0.0	0.4	0.4	0.1	0.1	0.1	0.1				0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.0	0.0
21	0.0	0.0	0.5	0.0	0.1	0.4	0.0	0.0	0.1	0.0	0.0	0.0	0.4				0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0
22	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.0				0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0				0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
24	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.0	0.5	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 10. Analyses of variance for length-weight regressions on female plaice. Plaice were sampled yearly from 1971-1995. Dependent variable was the natural logarithm of weight in grams.

Analysis of all data:
Number of observations in data set = 38061

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	49	8063.841	164.568	32514.08	0.0001
Error	38011	192.391	0.005		
Corrected Total	38060	8256.231			

R-Square	C.V.	Root MSE	LOGWT Mean
0.9767	3.0919	0.0711	2.3009

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLEN	1	8032.792	8032.795	99999.99	0.0001
YEAR	24	17.822	0.743	146.71	0.0001
LOGLEN*YEAR	24	13.224	0.551	108.86	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLEN	1	5120.745	5120.745	99999.99	0.0001
YEAR	24	14.985	0.624	123.36	0.0001
LOGLEN*YEAR	24	13.224	0.551	108.86	0.0001

Analysis of female plaice of 60-2900 g weight:
Number of observations in data set = 33055

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	49	4049.608	82.645	21438.03	0.0001
Error	33005	127.237	0.004		
Corrected Total	33054	4176.845			

R-Square	C.V.	Root MSE	LOGWT Mean
0.9695	2.5720	0.0621	2.4140

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLEN	1	4032.833	4032.833	99999.99	0.0001
YEAR	24	12.127	0.505	131.07	0.0001
LOGLEN*YEAR	24	4.649	0.194	50.24	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLEN	1	3359.288	3359.288	99999.99	0.0001
YEAR	24	5.176	0.216	55.94	0.0001
LOGLEN*YEAR	24	4.648	0.194	50.24	0.0001

Table 11. Analyses of variance for length-weight regressions on male plaice. Plaice were sampled yearly from 1971-1995. Dependent variable was the natural logarithm of weight in grams.

Analysis of all data:
Number of observations in data set = 27203

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	49	3794.369	77.436	12448.61	0.0001
Error	27153	168.904	0.006		
Corrected Total	27202	3963.273			

R-Square	C.V.	Root MSE	LOGWT Mean
0.9574	3.8159	0.0789	2.0669

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLEN	1	3751.214	3751.214	99999.99	0.0001
YEAR	24	27.296	1.137	182.84	0.0001
LOGLEN*YEAR	24	15.859	0.661	106.23	0.0001

Source	DF	Type II SS	Mean Square	F Value	Pr > F
LOGLEN	1	1893.789	1893.789	99999.99	0.0001
YEAR	24	18.398	0.767	123.23	0.0001
LOGLEN*YEAR	24	15.859	0.661	106.23	0.0001

Analysis of male plaice of 60-900 g weight:
Number of observations in data set = 21719

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	49	1174.879	23.977	6178.93	0.0001
Error	21669	84.086	0.004		
Corrected Total	21718	1258.965			

R-Square	C.V.	Root MSE	LOGWT Mean
0.9332	2.8227	0.0623	2.2069

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOGLEN	1	1161.251	1161.251	99999.99	0.0001
YEAR	24	11.927	0.497	128.07	0.0001
LOGLEN*YEAR	24	1.701	0.071	18.26	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOGLEN	1	934.584	934.584	99999.99	0.0001
YEAR	24	1.914	0.080	20.56	0.0001
LOGLEN*YEAR	24	1.701	0.071	18.26	0.0001

Table 12. Total mortality (Z) of male American plaice calculated from the mean number per tow in research surveys.

Age	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Mean
1	-1.75	-3.28	-3.08	-2.52	-	-	-1.65	-	-	-3.60	-0.91	-4.51					-3.12	-2.21	-3.68	-4.92	-2.48	-2.52	-0.15	-3.76	-2.76
2	-0.76	-1.72	-2.62	-0.72	-2.25	-4.87	-1.77	-1.93	-4.09	-1.74	-0.58	-1.11					-1.12	-1.08	-2.24	-1.64	-1.30	-0.88	-1.36	-2.02	-1.79
3	-0.50	-0.75	-1.65	-0.50	-1.75	-2.19	-0.69	-1.56	-2.56	-0.84	0.65	-0.58					-0.62	-0.49	-1.68	-0.80	-0.78	-0.48	-0.89	-0.58	-0.96
4	-0.23	-0.11	-1.22	-0.21	-1.14	-0.88	0.46	-0.30	-0.51	-0.24	0.78	-0.87					-0.08	-0.33	-1.14	-0.24	-0.02	0.11	0.04	0.23	-0.30
5	-0.32	0.35	-0.79	0.18	-0.40	0.20	0.71	-0.09	0.30	-0.39	1.01	-0.16					0.01	0.30	-0.38	0.13	0.35	0.41	0.10	0.42	0.10
6	-0.13	0.67	-0.65	0.13	-0.06	0.61	0.21	-0.19	0.90	-0.06	0.84	0.21					0.25	0.50	-0.03	0.13	0.80	0.62	0.16	0.66	0.28
7	0.52	0.43	-0.64	0.34	0.56	0.48	0.48	0.15	1.35	0.11	0.61	0.14					0.30	0.45	0.18	-0.04	0.75	0.42	0.27	0.43	0.36
8	1.04	0.35	-0.57	0.16	-0.06	0.56	0.86	0.36	2.02	0.58	0.89	0.56					0.10	0.96	0.15	-0.09	0.84	0.68	0.46	0.39	0.51
9	0.00	0.11	0.23	1.05	0.19	1.08	0.52	-0.27	1.61	0.10	1.27	0.12					0.66	0.78	0.13	0.25	1.15	0.90	0.13	0.33	0.52
10	0.48	0.76	0.18	0.10	0.43	1.41	0.60	-0.11	1.77	0.23	1.46	-0.59					0.27	0.87	0.16	0.13	0.99	0.62	0.10	0.66	0.53
11	0.53	0.11	0.14	1.07	0.81	0.97	1.12	0.01	2.05	0.71	3.12	-0.16					0.43	0.46	0.71	0.31	1.05	0.60	0.24	0.27	0.73
12	1.16	0.19	0.08	0.56	0.31	1.34	1.24	-0.34	1.99	0.84	2.21	-0.64					0.10	0.50	0.85	-0.22	1.08	0.86	0.62	0.87	0.68
13	2.42	-1.00	-0.75	0.36	0.85	2.76	0.66	-0.54	2.44	-	2.75	-0.33					-1.08	0.93	2.02	-0.38	1.19	1.78	0.94	1.07	0.85
14	1.57	-1.57	0.05	-	0.51	0.63	-1.09	0.15	-	-1.14	-	-2.01					0.32	1.51	1.59	-1.46	1.71	1.98	0.19	1.47	0.26
15	-	-0.24	1.03	1.09	-	2.21	1.69	-0.18	-	-	-	-					3.17	1.24	2.97	-1.21	2.16	1.28	-0.22	0.98	1.14
16	-	-	0.67	-	0.54	-	-	-0.26	-	-	-	-					0.88	-0.11	-	-2.79	3.00	1.35	-0.38	-	0.32
17	-	-	0.34	-0.13	-	-	-	-	-	-	-	-					1.71	-	-	-	3.30	0.36	-0.42	1.49	0.95
18	-	-	-	-	-	-	-	-	-	-	-	-					-	-	-	-	-	-	0.83	1.77	1.30

Table 13. Total mortality (Z) of female American plaice calculated from the mean number per tow in research surveys.

Age	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Mean
1	-	-2.56	-	-	-2.02	-	-	-	-	-2.25	-2.87	-3.69					-2.04	-1.12	-3.38	-5.96	-1.15	-3.74	-1.11	-4.86	-2.83
2	-0.82	-1.17	-1.82	-0.27	-2.31	-3.76	1.37	-	-3.30	-1.12	-0.11	-1.04					-1.38	-1.16	-2.62	-2.23	-0.38	-0.86	-1.34	-1.87	-1.38
3	-0.42	-0.64	-1.38	-0.42	-1.90	-1.71	1.15	-3.84	-2.19	-0.41	0.15	-0.91					-0.46	-0.78	-1.83	-0.92	-0.02	-0.23	-0.78	-0.53	-0.90
4	0.37	0.05	-0.86	-0.37	-1.03	-0.80	1.48	-1.96	-0.10	0.00	0.36	-0.57					-0.06	-0.42	-1.01	-0.12	0.30	-0.07	-0.31	-0.08	-0.26
5	0.22	-0.02	-0.59	0.24	-0.24	0.14	1.68	-1.13	0.59	0.11	0.88	0.06					-0.35	-0.09	-0.50	0.23	0.35	0.12	-0.07	0.12	0.09
6	-0.17	0.24	-0.42	0.30	-0.45	0.03	1.19	-1.04	0.38	-0.09	0.59	0.04					-0.11	0.37	-0.08	0.36	0.74	0.45	0.13	0.35	0.14
7	0.16	0.50	-0.40	0.11	0.00	0.28	0.82	-0.81	0.66	0.20	0.43	-0.06					-0.11	0.46	0.01	0.22	0.82	0.54	0.39	0.42	0.23
8	0.42	0.35	-0.49	0.49	0.00	0.50	0.96	-0.10	0.93	0.18	0.51	0.22					0.00	0.86	0.41	0.30	1.16	0.67	0.35	0.46	0.41
9	0.42	0.53	-0.46	0.69	0.04	0.70	0.24	-0.34	1.10	0.48	0.50	0.36					0.38	0.85	0.32	0.17	1.10	0.54	0.43	0.41	0.42
10	0.45	0.09	-0.50	0.90	-0.26	0.51	0.47	-0.08	0.70	0.54	0.78	-0.02					0.61	0.60	0.28	0.26	1.09	0.50	0.47	0.39	0.39
11	0.22	0.03	0.06	1.16	-0.10	1.13	0.38	-0.20	0.62	0.78	0.63	-0.53					0.13	0.61	-0.08	0.02	0.86	0.80	0.35	0.31	0.36
12	0.39	0.48	-0.19	0.64	-0.78	0.92	-0.25	-0.20	0.36	0.72	0.79	-0.31					0.34	0.82	0.02	0.55	1.17	0.77	0.33	0.72	0.36
13	0.05	-0.43	0.25	1.05	-0.98	1.08	0.60	0.04	0.70	0.80	0.24	-0.36					-0.27	0.83	0.40	0.47	0.62	1.12	0.89	0.54	0.38
14	1.02	-0.01	0.21	-0.07	-0.33	1.06	0.43	-0.50	1.46	0.96	0.41	0.15					0.12	1.02	0.15	0.00	0.94	1.51	0.57	-0.10	0.45
15	0.17	-0.96	0.00	0.80	-0.17	1.52	0.91	-0.51	1.74	-0.02	-0.35	0.05					-0.23	1.10	0.57	0.81	0.71	0.56	0.01	0.61	0.37
16	1.62	-0.52	0.96	2.06	-0.31	0.55	-0.92	0.02	1.55	0.25	0.24	0.11					-0.49	0.44	0.92	-0.24	0.93	1.23	1.26	1.65	0.56
17	1.52	-1.03	1.35	-0.79	-1.32	0.79	0.48	-0.25	1.21	0.68	0.07	-0.01					0.33	1.41	1.24	-0.54	1.27	0.54	0.91	1.55	0.47
18	2.00	-2.10	0.82	-0.25	1.31	0.12	-0.12	0.21	1.44	-0.71	-0.64	0.55					0.25	0.37	0.63	-0.34	1.03	0.65	0.71	0.21	0.31
19	2.28	-2.09	1.78	-1.03	1.67	2.52	0.22	0.53	1.91	0.45	0.73	1.86					1.25	0.73	1.13	-0.57	2.17	0.99	1.95	0.36	0.94
20	-	-3.58	2.41	1.12	0.37	2.53	-	1.76	2.19	-	2.40	-1.10					-0.41	0.17	0.91	-0.59	1.16	-1.05	0.28	-	0.53
21	-	-	2.25	-1.48	-0.04	-	-1.88	-	-0.04	-0.85	-	0.12					1.29	1.23	-	0.92	-	0.45	1.98	2.33	0.48
22	-0.20	-	-0.28	-	-	0.07	-	0.69	-	-	0.81	-					0.39	1.02	0.64	-	-	-	1.32	-	0.50
23	-	-2.23	-	-	-	-	-	-	-	-	-	-0.07					0.35	0.82	-	0.85	2.23	-	-	-	0.33
24	-	-	-	-	-	-	-	-	-	-	1.44	-					-	1.61	-	-	-	-0.94	-	-	0.70
25	-	-	-	-	-	-	-	-	-	-	-	-					0.84	-	-0.12	-	0.69	-	-	-	0.47
26	-	-	-	-	-	-	-	-	-	-	-	-					-	-	-	-	-	-0.45	-	-	-0.45

Table 14. Analysis of variance of multiplicative models of mean catch at age data for male, female and combined sexes of plaice aged 3-13 years. Model terms included age and year-class (YC).

Class	Levels	Values																	
AGE	11	3	4	5	6	7	8	9	10	11	12	13							
YC	35	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
		76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	

Males:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	373.804	8.496	31.96	0.0001
Error	197	52.365	0.266		
Corrected Total	241	426.169			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.8771	22.2991	0.5156	2.3121

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AGE	10	342.598	34.260	128.89	0.0001
YC	34	31.206	0.918	3.45	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AGE	10	262.041	26.204	98.58	0.0001
YC	34	31.206	0.918	3.45	0.0001

Females:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	238.921	5.430	25.55	0.0001
Error	197	41.864	0.213		
Corrected Total	241	280.786			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.8509	20.7346	0.4610	2.2233

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AGE	10	179.206	17.921	84.33	0.0001
YC	34	59.715	1.756	8.26	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AGE	10	118.579	11.858	55.80	0.0001
YC	34	59.715	1.756	8.26	0.0001

Sexes combined:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	290.307	6.598	41.51	0.0001
Error	230	36.557	0.159		
Corrected Total	274	326.863			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.8882	13.3760	0.3987	2.9805

Source	DF	Type I SS	Mean Square	F Value	Pr > F
AGE	10	235.392	23.539	148.10	0.0001
YC	34	54.915	1.615	10.16	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AGE	10	198.725	19.873	125.03	0.0001
YC	34	54.915	1.615	10.16	0.0001

Table 15. Analysis of variance of multiplicative model of relative fishing mortality, the log ratio of commercial catch to survey catch, based on 4T plaice >30 cm.

Class	Levels	Values																
SEX	2	1	2															
YEAR	17	76	77	78	79	80	81	82	83	87	88	89	90	91	92	93	94	95

Number of observations in data set = 827

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	36	817.553	22.710	31.21	0.0001
Error	756	550.184	0.728		
Corrected Total	792	1367.737			

R-Square	C.V.	Root MSE	RELF Mean
0.5977	-48.4865	0.8531	-1.7594

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SEX	1	62.497	62.497	85.88	0.0001
YEAR	16	263.362	16.460	22.62	0.0001
LENGTH	1	204.826	204.826	281.45	0.0001
LENGTH2	1	220.791	220.791	303.39	0.0001
SEX*YEAR	16	42.341	2.646	3.64	0.0001
LENGTH*SEX	1	23.736	23.736	32.62	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEX	1	21.391	21.391	29.39	0.0001
YEAR	16	244.155	15.260	20.97	0.0001
LENGTH	1	289.250	289.250	397.46	0.0001
LENGTH2	1	239.308	239.308	328.83	0.0001
SEX*YEAR	16	38.523	2.408	3.31	0.0001
LENGTH*SEX	1	23.736	23.736	32.62	0.0001

Table 16. Analysis of variance of multiplicative model of relative fishing mortality, the log ratio of commercial catch to survey catch, based on 4T plaice >30 cm with sexes combined.

Class	Levels	Values																
YEAR	17	76	77	78	79	80	81	82	83	87	88	89	90	91	92	93	94	95

Number of observations in data set = 661

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	583.079	27.76	50.51	0.0001
Error	619	340.252	0.550		
Corrected Total	640	923.331			

R-Square	C.V.	Root MSE	RELF Mean
0.6315	-49.4604	0.7414	-1.4990

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	19	213.785	11.252	20.47	0.0001
LENGTH	1	170.403	170.403	310.00	0.0001
LENGTH2	1	198.890	198.890	361.83	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	19	219.897	11.574	21.05	0.0001
LENGTH	1	237.679	237.680	432.40	0.0001
LENGTH2	1	198.890	198.890	361.83	0.0001

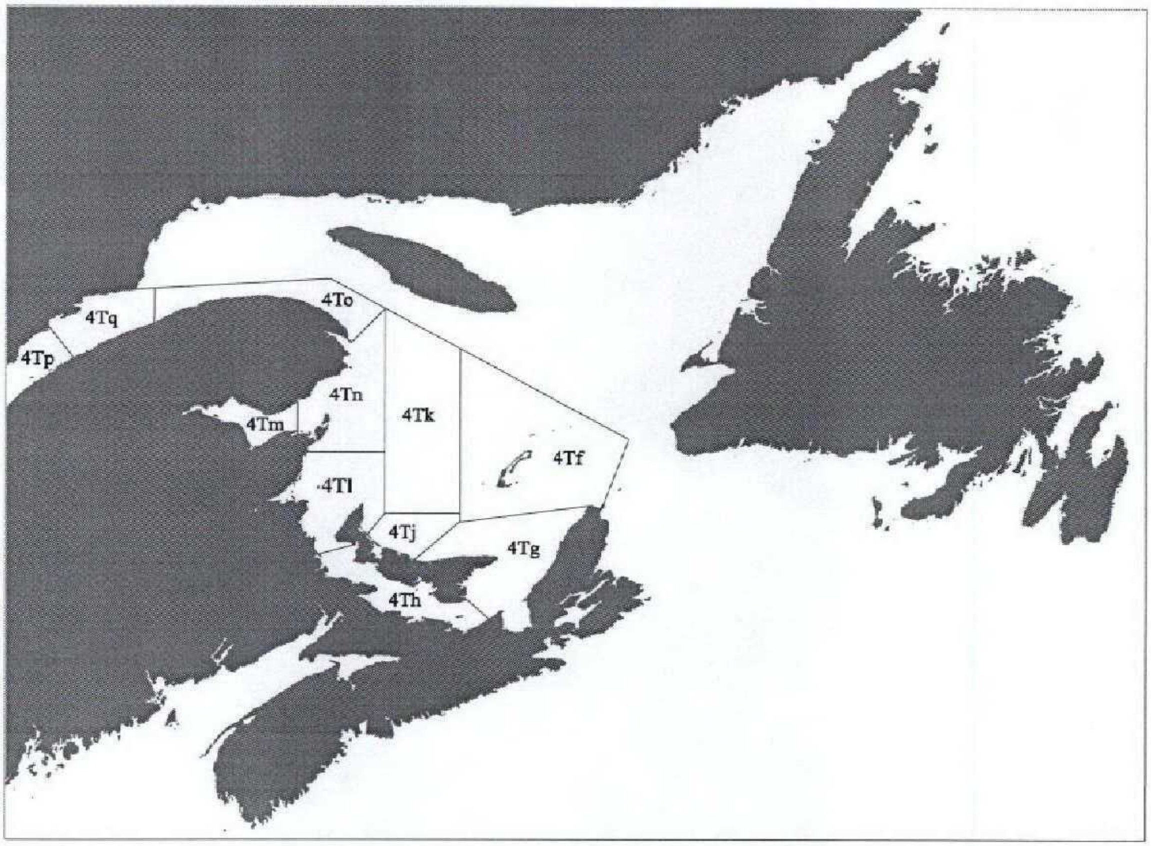

Figure 1. Area map showing Gulf of St. Lawrence and unit areas of NAFO Division 4T.

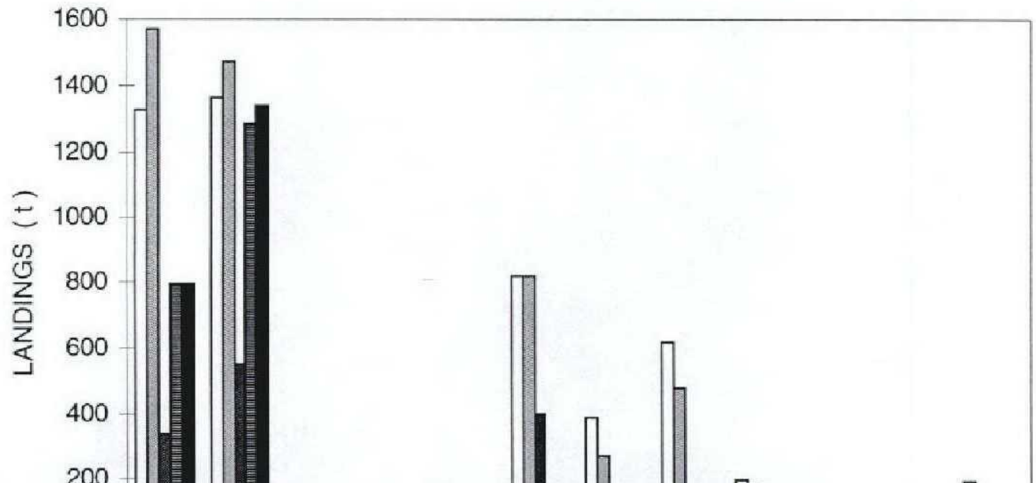

Figure 2. American plaice landings in 4T unit areas from 1991 (open columns) to 1995 (black columns).

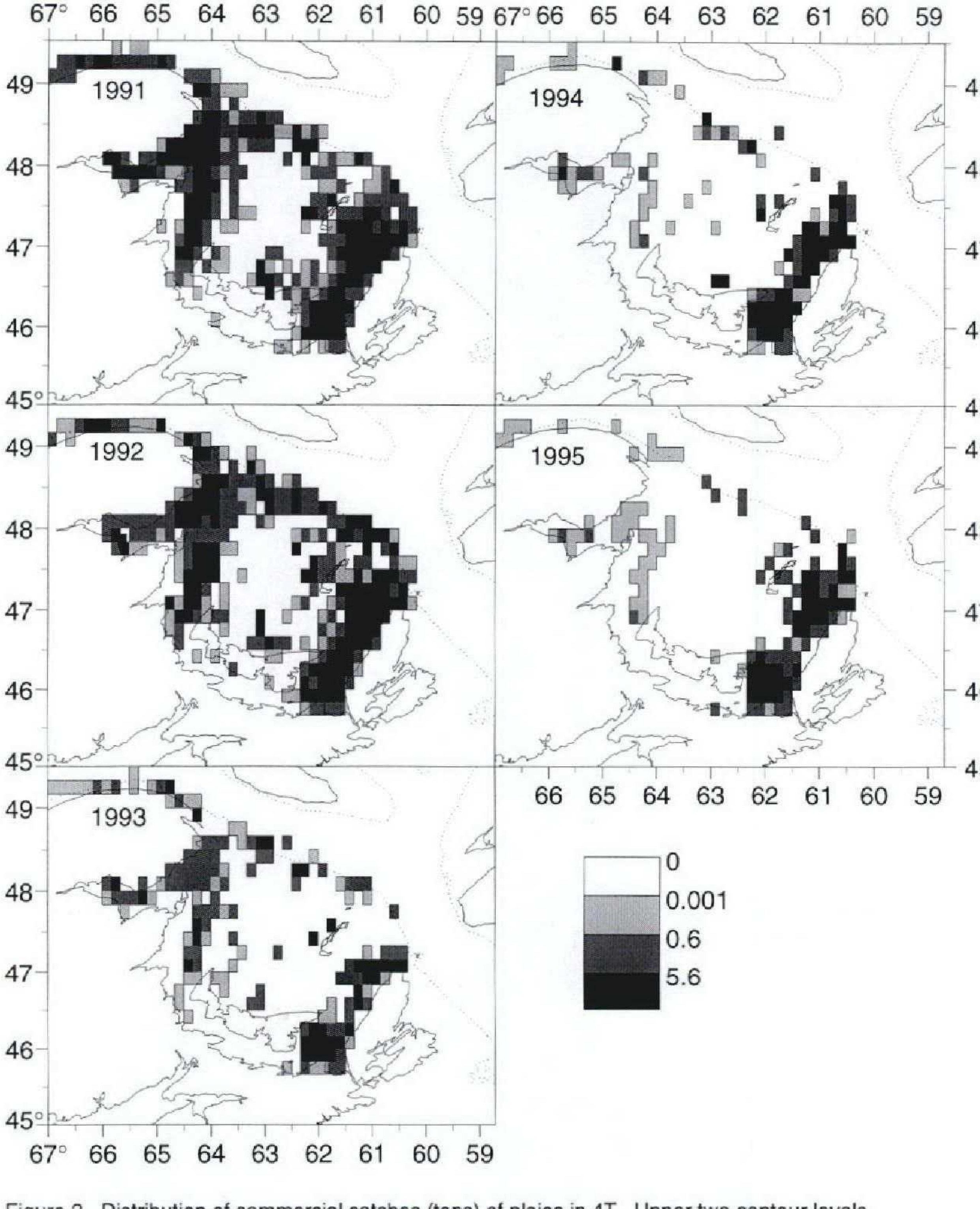

Figure 3. Distribution of commercial catches (tons) of plaice in 4T. Upper two contour levels correspond to average 33% and 67% quantiles of catch in 10-minute blocks.

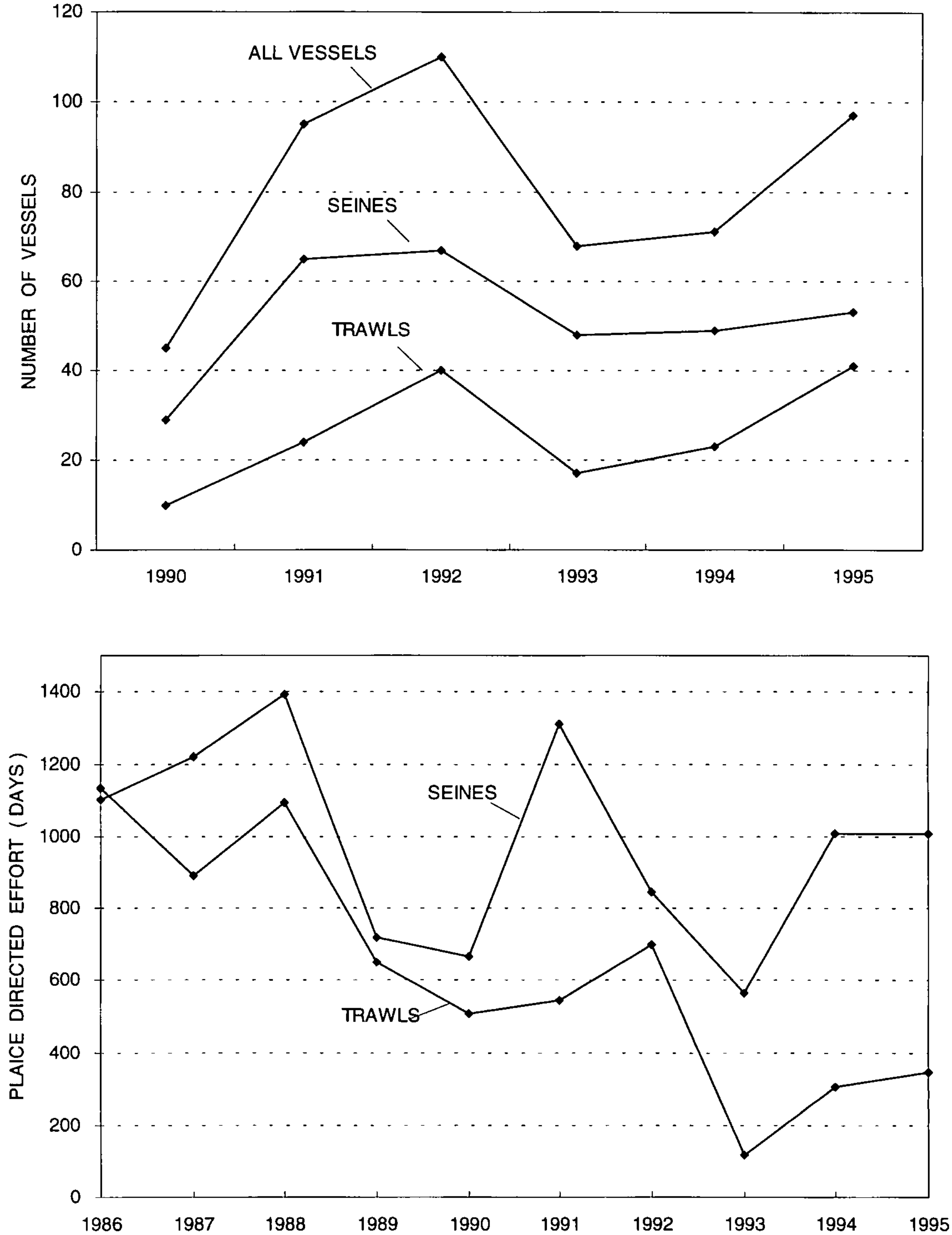

Figure 4. Nominal fishing effort in the directed 4T plaice fishery.

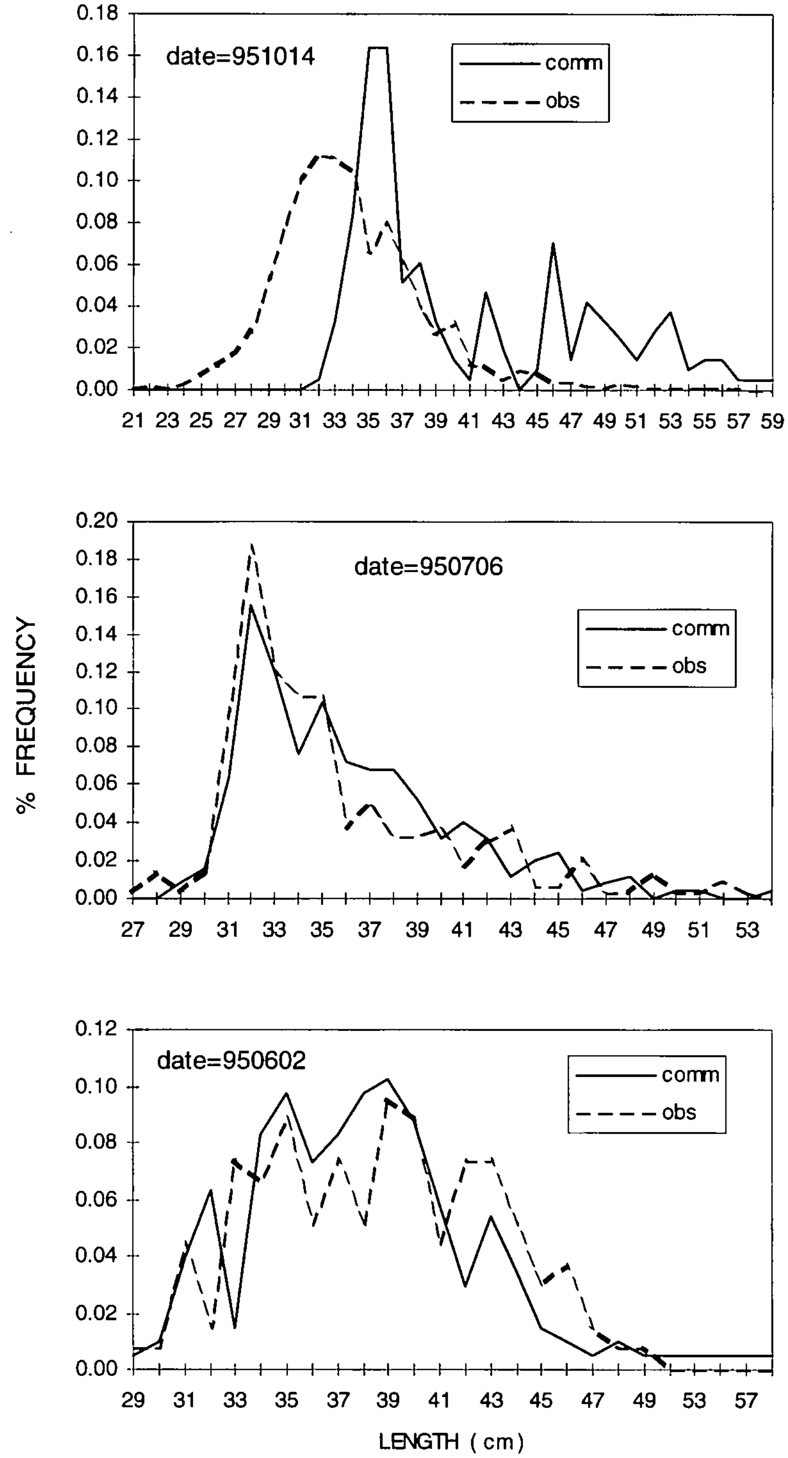

Figure 5. Comparisons of length composition of commercial plaice catches sampled at sea by observers (obs) and landed at port (comm).

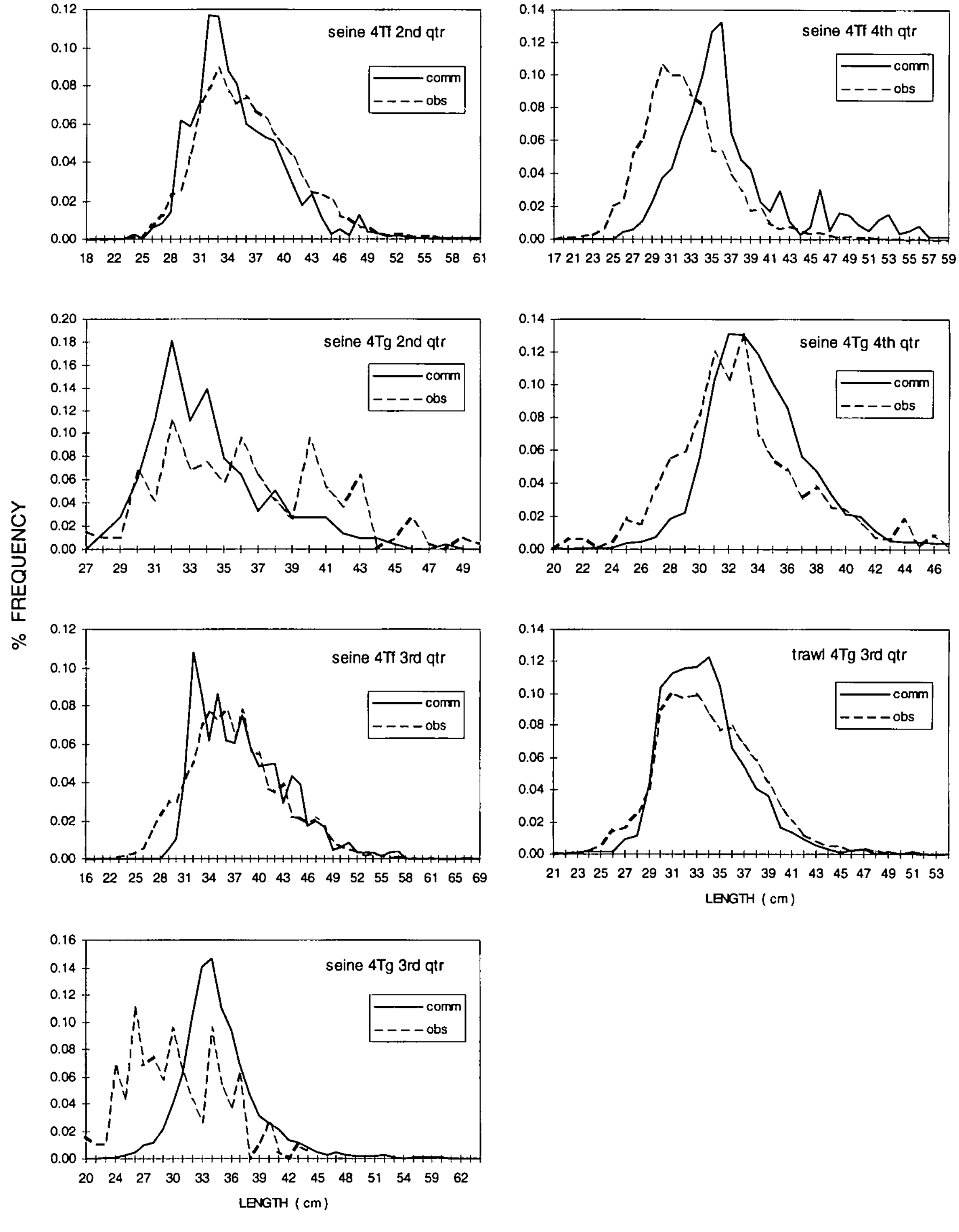

Figure 6. Length frequencies of commercial plaice catches from observer (obs) and port samples (comm) by gear, unit area and quarter.

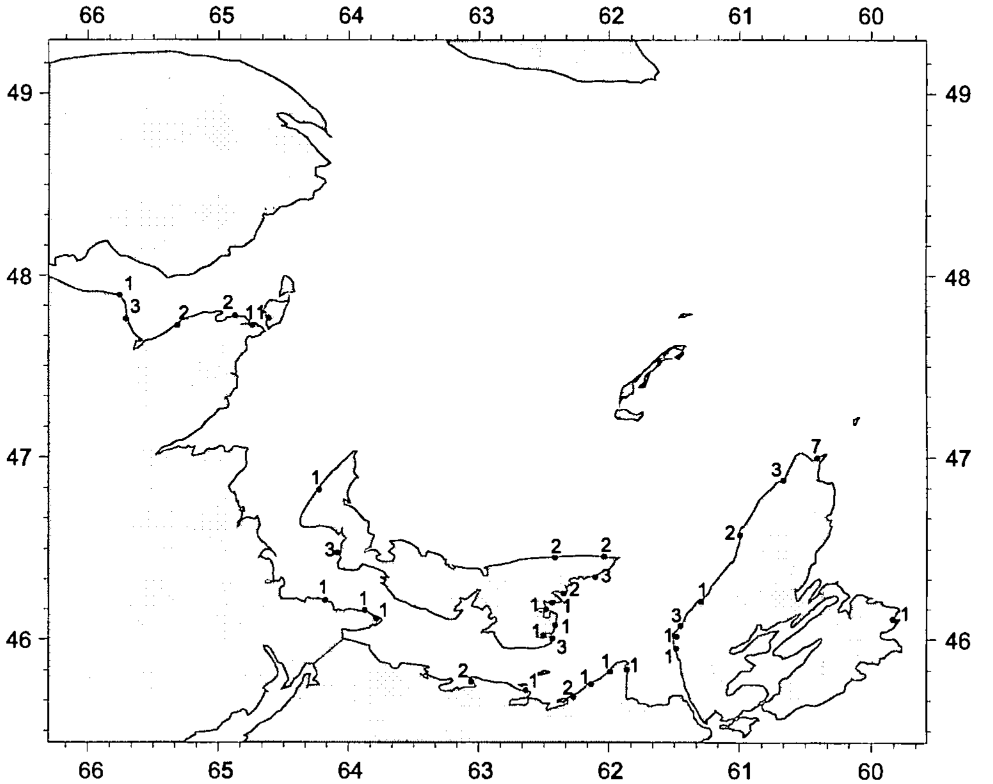

Figure 7. The number of fishers directing for American plaice who participated in a telephone survey on the status of southern Gulf groundfish, by home port.

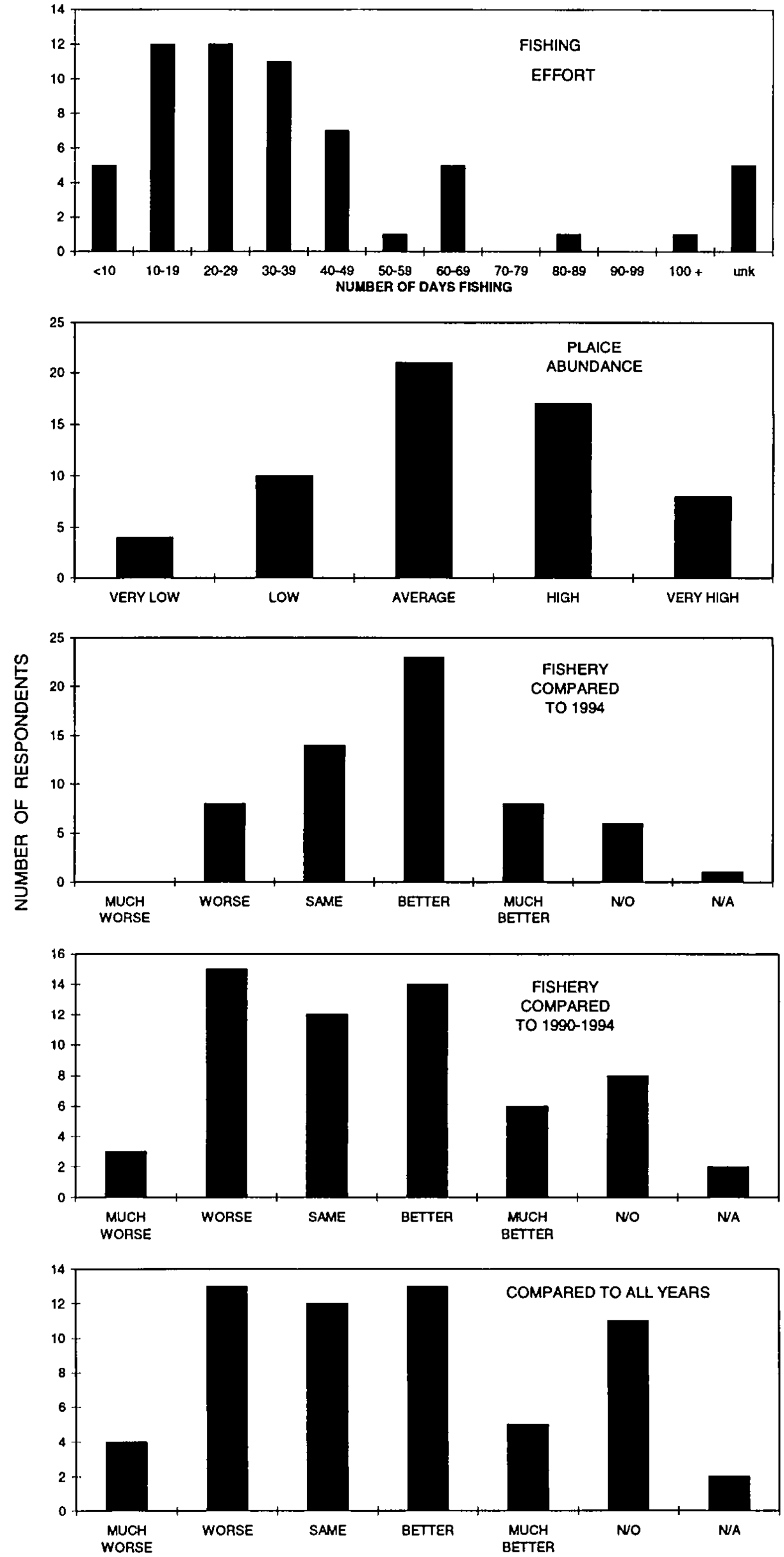

Figure 8. Responses of participants in telephone survey of directed 4T plaice fishery in 1995. N/O signifies "no opinion"; N/A signifies that respondent could not reply or question was not appropriate.

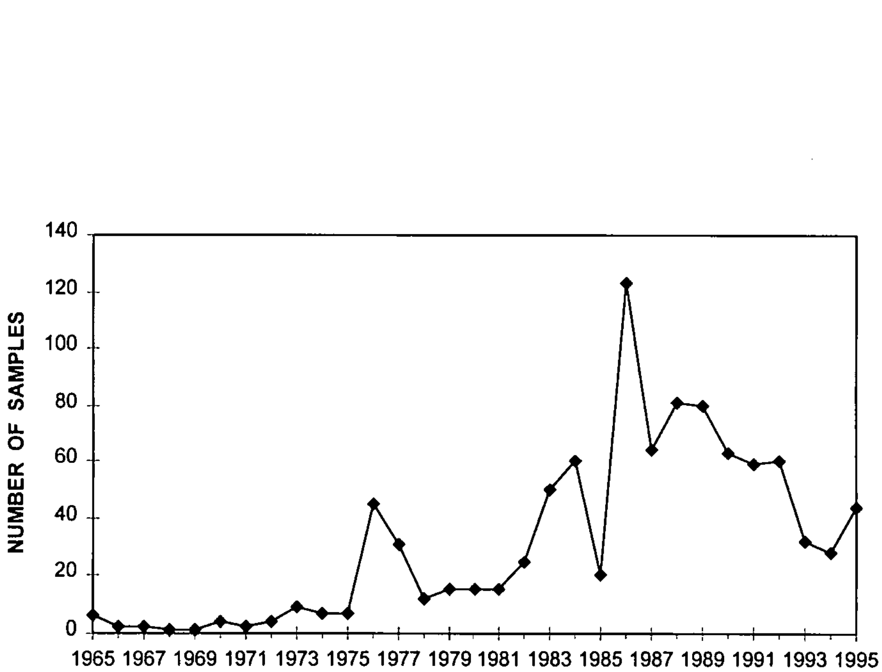

Figure 9. The number of landed catches of 4T American plaice sampled yearly at landing ports.

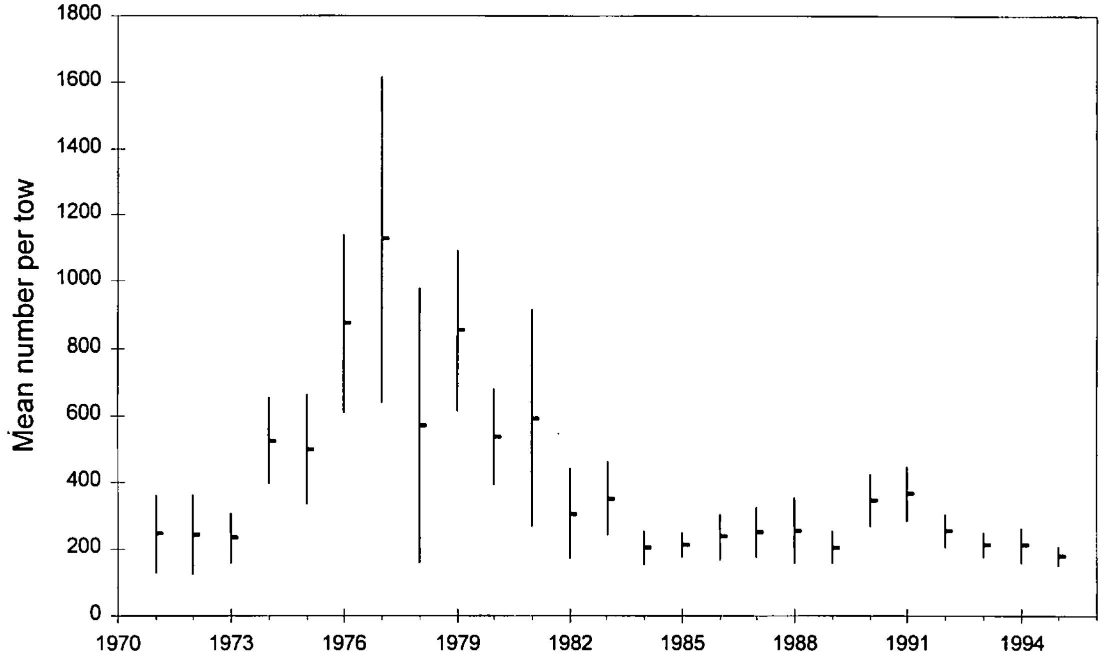

Figure 10. Mean stratified catch of American plaice as number per standard tow in research surveys of 4T. Vertical lines are +/- two standard deviations of the mean.

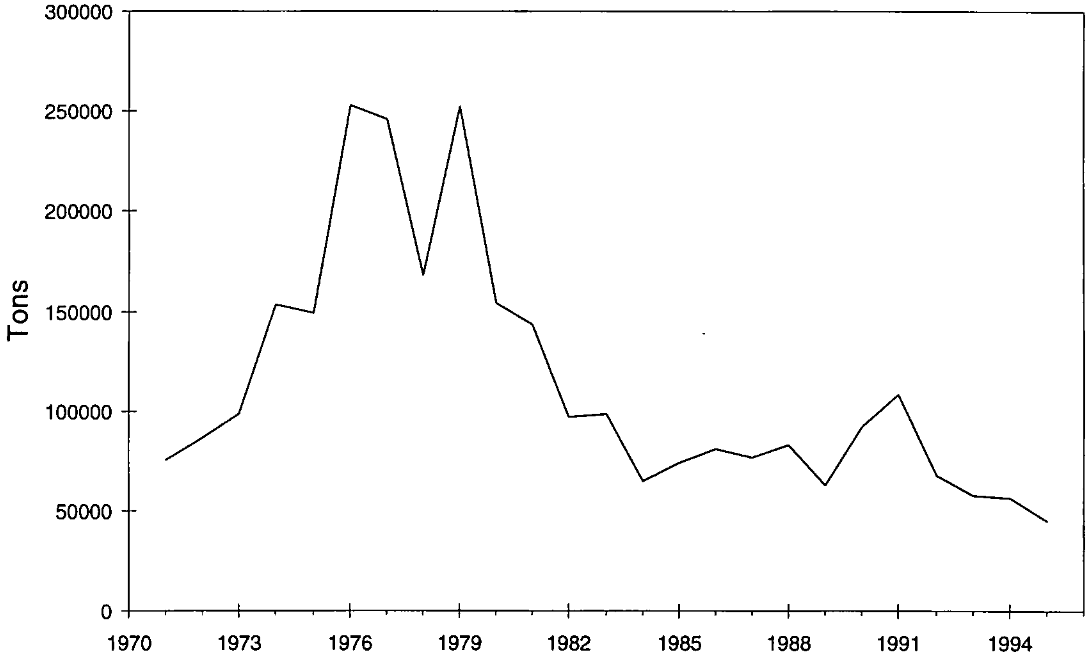

Figure 11. Biomass trends of 4T plaice based on research survey data of the *E.E. Prince* and the *Lady Hammond / Alfred Needler.*

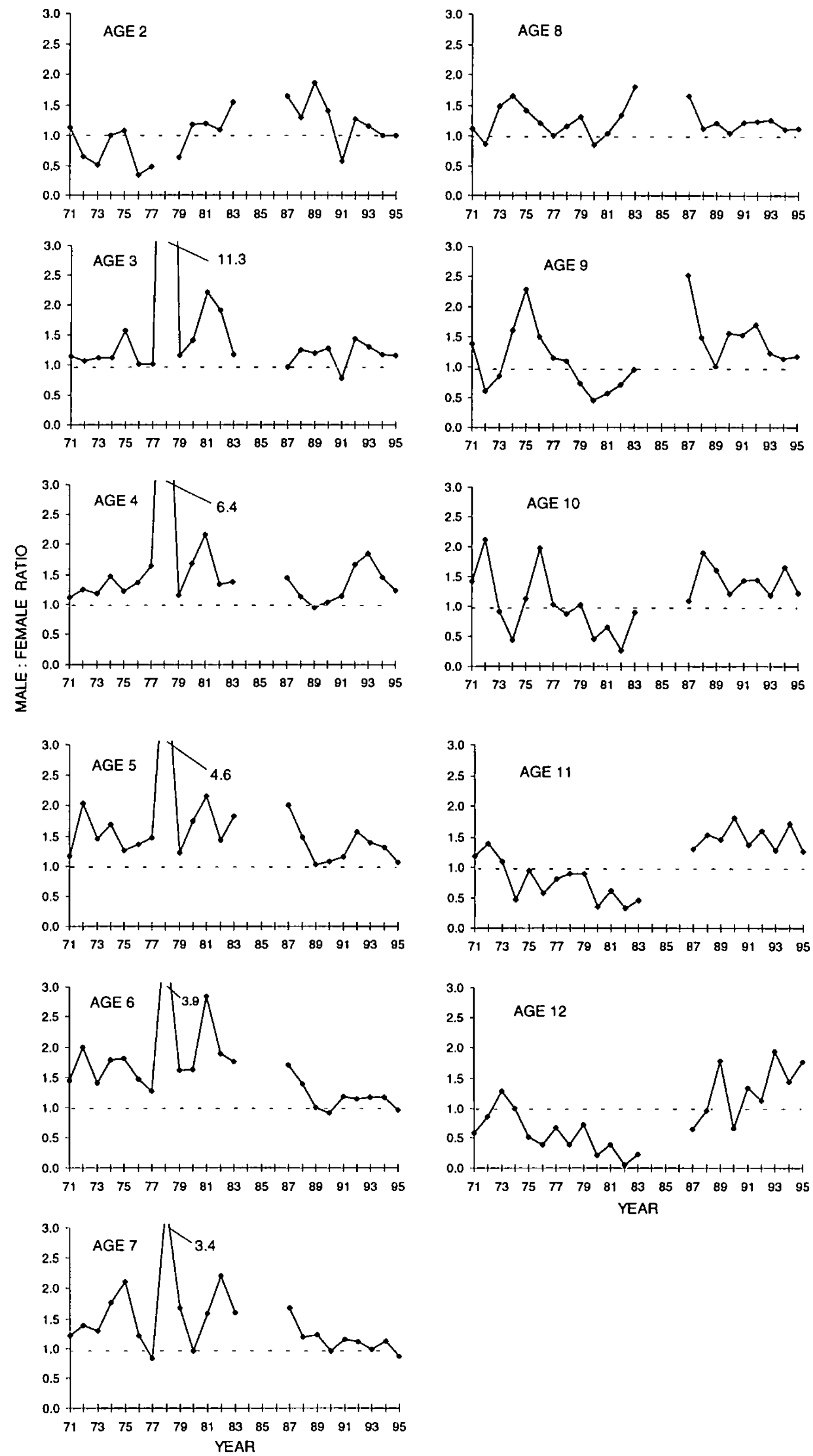

Figure 12. Sex ratios of plaice from 4T research surveys.

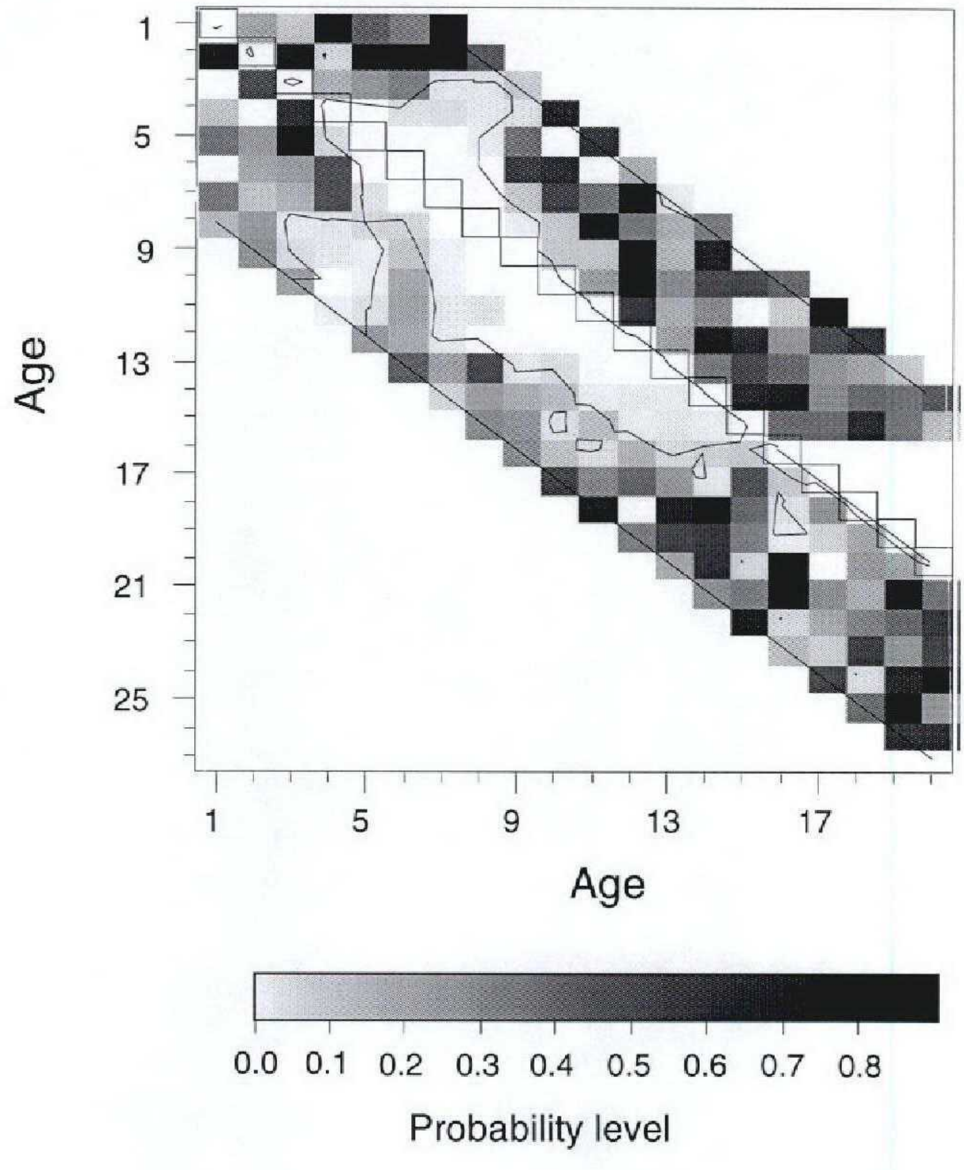

Figure 13. Results of correlation analysis of mean catch between successive ages of the same year-class. Diagonal squares represent correlations between the same ages; shaded squares above the diagonal represent significance level of correlations for male plaice. Shaded squares below the diagonal represent significance level of correlations for females. Contour line is shown for correlations significant at a level of P=0.05.

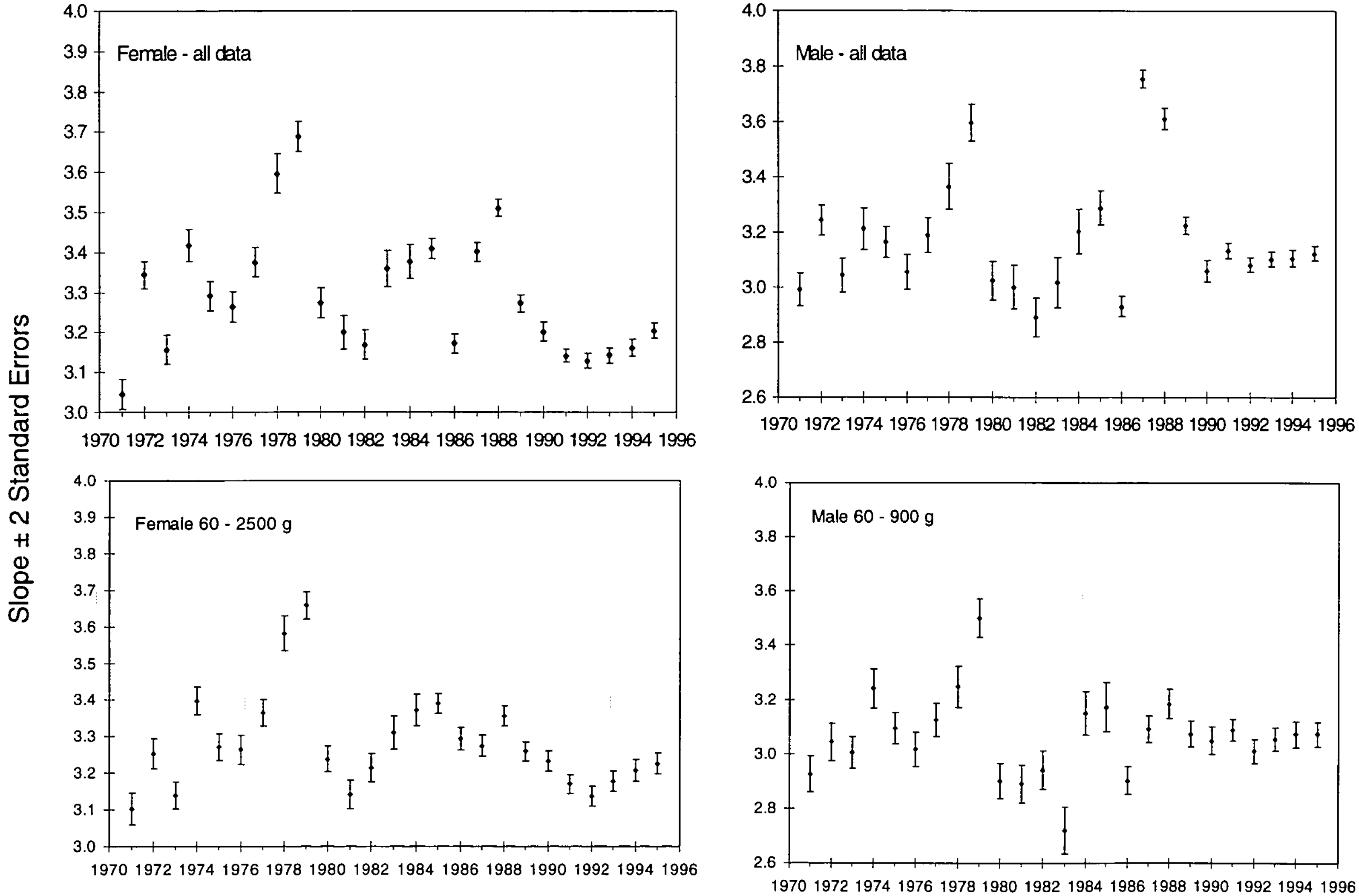

Figure 14. Comparison of slopes of log length-log weight regressions based on sampling of American plaice in research surveys of 4T.

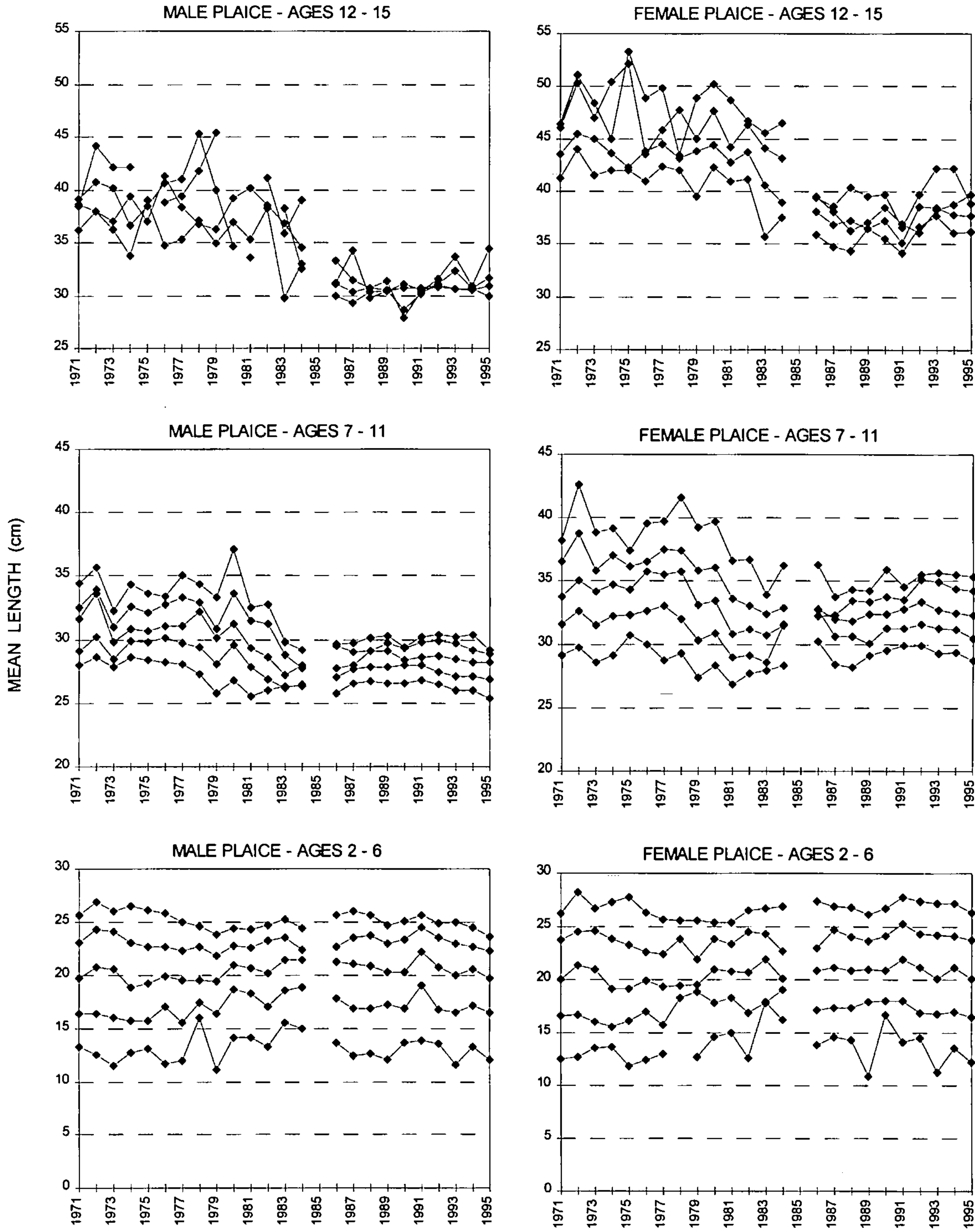

Figure 15. Mean length at age of 4T plaice based on research survey data.

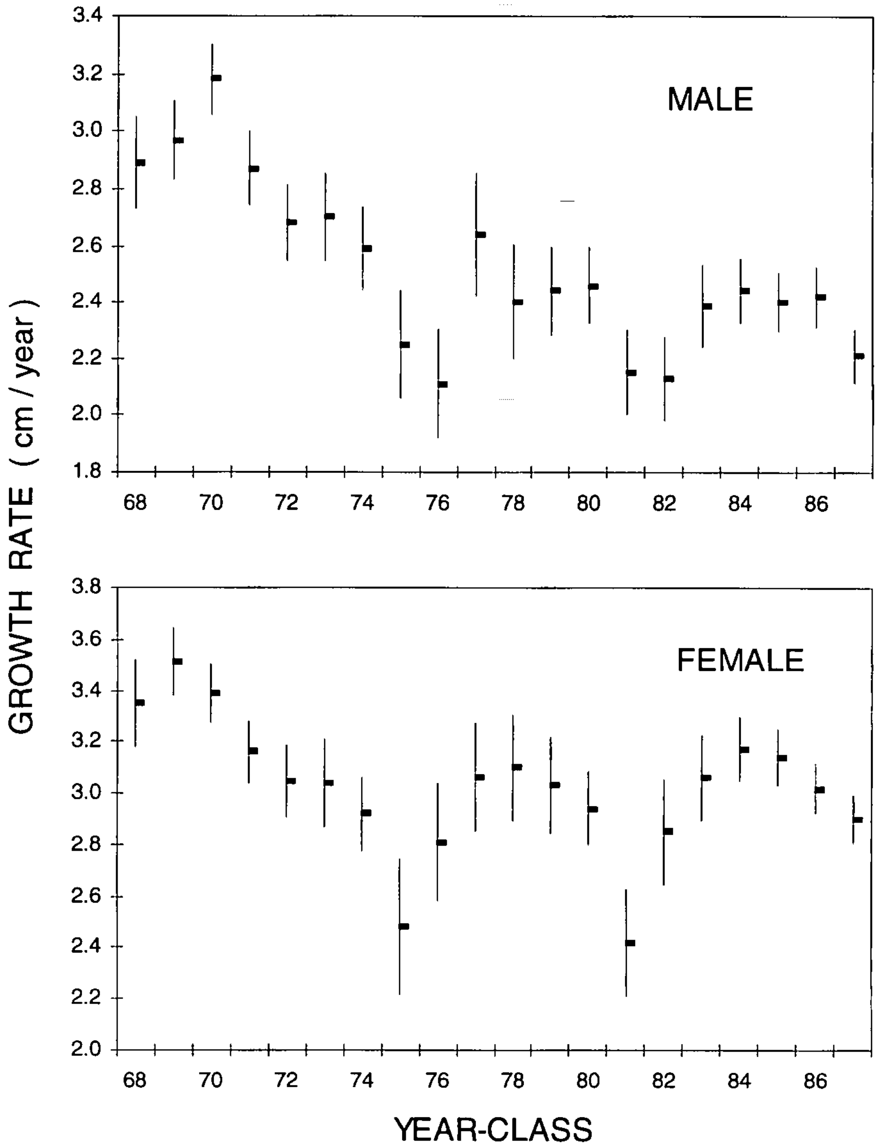

Figure 16. Growth rates of male and female plaice year-classes from ages 2 to 8 years, based on research survey data.

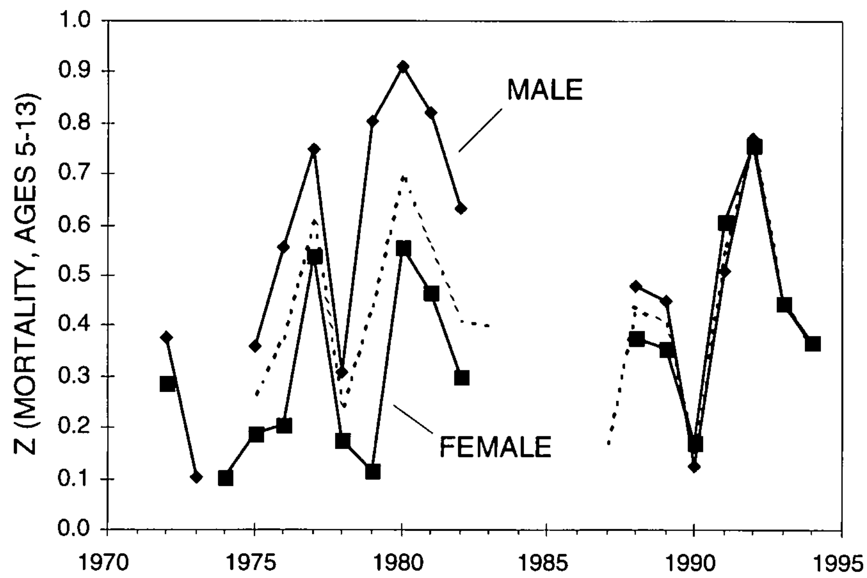

Figure 17. Total mortality (Z) based on survey catch data of male, female and combined plaice (dotted line). Plaice catches were not sexed from 1984-1986 and 1985 catch-at-age data on combined sexes were excluded from analysis.

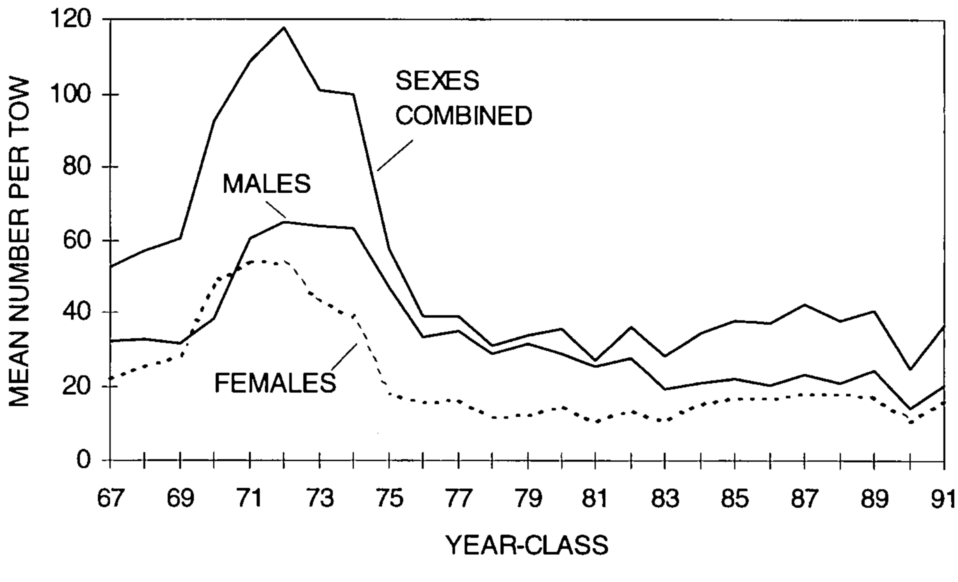

Figure 18. Standardized catches of 4T plaice year-classes based on multiplicative models of survey data. Model used age and year-class effects and estimates, based on age-4 plaice, were back-transformed from logarithms using bias correction.

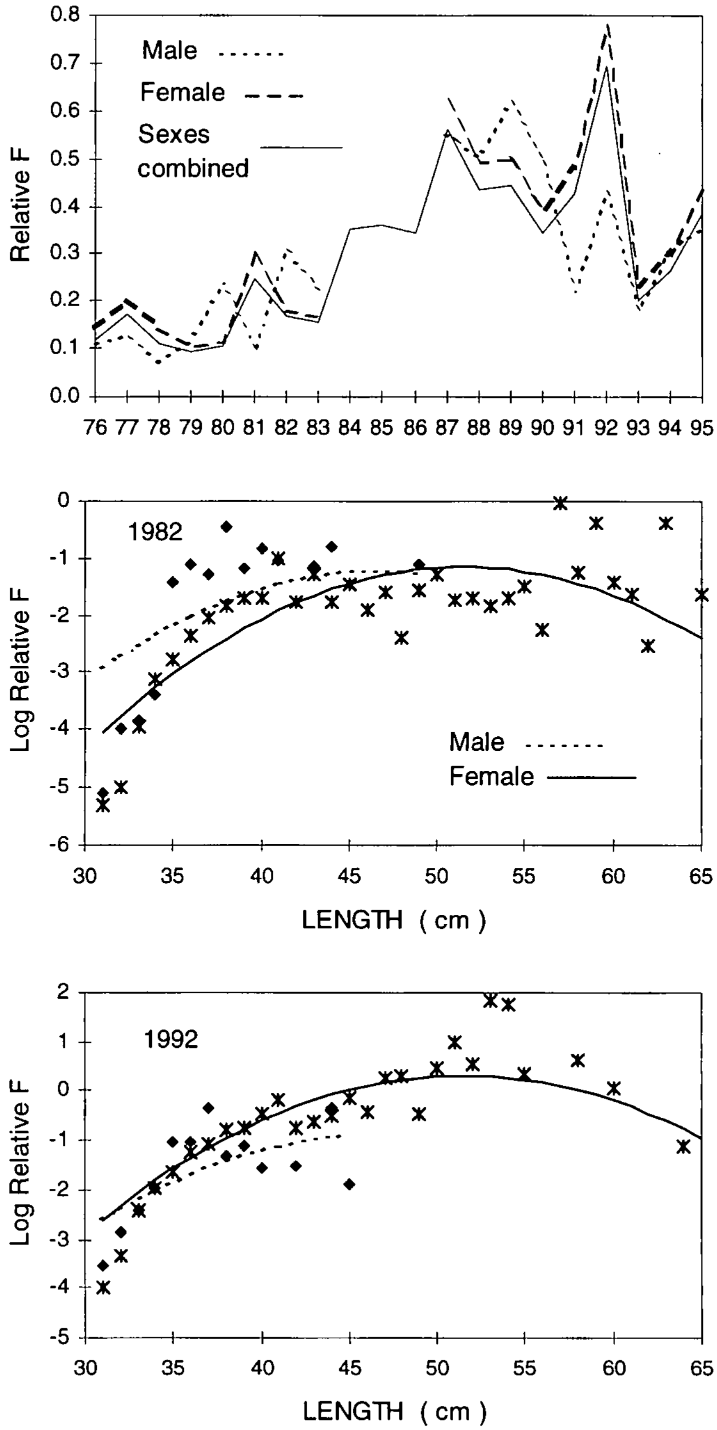

Figure 19. Upper panel shows estimated values of relative fishing mortality (Relative F) based on the ratio of commercial to survey catches of plaice lengths >30 cm. Lower panels show observed log relative F for male (diamonds) and female (asterisks) plaice with curves showing model predictions.

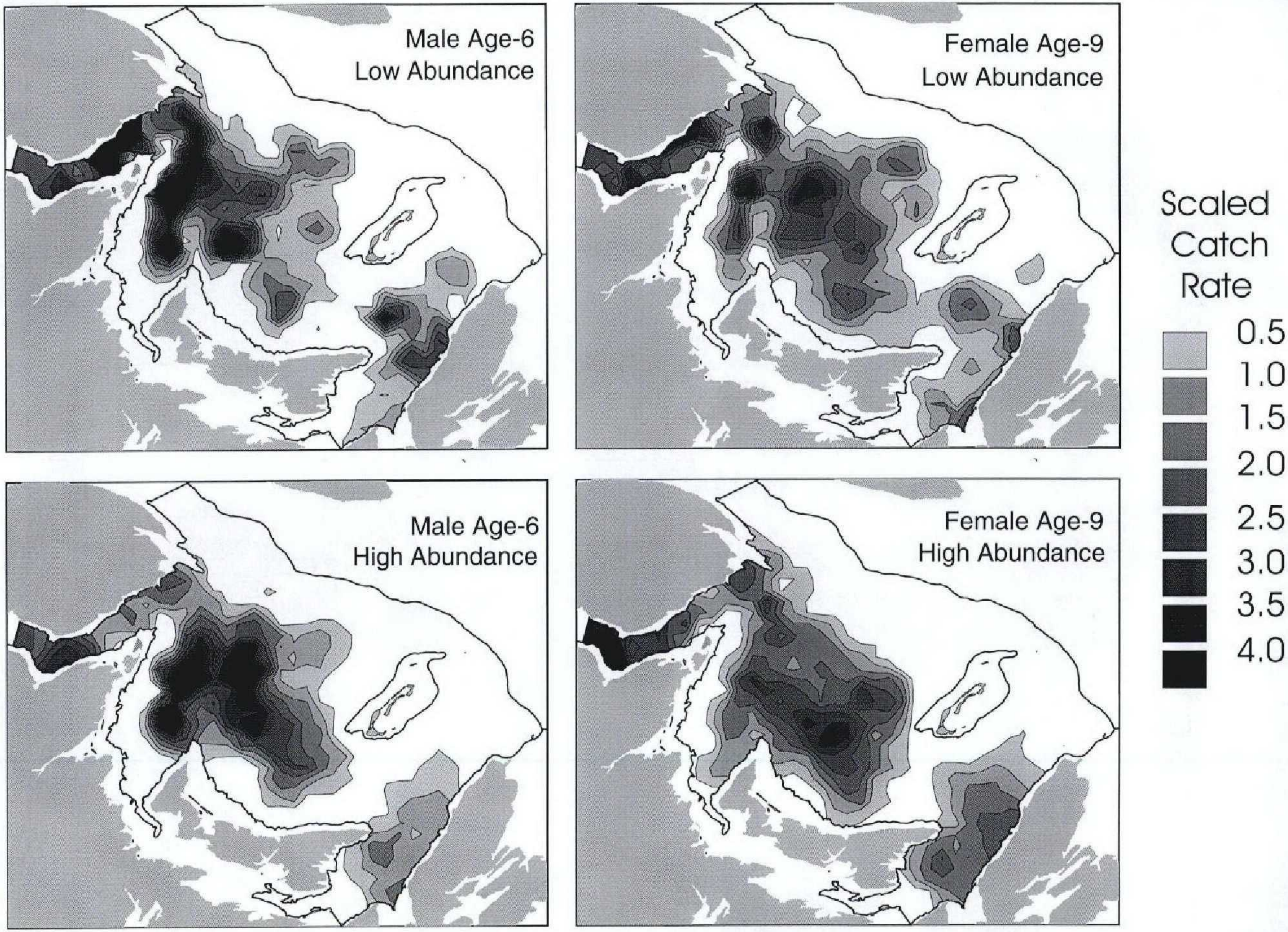

Figure 20. September distribution in the southern Gulf of St. Lawrence for two selected age/sex classes of American plaice. Distribution is shown for the 6 yr of lowest abundance and the 6 yr of highest abundance. Note that catch rates are standardized to the same average level (1.0) in both abundance periods to emphasize distribution rather than overall abundance (from Swain and Morin 1996).

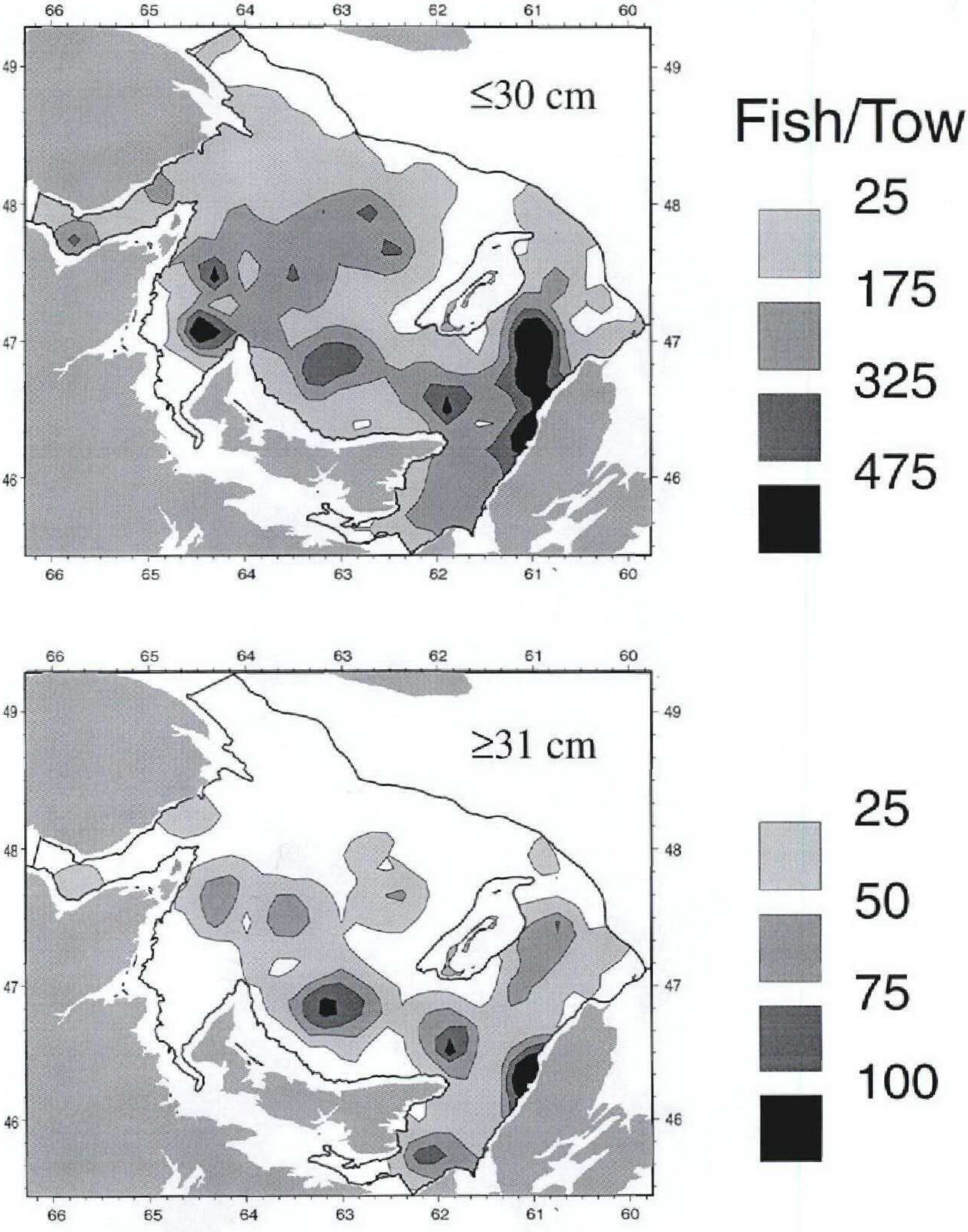

Figure 21. Geographic distribution of American plaice in the southern Gulf of St. Lawrence, September, 1995. Distribution is shown separately for small and large plaice.

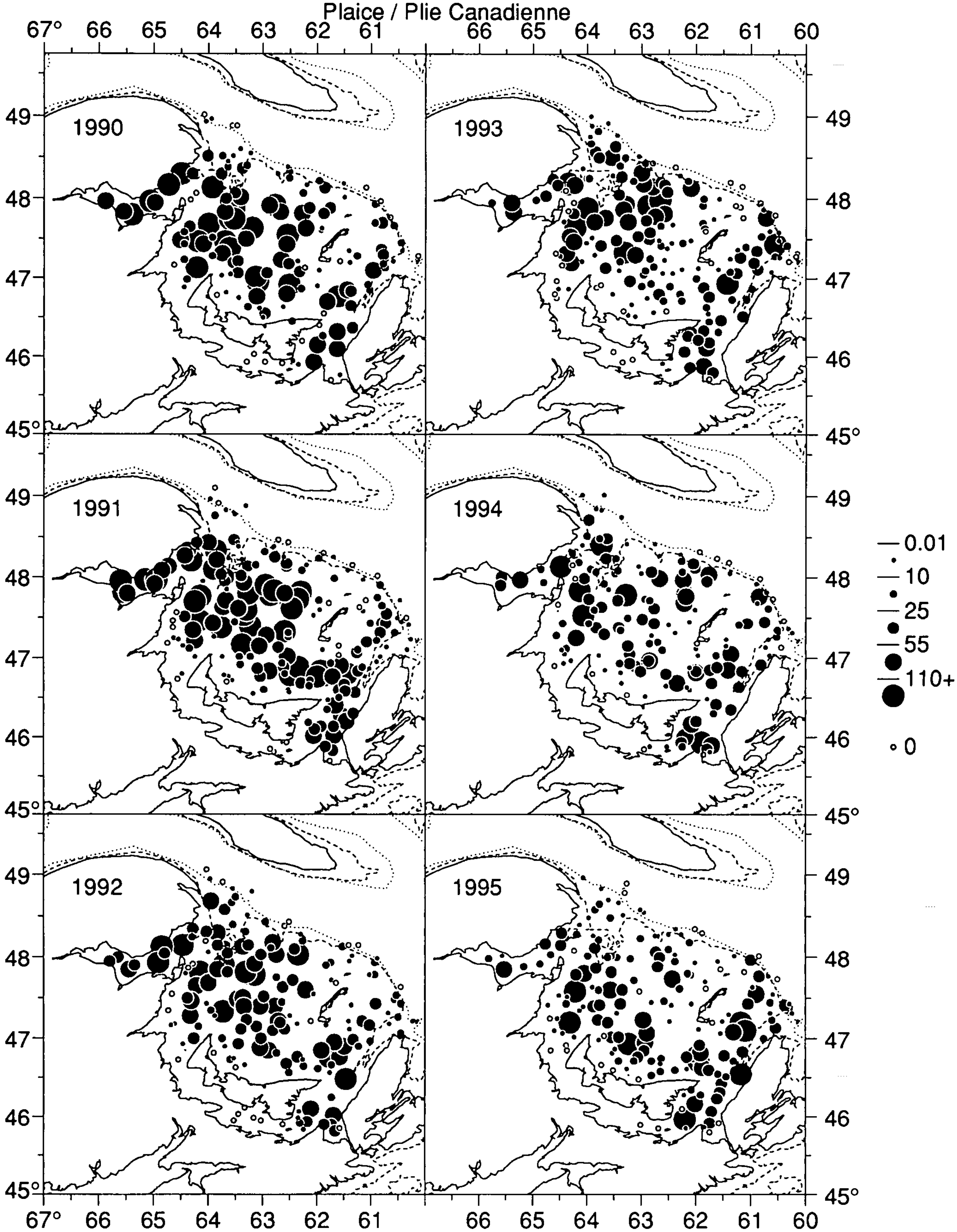

Figure 22. American plaice catches (kg) in the southern Gulf of St. Lawrence September groundfish surveys from 1990 to 1995.

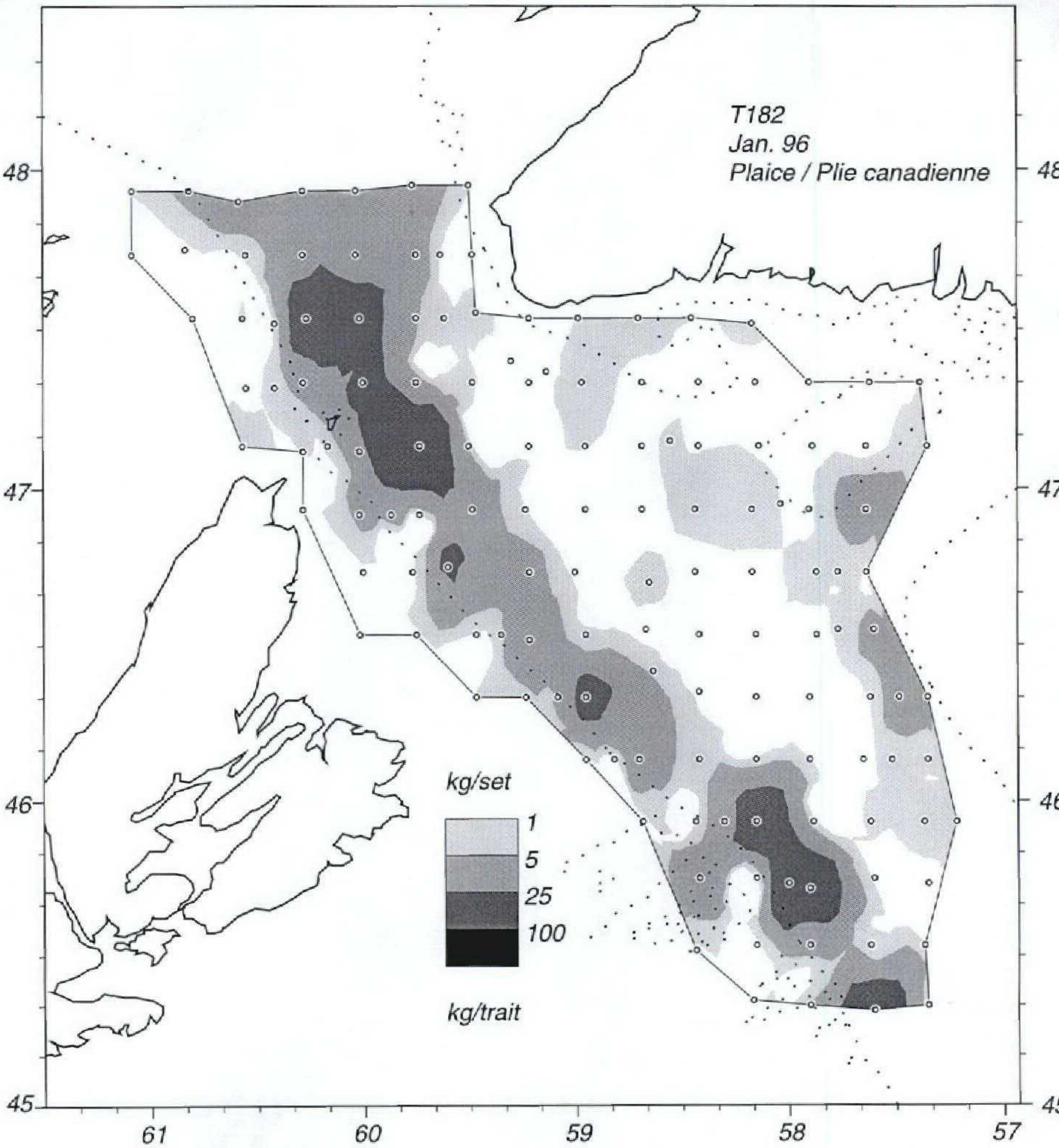

Figure 23. Winter distribution of American plaice in research survey of Cabot Strait and entrance to Gulf of St. Lawrence.

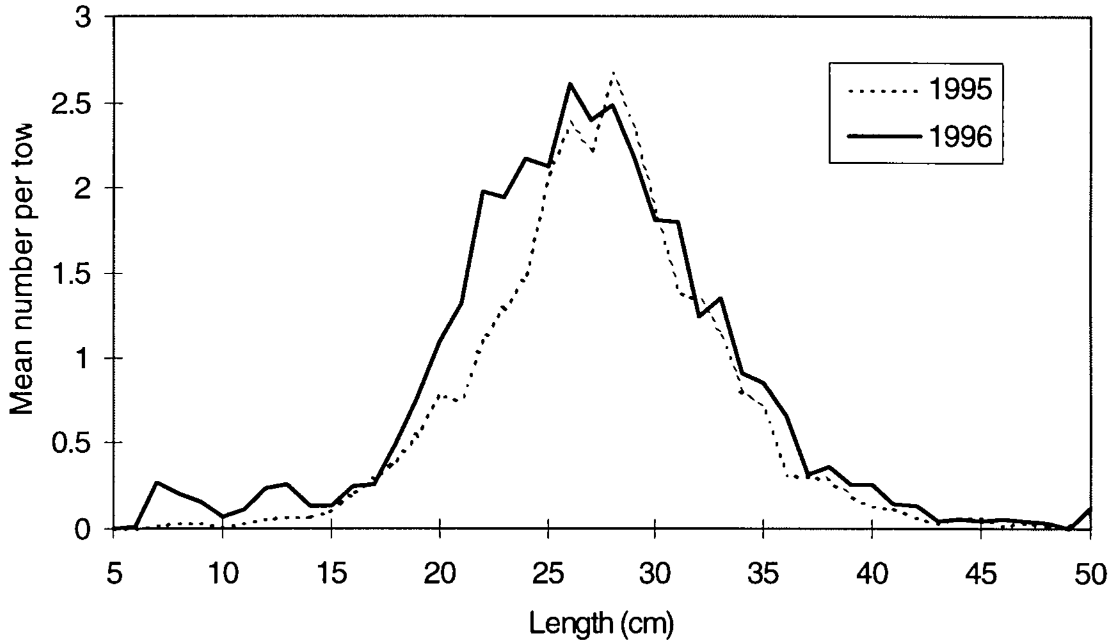

Figure 24. Length frequencies of American plaice from 1995 and 1996 January surveys of Cabot Strait.