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DFO Atlantic Fisheries
Research Document 94/ 48

MPO Pêches de l'Atlantique
Document de recherche 94/ 48

Status of winter flounder in NAFO Division 4T

by

R. Morin, D. Swain, I. Forest-Gallant, R. Hébert[1]

Department of Fisheries and Oceans
Marine and Anadromous Fish Division
Science Branch, Gulf Region
[1]Resource Allocation Division
P.O. Box 5030
Moncton, New Brunswick
E1C 9B6

ABSTRACT

The winter flounder fishery in NAFO Division 4T is not under quota management and has not been previously assessed. The provisional landings of winter flounder (*Pleuronectes americanus*) in 4T totalled 1,238 t in 1993. Since 1960, nominal landings of winter flounder have averaged 1,984 t annually, with a minimum of 149 t in 1984 and a maximum of 4,412 t in 1965. The yearly landings of winter flounder have varied widely in 4T and recent declines from 2,536 t in 1991 are within the range of variability previously observed. Winter flounder are landed mainly by otter trawls. Since 1990, from 81-88% of winter flounder landings have originated from the directed fishery. An additional 4-10% of the landings were from white hake-directed fisheries and cod-directed fisheries contributed no more than 6% of winter flounder landings. Research surveys of 4T indicate that winter flounder are currently at an intermediate level of abundance relative to levels observed since 1971. Analyses of survey data indicate that the abundance of winter flounder varies regionally, suggesting that winter flounder in 4T probably comprises several unit stocks.

RÉSUMÉ

La pêche à la plie rouge dans la division 4T de l'OPANO n'est pas gérée par un quota et n'a jamais fait objet d'un bilan. Selon les données provisoires, les débarquements de plie rouge (*Pleuronectes americanus*) dans 4T ont atteint 1 238 t en 1993. Depuis 1960, les débarquements annuels de plie rouge ont été en moyenne de 1 984 t, avec un minimum de 149 t en 1984 et un maximum de 4 412 t en 1965. Les débarquements annuels de la plie rouge ont variés largement dans 4T et le déclin de 2 539 t en 1991 au niveau actuel serait comparable à la variabilité observée auparavant. La plie rouge est pêchée surtout par les chaluts de fond. Depuis 1990, de 81 à 88% des débarquements de plie rouge provient d'une pêche dirigée. Les pêches dirigées vers la merluche blanche et la morue ont contribué de 4 à 10% et d'environ 6%, respectivement, des débarquements de la plie rouge. Les relevés scientifiques dans 4T indiquent dans l'ensemble que cette ressource est à un niveau intermédiaire d'abondance par rapport au patron observé depuis 1971. L'analyse des données des relevés indique que l'abondance varie régionalement, ce qui suggère que plusieurs unités de stock de plie rouge habitent 4T.

INTRODUCTION

Winter flounder (*Pleuronectes americanus*) is a mainly coastal flatfish preferring soft or moderately hard bottoms. In the southern Gulf of St. Lawrence (NAFO Division 4T, Figure 1), Clay (1991) reported that they are found mainly at depths less than 40 m. Capable of inhabiting freezing water conditions (Fletcher 1977), winter flounder appear to be well adapted to environmental conditions in the southern Gulf.

Winter flounder are exploited throughout the Gulf of St. Lawrence, but most intensively in the southern parts of 4T. General descriptions of this fishery tend to characterize it as of local importance and as a bycatch from other groundfish fisheries (Scott and Scott 1988, Clay 1991). The present fishery is not under quota management. With the exception of an analysis of commercial and research survey catch rates conducted by Clay and Nielsen (1983), the winter flounder resource in 4T has not been studied. Reductions in the quota allocations for cod and other groundfish species are expected to increase the exploitation on secondary species such as winter flounder.

This document describes the current status of winter flounder in 4T based on commercial landings and research surveys that have been conducted annually since 1971. Catch-at-age data from these two sources are presently available for the past four years.

Description of the fishery

The total annual landings of winter flounder in 4T have ranged between 149 and 4,412 t since 1960 (Table 1), showing no clear longterm trend (Figure 2). The 1993 landings of winter flounder, at 1,238 t, were 38% less than the average of 1,984 t since 1960. Although the landings have more than halved since 1991, this decline is within the range of variability that has been observed from 1960 to 1993 (Figure 2). Most of the decline in landings in 1993 from the previous year occurred in the southeastern Gulf, unit area 4Tg (Figure 3, unit areas are indicated in Figure 1).

Winter flounder are landed mainly by otter trawls (Table 1) and contribute to the landings of the inshore mobile fleet vessels <45′. Seines have also provided significant landings and gillnets have become prominent since 1980. Winter flounder were landed through the ice-free period, from May to October (Table 2).

New regulations and policies came into effect during 1993 that may have contributed to the recent pattern of winter flounder landings. In 1993, DFO introduced the concept of the Conservation Harvesting Plan as a measure to engage members of each fleet sector in the development of conservation measures for rebuilding fish stocks. The mobile fleet sector of vessels <45′ in Northumberland Strait that fish winter flounder and white hake agreed to increase mesh size from 108 mm diamond to 120 mm square in the codend and lengthening piece of otter trawls. This measure was undertaken at the request of fishermen concerned by declining catches of white hake and the need to protect juvenile hake. Measures were taken by DFO to eliminate the discarding of commercially undersized groundfish by requiring fishing vessels to land all groundfish caught. Bait fisheries that target small groundfish became regulated in 1993. Special permits were issued in 1993 to New Brunswick and PEI fishermen who fish small flatfish, including winter flounder, as bait for lobster traps. An agreement has been reached not to reissue these permits in 1994. These measures were undertaken to protect juvenile groundfish and to reduce unreported catches.

In July 1993, the Fisheries Resource Conservation Council (FRCC) recommended the closure of the 4T cod fishery because the cod stock biomass had reached its lowest recorded level. The Minister responded by closing this fishery on September 1. Further changes were made to mesh sizes in mobile gear: the minimum mesh size for flatfishes in Northumberland Strait became 130 mm square and the minimum mesh size outside the Strait became 145 mm square. New criteria for groundfish closures, particularly those involving cod bycatch, affected the winter flounder fishery in 1993. All groundfish fisheries were closed in sectors where cod bycatch exceeded 10%, by weight, of the total catch. Two such closures occurred in 1993 due to the winter flounder-directed fishery.

The 4T winter flounder fishery is no longer a bycatch fishery, as previously noted. Since 1990, from 81-88% of winter flounder landings were attributed to vessels directing for winter flounder. White hake-directed fisheries accounted for an additional 4-10% of the winter flounder landings during that period (Figure 4). The cod-directed fishery contributed no more than 6% of winter flounder landings since 1990; in 1993, this fishery accounted for only 1.5% of winter flounder landings.

Accurate landing statistics are difficult to obtain from unregulated secondary fisheries such as winter flounder. For example, winter flounder is known by several common names that vary regionally in english and french. Discrepancies that were noted in American plaice landings at a port located in northeastern New Brunswick during 1993 occurred because of incorrect naming of winter flounder. This problem was corrected when DFO personnel travelled to ports in that region and provided identification keys and related information to the personnel involved in recording landed catches. Other problems occur when catches are unrecorded, as in the bait fishery noted above, or when small fish are discarded. J.M. Hanson (DFO Moncton, pers. comm.) reports that winter flounder in the southern Gulf overwinter in river estuaries where they become part of the fall and winter smelt fishery. He reports that unestimated, but abundant catches of commercially undersized winter flounder are discarded, while winter flounder of commercial size are marketed locally. McKenzie (1959) also noted significant catches of undersized winter flounder in the smelt fishery of the upper Miramichi River estuary.

METHODS

Age determination

The age determination of winter flounder by otolith reading has not been conducted on commercial and research collections in 4T since at least 10 years. Since 1992, we have determined ages of the current year's collection of winter flounder. In 1993, we began to extend age determination to past collections, completing the 1990 and 1991 collections. In order to assure that age interpretations are consistent with previous readers and that the current reader maintains a consistent interpretation, we used procedures of calibration and error testing outlined by Chouinard et al (1987). A reference collection of winter flounder otoliths was established that had been aged by the previous reader (M. Strong, DFO St. Andrew's). One hundred otoliths from the reference collection were read at the outset of ageing and after every 1,500 otoliths aged. With each reading of the reference collection, the reader was tested for bias with the established ages of the collection.

Landings and weight at age

Port sampling of commercial winter flounder catches was conducted throughout the months of active fishing (Table 3). Each sample consisted of up to 250 winter flounder, sampled randomly from the landed catch, for which sexed length frequencies in 1-cm groupings were determined. Otoliths were removed at a rate of one sample per sex per centimeter. From 1990 to 1993, between 1,000 and 2,000 winter flounder were sexed and measured yearly from commercial landed catches. Age-length keys and length frequencies were made for each sex separately. This was done for three gear categories: otter trawls, seines (Danish and Scottish seines), and combined gillnets/longlines. Landings at age were calculated by applying the length frequencies associated with each gear category to the age-length key. The total landings at age were then adjusted for unsampled gear in the fishery, then summed over both sexes and all gear categories. The conversion of winter flounder lengths to weights was based on the length-weight regression from the September research survey.

Research survey data

Research vessel surveys have been conducted yearly since 1971 in the southern Gulf of St. Lawrence to provide an index of groundfish stock abundance. The surveys have been based on a stratified random design, except for the period 1984-1986 when randomly chosen fixed stations were used. The surveys are conducted in the month of September before groundfish stocks migrate from the Gulf.

Most sampling procedures in the southern Gulf groundfish surveys have remained constant since 1971 (Hurlbut and Clay 1990). The length frequencies of all flatfish species have been sex-based, with the exception of the period 1984-1986, when sexes were combined. Biological sampling of winter flounder, including length, weight, sex, maturity and otolith collection, was conducted at a rate of one specimen per centimeter, sex and set. Age-length keys based on 579 otoliths in 1990, 562 in 1991, 737 in 1992, and 864 in 1993.

The total number of winter flounder per standard tow since 1971 was obtained with the program RVAN (Clay 1989), compiled in the SAS programming language by G. Nielsen (DFO, Moncton). The mean number at age for 1990 to 1993 was computed with RVAN from the annual September surveys. Total mortalities at age (Z) were calculated for the four-year series using catch curve analysis (Ricker 1975) with consecutive ages from a cohort.

A survey aimed at sampling juvenile cod has been conducted yearly in July since 1990 in NAFO unit area 4Tl (Figure 1). Sampling and suvey protocol followed that described by Hurlbut and Clay (1990).

Abundance Indices

Abundance indices for 4T winter flounder were calculated from the September trawl surveys using two methods. First, stratified mean catches were computed using RVAN including all strata within 4T. Secondly, we calculated an index of abundance using a multiplicative analysis of catch rates. Winter flounder catches (number per standard 1.75-nm tow) were transformed as *ln*(catch+0.5) and weighted by stratum area. A model with year and stratum effects was fitted using the GLM procedure of SAS (SAS Institute 1990). Least square means for year were calculated to provide indices of relative abundance. In order to reduce the frequency of zero catches, we restricted the second analysis to strata 418-422, 428, 429, 432, 433, and 435 (Figure 5). Strata 401-403 were not included in the analysis because they were not fished during the 1971-1983 period. An assumption of this analysis is that there has been no significant expansion of winter flounder range to strata outside of the selected subset during periods of high abundance. Because the selected strata contained 99.8% of the winter flounder caught in 1971-1993 surveys (excluding strata 401-403; Figure 6), we believe that this assumption is reasonable.

Winter flounder inhabit inshore areas and appear to move into estuaries to overwinter (J.M. Hanson, DFO Moncton, unpublished data). Thus, it is possible that winter flounder in the southern Gulf comprise a number of local stocks. We repeated the above analysis for each of four subareas of the southern Gulf: the Chaleur Bay area (strata 418 and 419), the Miramichi area (strata 420 and 421), the Magdalen Islands (strata 428 and 435) and the area southeast of PEI (strata 432 and 433).

Depth Distribution

We used regression analysis to describe the depth distribution of winter flounder in 1993 based on the September groundfish survey and the July juvenile cod survey. For the September survey, we restricted the analysis to the subset of strata described above. The July survey was conducted in shallow water in the Miramichi area (in the vicinity of strata 20-22 in the September survey), and we used data from all strata in this survey. For each age and sex, we used Poisson regression models of the form

$$E[Y_i]=\mu_i=\exp(\beta_0+\beta_1X_i+\beta_2X_i^2) \qquad (1)$$

$$Var[Y_i]=\phi\ \mu_i \qquad (2)$$

where Y_i is the number of winter flounder of a particular age and sex caught in tow i; X_i is the depth of tow i; β_0, β_1, and β_2 are coefficients of the regression; and ø is a parameter for extra-Poisson variation. Significance of the effect of depth on winter flounder spatial pattern was tested for each age and sex by analysis of deviance (McCullagh and Nelder 1989) using the GLIM software package (Payne 1986). These tests used the change in scaled deviance between models with and without the depth term(s) being tested, and are equivalent to likelihood ratio tests (McCullagh and Nelder 1989). Three tests were performed. First, the overall effect of depth was tested by removing both depth terms (X_i, X_i^2) from the full model in equation 1. Then the X_i^2 and X_i terms were removed in sequence starting from the full model (equation 1) to test the quadratic and linear depth effects respectively. We also calculated the proportion of the total deviance that is explained by these depth effects by dividing the change in deviance due to removal of the depth term(s) by the deviance of the null model (i.e., the model containing only one parameter, representing a common μ for all the Y_i).

RESULTS AND DISCUSSION

Landings and catch at age

Male and female winter flounder in the commercial fisheries were of similar age range, mostly 3 to 12 year (Table 4). Winter flounder appeared in the sampled landings at a minimum average length of 25 cm, with few exceptions between 1990 and 1993. Growth differences between the two sexes were more apparent in weight data (Table 5; this observation was not tested statistically), where females had higher average body weight for most ages and gear types. The conversion of lengths to weights was based on the relation wt = $a\cdot len^b$, with length in cm and weight in g, where

males (1990):	a = 0.008307; b = 3.1357
females (1990):	a = 0.007437; b = 3.1765
males (1991):	a = 0.007368; b = 3.1729
females (1991):	a = 0.005527; b = 3.2626
males (1992):	a = 0.008791; b = 3.1146
females (1992):	a = 0.005640; b = 3.2542
males (1993);	a = 0.007108; b = 3.1796
females (1993):	a = 0.005163; b = 3.2821

All regressions were highly significant ($P < 0.001$, $R^2 \geq 0.98$).

Between 1990 and 1993, the landings were dominated by six-year-old fish.

Age composition of the catches varied between years (Table 6) with fish less than age-6 being captured in similar proportions in all gear (Figure 7). Coefficients of variation on the total estimated landings at age (column totals in Table 6) were consistently low, generally less than 5% (Table 7).

Research survey data

The dominant age class in September surveys since 1990 was age-4 or 5 and there were no apparent strong year classes (Table 8). Coefficients of variation for these estimates (Table 9) were higher than those observed for American plaice (Morin et al 1994), probably due to the limited distribution of winter flounder within the sampled range of 4T. Figure 8 illustrates the general pattern that was observed in mean catch-at-age over the four years that were analyzed. Total mortalities (Z) for winter flounder (Table 10) have varied considerably between years, but were lower than values of Z recorded for American plaice over the same years (Morin et al. 1994).

Abundance indices

The stratified mean numbers of winter flounder were low in the early 1970s, increased through the 1980s and were at an intermediate level of abundance in 1993 (Figure 9). This pattern was based on RVAN analyses of September trawl surveys that included all strata in 4T. A slightly different pattern resulted from a multiplicative analysis of selected strata. The effects of both year and stratum were significant (year: F=1.89, df=22,846, P=0.008; stratum: F=77.79, df=9,846, P=0.0001). Although the abundance index varied annually, this analysis suggests that abundance tended to be relatively low in the early to mid-1970s, relatively high in the late 1970s to early 1980s, and at intermediate levels in recent years (Figure 10).

By conducting the same multiplicative analysis within subareas of 4T some patterns emerged that may be specific to sectors or unit stocks within 4T. For the Chaleur Bay area, there was no significant trend in abundance over time (N=154, R^2=0.14, Figure 11); year and stratum effects were non-significant (P>0.05). For the Miramichi area (N=149, R^2=0.47), year and stratum were both highly significant (P<0.0001), with abundance relatively low in the early to mid-1970s and relatively high since the early 1980s (Figure 11). For the Magdalen Islands area (N=117, R^2=0.31), abundance was relatively high in the late 1970s and early 1980s and low in recent years (Figure 11). However, the year effect in this analysis was not significant (P=0.13). For the area southeast of PEI, there was no annual trend in abundance (N=173, R^2=0.30, Figure 11), but the stratum effect was highly significant (P<0.0001).

Some aspects of our treatment of winter flounder abundance will require further analysis. The differences that were noted between yearly stratified mean catches and the least-square means from the multiplicative analysis appear to be mainly due to logarithmic transformation. Preliminary analysis with Poisson models suggests that this may be a more appropriate model for treating winter flounder abundance data.

Depth distribution

The effect of depth on winter flounder catch rates was highly significant in all cases (Table 11). Depth explained 46-57% of the deviance in catch rates in the July survey and 32-49% of the deviance in the September survey (Table 11). The quadratic term was highly significant in all cases in the July survey, explaining 20-34% of the deviance (Table 11). The quadratic term was significant for all cases tested in the September survey except for age-9 males. Of the ages tested in the September survey, the proportion of the deviance explained by the quadratic term was highest for age 5 (17-19%) and least for age 9 (3-6%).

The depth distributions of winter flounder differed between the July and September surveys. In the July survey, catch rates were highest at depths of 22-23 m for all ages and both sexes of winter flounder (Figure 12). In the September survey, winter flounder occupied slightly greater depths, with peak catch rates at depths near 30 m for females aged 3-7 and males aged 3-5 (Figure 12). The September distribution of older winter flounder resembled their July distribution, with peak catch rates near 20-23 m. The difference in the depth distribution of younger flounder between the two surveys may reflect seasonal movements. McCracken (1963) reported that winter flounder occupy shallow inshore waters of Northumberland Strait during spring and early summer months. By mid summer, they concentrate at depths of 15-24 m. Differences in our observed seasonal depth distribuions may be due to geographic differences in the sampling distribution (the September data include the Chaleur Bay, Magdalen Islands and southeast PEI, areas not included in the July survey). Further work is required to identify the source of these differences in distribution.

Winter flounder are distributed in shallow water along the inshore edge of the September survey area. Variation in the depth distribution of sampling in the September survey (Figure 13) could affect abundance estimates from this survey. A possible solution would be to adjust for annual variation in the depths sampled by including depth terms in the model used to derive abundance indices. This approach requires the assumption that the effect of depth on winter flounder distribution does not vary from year to year. We tested this assumption using a Poisson regression model with terms for year, stratum, depth, $depth^2$, year*stratum interaction, year*depth and $year*depth^2$. We tested for annual variation in depth distribution by removing the latter two terms from the full model.

The interaction between year and depth distribution was highly significant ($P<0.000001$), explaining 6% of the deviance in winter flounder catch rates over the 23-yr time series. Annual variation in winter flounder depth distribution is shown in Figure 14. Depth distribution varied widely among years, with peak catch rates in the shallowest water sampled in some years and at greater depths in other years. These results indicate that it would be inappropriate to adjust winter flounder abundance indices to a constant depth for each year. They also suggest that the proportion of the winter flounder population(s) occurring outside of the survey area has varied widely from year to year. In analyses within years (Table 12), the effect of depth on winter flounder catch rates in the September survey was highly significant for all years but 1975 and 1980. The extent to which winter flounder abundance indices are affected by annual variation in the depths sampled and in the depth distribution of winter flounder requires further investigation.

Prognosis

Since 1960, nominal landings of winter flounder in 4T have averaged 1,984 t annually, with a minimum of 149 t in 1984 and a maximum of 4,412 t in 1965. Landings appear to have fluctuated at the longterm average over the past eight years. Further attention must be given to problems of misreporting and discarding in this fishery.

Current indices of stock abundance, based on research surveys, indicate that 4T winter flounder are at a level of intermediate abundance relative to the pattern since 1971. The abundance of winter flounder varies regionally and annually. This may be attributed partly due to the presence of different stock units of winter flounder within 4T.

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Table 1. Annual landings (t) of winter flounder in NAFO Division 4T by major gear types. Gear codes: OTB=otter trawls (unspecified), OTB1=otter trawls side, OTB2=otter trawls stern, SNU=seines, GNS=gillnets, LLS=longlines.

	GEAR							
YEAR	OTB	OTB1	OTB2	SNU	GNS	LLS	OTHER	TOTAL
1960	730	0	0	137	0	17	16	900
1961	1043	0	0	452	1	2	98	1596
1962	1407	0	0	642	115	8	140	2312
1963	2324	0	0	697	66	15	46	3148
1964	2247	0	0	546	0	0	209	3002
1965	4026	0	0	217	12	89	68	4412
1966	0	2639	1	300	53	0	63	3056
1967	0	1853	17	464	58	33	19	2444
1968	0	423	1	107	16	2	1	550
1969	0	1251	12	51	0	12	368	1694
1970	0	1724	85	576	142	21	136	2684
1971	0	1708	61	572	79	23	378	2821
1972	0	1191	2	533	36	44	16	1822
1973	0	1470	336	390	29	42	33	2300
1974	0	1323	6	388	23	4	176	1920
1975	0	1559	18	254	35	3	141	2010
1976	4	1738	400	96	24	3	142	2407
1977	0	709	194	48	24	6	254	1235
1978	0	571	173	104	77	13	183	1121
1979	0	944	336	52	64	10	179	1585
1980	1247	17	0	80	274	147	211	1976
1981	1563	42	0	30	215	16	75	1941
1982	1652	0	0	32	579	1	41	2305
1983	1405	0	8	131	231	7	17	1799
1984	0	6	37	32	13	4	57	149
1985	2	71	862	56	97	38	54	1180
1986	0	66	1101	243	538	6	90	2044
1987	0	20	804	307	526	85	69	1811
1988	0	24	759	280	321	20	10	1414
1989	0	109	1082	392	469	37	0	2089
1990	0	4	1167	274	588	32	12	2077
1991*	0	49	1815	188	347	14	123	2536
1992*	0	43	1190	226	324	4	106	1893
1993*	0	16	710	64	387	2	58	1238
MEAN	519	576	329	264	170	22	106	1984

* Provisional data

Table 2. Preliminary landings (t) of 4T winter flounder in 1993 by gear and month. Asterisk indicates a value less than 50 kg. Gear types: OTB1= otter trawl (side); OTB2= otter trawl (stern); OTM2= midwater trawl stern; PTB= bottom pair trawl; PTM= midwater pair trawl; SDN= Danish seine; GNS= set gillnets; LL= longlines; LHP= jiggers; LHB= baited handlines; FIX= traps; UNK= unknown gear.

	MONTH												
GEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
OTB1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	4.9	9.9	0.0	0.0	0.0	16.4
OTB2	0.0	0.0	0.0	0.0	124.7	67.7	85.0	68.0	268.6	96.0	0.0	0.0	709.9
OTM2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5
PTB	0.0	0.0	0.0	0.0	0.0	0.0	19.5	4.6	0.5	4.8	0.0	0.0	29.4
PTM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
SDN	0.0	0.0	0.0	0.0	0.0	0.0	2.6	10.7	34.5	16.3	0.0	0.0	64.2
GNS	0.0	0.0	0.0	0.6	58.7	136.1	33.2	85.8	66.0	6.9	0.0	0.0	387.4
LL	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.4	0.0*	0.7	0.0	0.0	2.3
LHP1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.0	0.0	0.0	0.5
LHP	0.0	0.0	0.0	0.0	10.0	2.0	4.6	0.1	1.7	0.0	0.0	0.0	18.4
FIX	0.1	0.0	0.0	0.0	5.2	3.2	0.0	0.0	0.0	0.0	0.0	0.0	8.5
UNK	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*
TOTAL	0.1	0.0	0.0	0.6	198.7	209.0	147.3	175.6	382.1	124.7	0.0	0.0	1238.1

Table 3. Numbers of winter flounder sampled for length-frequency (sized) and age determination (aged) from commercial fishery, with the number of monthly samples. "-" indicates no sampling.

YEAR	GEAR		MAY	JUNE	JUL	AUG	SEP	OCT	TOTAL
1990	GILLNETS	SIZED	-	-	189	17	-	-	206
		AGED	-	-	13	8	-	-	21
	SEINES	SIZED	256	-	-	-	152	349	757
		AGED	42	-	-	-	21	42	105
	TRAWLS	SIZED	40	-	-	152	204	154	550
		AGED	13	-	-	17	20	21	71
	SAMPLES		3	-	1	2	2	3	11
1991	GILLNETS	SIZED	-	-	89	24	66	-	179
		AGED	-	-	33	11	24	-	68
	SEINES	SIZED	-	124	199	-	175	203	701
		AGED	-	24	21	-	21	23	89
	TRAWLS	SIZED	-	-	-	-	225	-	225
		AGED	-	-	-	-	20	-	20
	SAMPLES		-	1	3	1	3	1	9
1992	GILLNETS	SIZED	-	-	277	-	14	-	291
		AGED	-	-	39	-	10	-	49
	SEINES	SIZED	-	114	259	-	-	-	373
		AGED	-	22	30	-	-	-	52
	TRAWLS	SIZED	-	324	238	389	611	-	1562
		AGED	-	56	32	39	72	-	199
	SAMPLES		-	7	6	2	4	-	19
1993	GILLNETS	SIZED	-	511	9	-	141	-	661
		AGED	-	59	7	-	46	-	112
	SEINES	SIZED	-	-	-	207	-	187	394
		AGED	-	-	-	18	-	0	18
	TRAWLS	SIZED	-	-	196	152	-	442	790
		AGED	-	-	19	25	-	50	94
	SAMPLES		-	3	2	2	3	3	13

Table 4. Mean length-at-age (cm) of winter flounder in commercial fisheries. Male flounder in upper panel; female flounder in lower panel. "-" indicates no data. GNS&LL: gillnets and longlines.

	1990			1991			1992			1993		
AGE	TRAWLS	SEINES	GNS&LL	TRAWLS	SEINES	GNS&LL	TRAWLS	SEINES	GNS&LL	TRAWLS	SEINES	GNS&LL
3	-	-	-	25.0	25.0	-	26.4	28.0	28.0	-	-	-
4	27.7	28.0	-	25.5	25.9	28.0	24.1	26.6	27.0	27.0	26.8	27.2
5	27.6	29.1	31.1	27.3	29.2	29.7	27.0	28.1	30.7	28.1	27.3	28.0
6	27.8	29.2	31.1	26.8	28.6	30.1	27.6	27.7	31.0	29.0	27.5	28.5
7	28.9	30.0	31.1	27.3	30.8	31.4	28.6	28.1	31.7	28.9	27.6	28.5
8	32.7	32.7	31.2	31.0	34.1	34.0	29.5	28.4	31.6	29.7	27.8	28.7
9	33.0	33.6	32.0	31.0	33.0	33.3	31.5	32.4	35.4	29.7	28.6	29.3
10	34.0	34.0	-	-	33.0	34.6	33.1	34.9	34.0	30.3	30.3	30.2
11	-	37.0	-	-	-	-	32.6	32.2	34.0	33.0	-	33.0
12	-	-	-	-	-	-	35.0	35.0	35.0	-	-	-

AGE	TRAWLS 1990	SEINES 1990	GNS&LL 1990	TRAWLS 1991	SEINES 1991	GNS&LL 1991	TRAWLS 1992	SEINES 1992	GNS&LL 1992	TRAWLS 1993	SEINES 1993	GNS&LL 1993
3	-	-	-	-	-	-	13.6	-	-	-	-	-
4	28.0	28.0	28.0	25.9	27.1	27.3	27.0	27.2	30.9	28.4	26.7	26.9
5	29.2	29.4	27.3	27.3	29.5	30.6	27.8	27.6	31.8	28.9	27.8	28.7
6	29.7	30.5	28.0	28.3	30.4	31.6	28.5	28.0	32.3	30.3	28.4	28.9
7	31.2	32.3	28.7	29.8	31.6	32.8	30.5	29.7	33.6	32.2	28.8	29.7
8	32.6	34.4	32.4	29.3	31.8	34.8	31.5	31.2	33.9	33.8	30.6	31.5
9	35.2	39.4	35.8	34.2	34.9	36.9	32.8	32.4	34.8	31.3	29.9	30.4
10	33.9	35.2	31.0	-	37.0	42.3	41.2	38.2	38.9	34.6	34.0	35.3
11	33.2	34.4	33.0	-	38.6	38.7	39.3	37.6	38.0	-	-	-
12	37.5	37.5	-	-	-	-	35.0	35.0	35.0	-	-	-
13	-	-	-	-	-	-	39.0	39.0	39.0	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	48.2	49.0	-	-	-

Table 5. Mean weight (kg) of winter flounder in commercial fisheries. Male flounder in upper panel; female flounder in lower panel. "-" indicates no data. GNS&LL: gillnets and longlines.

	1990			1991			1992			1993		
AGE	TRAWLS	SEINES	GNS&LL	TRAWLS	SEINES	GNS&LL	TRAWLS	SEINES	GNS&LL	TRAWLS	SEINES	GNS&LL
3	-	-	-	0.201	0.201	-	0.243	0.282	0.283	-	-	-
4	0.279	0.287	-	0.217	0.226	0.288	0.191	0.242	0.252	0.258	0.248	0.262
5	0.277	0.328	0.397	0.270	0.333	0.352	0.263	0.290	0.382	0.290	0.266	0.285
6	0.283	0.331	0.399	0.254	0.313	0.371	0.276	0.278	0.394	0.326	0.274	0.306
7	0.320	0.357	0.397	0.270	0.397	0.424	0.306	0.290	0.420	0.320	0.276	0.306
8	0.466	0.472	0.403	0.398	0.546	0.540	0.344	0.299	0.421	0.352	0.280	0.312
9	0.480	0.509	0.436	0.398	0.487	0.505	0.413	0.458	0.608	0.349	0.308	0.331
10	0.527	0.527	-	-	0.485	0.575	0.478	0.566	0.520	0.366	0.365	0.362
11	-	0.687	-	-	-	-	0.460	0.442	0.529	0.479	-	0.479
12	-	-	-	-	-	-	0.567	0.567	0.567	-	-	-
3	-	-	-	-	-	-	0.029	-	-	-	-	-
4	0.294	0.294	0.294	0.226	0.262	0.270	0.267	0.269	0.398	0.341	0.253	0.263
5	0.339	0.351	0.273	0.271	0.354	0.405	0.291	0.279	0.444	0.331	0.289	0.322
6	0.359	0.397	0.297	0.310	0.389	0.439	0.315	0.294	0.464	0.395	0.310	0.330
7	0.424	0.473	0.324	0.364	0.440	0.498	0.394	0.360	0.532	0.480	0.326	0.363
8	0.487	0.578	0.477	0.344	0.457	0.614	0.433	0.424	0.550	0.552	0.395	0.433
9	0.615	0.905	0.645	0.558	0.605	0.740	0.501	0.475	0.605	0.422	0.365	0.386
10	0.570	0.646	0.406	-	0.723	1.125	1.021	0.796	0.847	0.587	0.548	0.642
11	0.505	0.573	0.495	-	0.833	0.842	0.875	0.756	0.784	-	-	-
12	0.745	0.743	-	-	-	-	0.597	0.597	0.597	-	-	-
13	-	-	-	-	-	-	0.849	0.849	0.849	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	1.693	1.785	-	-	-

Table 6. Estimated landings at age (thousands of fish) of 4T winter flounder. Column totals include estimate for unsampled gear. Data for 1991-1993 are based on provisional landing statistics. GNS&LL: gillnets and longlines.

	1990				1991				1992				1993			
AGE	TRAWL	SEINE	GNS&LL	TOTAL	TRAWL	SEINE	GNS&LL	TOTAL	TRAWL	SEINE	GNS&LL	TOTAL	TRAWL	SEINE	GNS&LL	TOTAL
3	0	0	0	0	84	3	0	87	38	8	1	46	0	0	0	0
4	52	6	43	102	1388	19	9	1416	279	43	8	330	137	18	79	236
5	850	122	814	1794	1591	75	88	1754	897	168	54	1119	359	57	284	705
6	1096	184	842	2132	2993	187	258	3439	1443	289	132	1864	491	63	377	937
7	743	165	322	1236	818	117	197	1133	828	137	174	1139	518	50	286	859
8	259	80	50	391	219	39	78	336	441	71	127	639	285	18	132	438
9	52	33	6	91	27	24	81	132	137	16	64	218	113	9	54	177
10	31	10	9	51	0	4	27	31	19	6	35	59	63	1	18	83
11	28	9	2	38	0	2	11	12	35	2	35	72	6	0	1	7
12	2	4	0	5	0	0	0	0	6	1	7	14	0	0	0	0
13	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0
TOTAL	3112	613	2089	5839	7121	470	748	8341	4125	740	639	5504	1972	216	1231	3441

Table 7. Coefficients of variation (%) for estimated landings-at-age of 4T winter flounder.

AGE	1990	1991	1992	1993
3	0.00	2.07	2.91	0.0
4	4.99	4.13	3.40	2.50
5	1.72	1.95	1.61	1.38
6	1.52	1.05	1.07	1.21
7	1.94	1.77	1.29	1.30
8	3.00	3.62	1.83	1.85
9	4.87	3.80	2.76	3.30
10	7.14	2.82	5.74	3.97
11	3.02	1.41	3.80	2.13
12	2.01	0.0	7.13	0.0
13	0.0	0.0	4.46	0.0
14	0.0	0.0	0.0	0.0
15	0.0	0.0	0.04	0.0

Table 8. Mean catch-per-tow-at-age of winter flounder in 4T from September research surveys.

AGE	1990	1991	1992	1993
1	0.0	0.0	0.0	0.0
2	0.7	0.2	1.5	0.5
3	5.2	4.5	5.5	2.7
4	16.2	10.0	10.9	4.5
5	17.0	9.1	10.8	4.8
6	7.5	4.8	8.2	4.6
7	4.0	2.8	4.3	2.7
8	1.6	1.7	1.8	2.0
9	0.4	0.5	0.7	1.1
10	0.1	0.1	0.2	0.7
11	0.1	0.0	0.1	0.1
12	0.0	0.0	0.0	0.1
13	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0

Table 9. Coefficients of variation (%) for estimates of mean catch-per-tow-at-age in September research surveys. "-" indicates no data.

AGE	1990	1991	1992	1993
1	0.0	0.0	0.0	0.0
2	44.2	68.1	0.0	31.5
3	12.8	54.1	7.7	31.5
4	15.7	43.2	13.6	29.5
5	29.3	37.9	25.3	26.7
6	26.8	19.9	31.4	22.5
7	24.6	21.4	44.0	17.2
8	28.9	23.6	49.2	17.9
9	32.3	24.9	35.8	19.7
10	43.9	0.0	43.3	24.0
11	0.0	0.0	38.6	36.3
12	0.0	0.0	0.0	43.3
13	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	98.8

Table 10. Total mortalities (Z) of winter flounder in 4T calculated from mean number-per-tow in September research surveys.

AGE	1990	1991	1992
1	-	-	-4.57
2	-1.86	-3.33	-0.59
3	-0.66	-0.90	0.21
4	0.58	-0.07	0.82
5	1.27	0.10	0.84
6	0.97	0.11	1.10
7	0.88	0.48	0.77
8	1.15	0.80	0.43
9	1.86	0.74	0.07
10	0.67	-0.23	1.02
11	0.79	0.48	0.12
12	-	-	-0.20
13	-	-	-
14	-	-	-1.27

Table 11. Strength of the effect of depth on winter flounder catch rates during the 1993 July juvenile cod survey and the 1993 September groundfish survey. *D* is the percent of the total deviance explained by an effect, and *P* is the significance level associated with the effect. Only strata 418-422, 428, 429, 432, 433, and 435 are included for the September survey.

	Overall		Quadratic		Linear	
Age	*D*	*P*	*D*	*P*	*D*	*P*
A. July survey, Females:						
3	45.5	<0.0001	23.9	<0.0001	21.6	0.0001
5	54.6	<0.0001	33.6	<0.0001	20.9	0.0002
7	53.9	<0.0001	28.1	<0.0001	25.8	<0.0001
9	47.2	<0.0001	19.9	<0.0001	27.3	<0.0001
B. July survey, Males:						
3	54.0	<0.0001	30.0	<0.0001	24.0	0.0001
5	57.1	<0.0001	30.8	<0.0001	26.3	<0.0001
7	54.1	<0.0001	28.6	<0.0001	25.5	<0.0001
9	45.5	<0.0001	24.1	<0.0001	21.4	0.0002
C. September survey, Females						
3	32.4	<0.0001	12.2	0.0007	20.2	<0.0001
5	39.1	<0.0001	18.8	<0.0001	20.3	<0.0001
7	44.9	<0.0001	13.9	<0.0001	31.0	<0.0001
9	48.8	<0.0001	6.3	0.0054	42.6	<0.0001
D. September survey, Males						
3	33.5	<0.0001	12.6	0.0005	20.9	<0.0001
5	38.0	<0.0001	17.2	<0.0001	20.8	<0.0001
7	38.9	<0.0001	7.2	0.0064	31.7	<0.0001
9	40.2	<0.0001	2.9	0.083	37.4	<0.0001

Table 12. Significance of the effect of depth on winter flounder catch rates within years. *D* is the percent of the deviance explained by depth (depth+depth^2). *N* is the number of tows in the selected strata.

Year	*N*	*D*	*P*
71	27	38.5	0.0006
72	28	69.0	<0.0001
73	29	76.3	<0.0001
74	25	30.0	0.0083
75	28	10.7	0.22
76	27	43.4	0.0001
77	26	50.3	<0.0001
78	25	60.3	<0.0001
79	30	40.8	<0.0001
80	28	18.7	0.056
81	28	73.5	<0.0001
82	28	46.3	<0.0001
83	27	33.7	0.0023
84	44	52.0	<0.0001
85	29	57.5	<0.0001
86	55	48.0	<0.0001
87	55	38.2	<0.0001
88	31	41.3	<0.0001
89	64	48.3	<0.0001
90	50	25.9	0.0003
91	67	46.8	<0.0001
92	61	41.0	<0.0001
93	66	40.4	<0.0001

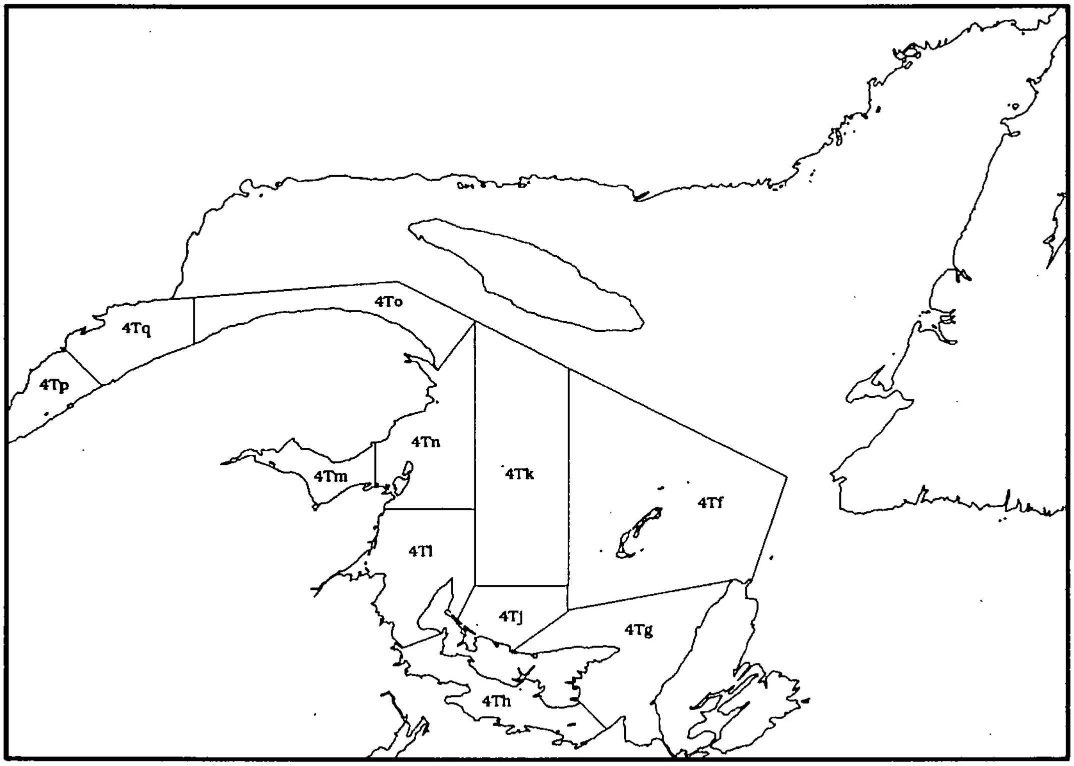

Figure 1. Gulf of St. Lawrence showing unit areas of NAFO Division 4T.

Figure 2. Nominal landings of winter flounder in 4T.

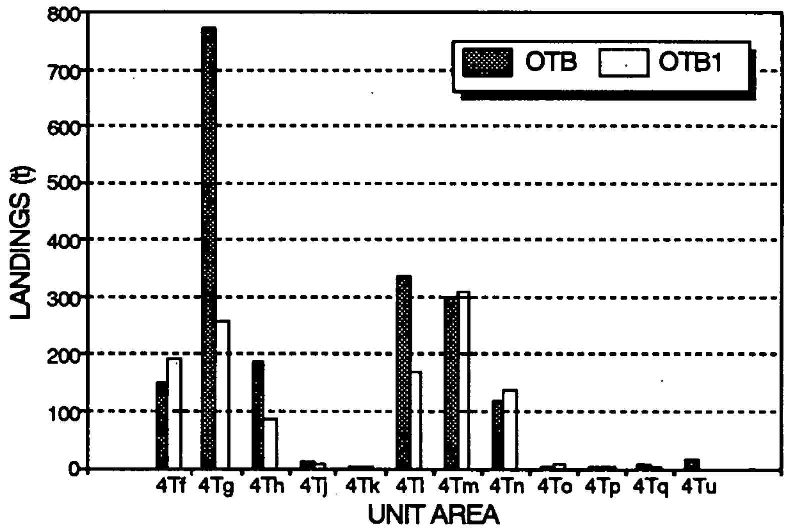

Figure 3. Nominal landings of winter flounder by unit area of 4T.

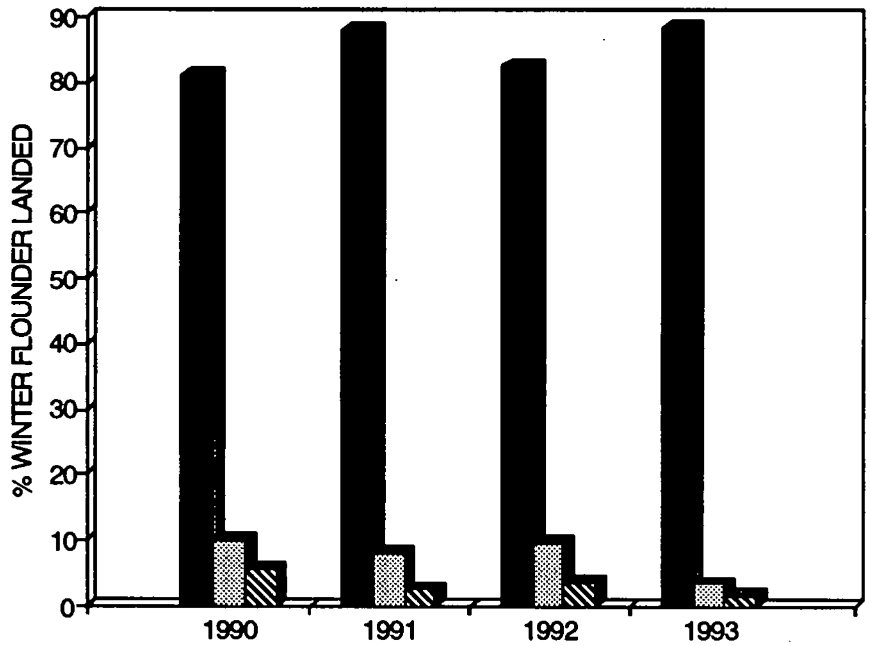

Figure 4. Percent of winter flounder landed by directed species in 4T fisheries. Directed species are: winter flounder (dark column); white hake (stippled column); cod (hatched column).

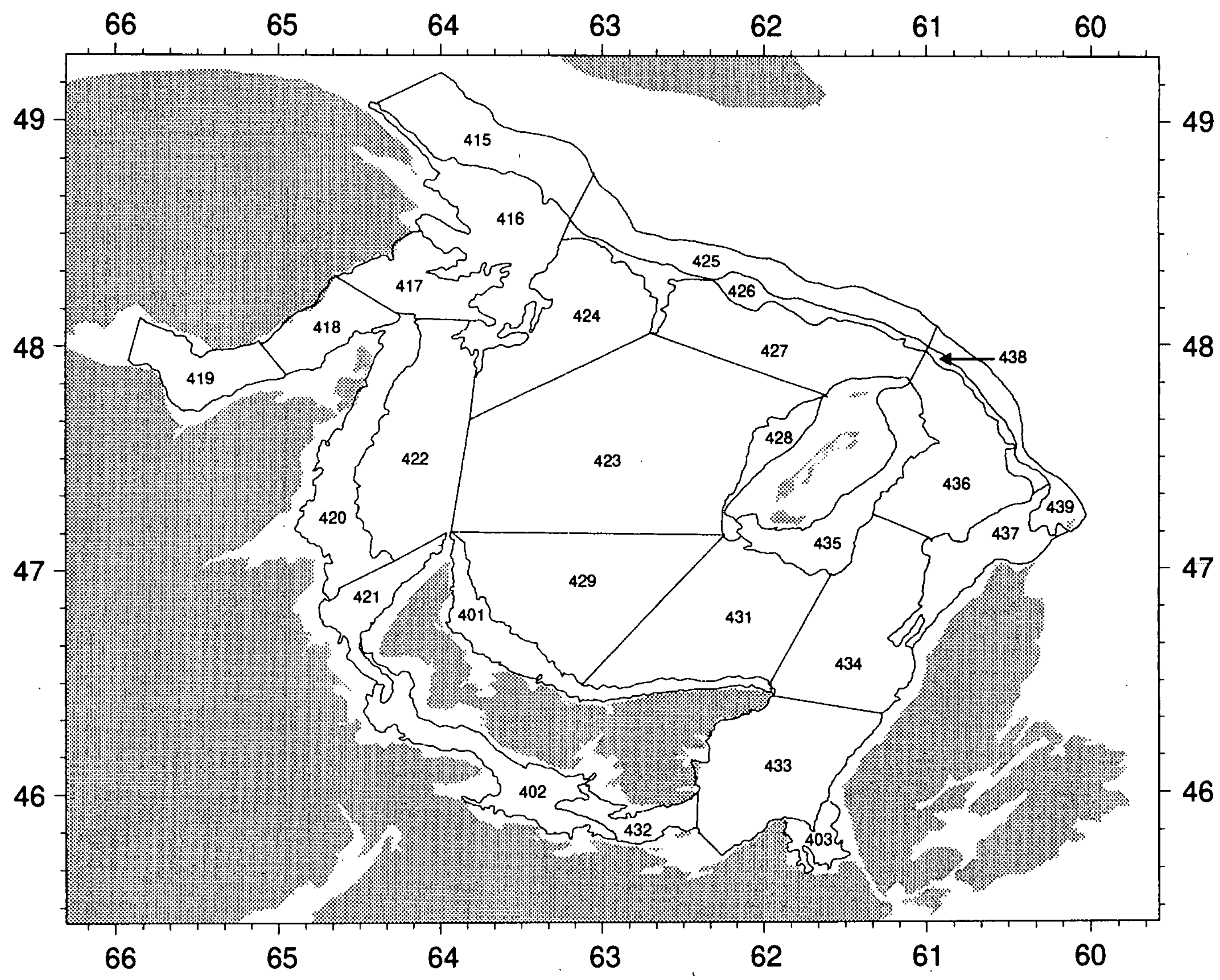

Fig. 5. Stratification for the September groundfish abundance survey of the southern Gulf of St. Lawrence.

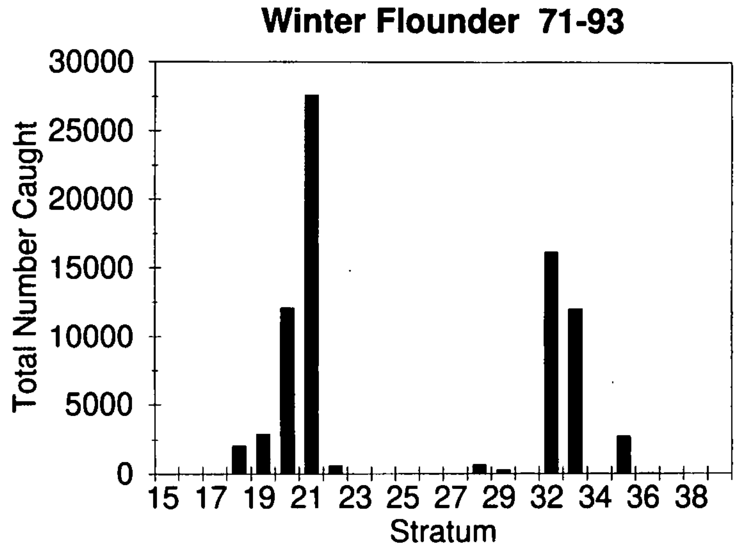

Fig. 6. Total catches of winter flounder by stratum in the 1971-1993 bottom trawl surveys of the southern Gulf of St. Lawrence.

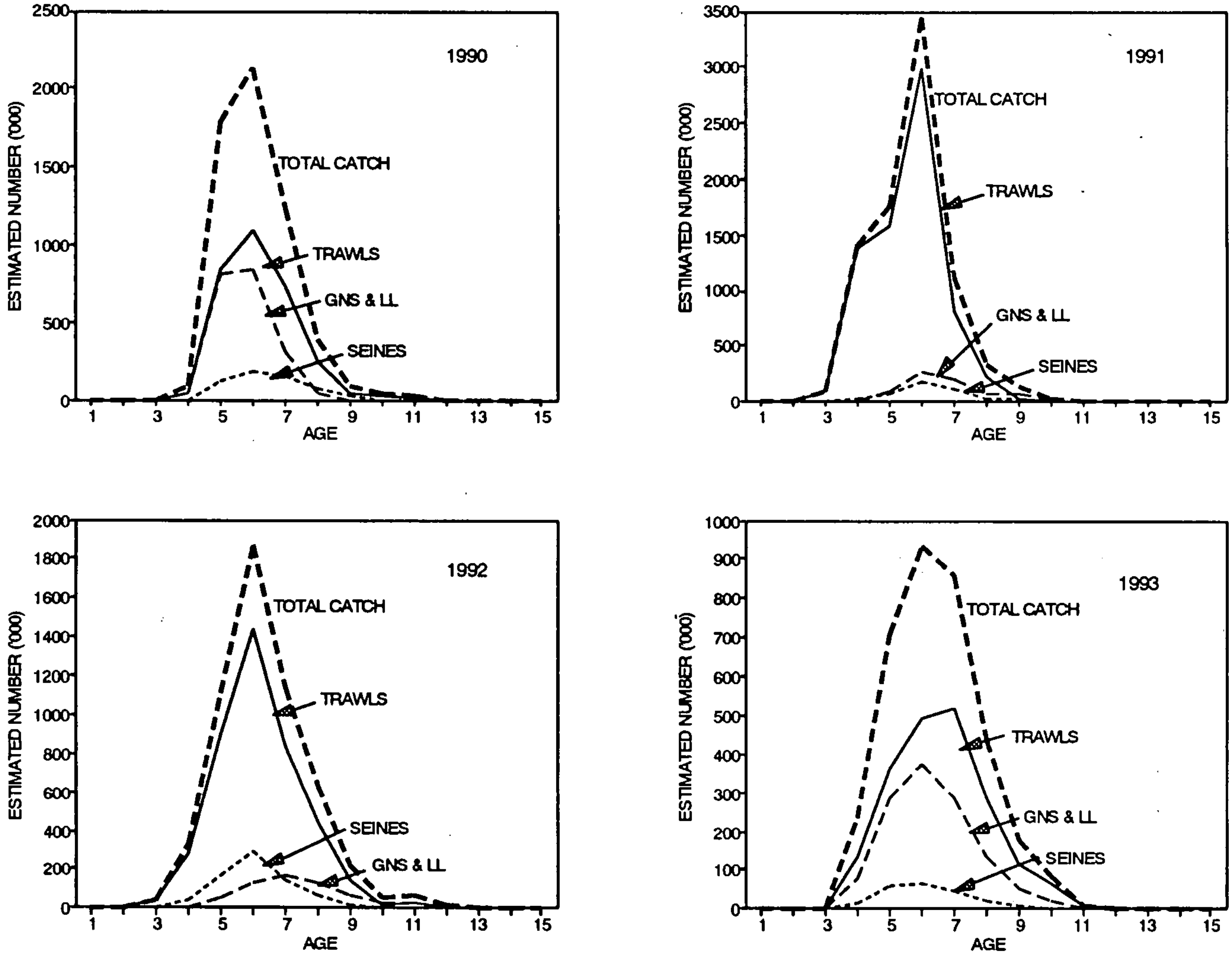

Figure 7. Estimated catch-at-age of winter flounder in 4T by main gear types, 1990-1993. GNS & LL: gillnets and longlines.

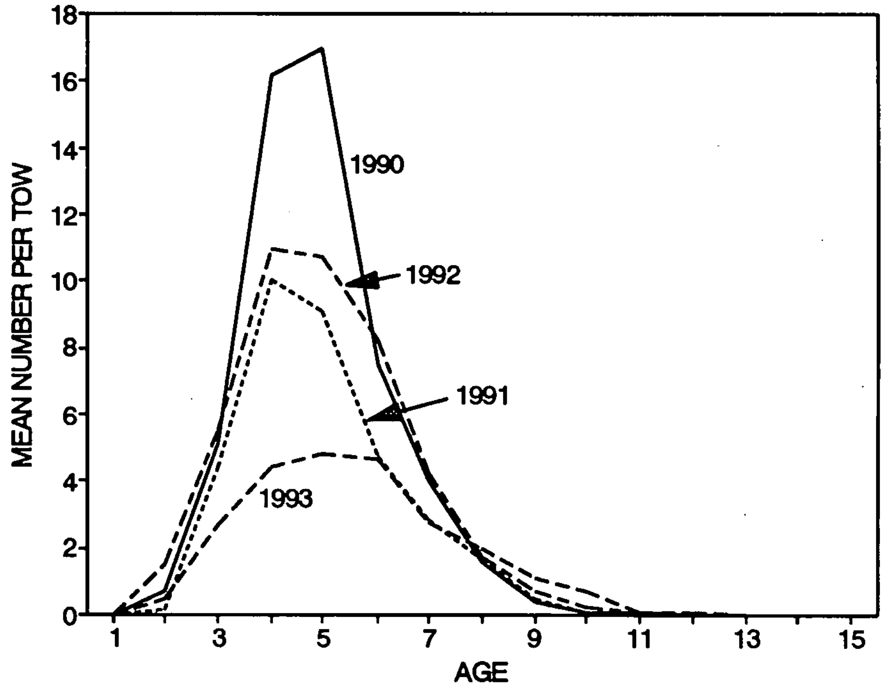

Figure 8. Annual mean catch-at-age of winter flounder from September research surveys in 4T.

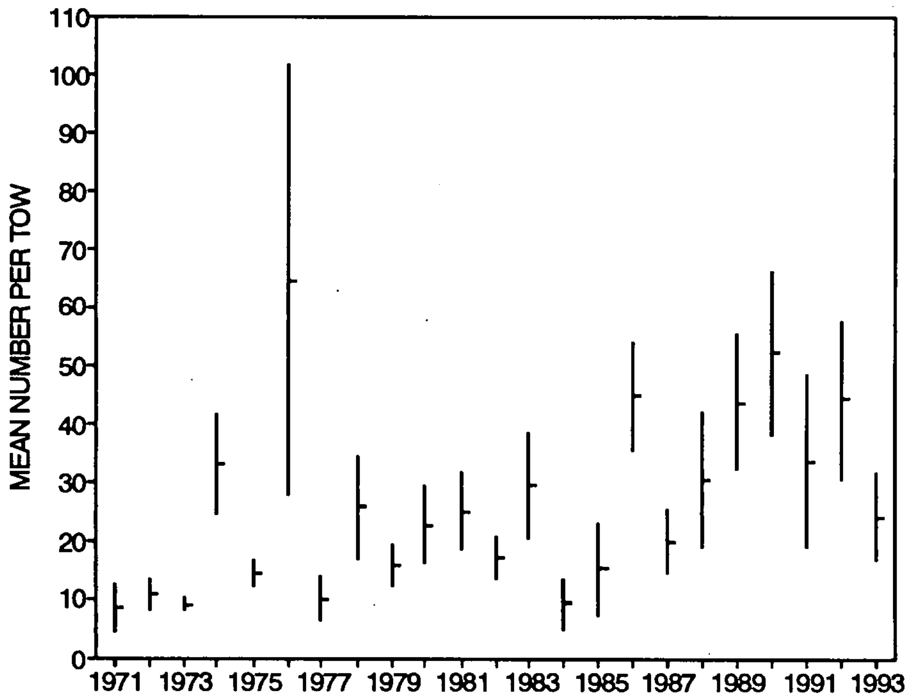

Figure 9. Mean catch of winter flounder in September trawl surveys of the southern Gulf of St. Lawrence, including all strata. Vertical lines represent +/- one standard deviation.

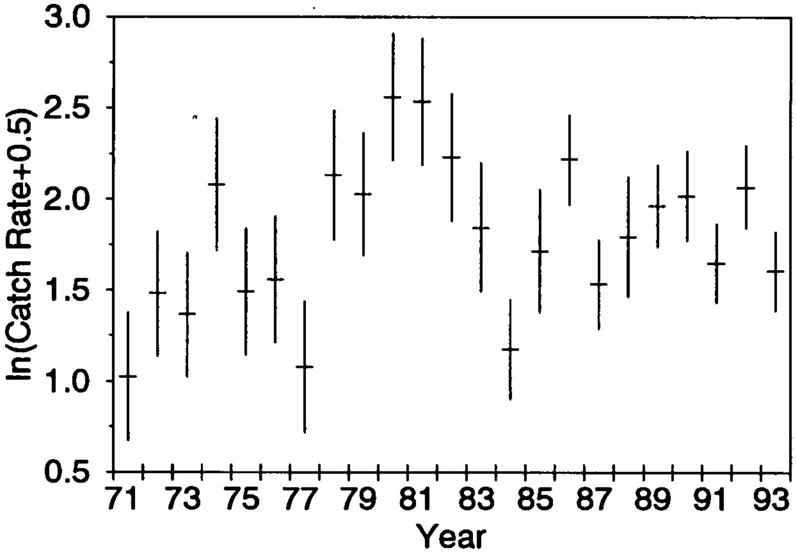

Figure 10. Catch rates of winter flounder in selected strata of the September bottom trawl survey of the southern Gulf of St. Lawrence. Catch rate is the number caught per standard tow. Horizontal lines show the least square means and vertical lines are +/- one standard error.

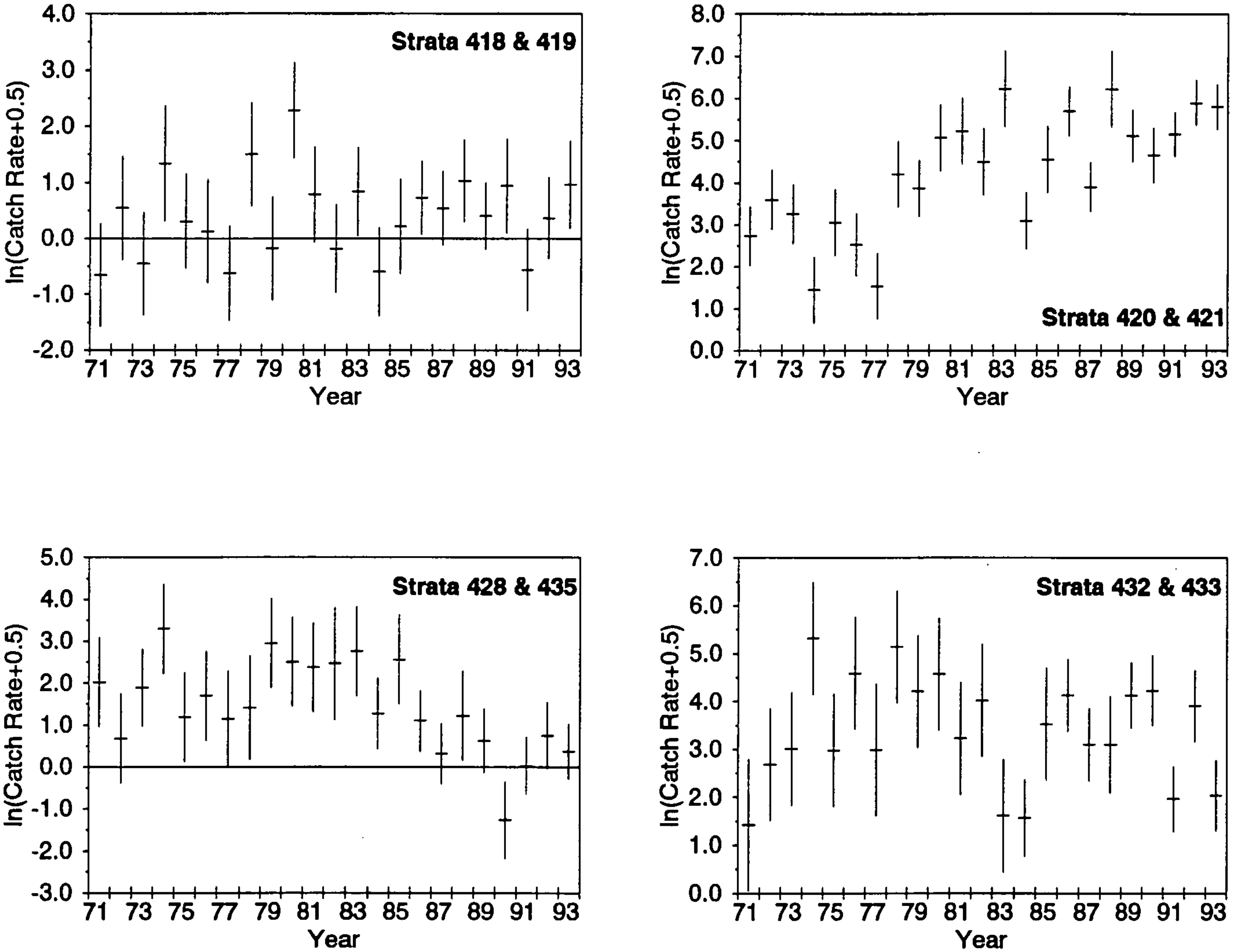

Figure 11. Catch rates of winter flounder in subareas of the southern Gulf of St. Lawrence. Data are from September bottom trawl surveys. Catch rate is the number caught per standard tow. Horizontal lines show least square means. Vertical bars are +/- one standard error.

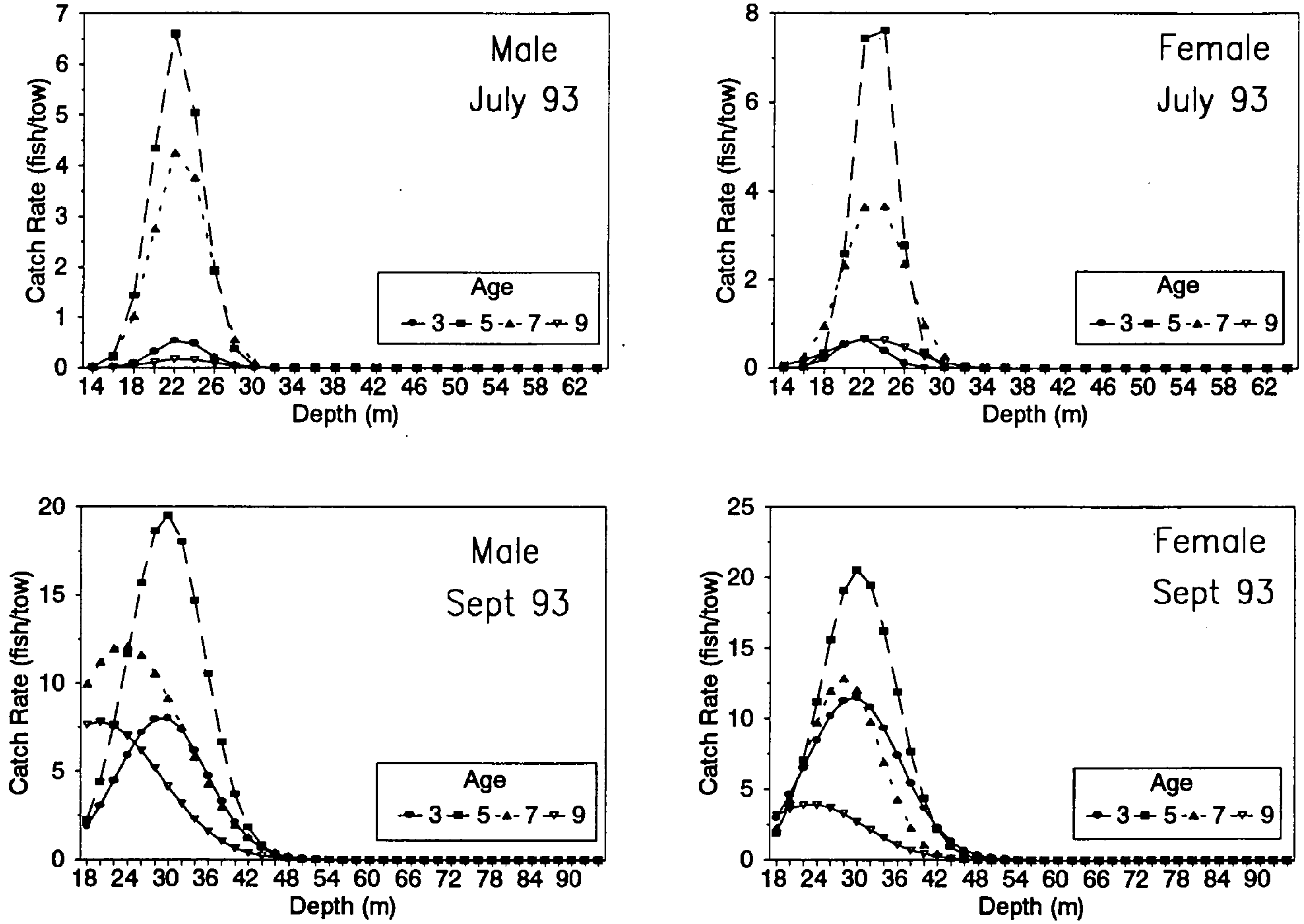

Figure 12. Depth distribution of winter flounder in the July juvenile cod and September groundfish abundance surveys in the southern Gulf of St. Lawrence, 1993.

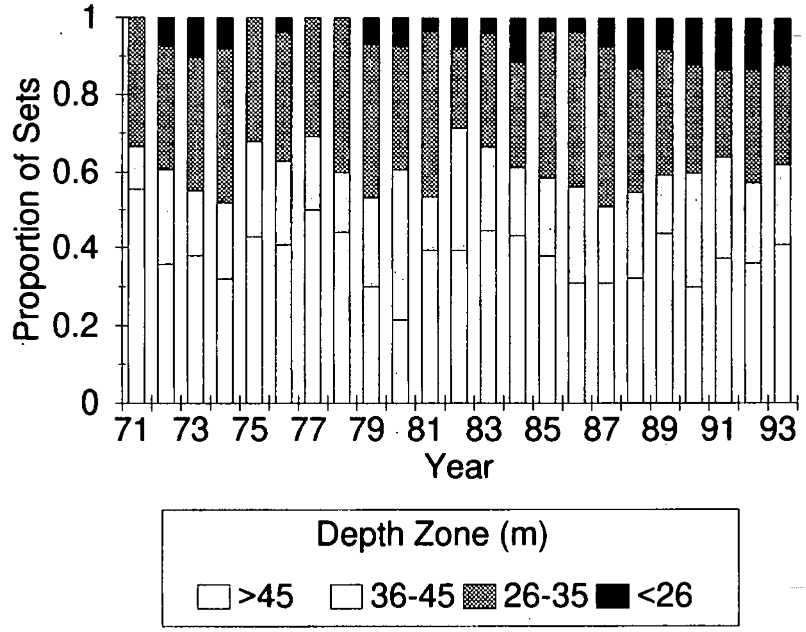

Figure 13. Proportion of sets by depth zone in the September abundance survey of the southern Gulf of St. Lawrence (strata 418-422, 428, 429, 432, 433, and 435 only).

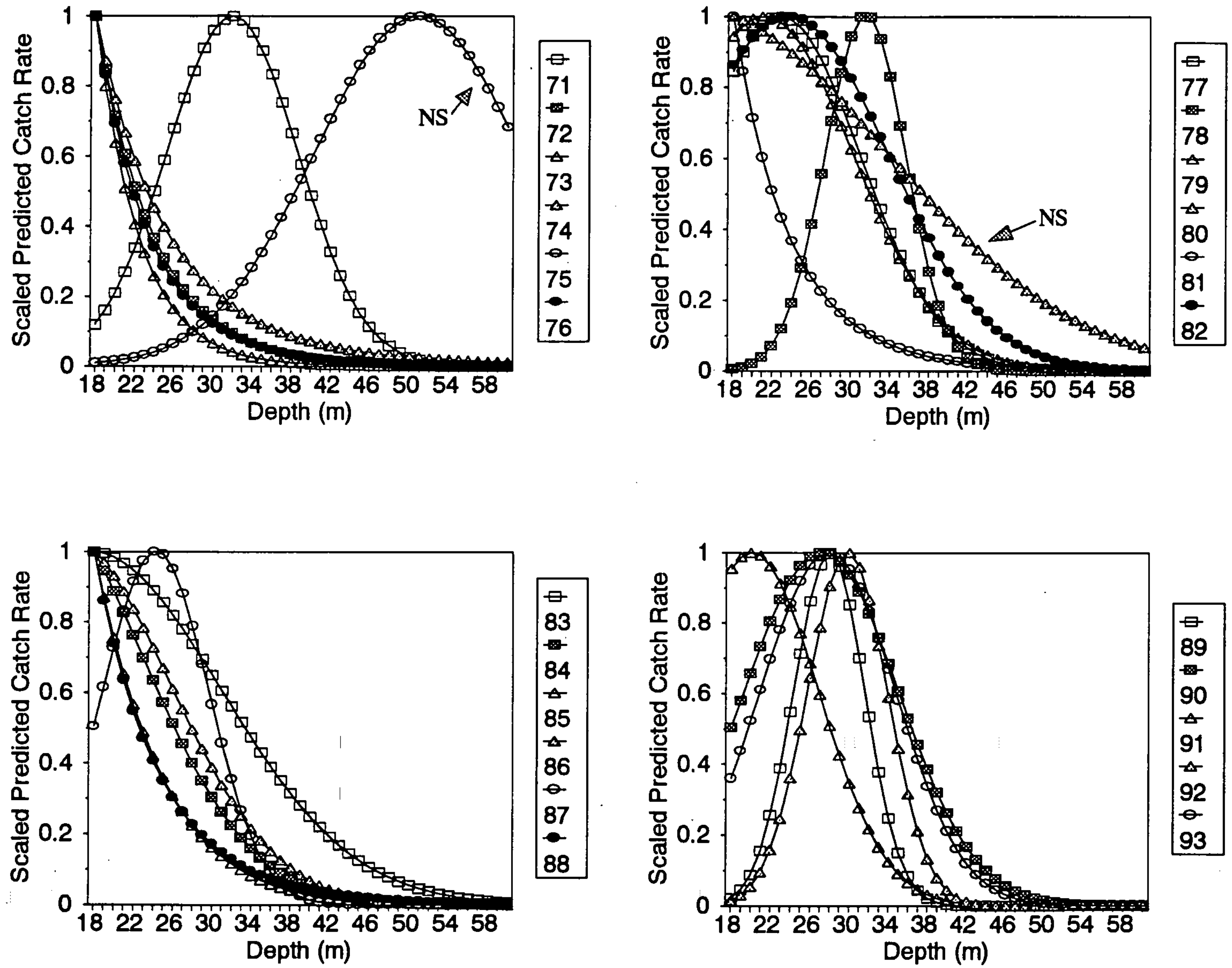

Figure 14. Winter flounder depth distributions in the southern Gulf of St. Lawrence in September, 1971-1993. Predicted catch rate (number per standard tow) is scaled by the maximum rate in each year. Data are for strata 418-422, 428, 429, 432, 433, and 435. Models are highly significant (P<0.01) in all years but 1975 and 1980.