DFO Atlantic Fisheries
Research Document 96/71

MPO Pêches de l'Atlantique
Document de recherche 96/71

Status of Witch Flounder in NAFO Divisions 4RST, 1995

by

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Abstract

The provisional landings of witch flounder totalled 320 t in the Gulf of St. Lawrence (NAFO divisions 4RST) in 1995, their lowest level over the time series of landings statistics since 1960. Annual landings of witch since 1960 have averaged 2742 t in 4RST. Although most landings were made in 4T (263 t), declines were registered in all areas of the Gulf. Seines contributed most of the landings. The number of days seiners spent directing for witch flounder has declined in 4RST over the past five years, totaling 213 days in 1995. Directed effort by trawlers declined to only 5 days of fishing in 1993 and increased to 23 days in 1995. Research surveys conducted in the northern and southern Gulf indicated that witch abundance declined during the late 1980s. Northern Gulf surveys indicated that abundance peaked in 1985 or 1986 and that the stock is currently at its lowest level since the northern Gulf surveys began in the late 1970s. In the southern Gulf, witch abundance was low during the early 1980s, rose to a peak in 1988, then declined yearly until 1992. Abundance estimates in the 4T survey since 1993 are in the upper range of values observed since the survey began in 1971. Research survey data suggest that the witch resource was more abundant and more widely distributed in the northern Gulf. Survey indices from the northern Gulf survey may therefore be more representative of the status of the 4RST witch resource.

Résumé

Les débarquements provisoires de la plie grise ont atteint 320 t dans le golfe du Saint-Laurent (divisions 4RST de l'OPANO) en 1995, soit le plus bas niveau enregistré depuis le début de la série des statistiques en 1960. Depuis 1960, les débarquements annuels de plie grise ont atteint en moyenne 2 742 t dans les divisions 4RST. La plupart des débarquements de la plie grise provenait de la division 4T en 1995 (263 t); cependant, les débarquements ont décliné dans tous les secteurs du Golfe. Les sennes ont contribué à la plus grande partie des débarquements de la plie grise. Le nombre de jours de pêche par les senneurs qui dirigaient pour la plie grise de 4RST a diminué au cours des derniers cinq ans, pour atteindre un total de 213 jours de pêche en 1995. L'effort dirigé de pêche par les chalutiers ont diminué durant la même période jusqu'à un minimum de 5 jours en 1993, augmentant à 23 jours de pêche en 1995. Les relevés scientifiques du nord et du sud du Golfe indiquent que l'abondance de la plie grise a décliné durant la fin des années 1980. Les relevés du nord du Golfe indiquent que l'abondance a atteint un sommet en 1985 ou en 1986 et que le stock est presentement à son plus bas niveau depuis que ces relevés ont débuté vers la fin des années 1970. Dans le sud du Golfe, l'abondance de la plie grise était faible durant le début des années 1980, mais elle a augmenté pour atteindre un sommet en 1988, et ensuite a décliné annuellement jusqu'à 1992. Les indices d'abondance pour la plie grise de 4T depuis 1993 sont parmi les plus élevés depuis 1971. Les données de recherche suggèrent que la ressource de plie grise était de nature plus abondante et plus répandue dans le nord du Golfe. Ceci nous laisse croire que l'indice d'abondance provenant du relevé du nord du Golfe serait plus représentatif de l'état de la ressource dans l'ensemble de 4RST.

Introduction

Witch flounder in the northern Gulf of St. Lawrence (NAFO divisions 4RS, Figure 1) has been under total allowable catch (TAC) regulation since 1977. This management unit recognized the fishery that developed in 4R in the 1950s and that later extended offshore into the Esquiman Channel (Bowering 1979). The adequacy of this management unit is a long-standing issue. Bowering (1978) first questioned whether witch fished in 4T off the coast of Cape Breton should be considered as part of the stocks managed within 4RS. The issue was examined by Morin and Hurlbut (1994) who showed that witch stocks straddle the 4RS-4T boundary, especially in winter. The Fisheries Resource Conservation Council (FRCC) recommended that a management unit including all of the Gulf of St. Lawrence (4RST) would be more appropriate (FRCC 1994) and DFO implemented this in 1995.

Description of the Fishery

Landings of witch flounder in 4RST declined to 320 tons in 1995, their lowest level since 1960 (Table 1, Figure 2). All divisions reported reduced landings of witch (Figure 3), with 263 t landed in 4T, 54 t landed in 4R and 2 t landed in 4S. Most witch landings have originated from the 4T fishery since 1984 (Figure 3). All gear sectors reported witch landings that were well below their allocated quotas for 1995 (Table 2).

The witch fishery developed in the 1950s and 1960s with seiners concentrated in summer in St. George's Bay (4R). Witch were caught in the winter as a bycatch of the cod and redfish fisheries. Seines have usually contributed most of the annual landings in 4RST since 1960, with the exception of the period of 1976-1980, when otter trawls dominated the landings in 4RS. Seines were the dominant gear landing witch in 4RST in 1995 (Table 1). Since the Gulf cod fishery was suspended in 1993, the witch fishery has been restricted by closures resulting from regulations on cod bycatch in flatfish-directed fisheries. The timing of the yearly migrations of witch and cod to and from the Gulf of St. Lawrence is reportedly similar, leading to elevated cod bycatches and frequent closures.

Landings of witch flounder over the past five years have been concentrated in the 4Rd, 4Tf, 4Tg, 4Tk, 4Tn, 4To and 4Tq unit areas (Figure 4). These unit areas accounted for >87% of the annual 4RST landings since 1991. The strongest decline occurred in 1994 in 4Rd. Landings in 4Tf and 4Tg have declined since 1991, but have maintained a fairly stable level over the past three years. Landings from the western Gulf in unit areas off the Gaspé Peninsula (4Tnoq) and on the Magdalen Shallows (4Tk) declined sharply in 1993 or 1994 and have remained low.

The Gulf witch flounder fishery has become a mainly directed activity (Morin et al. 1995). Since 1991, the directed witch fishery accounted for 62-80% of the annual landed catches of witch by seines. Trawls directing for witch flounder landed 66 and 76% of the total 4RST witch landings in 1994 and 1995, respectively.

Nominal fishing effort has been monitored to detect trends in fishing pressure. Fishing effort data originate from vessel logbooks and are expressed as the number of days spent fishing. Since 1991, the directed effort on witch flounder has declined throughout the Gulf (Figure 5). Directed effort by seines in 4R has dropped sharply since 1993 from 191 days to 34 days in 1995. The logbook data indicated that trawls have not exerted directed effort on witch in 4R since 1993. In 4T, seines directing for witch recorded 200 days of fishing in 1993, a significant decline from previous years. In 1994, seiners increased their effort to 264 days directing for witch, but declined to 179 days in 1995. Otter trawls directing for witch in 4RST reduced their effort to only five days in 1993, but increased it to 23 days in 1995 (Figure 5).

Figure 5 maps the distribution of witch catches throughout the Gulf in 10-minute blocks. Positional data from western Newfoundland were available from the former Gulf Region database until 1993. When responsibility for catch and effort data for this sector was transferred to the Newfoundland Region, positional data were no longer provided in the electronic database, although the information continues to be recorded in vessel logbooks. Although catches from western Newfoundland are not shown for 1994 and 1995, Figure 5 illustrates the pronounced decline in catches in western 4S and throughout western 4T. Figure 5 includes data on Scotian Shelf catches in 1995. For that year, catches of witch appear to be continuous across the 4T-4Vn boundary.

Most of the recent consultations with fishing industry have not been successful in sounding the views of active participants in the witch fishery. Frequently the meetings were not well attended or failed to elicit a clear response from the participants. At meetings in Caraquet (N.B.), Charlottetown (PEI) and Port Hawkesbury (N.S.), no comment was made by attending fishers on the status of the witch resource. At meetings in Grande Rivière (Gaspé) and the Magdalen Islands, fishers agreed that the resource is not presently abundant. At a meeting held in Port Hawkesbury in July, a fisher expressed his concerns with the new 4RST management unit for witch flounder, since two or three recognizable stocks of witch may be found in the Gulf. Witch from 4RST also differ in appearance from those of 4Vn. He recommended tagging studies to resolve differences in stock structure of witch in 4RST. Mr. James Baird (DFO Resource Allocation, St. John's, Newfoundland) reported that during consultations in western Newfoundland fishers reported strong declines in the abundance of witch flounder throughout 4R, particularly in the St. George's Bay area (4Rd).

Research Data

Northern Gulf Survey

The northern Gulf of St. Lawrence, including 4R, 4S and the Laurentian Channel of 4T, has been surveyed every August since 1984. Strata were defined by 50-fathom depth intervals, with the shallowest stratum at <50 fathoms and the deepest stratum at >200 fathoms (Figure 7, Pitt et al. 1981). The survey has been conducted with a stratified random sampling design, allocating the number of trawling sets proportionally to the stratum area. Sampling procedures were detailed by Schwab and Hurtubise (1987) and are similar to procedures in surveys of the southern Gulf described by Koeller (1981) and Hurlbut and Clay (1990).

Although the survey sampling design and sampling procedures have remained relatively constant since 1984, important changes were made in 1990 when the vessel and sampling gear were replaced. From 1984 to 1989, the *Lady Hammond* was used with a Western IIA trawl. Since 1990, the *Alfred Needler* and a U.R.I. shrimp trawl have been in use. These changes were made when it became necessary to combine groundfish and shrimp trawl surveys. A comparative fishing experiment conducted in 1990 with the two vessels resulted in significant differences in the catch rates for Atlantic cod (Fréchet et al. 1991). A similar comparison of witch catch rates between the *Lady Hammond* and *Alfred Needler* appears not to have been made; however, we have assumed that the combined effect of changing vessels and gear is sufficient basis to consider the two surveys as separate.

Stratum coverage in the northern Gulf surveys has frequently been limited by the lack of trawlable bottom in some sectors. Strata 825, 826 and 834 were permanently dropped from the survey for this reason. In 1991, strata 835-841 were added to the survey, extending coverage along the coast of western Newfoundland and into the Strait of Belle Isle. Table 3 indicates the mean catches of witch in all strata since 1984 and illustrates the changes that have occurred in stratum coverage. Witch were captured only once in strata 836-841; however, witch have been found in all of the remaining 47 strata (401-835). Witch have tended to concentrate in strata 403 and 409-414 located off the Gaspé Peninsula at depths greater than 100 fathoms.

To obtain an index of witch abundance comparable over years in which the same vessel and gear were used, multiplicative analyses were conducted using year and stratum effects to estimate abundance in strata that were not fished in particular years. The data were the number of witch caught per standard tow of 1.8 nautical miles for the *Lady Hammond* and 0.8 nautical mile for the *Alfred Needler*. We used the same procedure as was used to estimate abundance in strata that were missed in the 3LNO survey (Brodie and Bowering 1989). Separate analyses were conducted on data from the 1984-1989 and the 1990-1995 periods, with catches weighted by the stratum area divided by the number of sets. All catches were transformed by $\log_e(\text{catch} + 0.5)$ to allow logarithms of zero catches to be included in the model. Estimates were later back-transformed using the bias correction of Bradu and Mundlak (1970) and 0.5 subtracted. The stratified mean catch was calculated, encorporating the estimated values for missed strata. Since our procedure did not include variance estimates for the missed strata, the variance of the stratified mean catch by this method is negatively biased.

To estimate witch catches in missed strata, we first conducted multiplicative analyses with models that included all years and strata in each time period (1984-1989; 1990-1995), including a year*stratum effect. The interactive term was significant in both models ($P<0.05$), indicating that the abundance of witch changed differently over time in areas covered by the surveys. We therefore estimated the abundance of witch in unsampled strata by including neighboring strata. Strata 409-414 and 831, missed variably between 1984 and 1987, were estimated from catches in neighboring strata 406-414, 805, 817, 831 and 832 over the years 1984-1989 (Table 4). Stratum 409, missed in 1994, was estimated from strata 409-414 and stratum 805 over the years 1990-1995 (Table 5). Stratum 814 in 1995 was estimated from strata 801, 813 and 814 (Table 6) and stratum 831 in 1991 was estimated from strata 817, 818 and 831 (Table 7), over the years 1990-1995. Each of the four analyses (Tables 4-7) resulted in highly significant ($P=0.0001$) models with non-significant year*stratum interactions ($P>0.05$). Several models were attempted to estimate the abundance of witch in strata 827-829 and 833. These strata were not estimated because all models produced significant year*stratum interactions. Estimated mean number of witch per tow for the remaining missed strata, based on multiplicative analyses, are presented in Table 8.

One other problem with the coverage of the northern Gulf survey is the occurrence of strata that have not been sampled with replication. Boxed cells in Table 3 indicate the cases where only one set was made in a stratum. In order to maintain a comparable index of abundance across years, we have included these strata in calculations of the stratified mean number of witch. Including strata for which mean abundance is based on a single observation and the variance is zero causes the estimated variance of the stratified mean to be negatively biased.

The stratified mean number of witch per tow was calculated for strata 401-833 (excluding strata 825 and 826) according to three procedures. Including only sampled strata and strata with or without replicate sets, or including strata with abundance estimated from multiplicative analyses, had minor effects on the stratified mean number of witch per tow in most years (Table 9). The largest variations in the stratified means, relative to the method of estimation, were in 1985 and 1986 when the estimates based on the multiplicative models differed from the remaining estimates by over 2 witch per tow. Including strata with only one observation had a minor effect on the annual stratified mean numbers per tow and no detectable effect on the coefficients of variation, compared to estimates with a minimum of two sets per stratum, in all years except 1994 and 1995 (c.v.'s differ by $\leq$1.2%, Table 9). Coefficients of variation on stratified mean catch per tow using stratum estimates derived from multiplicative models resulted in lower coefficients of variation in most years (c.v.'s 2.7-4.8% lower than by other methods in years 1984-1986). All methods showed similar patterns of annual variation in witch abundance, with the catch rates peaking in 1986 and attaining their lowest level in 1993.

Comparison of Indices

Annual groundfish surveys of the Gulf of St. Lawrence are conducted by the Laurentian and Maritimes regions of DFO. The Laurentian Region (formerly the Québec Region) has surveyed the northern Gulf (4R, 4S and part of 4T) yearly in August since 1984 (described above) and in January from 1978-1994. The southern Gulf has been surveyed by the Maritimes Region (formerly the Gulf Region) every September since 1971. Descriptions of the northern Gulf January survey and the 4T survey were made by Morin et al. (1995).

Abundance indices indicating mean number of witch per tow are presented in Figure 8 for the three surveys. Coefficients of variation for the winter survey of the northern Gulf ranged between 11 and 43% over most years. Data were not available for 1982 and it was not possible to estimate variance for the 1984 estimate. The abundance index for the summer survey of the northern Gulf is based on estimates using the multiplicative models described above. Error bars for this index are not shown because of the bias in variance discussed in the previous section. Abundance indices from the southern Gulf survey have produced coefficients of variance ranging from 14 to 52%.

The surveys of the northern Gulf indicate that abundance was highest in 1985 or 1986. The maximum catch rate in the January survey of the northern Gulf was reached in 1995; in the following August (1996), the summer survey of the northern Gulf recorded its highest mean catch of witch (Figure 8). Both surveys of the northern Gulf showed a declining trend in abundance following the 1985-1986 surveys, with lowest catches recorded in January 1992 and August 1993. The most recent indices from the northern Gulf surveys fail to indicate any significant improvement in stock abundance (Figure 8).

The southern Gulf survey, conducted every September since 1971, indicates a variable pattern of abundance through the 1970s, followed by a period of low stock abundance in the early 1980s (Figure 8). From 1986 to 1990, the index flucturated at a higher level than the previous six years. The index dropped to a lower level in 1991 and 1992, but since 1993 witch abundance appears at the upper range of values recorded for this survey since 1971.

Although the northern and southern Gulf surveys have been conducted with different trawling gear since 1990, the range of estimated mean catches suggests that witch flounder is more abundant and more widely distributed in the northern Gulf. From 1985 to 1989, when the same vessel and gear were used in the two surveys, the mean catch of witch in the southern Gulf survey ranged between 1 and 2 per standard tow, while mean catches were 6-30 witch per tow in the northern Gulf survey. Witch flounder are found in most strata of the northern Gulf survey (Table 3), but are absent from several strata of the southern Gulf survey. The wider distribution of witch in the northern Gulf was illustrated in Gulf-wide distribution maps of the 1985-1989 survey data, presented by Morin and Hurlbut (1994). Biomass estimates of Gulf witch, uncorrected for sampling gear bias, indicated that the northern Gulf survey, covering 4R, 4S and the 4T Laurentian Channel, contributed the major portion of the total Gulf biomass of witch flounder (Morin et al. 1995). It is therefore probable that the northern Gulf survey is most indicative of trends in the 4RST witch resource.

Comparison of Size Composition

An earlier review of the 4RST witch assessment suggested a combined Gulf estimate of biomass based on the two research surveys, with a comparison of biomass estimates from the two surveys (Marine and Anadromous Division 1994). It was later suggested that comparisons of the size composition of witch be made before research survey biomass estimates are combined (Science Branch 1995). Morin et al. (1995) presented analyses of catch rates in a sector of the Gulf that is sampled by the two surveys since 1990. The analyses concluded that there was no significant difference in the mean number per tow, but the two surveys differed in the mean weights per tow. This indicated that the size composition of the catches by the two regions was different, and not readily comparable.

Correspondence analyses were run on three years of survey data to evaluate differences in the length frequencies of samples from the two survey regions. The 1988 surveys were chosen because the same vessel and trawl were used throughout the Gulf. The remaining analyses were conducted on 1993 and 1994 data, when the vessel was the same, but the northern Gulf survey was conducted with a URI shrimp trawl and the southern Gulf survey used a Western IIA. The data were individual sampled catches, separated by sex when possible (1994 northern Gulf samples were not sexed), and aggregated into 2-cm intervals. The analyses of 1993 and 1994 data included minimum sample sizes of 30 fish. There were fewer samples of large catches in the 1988 data, so a minimum sample size of 25 witch was used.

Correspondence analysis resulted in a clear separation of the two surveys within the first two dimensions of Euclidean space. The amount of inertia explained by the first two axes (comparable to the variation accounted for) was 58% for the 1988 samples, 76% for the 1993 samples, and 78% for the 1994 samples. The analysis of data from 1988, when the same vessel and trawl were used, indicated regional separation in size composition (Figure 9), possibly reflecting differences due to stock characteristics or the occurrence of more small witch in the deep waters of the northern Gulf. Samples from the northern Gulf survey were associated with smaller witch, while the southern Gulf samples were associated with larger fish. Analyses of the 1993 and 1994 data indicated a larger degree of regional separation in size composition, compared to the 1988 data. This pattern is most likely accounted for by the recent use of the URI shrimp trawl, a gear that may retain more small witch than the Western IIA trawl, thus augmenting the regional difference in length frequencies.

Assessment Results

Landings of witch flounder in 4RST are at their lowest level recorded since 1960. The decline in landings has occurred in all gear sectors and in all of the main unit areas of 4RST. Research survey indices of the northern Gulf of St. Lawrence, where most of the resource is found, indicate that the stock is at its lowest level since the late 1980s. The 4T survey index indicates that stock abundance was low in the early 1980s. Since 1993, abundance indices for 4T are in the upper range of values that have been observed since the survey began in 1971. Analyses of the length composition of witch flounder in the two surveys indicate that more small witch flounder are found in the northern Gulf and that sampling gear used since 1990 in the northern Gulf is more selective for small witch. The decline in the abundance of witch flounder in the northern Gulf, indicated by research surveys and commercial fishers, may also be a sign of weak recruitment.

Ecological Considerations

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 these surveys was to determine the distribution and relative abundance of groundfish species and herring in the Cabot Strait area during the winter. In addition, the 1996 survey was part of a project to identify the stock origin of cod concentrations in the area.

The 1994 and 1995 surveys were conducted with the research vessel *Alfred Needler*. Fishing sets were done with an Atlantic Western IIA trawl and the tow duration was 30 minutes.

In 1996, the survey design followed a grid pattern with increased sampling intensity between 200 and 400 m and covered waters deeper than 50 m. The survey extended from about 45° 15' to 48° North and from about 58° to 61° West. The survey proceeded in a north-south direction to minimize problems with ice. At each location, a standard 15-minute tow (calculated from touchdown) was conducted using a Campelen 1800 trawl with a 19 mm liner in the lengthening piece and codend. Depth profiles of conductivity, temperature and oxygen concentrations were also done. A total of 139 sets were attempted, of which 138 were successful.

A contoured map of the witch catches in kg per tow (Figure 10) shows that catches were made throughout the deepest waters of the Laurentian Channel. Concentrations were found off the western coast of Newfoundland (Codroy-Port-aux-Basques area) and off Misaine Bank as in 1994 (Chouinard 1994) and in 1995 (Morin et al. 1995).

The length-frequency distributions for witch in winter surveys of 1994, 1995 and 1996 were compared. It should be noted that the 1994 survey covered mostly the southern edge of the Laurentian Channel (4T and 4Vn). The coverage of the 1995 and 1996 surveys was relatively similar. The 1996 frequencies show a mode between 10 and 20 cm which may correspond to a mode seen at 5 cm in 1995 (Figure 11). Both the 1994 and 1995 surveys showed a paucity of fish in the 10 to 20-cm range. Most witch flounder caught in the survey were between 20 and 40 cm. Although the Campelen trawl is thought to have a higher catchability for smaller fish, few witch were found below 10 cm in 1996.

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Table 1. Yearly landings of witch flounder in NAFO division 4RST 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	1912	0	0	1309	0	72	45	3338
1961	1428	0	0	1907	7	19	135	3496
1962	1342	0	0	2012	0	28	5	3387
1963	1561	0	0	2612	37	25	15	4250
1964	1377	0	0	1657	0	86	230	3350
1965	1137	0	0	2389	1	67	14	3608
1966	0	1620	39	1845	93	5	110	3712
1967	1	964	33	1647	36	23	10	2714
1968	0	1227	102	1995	46	13	7	3390
1969	3	1286	294	3179	0	1	0	4763
1970	12	1203	504	3078	8	0	0	4805
1971	17	1108	183	2352	11	137	13	3821
1972	30	968	329	636	2	7	29	2001
1973	68	613	56	1330	39	12	106	2224
1974	0	707	946	1569	15	0	10	3247
1975	82	771	371	1449	25	4	20	2722
1976	111	1606	4303	730	9	0	116	6875
1977	99	962	1248	715	4	0	8	3036
1978	3	616	2767	938	69	3	114	4510
1979	62	1065	1970	1309	120	14	21	4561
1980	106	548	1618	1100	98	30	27	3527
1981	108	446	267	1032	24	33	2	1912
1982	93	105	122	934	24	4	0	1282
1983	137	116	52	829	27	10	6	1177
1984	75	110	314	536	51	19	2	1107
1985	27	89	161	1127	28	7	221	1660
1986	49	63	79	1216	6	2	408	1823
1987	58	157	212	1671	7	0	504	2609
1988	56	177	177	1835	34	1	250	2530
1989	45	199	358	1698	47	0	0	2347
1990	12	120	236	873	16	8	7	1272
1991	0	5	180	752	37	2	17	993
1992	11	3	129	825	16	2	3	989
1993	0	0	103	691	11	0	96	901
1994	0	0	31	384	4	0	28	448
1995	0	2	18	292	4	0	4	320
MEAN	278	468	478	1401	27	18	72	2742

Table 2. Resource allocation scheme for witch flounder in 4RST (M.G.=mobile gear; F.G.=fixed gear). Total landings (tons) are preliminary data taken from year-end quota reports.

GEAR	FINAL ALLOCATION	LANDINGS
M.G. <65 4R, 3Pn seiners	416	57
M.G. <65 based in 4ST	437	246
M.G. <65 based in Scotia-Fundy	27	8
M.G. 65-100	70	17
BY-CATCH OTHERS	50	0

Table 3. Mean number of witch flounder in strata sampled in northern Gulf surveys. The *Lady Hammond* was used from 1984-1989, followed by the *Alfred Needler*. Empty cells indicate strata that were not sampled; boxed cells indicate strata that were sampled once.

	Year											
Stratum	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
401	0.67	2.20	0.00	0.00	5.33	2.33	3.33	0.50	0.50	0.00	1.00	0.67
402	3.00	8.60	3.00	7.00	5.33	5.33	17.67	11.00	0.80	0.00	0.33	1.00
403	0.00	51.80	56.75	3.50	39.67	6.00	2.67	3.00	0.67	2.00	3.67	6.00
404	2.67	3.20	4.00	8.00	2.67	1.67	0.33	0.00	0.33	0.33	0.67	1.00
405	2.50	2.20	1.67	6.00	3.33	1.00	0.50	0.33	0.00	0.00	0.00	0.33
406	2.00	5.20	4.33	2.75	4.00	0.80	2.00	0.67	0.33	0.00	1.33	0.00
407	3.25	2.80	4.40	6.00	11.00	8.00	2.40	1.00	0.67	0.00	0.00	1.33
408	2.25	3.40	11.40	4.80	3.80	2.00	1.50	1.80	0.60	0.33	0.00	3.67
409				42.50	29.00	13.33	19.33	22.33	14.00	1.33		22.33
410			19.50		10.00	6.33	1.33	16.00	0.67	0.33	6.25	4.00
411				41.50	15.67	0.00	16.00	22.33	35.00	5.33	15.75	10.14
412				64.50	18.33	0.00	18.67	36.33	41.33	23.67	72.25	5.00
413				48.00	21.67	0.00	19.00	12.75	34.33	1.33		5.67
414				4.00	22.33	0.00	15.33	13.00	8.67	1.00	87.00	3.00
801	28.00	5.50	12.00	2.00	5.67	4.67	7.33	7.00	1.33	0.00	2.33	4.67
802	7.75	6.00	13.33	8.00	14.33	6.67	6.67	2.00	0.00	0.00	0.00	1.00
803	8.25	4.00	11.40	5.17	7.31	9.22	1.71	6.33	0.00	0.00	0.67	4.33
804	6.00	3.20	9.60	6.33	6.25	2.75	0.20	1.00	0.67	0.33	0.25	0.67
805	9.25	27.40	14.86	8.70	7.00	1.75	3.15	2.86	4.50	1.33	2.71	2.75
806	9.00	1.00	10.00	5.60	6.50	0.33	1.25	0.75	0.33	0.33	1.00	0.67
807	1.00	3.20	10.00	3.00	4.25	1.25	1.33	1.17	0.09	0.20	0.00	0.20
808	3.50	1.50	3.75	4.00	5.75	3.00	2.00	0.43	0.17	1.00	1.00	3.50
809	2.67	6.40	2.00	7.00	4.00	2.00	3.33	1.67	0.43	0.00	0.00	0.67
810	3.00	13.25	5.00	11.00	6.67	3.00	1.67	0.50	0.80	0.75	0.50	3.00
811	1.50	9.00	8.50	5.00	1.67	1.67	3.33	1.00	2.00	0.00	0.80	2.00
812	1.20	1.80	3.67	3.90	3.00	1.83	4.00	0.44	1.75	0.45	0.25	0.67
813	4.00	6.50	21.88	7.38	3.20	3.20	0.50	3.33	0.00	0.78	0.00	3.00
814	1.67	1.00	0.50	5.00	6.33	2.33	1.00	2.25	0.75	0.00	1.33	
815	1.67	3.60	3.78	3.44	2.13	1.67	0.56	0.40	0.36	0.50	0.20	2.00
816	11.75	5.60	15.67	5.80	7.44	4.29	8.67	5.18	1.56	0.56	0.20	1.17
817	6.00	14.40	17.25	16.83	9.75	6.33	3.50	16.28	12.55	0.57	1.44	0.80
818	14.50	2.80	25.00	19.50	5.50	6.40	2.00	1.43	0.80	0.25	1.00	1.00
819	1.00	2.80	5.00	4.75	4.33	0.67	0.33	1.29	1.00	0.40	0.25	1.20
820	0.00	2.40	5.00	10.00	19.00	0.33	1.00	2.00	6.00	0.00	0.00	2.00
821	1.00	0.80	7.00	1.00	1.33	4.00	1.00	0.67	0.33	0.00	0.00	0.67
822	4.50	4.80	3.33	4.83	5.67	3.40	2.83	0.75	0.33	1.00	0.00	2.33
823	15.50	7.40	10.00	54.00	30.50	26.00	0.00	1.00	0.33	0.00	0.00	0.00
824	7.00	2.00	4.00	46.00	5.67	2.33	1.33	0.00	0.00	0.00	0.67	0.67
825	0.00	50.50	4.75									
827		8.50	1.75	3.40	4.50			0.00	0.00	0.00	0.33	1.00
828		2.00	1.00	0.50	8.25	11.00	0.00	0.00	0.00	0.00	0.00	0.00
829		2.17	12.00	0.00	6.20	4.33	2.33	3.50	0.67	0.00	0.33	0.67
830	1.50	0.75	5.14	0.25	3.50	1.00	3.33	0.00	1.33	0.00	0.00	0.00
831		2.00	0.50	10.00	14.67	8.00	1.00		1.50	0.00	0.50	0.33
832		40.40	506.25	30.43	39.71	45.83	19.00	12.91	0.00	3.00	3.86	0.44
833				0.50	1.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00
835								0.17	0.86	0.00	0.33	0.00
836								0.00	0.00	0.00	0.00	0.00
837								0.00	0.00	0.00	0.00	0.00
838								0.00	0.00	0.00	0.00	0.00
839								0.50	0.00	0.00	0.00	0.00
840								0.00	0.00		0.00	
841									0.00	0.00	0.00	0.00

Table 4. Analysis of variance from multiplicative model estimating mean witch abundance in strata 409-414, 831 and 832 (see Table 3 for missed years) that were not covered during surveys of the *Lady Hammond*. The values shown for the class variables year and stratum (STRAT) indicate the years and strata that were included in the analyses. The upper panel shows analysis used to estimate abundance; lower panel shows results of analysis with year·stratum interaction term.

Class	Levels	Values										
YEAR	6	84	85	86	87	88	89					
STRAT	11	406	409	410	411	412	413	414	805	817	831	832

Number of observations in data set = 186

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	1520375.6902	101358.3793	4.09	0.0001
Error	170	4216612.6677	24803.6039		
Corrected Total	185	5736988.3579			

R-Square	C.V.	Root MSE	LNCAT Mean
0.2650	7771.879	157.4916	2.0264

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	325951.6902	65190.3380	2.63	0.0256
STRAT	10	1194423.1000	119442.4000	4.82	0.0001
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
YEAR	5	244395.5940	48879.1188	1.97	0.0854
STRAT	10	1194424.0000	119442.4000	4.82	0.0001

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	41	2138120.3230	52149.2762	2.09	0.0008
Error	144	3598868.0349	24992.1391		
Corrected Total	185	5736988.3579			

R-Square	C.V.	Root MSE	LNCAT Mean
0.3727	7801.360	158.0890	2.0264

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	325951.6902	65190.3380	2.61	0.0273
STRAT	10	1194424.0000	119442.4000	4.78	0.0001
YEAR*STRAT	26	617744.6328	23759.4090	0.95	0.5383
Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
YEAR	5	129451.8747	25890.3749	1.04	0.3989
STRAT	10	1127859.7074	112785.9707	4.51	0.0001
YEAR*STRAT	26	617744.6328	23759.4090	0.95	0.5383

Table 5. Analysis of variance from multiplicative model estimating mean witch abundance in strata 409 and 413 that were not covered by the *Alfred Needler* in 1994 The values shown for the class variables year and stratum (STRAT) indicate the years and strata that were included in the analyses. The upper panel shows analysis used to estimate abundance; lower panel shows results of analysis with year·stratum interaction term.

Class	Levels	Values
YEAR	6	90 91 92 93 94 95
STRAT	7	409 410 411 412 413 414 805

Number of observations in data set = 150

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	3502572.5642	318415.6877	11.47	0.0001
Error	138	3830026.7174	27753.8168		
Corrected total	149	7332599.2817			

R-Square	C.V.	Root MSE	LNCAT Mean
0.4777	9999.99	166.5948	1.4285

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	724844.8687	144968.9737	5.22	0.0002
STRAT	6	2777727.6956	462954.6159	16.68	0.0001
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	773711.9254	154742.3851	5.58	0.0001
STRAT	6	2777727.6956	462954.6159	16.68	0.0001

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	39	4508116.6556	115592.7348	4.50	0.0001
Error	110	2824482.6261	25677.1148		
Corrected total	149	7332599.2817			

R-Square	C.V.	Root MSE	LNCAT Mean
0.6148	9999.99	160.2408	1.4285

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	724844.8687	144968.9737	5.65	0.0001
STRAT	6	2777727.6956	462954.6159	18.03	0.0001
YEAR*STRAT	28	1005544.0913	35912.2890	1.40	0.1129
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	932120.3814	186424.0763	7.26	0.0001
STRAT	6	2832313.4638	472052.2440	18.38	0.0001
YEAR*STRAT	28	1005544.0913	35912.2890	1.40	0.1129

Table 6. Analysis of variance from multiplicative model estimating mean witch abundance in stratum 814 in the northern Gulf of St. Lawrence that was not sampled by the *Alfred Needler* in 1995. The values shown for the class variables year and stratum (STRAT) indicate the years and strata that were included in the analyses. The upper panel shows analysis used to estimate abundance; lower panel shows results of analysis with year·stratum interaction term.

Class	Levels	Values					
YEAR	6	90	91	92	93	94	95
STRAT	3	801	813	814			

Number of observations in data set = 70

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	862515.1099	123216.4443	6.56	0.0001
Error	62	1165009.2618	18790.4720		
Corrected Total	69	2027524.3717			

R-Square	C.V.	Root MSE	LNCAT Mean
0.42540	9999.99	137.0783	0.14176917

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	588871.3164	117774.2633	6.27	0.0001
STRAT	2	273643.7935	136821.8967	7.28	0.0014
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	606528.1992	121305.6398	6.46	0.0001
STRAT	2	273643.7935	136821.8967	7.28	0.0014

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	1072549.6122	67034.3508	3.72	0.0002
Error	53	954974.7595	18018.3917		
Corrected Total	69	2027524.3717			

R-Square	C.V.	Root MSE	LNCAT Mean
0.5290	9999.99	134.2326	0.14176917

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	588871.3164	117774.2633	6.54	0.0001
STRAT	2	273643.7935	136821.8967	7.59	0.0013
YEAR*STRAT	9	210034.5024	23337.1669	1.30	0.2616
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	501003.1522	100200.6304	5.56	0.0003
STRAT	2	271030.2778	135515.1389	7.52	0.0013
YEAR*STRAT	9	210034.5024	23337.1669	1.30	0.2616

Table 7. Analysis of variance from multiplicative model estimating mean witch abundance in stratum 831in the northern Gulf of St. Lawrence that was not sampled by the *Alfred Needler* in 1991. The values shown for the class variables year and stratum (STRAT) indicate the years and strata that were included in the analyses. The upper panel shows analysis used to estimate abundance; lower panel shows results of analysis with year·stratum interaction term.

Class	Levels	Values					
YEAR	6	90	91	92	93	94	95
STRAT	3	817	818	831			

Number of observations in data set = 102

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	910156.0888	130022.2984	7.31	0.0001
Error	94	1670960.6967	17776.1776		
Corrected Total	101	2581116.7855			

R-Square	C.V.	Root MSE	LNCAT Mean
0.3526	9999.99	133.3273	0.44791470

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	604872.7437	120974.5487	6.81	0.0001
STRAT	2	305283.3452	152641.6726	8.59	0.0004
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	534420.8552	106884.1710	6.01	0.0001
STRAT	2	305283.3452	152641.6726	8.59	0.0004

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	1144082.8574	71505.1786	4.23	0.0001
Error	85	1437033.9282	16906.2815		
Corrected Total	101	2581116.7855			

R-Square	C.V.	Root MSE	LNCAT Mean
0.4433	9999.99	130.0242	0.4479

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	604872.7437	120974.5487	7.16	0.0001
STRAT	2	305283.3452	152641.6726	9.03	0.0003
YEAR*STRAT	9	233926.7685	25991.8632	1.54	0.1480
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	327736.5393	65547.3079	3.88	0.0033
STRAT	2	315655.4945	157827.7473	9.34	0.0002
YEAR*STRAT	9	233926.7685	25991.8632	1.54	0.1480

Table 8. Estimated number of witch flounder in strata not sampled by the northern Gulf survey (see missing cells in Table 3), based on multiplicative analyses. "-" denotes cells that could not be estimated.

Stratum	1984	1985	1986	1987	1989	1990	1991	1994	1995
409	41.11	60.87	30.12					18.01	
410	14.36	21.47		15.61					
411	23.20	34.56	16.88						
412	37.92	56.17	27.67						
413	40.68	60.24	29.70					18.38	
414	11.58	17.32	8.36						
814									4.49
827	-				-	-			
828	-								
829	-								
831	4.41						0.27		
832	18.40								
833	-	-	-						

Table 9. Comparison of estimated stratified mean number of witch flounder per tow and coefficients of variation (c.v.'s), based on sampled strata with non-replicated sets (Sampled, n≥1) in years indicated by "†", sampled strata excluding strata with non-replicated strata (Sampled, n>1) and all strata. Estimates from all strata include stratum estimates based on multiplicative analyses, in years indicated by "*".

	Stratified means			c.v.'s		
Year	Sampled n≥1	Sampled n>1	All strata	Sampled n≥1	Sampled n>1	All strata
1984*†	5.39	5.47	7.67	9.5	9.5	5.7
1985*	8.11	8.11	10.42	17.2	17.2	12.4
1986*†	31.25	31.44	30.81	63.8	63.8	61.3
1987*	9.60	9.60	9.53	8.2	8.2	8.1
1988	8.70	8.70	8.70	9.1	9.1	9.1
1989	5.92	5.92	5.92	19.0	19.0	19.0
1990	4.10	4.10	4.10	20.5	20.5	20.5
1991*†	4.52	4.88	4.47	13.2	13.2	13.2
1992†	2.90	3.00	2.90	18.6	18.6	18.6
1993†	0.92	0.96	0.92	24.9	24.9	24.9
1994*†	2.46	2.11	2.65	19.5	22.7	17.3
1995*†	2.16	2.17	2.18	13.1	13.2	12.9

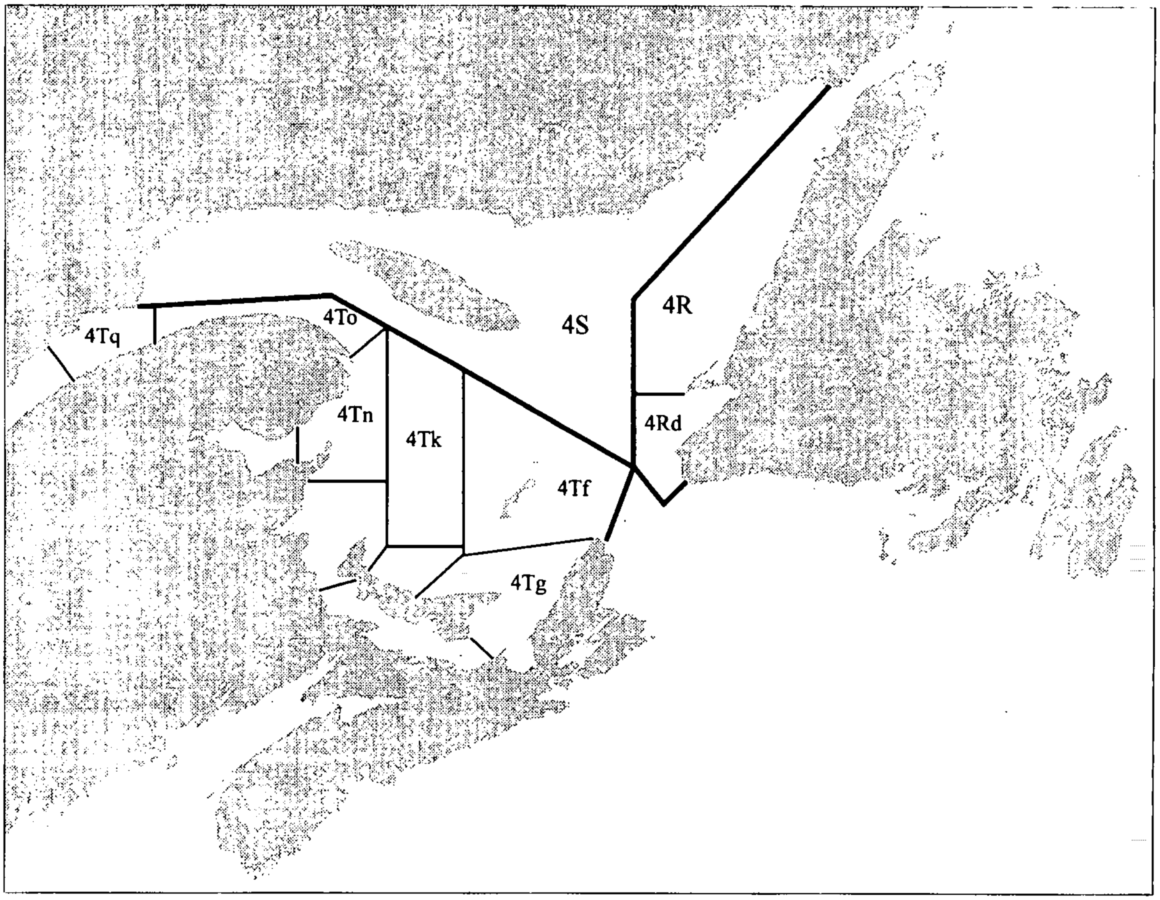

Figure 1. Map of the Gulf of St. Lawrence, showing NAFO divisions 4R, 4S and 4T bordered by heavy lines. Lower case labels indicate the main unit areas where witch flounder are caught in commercial fisheries.

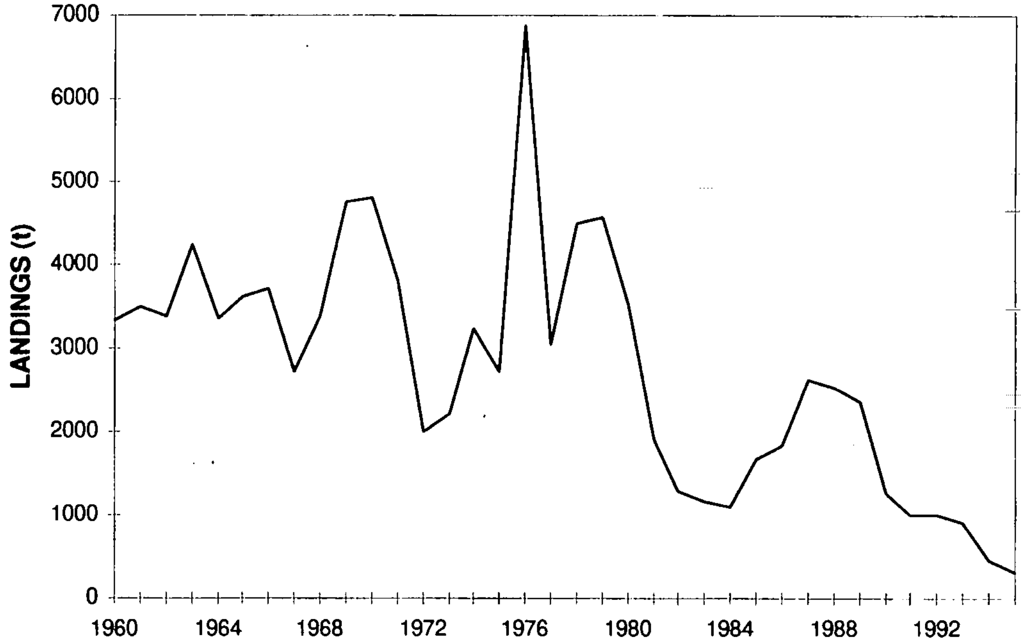

Figure 2. Nominal landings of witch flounder in NAFO division 4RST.

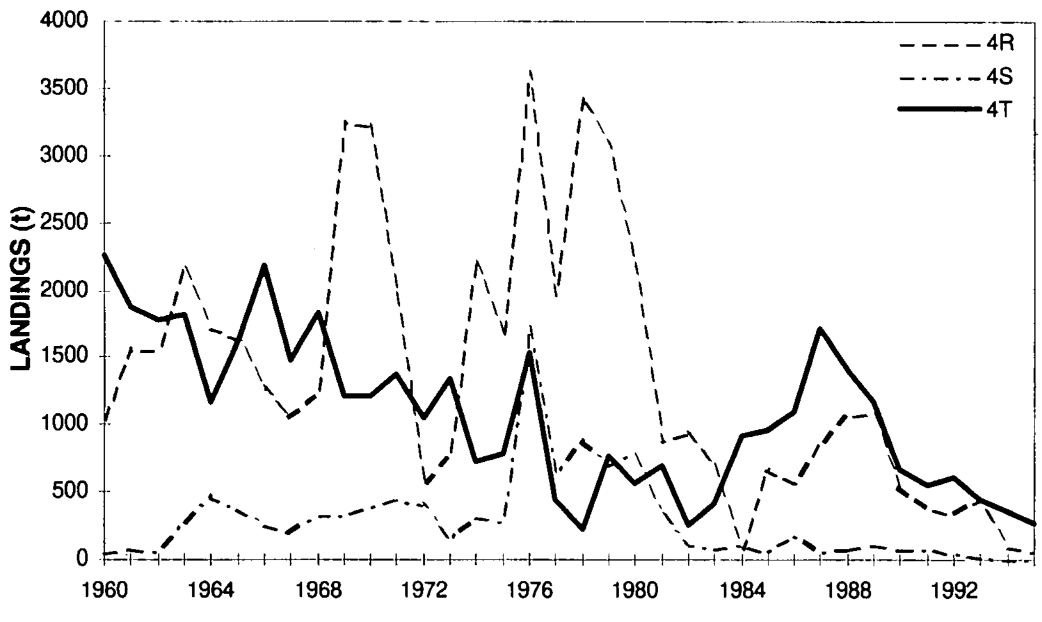

Figure 3. Nominal landings of witch flounder by NAFO division.

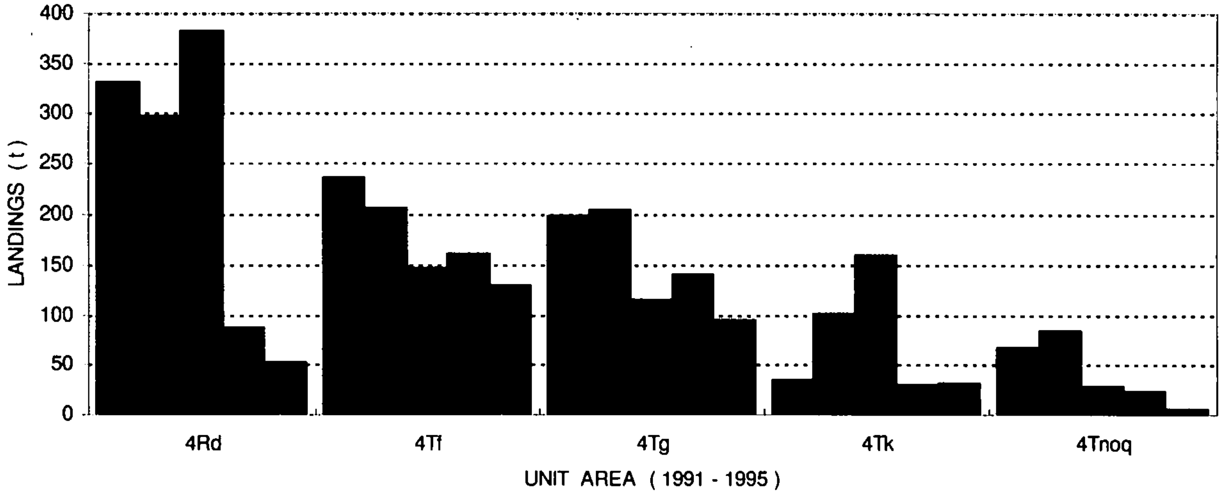

Figure 4. Annual landings of witch flounder by the main unit areas of the Gulf of St. Lawrence (4RST).

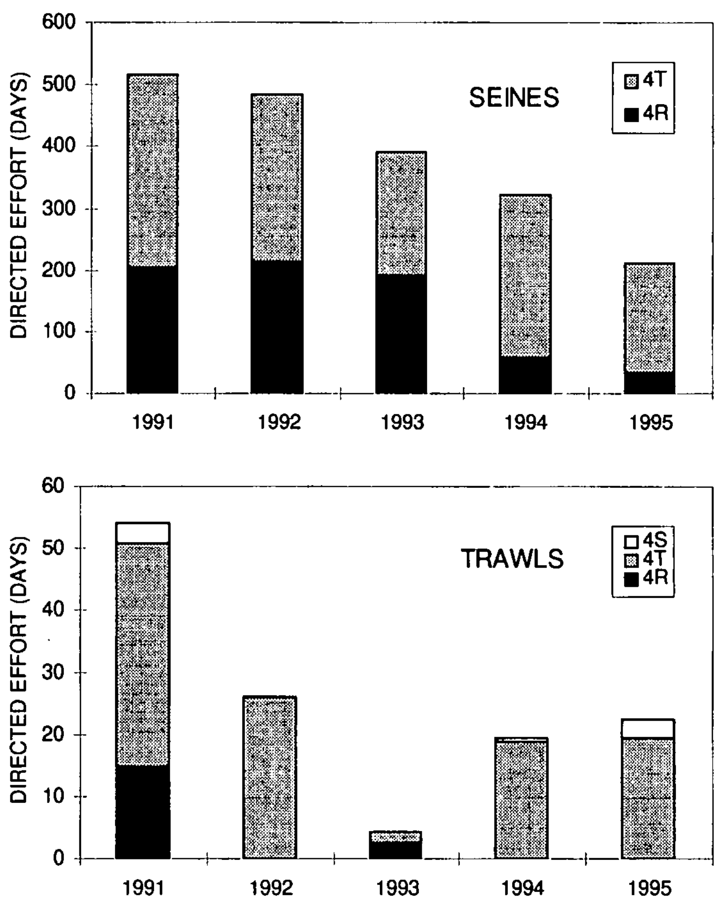

Figure 5. Nominal fishing effort of seines and trawls directing for witch flounder, by NAFO division.

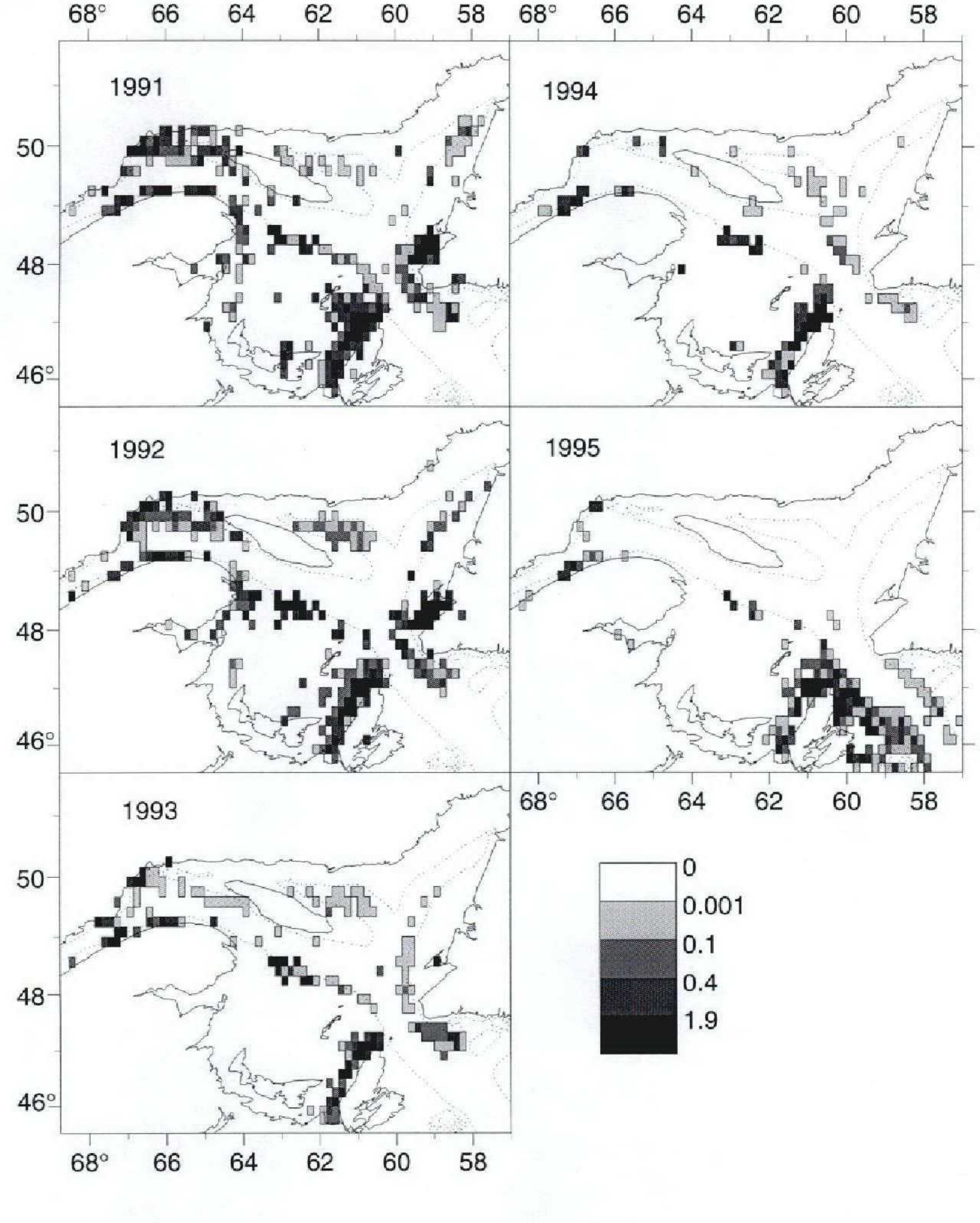

Figure 6 . Distributions of commercial witch flounder catches. Upper three contours represent averages (tons) of 40%, 60%, and 80% quantiles in 10-minute blocks. Coordinates of Newfoundland catches not available in 1994 and 1995. Distribution of 1995 catches includes data from Scotian Shelf.

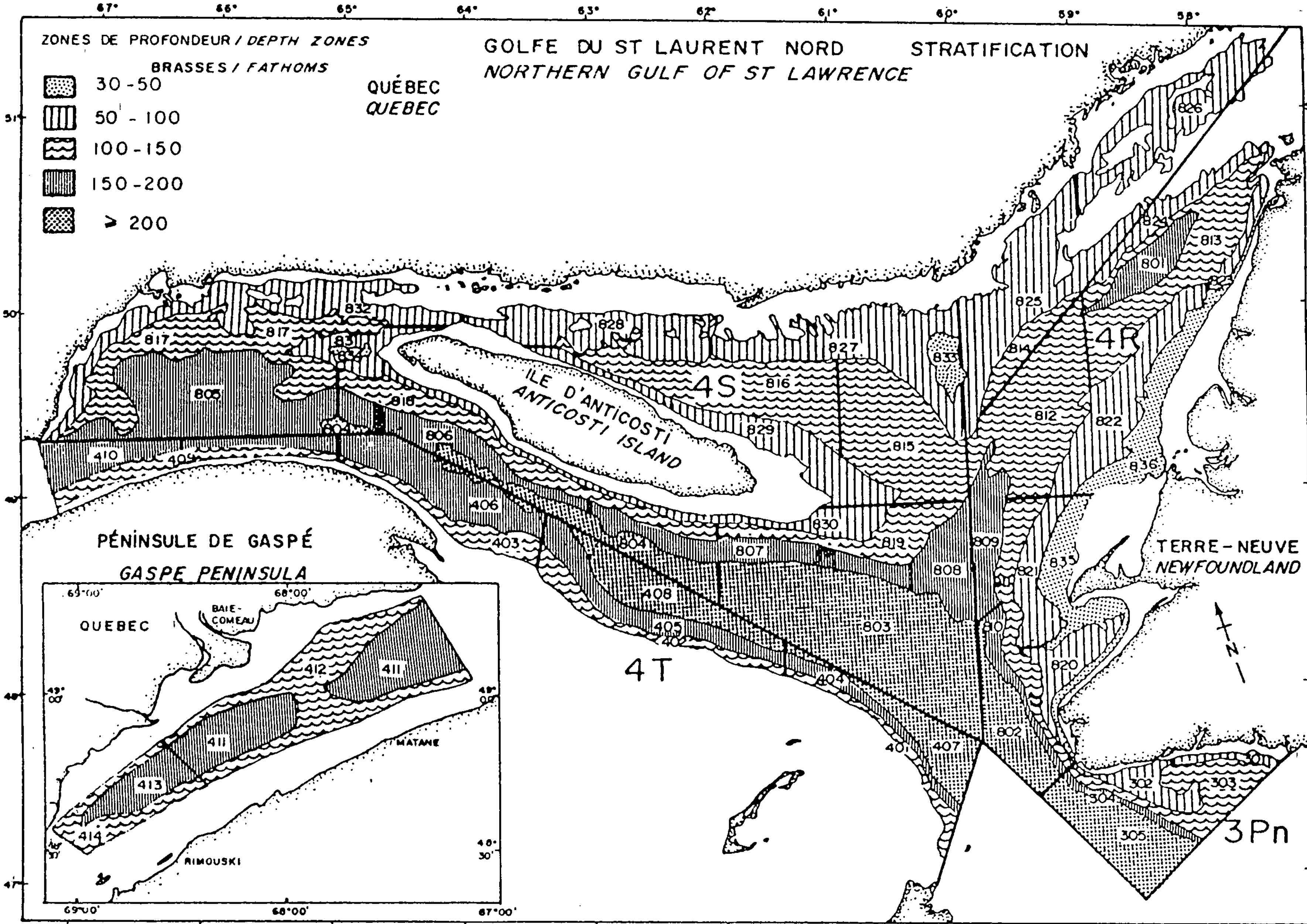

Figure 7. Stratification of northern Gulf surveys of the Laurention Region, DFO.

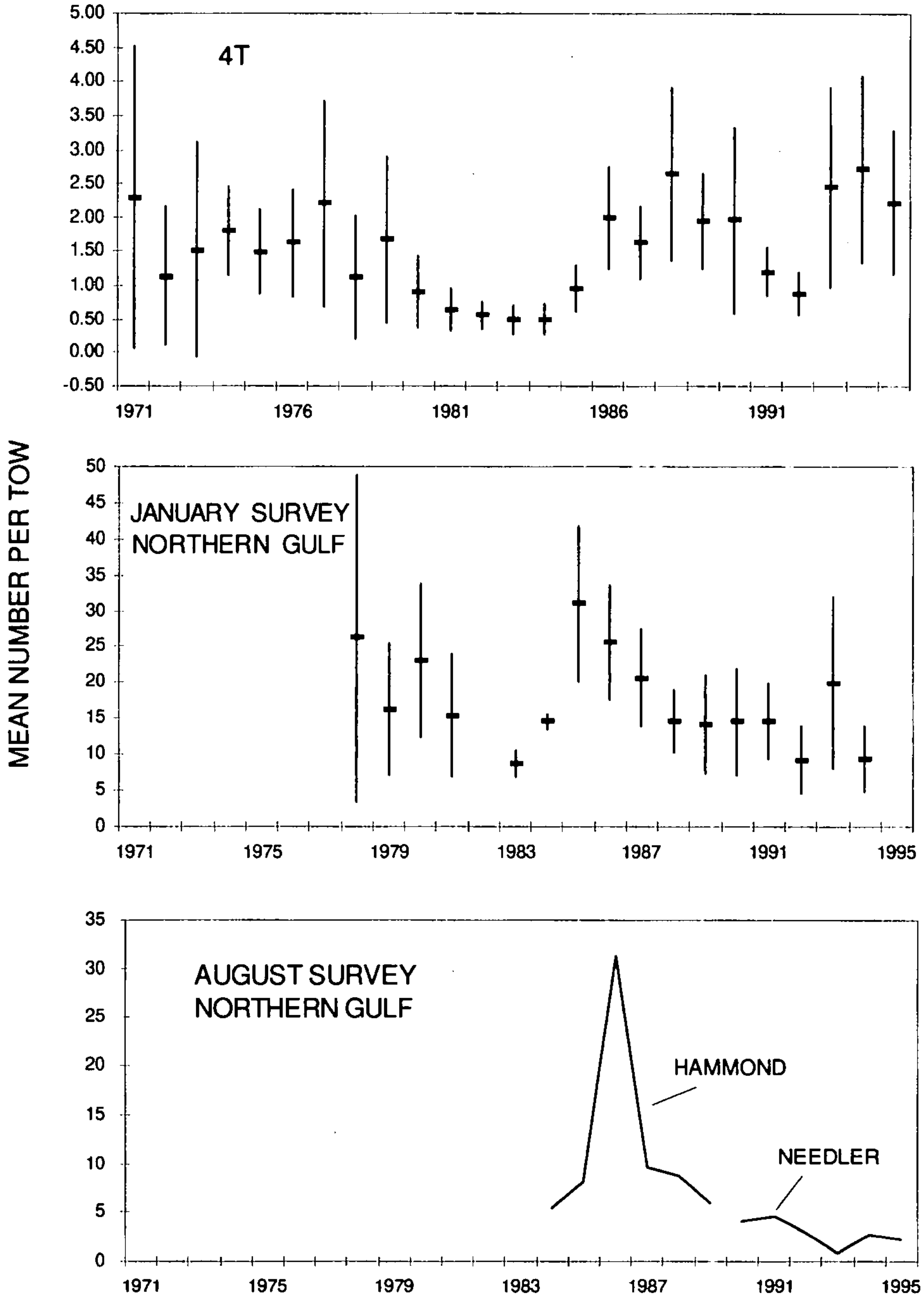

Figure 8. Abundance indices of witch flounder based on research surveys of 4RST. Error bars are ± two standard deviations.

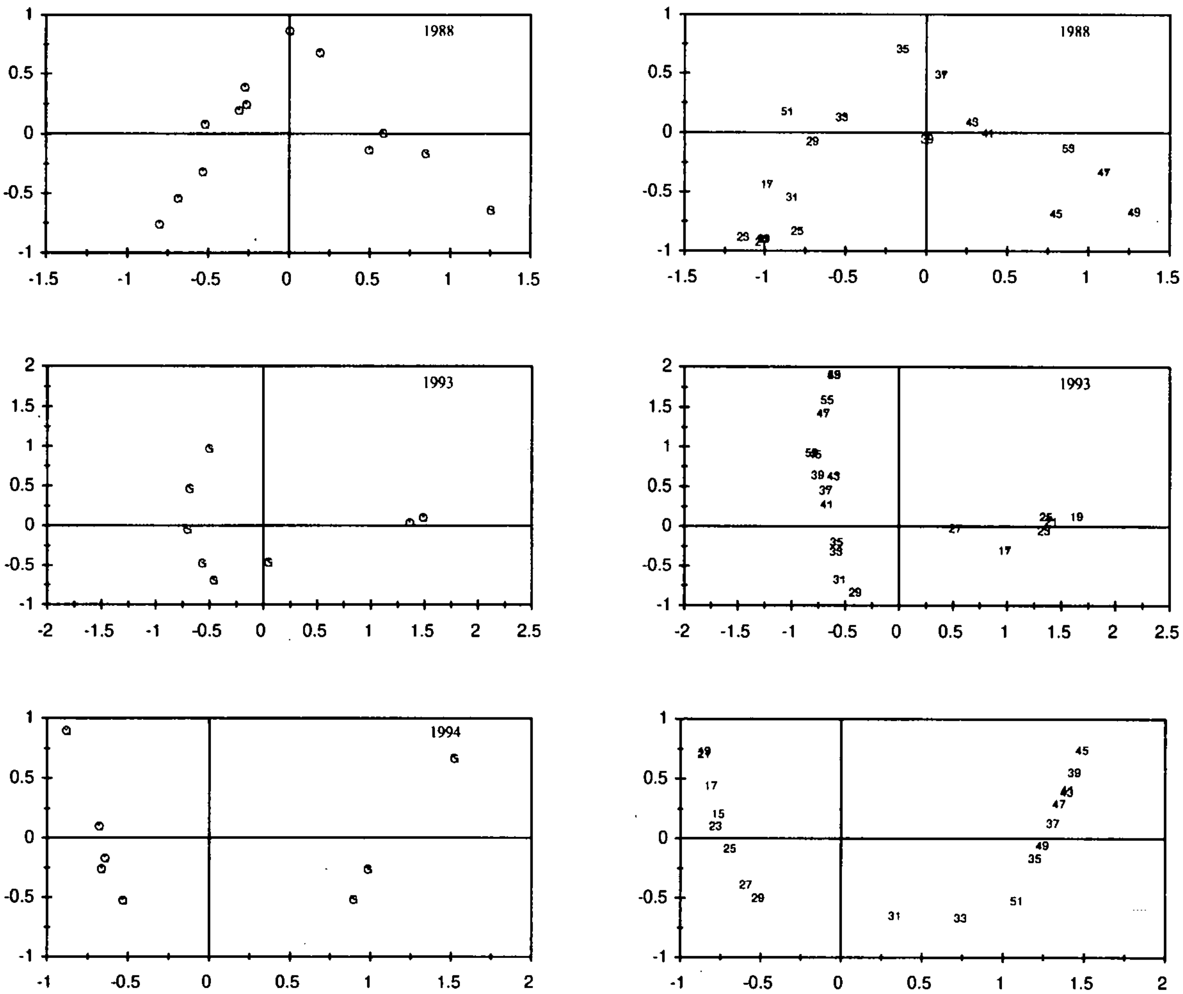

Figure 9. Correspondence analysis of length-frequency data from research surveys of DFO Maritimes Region, Gulf Fisheries Centre (G), covering the southern Gulf, and Laurention Region, Québec (Q), covering the northern Gulf. Graphs on left show the distribution of samples on the first two axes, with the corresponding distribution of modal length at right. In 1988, the two regions conducted their surveys with the same vessel and gear; since 1990, a shrimp trawl has been used in the survey of the northern Gulf whereas a groundfish trawl has been used in the southern Gulf survey.

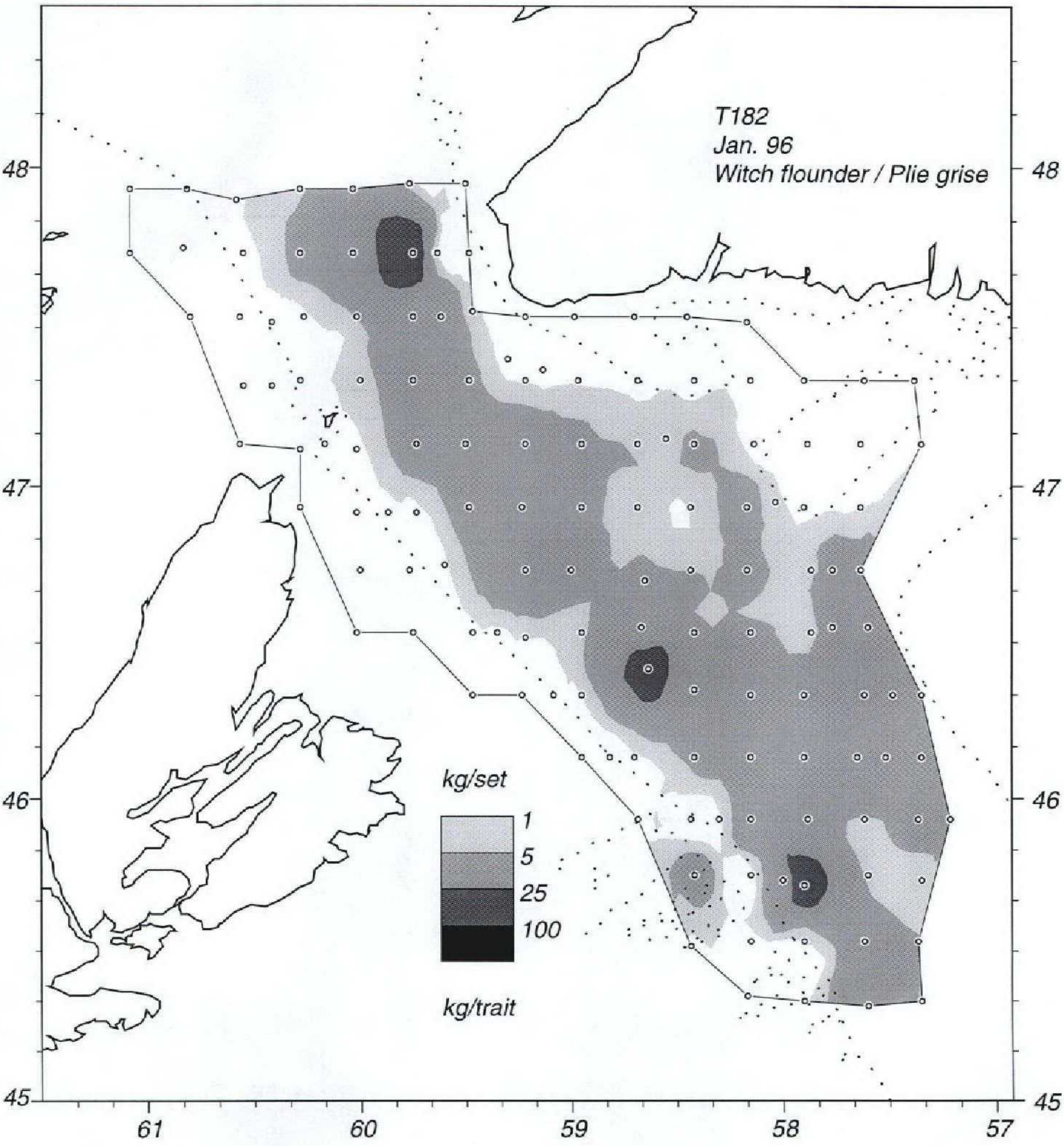

Figure 10 Witch flounder catches (kg/standard tow) during the January 1996 groundfish survey in Cabot Strait. Open circles are set locations and dotted line is 200 m contour.

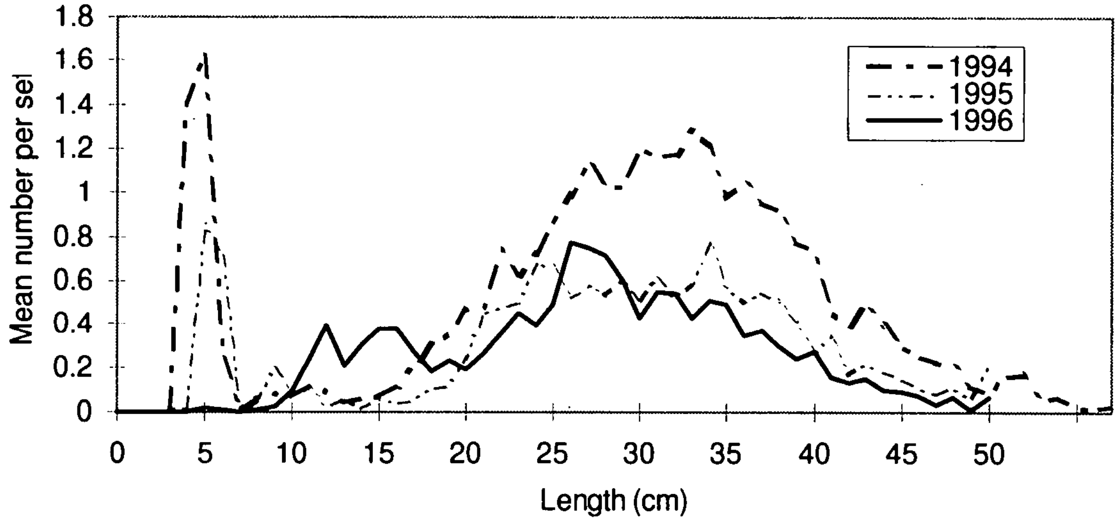

Figure 11. Length frequencies of witch flounder in the January groundfish surveys in Cabot Strait.