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Status of witch flounder in NAFO Divisions 4RST, January 1998

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Abstract.
Provisional landings of witch flounder in the Gulf of St. Lawrence (NAFO divisions 4RST) were 498 t in 1996 and 528 t in 1997, slightly above the low 1995 value but well below the longterm (1960-1990) average of 3066 t. Landings were almost entirely by mobile gear, mostly (86-96%) seines. Landings were mostly from areas 4Tf and 4Tg (75%) and 4Rd (15%). Witch-directed effort by seines has remained steady in 4T since 1991 but declined sharply in 1994 in 4R where it has remained low to the present. The size composition of landings has remained fairly stable in recent years, with peak catches in the 35-40 cm range. The lengths of fish landed have increased slightly since 1988 but are well below the lengths landed in the late 1970s and early 1980s. A composite abundance index for the entire Gulf of St. Lawrence was constructed by combining data from the September surveys of the southern Gulf and the August surveys of the northern Gulf, adjusting for variations in fishing efficiency between day and night and between vessels and gears. The index was restricted to lengths of 24 cm and greater due to changes in the size selectivity of gears. The index suggested a gradual decline in abundance since the late 1980s. Declines in abundance were progressively greater for larger sizes. This was reflected in large declines in trawlable biomass. Biomass in 1994-1997 was estimated to be 30% of that in 1987-1990 at lengths of 30 cm and greater, and 21% of the earlier level at lengths of 40 cm and greater. Biomass declines did not appear to be spatially uniform. In the eastern 4T area, biomass in 1994-1997 appeared to be similar to that in 1987-1990. The ratio of catch at length divided by the RV index of population abundance at length (relative F) did not indicate any time trends in fishing mortality. Abundance of small fish (length < 15cm) appears to have been relatively high in 1990 and 1991, low from 1992 to 1996 and high in 1997.

Résumé

Les débarquements (valeurs provisoires) de plie grise du golfe du Saint-Laurent (divisions 4RST de l'OPANO) ont atteint 498 t en 1996 et 528 t en 1997, valeurs légèrement supérieures à la faible valeur de 1995, mais bien en deçà de la moyenne à long terme (1960-1990), de 3 066 t. Les captures ont presque toutes été faites à l'engin mobile, surtout (86-96 %) à la senne. Les débarquements provenaient en grande partie des zones 4Tf et 4Tg (75 %) et 4Rd (15 %). L'effort de pêche dirigé des senneurs de plie grise est demeuré constant en 4T depuis 1991, mais a diminué de façon abrupte en 4R, en 1994, où il est demeuré faible depuis lors. La composition par taille des débarquements est demeurée relativement stable au cours des dernières années et présente des pics pour la gamme des 35-40 cm. La longueur des poissons débarqués a augmenté légèrement depuis 1988 mais demeure bien en deçà des longueurs notées à la fin des années 1970 et au début des années 1980. Un indice composé de l'abondance pour l'ensemble du golfe du Saint-Laurent a été établi en regroupant les données des relevés de septembre du sud du Golfe et des relevés d'août du nord du Golfe et en corrigeant pour les variations de l'efficacité de pêche entre le jour et la nuit, les bateaux et les engins. L'indice a été limité aux longueurs de 24 cm et plus étant donné les variations de la sélectivité selon la taille des engins. Cet indice porte à croire à un déclin graduel de l'abondance depuis la fin des années 1980. Les déclins d'abondance ont progressivement augmenté avec le temps pour les poissons de plus grande taille. Cela s'est traduit par d'importantes réductions de la biomasse chalutable. La biomasse de 1994-1997 a été estimée à 30 % de celle de 1987-1990 pour les longueurs de 30 cm et plus et à 21 % de celle des 40 cm et plus. La baisse de biomasse ne semble pas être uniformément répartie dans toutes les régions. Dans la partie est de 4T, la biomasse de 1994 à 1997 est semblable à celle notée de 1987 à 1990. Le rapport des captures selon la longueur divisées par l'indice d'abondance de la population selon la longueur, déterminé par navires de recherche (F relatif), n'indique pas de tendance temporelle pour la mortalité par pêche. L'abondance des poissons de petite taille (moins de 15 cm) semble avoir été relativement élevée en 1990 et 1991, faible de 1992 à 1996 et élevée en 1997.

1. Introduction

Witch flounder occur in the Northwest Atlantic from off southern Labrador to Cape Hatteras. They most commonly occur in deep holes and channels and along the shelf slope on muddy bottom. In the Gulf of St. Lawrence, witch flounder form dense concentrations in deep water in winter months and become more widely dispersed throughout the Gulf in summer (Bowering and Brodie 1984). In the early 1950s, a commercial fishery for witch flounder developed at the south side of St. George's Bay, Newfoundland, where boats with Danish seines fished during the summer months (Bowering and Brodie 1984). In the late 1970s, large quantities of witch flounder were landed by offshore otter trawlers fishing in the winter months in the Esquiman Channel southwest of St. George's Bay. This led to the first catch quota for this stock, set in 1977 at a precautionary level of 3500 t for NAFO divisions 4RS. An assessment at this time revealed large numbers of old, slow-growing fish which were frequently landed in a "jellied" condition (Bowering 1978). In 1979, the total allowable catch (TAC) was raised to 5000 t to reduce the numbers of these old fish and stimulate growth. The TAC was reduced back to 3500 t in 1982, once this objective appeared to have been met (Bowering and Brodie 1980, Bowering 1981).

From 1977 to 1994, the fishery for witch flounder in the Gulf of St. Lawrence was regulated within NAFO divisions 4RS. The relationship between witch in the northern Gulf (NAFO 4RS) and those off Cape Breton in the southern Gulf (NAFO 4T) has long been questioned (Bowering 1978). Following an analysis of the distribution of witch flounder in the Gulf of St. Lawrence (Morin and Hurlbut 1994), 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 recommendation in 1995. This assessment of stock status assumes a 4RST stock unit.

2. Fishery Data

2.1 Landings

Landings of witch flounder in the Gulf of St. Lawrence averaged 3400 t from 1960 to 1975 (Fig. 1, Table 1). Fisheries in 4R and 4T contributed roughly equally to these landings, with relatively minor contributions from 4S (Fig. 2). Landings rose sharply in 1976 with the onset of a winter fishery by large otter trawlers exploiting winter concentrations of witch in the Esquiman Channel. Landings dropped sharply in 1981 when these large trawlers were excluded from the northern Gulf cod fishery. Landings increased from low levels near 1000 t in the early 1980s to levels near 2500 t by the late 1980s. However, landings declined throughout the early 1990s to an historical low of 320 t in 1995. Landings increased somewhat in 1996 and 1997 but remained below the allocated quotas for all gear sectors (Table 2). The decline in landings has been particularly strong for 4R-based Danish seiners, whose landings now reach only about one-quarter of their allocation (Table 2). The fishery is now dominated by landings in 4T (Fig. 2). In 1996 and 1997, 4T-based vessels caught about 75-80% of the allocation (Table 2). Restrictions on fishing practices may have contributed to landing shortfalls. The 4T groundfishery in 1996 was characterized by frequent closures due to excessive cod by-catch (R. Hébert, DFO Resource Allocation, Moncton, pers. comm.). Closures were less frequent in 1997 due to increased cod by-catch allowances and were applied to individual vessels rather than to entire fleets. However, delays in the opening of the fishery until June precluded traditional fisheries during spring movements of witch and may have contributed to the 1997 shortfall (R. Hébert, pers. comm.).

Witch landings have been almost entirely by mobile gears (Table 1). Danish seines have dominatd the landings, except during the 1976-1980 period when winter catches by offshore trawlers contributed heavily to the landings. Since 1991, 87-100% of landings have been from unit areas 4Rd, 4Tf, 4Tg, 4Tk and 4Tnoq (Fig. 3 and 4). The proportion of landings were highest from 4Rd until 1994 when landings in this unit area declined sharply (Fig. 4). Landings in 4Rd have remained low since then. Landings have remained fairly steady in 4Tf and 4Tg, and these areas now dominate the fishery (Fig 4, 5). Contributions from 4Tk and 4Tnoq are now fairly minor.

The fishery for witch flounder is primarily a directed fishery (Fig. 6). Trawls directing for witch are largely restricted to 4T. Since 1994, directed effort by trawls has been at an intermediate level, well above the very low level in 1993 (when the cod fishery closed) but below the high level of 1991 (Fig. 7). However, directed effort by trawls has been slight in all years compared to that by seines. In 4R, directed effort by seines decreased sharply in 1994 and has remained low since than. In contrast, directed effort by seines has remained high in 4T.

2.2 Catch-at-length

We attempted to estimate mobile gear catch-at-length for 1987-1997, the period when relative estimates of population numbers at length were available for the entire 4RST region from summer RV surveys (see below). Port sampling of witch landings has been sparse and limits how finely catches can be disaggregated by gear, fishing zone and season for the calculation of catch at length. Most samples were from seines (the gear which landed most of the catch), but several trawl samples were also available. A preliminary examination of length frequencies did not reveal any consistent differences between the two gears or between seasons (January-June versus July-December). Thus, samples and catches were pooled over gears and months. Lengths in the catch did however appear to differ among fishing zones (Fig. 8). Fish landed in 4R tended to be smaller than those landed in 4T since 1990, so where possible we applied 4T samples to 4T landings and 4R samples to 4R (and 4S) landings (4S landings were low and mostly unsampled - see Table 3). Only one 4T sample was collected in 1989. Length distributions of the 4T and 4S samples in 1989 appeared to match the 4R distribution in that year fairly well (Fig. 8), and we constructed the catch at length for 1989 by combining all samples for the three regions. No samples were available from 4R in 1987, so we did not estimate catch at length for that year. Numbers of fish sampled for length, and the landings to which these samples were applied, are summarized in Table 3. Sample weights were estimated from length-weight relationships determined from data collected on the summer RV surveys. Estimates obtained from the southern Gulf survey in each year were applied to 4T samples in the corresponding year. Estimates obtained from the northern Gulf August survey in 1993-1997 were applied to 4R samples in those years. Length-weight data were unavailable for the August surveys in earlier years, so parameter estimates from the southern Gulf survey were applied to 4RS samples in 1988-1992.

Length composition of the landings are given in Table 4 and Figures 9 and 10. The large drop in the landings from 1989 to 1990 (Fig. 9) is not accompanied by any decrease in the size of the fish landed (Fig. 10). The fish landed in recent years tend to be larger than those landed in 1988 and 1989. For example, a higher proportion of witch landings tended to be in the 38-43 cm length range in 1993-1997 than in 1988 and 1989 (Fig. 10). Increases in mesh size may contribute to this difference. The sizes of fish landed in recent years are considerably smaller than those landed in the mid 1970s and early 1980s (Fig. 11).

2.3 End-of-Season Telephone Survey

Fishermen that participated in the groundfish fishery in the southern Gulf in 1997 were surveyed by telephone for their opinions on the current status of groundfish stocks (Hurlbut and Stevens 1998). Of the 172 respondents that were interviewed, 13 indicated that they directed for witch flounder in 1997 to some extent (i.e., first, second or third priority), and of them, 5 fishers said that witch flounder was their first priority. None of the respondents were participants in the Sentinel fishery in 1997. Of these 13 respondents, 10 were located on Cape Breton Island, and one each from the Magdalen Islands, Acadian Peninsula and Gaspé Peninsula. All fished with seines. Effort by most of these fishers was the same as or less than in previous years (Fig. 12 and 13). Most considered the abundance of witch flounder in 1997 to be average (Fig. 14). Of the five fishers with witch as their first priority, three considered abundance in 1997 to be the same as in 1996, one considered it lower, and one higher. Opinions of these five fishers concerning witch abundance in 1997 compared to 1992-1996 and to all their years fishing for witch were evenly split between lower and higher (Fig. 15). Further details can be obtained in Hurlbut and Stevens (1998).

3. Research Survey Data

Three series of stratified random bottom-trawl surveys provide information on the status of 4RST witch flounder: a survey of the southern Gulf of St. Lawrence conducted each September since 1971 (Fig. 16), a survey of the northern Gulf conducted each August since 1984 (Fig. 17), and a January survey conducted in the northern Gulf from 1978 to 1994 (except 1982). Fishing in the September survey was by the *E.E.Prince* using a Yankee-36 trawl from 1971-1985, by the *Lady Hammond* using a Western IIA trawl from 1985-1991, and by the *Alfred Needler* using a Western IIA trawl since 1992. In the August survey, fishing was by the *Lady Hammond* using a Western IIA trawl from 1984 to 1989 and by the *Alfred Needler* using a URI shrimp trawl since 1990. In the winter surveys, fishing was by the *Gadus Atlantica* using a Western IIA trawl from 1978 to 1988 and an Engels-145 trawl from 1989 to 1994. In all years, the target fishing procedure in the September survey was a 30-min tow at 3.5 knots, producing a standard tow

of 1.75 nautical miles. Target fishing procedures in the August survey were a 30-min tow at 3.5 knots in 1984-1989 (standard tow = 1.75 nautical miles), a 20-min tow at 2.5 knots in 1990-1992 (standard tow = 0.83 nautical miles), a 24-min tow at 2.5 knots in 1993 (standard tow = 1.0 nautical mile), and a 24-min tow at 3.0 knots since 1994 (standard tow = 1.2 nautical miles). Further details of procedures for the southern Gulf survey are given by Hurlbut and Clay (1990).

Neither summer survey alone covers the entire area occupied by this stock, and a major focus of this analysis was to try to combine data from both surveys into a single index of abundance covering the entire stock area. This required adjustments for changes in fishing practices, gears and vessels. Catches of witch flounder in the summer surveys tend to be higher at night than in day (Swain and Poirier 1998). In the September surveys, fishing was conducted only in daytime hours prior to 1985 but throughout the 24-h day since then. Even since 1985, the porportion of sets conducted at night has varied widely among years for the strata where witch are likely to be caught (Swain and Poirier 1998). Thus, for both the September and August surveys, we adjusted day catches to be equivalent to night catches as described by Swain and Poirier (1998). A comparative fishing experiment in 1985 failed to reveal significant differences in fishing efficiency for witch flounder between the *E.E.Prince*/Yankee-36 trawl and the *Lady Hammond*/Western IIA trawl. However, comparative fishing using the Western IIA trawl in the southern Gulf in 1992 indicated that fishing efficiency of the *Alfred Needler* for witch flounder was significantly greater than that of the *Lady Hammond* (Swain et al. 1998). We adjusted September catches by the *Alfred Needler* since 1992 to be equivalent to *Lady Hammond* catches as described by Swain et al. (1998). Comparative fishing during the 1990 August survey in the northern Gulf indicated substantial differences in fishing efficiency for witch between the *Lady Hammond* using a Western IIA trawl and the *Alfred Needler* using the URI trawl (Swain et al. 1998). The differences were length-dependent, reversing as length increased from 10 cm to lengths above 24 cm. Because of the dramatic change in relative fishing efficiency with length, consistent indices could only be produced using a restricted range of lengths. Swain et al. (1998) estimated relative fishing efficiency between the Western IIA and URI trawls for witch flounder 24 cm or greater in length. We used this estimate to convert catches of witch in this size range in the August survey since 1990 to be equivalent to catches in a standard 1.75-nautical mile tow by the *Lady Hammond* using a Western IIA trawl. The construction of a consistent catch rate index for witch flounder is summarized in Fig. 18. Effects of the various adjustments on the abundance indices are described by Swain and Poirier (1998) and Swain et al. (1998).

When ice conditions permitted, the winter survey likely covered most of the area occupied by 4RST witch flounder. However, this survey has been discontinued and thus provides no information on the current status of this stock. We had hoped to use this survey to corroborate trends in the combined August/September index for years before 1995. However, a number of inconsistencies were discovered in the data, and analyses of these data were defered until further editting of the data could be completed. The abundance index from this survey, presented by Morin et al. (1996), is reproduced here without further analysis for provisional comparison with the summer index.

3.1 Abundance Indices

Mean catch rates of witch in September in the southern Gulf strata are shown in Table 5. Catch rates were highest in strata along the slope of the Laurentian Channel and in the relatively deep water off the Gaspé Peninsula and in the Cape Breton Trough (strata 415-417, 425, 426, 437-439) and were generally very low over the Magdalen Shallows. Strata were not sampled on four occasions over the 27-yr time series (shaded cells in the table). The missed strata were ones where catch rates of witch were low (stratum 424) or very low (strata 421, 428). To calculate stratified means, these missing values were replaced by the stratum averages over the time series.

Mean catch rates of witch in August in the northern Gulf strata are shown in Table 6. These means include all lengths of witch, and no adjustments have yet been applied for the change in vessel and gear in 1990. This table only includes the strata used here to calculate abundance indices. Strata 825, 826 and 834 were rarely sampled because of lack of trawlable bottom and have now been dropped from the survey. We also dropped stratum 833 because it contained a number of missing cells and rarely contained witch (no witch were caught in this stratum in most years sampled). Additional strata (835-841) were added to the survey in 1991, extending coverage into the Strait of Belle Isle and into inshore areas along the west coast of Newfoundland. We did not include these strata because they rarely contained witch (only a single witch was captured in strata 836-841 from 1991 to 1995). Mean catch rates in the strata not included here can be found in Table 3 of Morin et al. (1996).

Witch were more widespread in the northern Gulf and were caught in most strata in most years. Mean catch rates tended to be highest in strata off the Gaspé coast and in the St. Lawrence estuary (strata 409-414) and, particularly in the earlier years, in the Esquiman Channel (strata 801, 823, 824). Missing values were more common in the August survey and occurred in the strata where witch catch rates tended to be highest. Three options exist for replacing missing stratum means to calculate the stratified mean. A missing value for a particular stratum in a particular year can be replaced by (1) the average value for all sampled strata in that year, (2) the average value for that stratum over all sampled years, or (3) the predicted value from a statistical model describing variation in catch rates among strata and years. We compared these three approaches. For both methods 2 and 3, means or effects were calculated separately for the 1984-1989 and 1990-1997 periods because of the change in vessel and gear in 1990. We used Poisson models to describe effects of year and stratum on witch catch rates. These models have the advantage over lognormal models that estimated effects are not adversely affected by zero catches and no back-transformation and bias correction is required (see Swain and Poirier (1998) for details on this type of model). Previous multiplicative analyses (Morin et al. 1996) revealed a significant year×stratum interaction when all strata were included in models. This indicates significant interannual shifts in distribution that preclude estimating missing values from year and stratum effects when all strata and years are included in the analysis. Following Morin et al. (1996), we selected subsets of neighboring strata which showed no significant year×stratum interaction in order to estimate missing values (Table 7). No estimate could be made in three cases (stratum 827 in 1990 and 1996 and stratum 829 in 1997) because no model without a significant interaction term could be found. Estimates for the missed strata are compared among the three approaches in Table 8. Estimates based on the stratum mean and the Poisson model tended to be similar and to differ from those based on the year mean, particularly for strata 409-414. Catch rates for these strata tended to be well above survey averages and were thus underestimated by year means. For most years, stratified means were very similar using all three approaches (Fig. 19). Exceptions were 1984-1986 and, to a lesser degree, 1989. In these years, most strata in the 409-414 group were missed, and replacing the missed values by the year mean likely biases the stratified mean downward. We used the stratum mean to replace missing values to calculate the stratified means presented in Figures 20 and 21. For other analyses where means were calculated for each 2-cm length interval, we adopted the simpler method of replacing missing values with the year mean. These latter analyses are restricted to the 1987 to 1997 period when all three approaches produced similar results.

Abundance indices including all lengths of witch flounder are compared among surveys in Figure 20. Abundance in September in the southern Gulf appeared to be relatively high throughout the 1970s and relatively low in the early to mid 1980s. Catch rates in the September survey have varied widely since the mid 1980s, tending to be relatively high in the mid to late 1980s and relatively low in the early 1990s. The mean catch rate increased abruptly in 1996 to the highest level observed in the time series but decreased to a relatively low level in 1997. Several large catches contributed to the high 1996 mean. Because the September survey covers only the southern edge of the range of this stock, much of the variation in this index could reflect shifts in distribution rather than actual changes in abundance.

The index from the August survey, which covers more of the stock range, suggests a gradual but steady decline in abundance from the mid 1980s to the mid 1990s. However, this index for all lengths of witch has not been adjusted for the change in vessel and gear in 1990. Thus, catch rates in this index are not directly comparable between the 1984-1989 and 1990-1997 periods. Because of the marked difference in selectivity between the two gears (Swain et al. 1998), small fish will contribute more heavily to the index in the 1990-1997 period than in the 1984-1989 period. Also note that a single exceptionally large catch (set 144) has been omitted from the index for 1986. If this catch is included, the mean catch rate for 1986 more than doubles to 34.1 fish/tow. However, with a SE of 18.4, the mean including set 144 is not significantly different from the more believable mean shown in Figure 20 (or from 0).

Mean catch rates in the winter survey fluctuate widely between the late 1970s and mid 1980s. They suggest low abundance in 1983 and very high abundance in 1985. The change between 1983 and 1985 seems unreasonably large since no large pulse of recruitment is evident between these years in the length frequencies of the catches (see Morin et al. 1995). Like the August survey, the January survey suggests a decline in abundance from the mid to late 1980s. Unlike the August survey, the January survey suggests a steady level of abundance from 1988 to 1994. Coverage in this survey has varied widely among years due to varying ice conditions. No adjustments for varying coverage have been made to the index reported in Figure 20. Inconsistencies in this index, and between it and the August index, could reflect this varying coverage.

Abundance indices for witch flounder 24 cm and greater in length are shown in Figure 21. For the southern Gulf, this index is almost identical to that including all lengths (Fig. 20), since few witch smaller than 24 cm are caught in this area. For the northern Gulf, 1984-1986 could not be included in this index because length frequencies of the catch were not available for these years. Like the index for all lengths, this index suggests a gradual decline in abundance in the northern Gulf between the late 1980s and the mid 1990s. Catch rates in the two surveys are combined into a single index in the bottom panel. To calculate this combined index, stratum weights were adjusted for the overlap between the two surveys. Strata 415, 425 and 439 of the southern Gulf survey cover roughly the same grounds as strata 401-406 of the northern Gulf survey. Weights for these strata were halved in the calculation of stratified means. Like the index for the northern Gulf alone, this index for the entire stock range suggests a gradual decline in abundance since the late 1980s, though the decline is slightly less steep than for the northern Gulf alone.

3.2 Geographic Distribution

No major shifts in the September distribution of witch flounder are evident in the southern Gulf throughout the 1970s and 1980s (Fig. 22). Two main concentrations occur throughout this period, one along the west coast of Cape Breton Island and a second off the Gaspé coast. Witch tended to penetrate fairly deeply into the southern Gulf throughout this period, with appreciable catches extending into the outer Shediac Valley in the southwestern Gulf. Distribution appears to shift in the 1990s, with fewer witch caught on the Magdalen Shallows and in the Shediac Valley and Chaleur Trough and a higher proportion of witch caught along the slope of the Laurentain Channel and outer region of the Cape Breton Trough. This apparent shift could reflect (1) range contraction due to an overall decline in stock size, (2) avoidance of the cold bottom conditions persisting on the Magdalen Shallows throughout the 1990s (Gilbert et al. 1997), or (3) the disappearance of the older, larger fish which have tended to penetrate most deeply into the southern Gulf (see below).

Witch flounder are more widely distributed throughout the northern Gulf. Catches have tended to be highest in the estuary between the Gaspé coast and the Québec north shore and off the Newfoundland coast southwest of St. George's Bay. However, considerable interannual fluctuation in the distribution of catches has occurred. For example, in 1996 the highest catch rates occurred in the region north of eastern Anticosti Island, and in 1997 catch rates between the Gaspé coast and Québec north shore were exceptionally poor. The composite maps for the northern Gulf in 1986-1990 and 1991-1995 have a mottled appearance that could reflect interannual variation in abundance or distribution. Thus, we plotted distribution in the northern Gulf separately for each year in Figures 23 and 24. The distribution of catches appears to be fairly consistent throughout the 1984-1989 period, with relatively high catch rates in the estuary and southwest of St. George's Bay in most years (Fig. 23). Although the distribution of catches remained fairly consistent throughout most years in the 1990-1995 period, substantial changes in abundance are suggested by the distribution maps for this period, with abundance at minimum levels in 1993 (Fig. 24). Except in 1991, catches in the region between the Gaspé coast and Québec north shore were relatively low in this period compared to the earlier period.

3.3 Length Distributions

Length distributions of witch catches in the August survey are shown in Figure 25. No adjustment for the change in gear in 1990 has been made in this figure. Catches by the Western IIA trawl in 1987-1989 show a strong mode in the 30-35 cm range. A mode near these sizes is also apparent in the URI catches in 1990-1992. The height of this mode is lower in the URI catches, but this is expected given the lower efficiency of this trawl at these larger sizes (Swain et al. 1998). There is a tendency for this mode to occur at progressively larger sizes from 1987 to 1992. But the rate of this change is too slow to be attributed to annual growth at the rates described by Bowering and Brodie (1984). Even accounting for the change in gear in 1990, there is also a tendency for the height of this mode to decrease over time, and it has entirely disappeared by 1993. Other modes can be followed from 1990 to 1997, and shifts in their lengths are generally consistent with the growth rates reported by Bowering and Brodie (1984). Few fish have been caught in this survey at lengths greater than 30 cm since 1992. Catches of small fish increase dramatically with the introduction of the URI trawl in 1990. Catches at these small sizes have varied widely among years, suggesting that recruitment has been quite variable. Catches at small sizes near 10 cm were relatively high in 1990, 1991 and 1997 but very low from 1992 to 1996.

Length frequency distributions in the southern Gulf surveys fluctuate more erratically than those in the northern Gulf (Fig. 26), reflecting the lower catch rates in the southern Gulf. Modal or mean length tended to increase from the early 1970s to the early 1980s. In the late 1970s and early 1980s, most witch caught in the southern Gulf survey were greater than 38 cm in length. Length distributions were wider in the mid to late 1980s, containing a relatively high proportion of fish under 40 cm. By the mid 1990s, length distributions in the southern Gulf were dominated by fish under 40 cm, reflecting a substantial shift toward smaller sizes compared to the mid 1980s.

Catches from both the August and September surveys are combined into a single length frequency distribution for the entire Gulf in Figure 27. Stratum weights were again adjusted for the overlap between the two surveys. Estimates of "trawlable" population size at length based on these length frequencies are shown in Table 9. Catches by the URI trawl are adjusted to be comparable to those by the Western IIA in this figure, so distributions are restricted to lengths of 24 cm and greater (Swain et al. 1998). Even with this restriction, there is a sharp increase in the proportion of small fish in 1990. Comparative fishing in 1990 indicated that differences in efficiency between the URI and Western IIA were independent of length over the length range in this figure, so this increase may be real. Alternatively, adjustment for the change in gears may not have been entirely effective due to inaccuracies in the results of the comparative fishing, and this increase in the porportion of small fish may be at least partly attributable to the change in gear. Nonetheless, this trend toward a decreasing proportion of large fish continued from 1990 to 1994, and thus cannot be attributed solely to the change in gear. The proportion of fish 30 cm and greater in length declined by 50% from 1990 to 1994. The proportion of large fish has increased since 1994 but remains well below the 1990 level.

Figure 28 shows changes in relative abundance by size class for the entire Gulf. Adjustments for the change in gear between 1989 and 1990 have again been applied. Abundance of the smallest size class (24-29 cm) appears to have increased from 1987-90 to 1994-97. However, no trend in relative abundance has occurred for this size class since 1990, so it is unclear whether this increase is real or reflects ineffective adjustment for the change in gear in 1990. All larger size classes show a decline in relative abundance between 1987-90 and 1994-97, and the severity of the decline increases with size. In all these cases, the decline has occurred since 1990, and thus cannot be attributed to the change in gear.

Figure 29 summarizes spatial and temporal variation in mean size. Means are for fish greater than 24 cm in length to permit comparison between URI and Western IIA catches. Clear patterns in mean size are evident along both spatial and temporal axes. Mean size tended to be greatest in the southern Gulf strata, particularly the shallower strata inshore of the Laurentian slope. Mean size also tends to decrease progressively over time in both the northern and southern Gulf strata.

3.4 Trawlable Biomass

Estimates of trawlable biomass of witch 24 cm and longer were obtained for the entire Gulf from the length distribution of catches and estimates of the length-weight relationship for witch. There was no indication of sexual dimorphism in the length-weight relationship, so data for both sexes were pooled to estimate the length-weight parameters. Estimates were obtained using the NLIN procedure of SAS. Where possible parameters estimated from a particular survey were applied to the length distributions of that survey. No length-weight data were available for the 1987-1992 August surveys, so parameters estimated from September survey data were applied to the northern Gulf length distributions in these years.

Trawlable biomass declined sharply from the 1987-1990 period to the 1994-1997 period (Fig. 30). The decline occurred after 1990 and thus cannot be attributed to the change in gear in 1990. The decline in biomass is considerably sharper than the decline in abundance (Fig. 21). It reflects a decrease in mean size (Fig. 28, 29) as well as a decline in abundance. Estimated biomass reached a minimum in 1993, reflecting the very low abundance estimate in that year. Biomass has remained stable at a low level from 1994 to 1997.

3.5 Regional Abundance Indices

To examine regional variation in abundance trends in the Gulf of St. Lawrence, we calculated stratified mean catch rates of witch flounder 24 cm and greater in length for each of three regions: 4T east (strata 401, 404, 407, 415-439),

4T west and most of 4S (strata 402, 403, 405, 406, 408-429, 4S excluding strata 803, 808 and 814), and 4R plus the latter 4S strata. These regional indices fluctuate fairly erratically, but some regional differences in abundance trends are suggested, particularly in terms of biomass (Fig. 31). For both the 4T west / 4S region and the 4R region, mean weight per tow declined sharply from the late 1980s to 1993 and remained below the earlier levels from 1994 to the present. For 4T east, no clear trend in biomass is evident and current levels are at or above those of the late 1980s. Patterns are similar though less clear in terms of numbers per tow. In the 4T west/ 4S region, mean number per tow tends to be lower in recent years than in the earlier years. In 4R, there was a steady decline in mean number per tow from 1987 to 1993, but catch rates have improved somewhat since 1993. In 4T east, mean number per tow was at a minimum in 1992, but current catch rates are as high or higher than those in the late 1980s.

4. Relative Fishing Mortality

We looked for trends in fishing mortality (F) by calculating relative F (R) at length, the ratio of catch at length divided by the RV index of population abundance at length (Sinclair 1998). R increased with length from values near 0 below 30 cm to maximum values by about 40 cm (Table 10, Fig. 32). No trend over time was evident in R. A sharp peak in R occurred in 1993. However, the survey abundance index was unusually low in 1993 (Fig. 21), so this may reflect a year effect in the survey rather than an increase in F.

The value of R and its relationship with F will depend on the relative timing of the survey and fishery (Sinclair 1998). For a given value of F, R will decrease as survey timing becomes earlier. The proportion of the 4RST witch catch that has been made prior to the August and September surveys has varied substantially over the 1988-1997 period. In the 1988-1992 period, 51-59% of the witch landings occurred before August. This increased to 66% in 1993 and then dropped to 26-34% in 1994-1997. Thus, values of R late in the time series are biased downward relative to those early in the time series. A slight increase in F might be obscured by the earlier timing of the surveys relative to the fishery in recent years.

5. Uncertainty

This assessment contains many uncertainties. Unfortunately, most of these uncertainties are not currently quantifiable. Fishing efficiency for witch flounder varies substantially between day and night and among the vessels and gears used to conduct the summer research surveys. We have attempted to adjust for these variations in catchability, but the uncertainty associated with these adjustments is not incorporated in the error bars around the survey abundance indices. A substantial increase in the catch rates of small fish occurred in the 1990 survey when the gear used in August changed to the URI trawl. It is unclear whether this increase reflects improved recruitment in 1990 or ineffective adjustment for the change in gear. However, declines in survey catch rates, biomass and mean length all occurred after 1990, and so cannot be attributed to the gear change in 1990.

Stock structure remains a major uncertainty. The fishery for witch flounder in the Gulf is now confined mostly to the 4Tg and 4Tf areas. The recent declines in abundance evident throughout most of the Gulf from the summer research surveys are not evident in eastern 4T. Distribution of witch flounder appears to be continuous between the Cape Breton trough area of 4T and Sydney Bight in 4Vn (McRuer et al. 1997). Abundance of pre-recruit witch appears high in 4VW in recent years, though the distribution of these pre-recruits is strongly localized to areas of 4VsW (McRuer et al. 1997). Prospects for witch in eastern 4T may depend on whether they are more closely affiliated wth witch in 4R, 4S and western 4T or with those in 4Vn and 4VsW.

6. Conclusions

Landings of 4RST witch flounder are currently at the lowest levels in the 1960-1997 time series, about 15% of the average 1960-1975 level. The fishery is now confined mostly to the eastern 4T area. Catch rates in the summer research surveys of the northern and southern Gulf indicate a gradual decline in abundance since about 1990. The decline in abundance has been particularly strong for larger fish. This is reflected in a strong decline in trawlable biomass from 1990 to 1993. Trawlable biomass has remained relatively low from 1994 to the present. Recruitment appears to have been poor in most years from 1992 to 1996, but the length distribution of survey catches suggests improved abundance of pre-recruits in 1997.

The declines in abundance and biomass do not appear to have been uniform throughout the Gulf and are not evident in the eastern 4T strata. The significance of this regional variation in abundance trends depends on stock structure. If witch throughout 4RST comprise a single isolated population, then this regional variation in abundance trends simply reflects shifts in distribution. If witch in eastern 4T are more closely affiliated with those in 4VW than those in other areas of the Gulf, then this regional variation in abundance trends may indicate better prospects for the eastern 4T area than for other parts of the Gulf.

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Table 1. Landings (t) of witch flounder in NAFO divisions 4RST by gear type. OTB=otter trawl, OTB1=side otter trawl, OTB2=stern otter trawl, SNU=seine, GNS=gillnet, LLS=longline.

YEAR	OTB	OTB1	OTB2	SNU	GNS	LLS	OTHER	TOTAL	TAC
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	3500
1978	3	616	2767	938	69	3	114	4510	3500
1979	62	1065	1970	1309	120	14	21	4561	5000
1980	106	548	1618	1100	98	30	27	3527	5000
1981	108	446	267	1032	24	33	2	1912	5000
1982	93	105	122	934	24	4	0	1282	3500
1983	137	116	52	829	27	10	6	1177	3500
1984	75	110	314	536	51	19	2	1107	3500
1985	27	89	161	1127	28	7	221	1660	3500
1986	49	63	79	1216	6	2	408	1823	3500
1987	58	157	212	1671	7	0	504	2609	3500
1988	56	177	177	1835	34	1	250	2530	3500
1989	45	199	358	1698	47	0	0	2347	3500
1990	12	120	236	873	16	8	7	1272	3500
1991	0	5	180	752	37	2	17	993	3500
1992	11	3	129	825	16	2	3	989	3500
1993	0	0	103	691	11	0	96	901	3500
1994	0	0	31	384	4	0	28	448	1000
1995	0	2	18	292	4	0	4	320	1000
1996	0	1	12	479	0	0	6	498	1000
1997	0	0	72	452	3	0	0	528	1000
MEAN	264	444	455	1352	25	17	68	2625	

Table 2. Resource allocation scheme for witch flounder in 4RST in 1996 and 1997. (M.G.=mobile gear; F.G.=fixed gear). Total landings (tons) are preliminary data taken from year-end quota reports.

1997:

GEAR	FINAL ALLOCATION	LANDINGS
M.G. <65 4R, 3Pn seiners	416	100
M.G. <65 based in 4ST	437	377
M.G. <65 based in Scotia-Fundy	27	9
M.G. 65-100	70	43
BY-CATCH OTHERS	50	2

1996:

GEAR	FINAL ALLOCATION	LANDINGS
M.G. <65 4R, 3Pn seiners	416	107
M.G. <65 based in 4ST	437	343
M.G. <65 based in Scotia-Fundy	27	21
M.G. 65-100	70	43
BY-CATCH OTHERS	50	0

Table 3. Numbers of witch flounder sampled for length from mobile-gear landings in 4RST, 1987-1997.

	4R				4S				4T			
	JanJun lengths	catch	JulDec lengths	catch	JanJun lengths	catch	JulDec lengths	catch	JanJun lengths	catch	JulDec lengths	catch
1987	0	332	0	516	250	13	129	43	475	653	2652	1052
1988	758	298	512	763	0	16	0	56	874	639	1207	758
1989	761	406	496	674	41	20	0	85	105	566	0	596
1990	996	212	768	317	0	33	0	47	0	330	523	333
1991	255	110	256	265	0	34	0	40	0	239	253	305
1992	974	113	1517	231	0	11	0	31	0	273	602	330
1993	1272	205	1497	232	0	0	0	12	378	282	436	166
1994	0	3	777	92	0	0	0	4	459	71	490	280
1995	0	6	428	48	0	0	0	2	340	45	862	227
1996	255	4	1790	79	0	0	0	0	378	41	2174	369
1997	0	10	1281	70	0	0	0	0	689	105	542	343

Table 4. Estimated catch-at length (thousands) for mobile-gear witch flounder landings in NAFO divisions 4RST, 1988-1997.

Length	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	6.61	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.17	1.82	0.00	0.00	0.00	0.00
26	22.29	0.00	0.00	0.00	3.51	3.19	0.00	0.00	0.56	0.00
27	19.22	0.00	0.00	0.00	6.16	5.08	0.07	1.38	0.48	0.17
28	42.44	25.53	0.00	1.59	7.72	11.92	2.37	1.85	6.41	2.11
29	81.36	0.00	0.23	11.52	17.68	21.06	4.27	2.76	9.64	6.68
30	73.33	38.85	18.46	4.76	20.17	36.29	8.47	7.85	20.70	17.76
31	191.85	116.44	32.63	18.95	56.75	47.97	17.13	15.79	23.36	24.56
32	314.16	244.20	98.77	30.73	58.62	48.07	19.78	19.01	34.77	39.48
33	343.89	276.45	115.46	61.19	90.09	75.59	30.97	27.62	51.25	42.77
34	407.52	305.76	162.50	79.76	126.10	118.91	50.31	35.84	73.29	70.50
35	497.68	412.06	190.15	131.77	150.03	132.06	53.05	63.72	117.91	84.71
36	592.52	429.63	189.54	126.01	143.26	167.04	71.50	68.28	140.25	118.06
37	512.91	516.23	200.90	151.74	178.17	181.37	77.52	66.73	144.15	100.38
38	475.98	409.22	159.83	148.65	172.24	170.68	94.85	68.64	141.29	132.52
39	355.19	416.03	151.38	138.16	223.71	159.06	78.58	82.40	104.64	129.44
40	352.05	303.92	183.88	102.93	195.79	138.20	69.62	85.44	97.59	108.68
41	252.58	306.12	155.56	116.61	142.41	140.29	66.63	45.08	80.15	96.60
42	208.10	262.83	170.03	137.00	121.20	127.88	65.88	29.00	52.98	74.36
43	203.12	188.29	134.24	84.22	108.80	119.46	45.49	45.91	44.10	51.42
44	216.66	193.41	114.02	94.35	86.57	92.59	45.95	16.64	43.32	38.82
45	170.00	150.55	96.54	52.67	76.84	69.79	25.17	14.54	22.60	23.75
46	160.28	209.83	80.47	57.32	51.05	49.59	26.55	17.91	25.18	39.06
47	104.03	94.35	82.29	44.06	41.09	47.74	18.25	16.31	14.00	22.91
48	115.61	59.94	54.53	26.02	36.24	31.23	15.51	19.15	12.15	17.57
49	71.63	63.43	51.58	20.97	17.90	18.20	13.69	5.47	10.50	4.88
50	58.43	52.10	31.38	17.49	11.01	24.16	6.88	13.13	3.15	7.94
51	36.43	43.22	18.21	52.58	20.25	16.10	7.11	5.10	2.31	2.98
52	28.64	16.96	14.77	13.40	5.61	8.44	8.61	1.05	2.50	0.50
53	19.52	28.34	5.93	18.85	9.43	7.59	4.23	0.79	2.09	2.87
54	22.88	7.44	4.37	28.15	8.66	4.16	3.17	0.20	3.30	0.46
55	15.44	5.88	13.96	19.77	2.04	3.88	2.71	0.29	0.80	0.44
56	25.59	1.63	13.43	13.28	1.31	6.94	1.91	0.47	1.83	0.54
57	10.71	0.00	7.67	7.16	1.13	0.72	2.71	0.17	1.12	0.02
58	2.89	11.81	2.15	3.32	1.51	1.71	3.83	0.04	0.96	2.81
59	0.27	1.63	4.37	3.32	0.97	0.74	3.20	0.19	0.05	0.00

Table 5. Mean number of witch flounder caught in the September surveys of the southern Gulf of St. Lawrence. Shaded cells indicate missing values replaced by the average value for the stratum in 1971-1997. Catches are adjusted to night catchability by the *Lady Hammond* using a Western IIA trawl. Stratified means and 1971-1997 stratum averages are shown at margins.

Stratum	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
415	0.643	12.303	15.243	34.550	12.950	8.115	9.047	13.850	5.117	6.587	4.107	10.790	8.923	3.713
416	1.380	4.837	1.895	7.915	10.090	14.542	4.770	18.712	24.618	18.623	5.657	2.325	6.184	4.413
417	34.363	0.360	12.012	9.968	12.425	11.522	1.302	4.187	19.872	1.693	0.368	3.832	0.432	2.168
418	1.750	0.680	0.680	2.450	2.980	0.000	5.797	0.000	0.000	0.000	1.148	0.000	0.575	0.000
419	0.000	0.000	0.875	1.225	0.000	1.020	2.160	0.000	3.060	0.000	0.000	0.000	0.000	0.000
420	0.000	0.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
421	0.000	0.000	0.000	0.000	3.980	0.000	0.000	3.935	0.000	0.000	0.000	0.000	0.392	0.000
422	0.540	0.000	27.114	2.625	1.838	11.836	3.612	0.000	1.172	0.386	1.296	0.000	0.000	1.547
423	0.000	3.125	0.000	0.643	0.000	0.000	0.000	0.000	0.000	0.000	0.243	0.000	0.000	0.000
424	0.000	0.000	2.450	0.000	0.000	0.767	1.400	1.085	2.040	3.453	3.603	0.000	0.000	0.000
425	23.480	3.935	0.000	11.725	24.500	8.375	30.780	13.735	1.935	0.000	7.710	3.445	3.160	3.223
426	0.000	2.160	0.835	14.605	17.150	10.210	0.000	2.305	55.125	4.085	2.170	0.000	0.000	3.500
427	0.000	0.000	0.000	0.000	0.000	0.000	1.310	0.000	0.000	0.000	0.000	0.000	0.000	0.000
428	0.000	0.000	2.160	0.000	0.000	0.000	0.000	0.089	0.000	0.000	0.000	0.000	0.000	0.000
429	0.000	0.000	0.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.343	0.000	0.000
431	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
432	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
433	5.250	0.000	0.000	0.000	1.530	0.000	22.120	0.000	0.000	0.000	0.680	0.000	0.000	0.000
434	0.545	0.000	1.750	0.000	2.040	5.043	0.363	0.000	0.000	0.000	0.613	0.000	0.000	0.000
435	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
436	1.150	0.000	0.000	3.445	0.000	0.000	0.515	0.000	0.000	0.000	0.000	0.965	0.000	0.000
437	95.540	3.747	6.123	21.640	1.750	7.193	32.273	0.000	3.197	3.200	2.450	6.563	9.113	10.355
438	3.675	3.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.965	7.090	0.000	2.160	1.935
439	12.310	11.240	0.965	6.430	3.350	0.000	4.755	2.170	3.245	2.100	1.020	0.965	0.000	8.005
Mean	4.726	1.732	3.157	3.738	2.960	3.071	4.284	2.231	3.476	1.665	1.275	0.981	1.023	1.092

Stratum	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Average
415	4.882	22.308	17.707	27.045	1.775	5.260	4.096	5.980	10.490	11.140	8.418	9.147	4.043	10.305
416	4.030	9.249	12.044	20.706	11.986	12.439	5.724	5.270	8.154	17.370	11.627	7.326	3.881	9.473
417	1.466	5.919	1.690	12.854	3.367	5.613	0.872	2.868	1.663	0.000	0.409	0.461	0.000	5.618
418	1.290	0.400	2.045	3.848	2.278	0.000	0.000	0.000	0.151	0.722	0.000	0.000	0.000	0.992
419	2.150	3.555	3.125	0.383	0.000	0.000	0.000	0.169	0.000	0.000	0.000	0.000	0.000	0.656
420	0.000	0.000	0.000	0.000	0.000	0.000	0.548	0.000	0.000	0.000	0.000	0.000	0.000	0.047
421	0.510	0.000	0.643	0.392	0.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.392
422	1.307	2.885	0.744	0.082	0.186	5.186	1.374	0.381	0.384	0.744	0.219	0.058	0.045	2.428
423	0.136	1.000	0.134	0.515	0.945	0.408	0.769	0.114	0.026	0.248	0.031	0.028	0.000	0.310
424	2.747	3.403	0.677	1.200	0.874	2.497	1.280	0.080	0.557	0.401	0.336	0.434	0.000	1.085
425	1.887	2.527	11.550	12.793	1.263	2.687	8.842	7.253	5.559	6.262	4.793	33.771	6.584	8.955
426	1.293	0.343	1.633	0.757	7.003	0.000	7.783	6.140	14.109	2.941	20.314	19.916	16.433	7.808
427	0.000	0.000	0.000	0.000	0.000	1.020	0.617	0.759	0.000	0.127	0.091	0.451	0.301	0.173
428	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.166	0.089
429	0.000	0.000	0.000	0.000	0.000	0.114	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.044
431	0.000	0.000	0.000	0.000	0.000	0.000	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.003
432	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
433	0.194	1.404	0.274	0.258	2.811	0.000	2.854	0.000	0.000	0.426	0.065	0.000	0.327	1.415
434	0.746	0.309	0.000	0.408	7.246	0.545	0.753	0.336	0.128	6.396	0.064	3.234	1.190	1.174
435	0.000	0.000	0.000	0.290	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.345	0.024
436	0.368	0.360	0.000	0.000	0.000	0.255	0.219	0.000	0.000	0.548	0.239	0.000	0.000	0.299
437	4.706	26.620	13.444	27.763	38.164	25.760	3.640	1.980	19.239	32.340	25.766	92.754	30.418	20.213
438	5.683	4.323	2.450	0.275	0.987	2.103	4.688	3.566	9.786	2.825	1.929	9.251	7.597	2.770
439	3.527	1.080	1.450	3.550	3.805	10.233	5.396	1.173	0.545	4.633	4.405	1.068	2.505	3.701
Mean	1.132	2.967	2.331	3.859	2.807	2.505	1.663	1.116	1.926	3.019	2.244	4.748	1.833	

Table 6. Mean number of witch flounder caught in August surveys of the northern Gulf of St. Lawrence. Catches are adjusted to a standard tow of 1.75 nautical miles and to night catchability. The survey vessel and gear changed in 1990.

stratum	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
401	0.73	2.93	0.00	2.04	5.48	2.31	7.13	1.09	1.42	0.00	2.43	1.61	0.45	3.89
402	3.15	9.31	4.45	14.29	7.07	5.17	38.38	24.27	1.87	0.00	0.78	1.25	4.38	0.00
403	0.00	50.47	57.73	5.87	72.78	5.83	8.90	9.82	1.62	4.34	12.32	19.70	5.51	3.51
404	3.18	3.75	5.02	13.80	5.44	3.09	1.04	0.00	0.73	0.45	1.46	3.11	0.49	0.00
405	2.22	4.60	1.66	12.25	7.05	2.13	1.04	0.65	0.00	0.00	0.00	1.44	0.78	1.17
406	2.43	4.96	4.50	2.62	6.46	1.63	6.38	1.23	1.04	0.00	2.92	0.00	0.00	0.00
407	3.79	4.97	5.28	10.09	13.68	11.80	6.69	3.11	2.24	0.00	0.00	3.06	1.26	10.05
408	3.64	6.30	12.75	7.67	5.70	2.56	3.97	5.78	1.87	0.45	0.00	8.26	3.11	8.38
409				56.51	44.47	27.40	44.95	48.94	47.25	4.26		48.76	14.58	8.46
410			19.01		16.36	12.93	2.19	38.63	1.52	1.70	16.11	9.26	3.80	3.32
411				65.06	32.23		52.05	54.19	122.27	19.22	47.10	32.33	15.69	16.92
412				62.71	37.47		44.59	79.27	145.01	52.60	186.89	17.18	15.56	30.52
413				64.19	21.15		41.56	44.96	74.81	2.98		16.83	13.61	11.24
414				8.17	38.58		36.04	45.27	18.96	2.46	303.33	6.73	2.39	0.72
801	43.19	5.65	21.29	4.08	11.41	6.91	17.53	16.24	4.15	0.00	7.78	12.80	4.08	10.68
802	13.19	6.26	14.03	12.28	24.79	9.65	17.05	6.18	0.00	0.00	0.00	2.36	4.76	19.64
803	8.02	6.74	18.04	9.17	9.80	9.86	5.20	22.20	0.00	0.00	2.33	9.72	1.26	8.70
804	7.28	5.35	15.15	8.05	9.11	4.21	0.39	2.33	2.20	0.45	0.58	2.21	16.72	1.46
805	15.52	52.54	26.22	15.38	9.61	2.22	9.49	7.91	10.40	7.49	8.64	9.29	3.16	0.18
806	8.59	1.52	15.18	8.03	10.06	0.68	3.62	2.33	0.65	0.49	2.43	1.46	4.74	0.72
807	1.11	5.31	16.54	4.38	5.99	2.53	3.37	3.31	0.28	0.40	0.00	1.03	4.74	5.30
808	3.38	2.03	3.55	8.33	10.46	2.83	6.71	0.83	0.32	2.02	2.51	7.91	0.97	6.81
809	2.69	7.54	3.27	14.29	8.19	1.94	7.74	4.82	0.83	0.00	0.00	1.88	0.49	7.88
810	3.63	26.35	10.30	22.67	13.53	5.41	4.96	0.97	2.01	1.71	1.46	6.89	0.49	5.83
811	1.46	17.05	8.52	7.84	1.68	1.62	7.13	3.21	4.50	0.00	2.10	6.82	4.39	10.84
812	2.39	3.39	4.91	4.90	5.33	2.40	9.88	0.89	5.84	0.97	0.73	2.33	1.62	7.00
813	3.75	9.00	24.48	13.82	5.19	4.78	1.05	7.41	0.00	1.65	0.00	9.47	1.72	13.42
814	1.80	1.49	0.51	5.07	6.16	2.27	3.50	6.36	1.47	0.00	2.92		0.49	1.26
815	1.53	4.45	6.56	7.09	3.94	2.40	1.42	1.20	0.96	1.22	0.93	4.48	53.08	2.43
816	23.63	5.41	16.91	6.99	9.67	5.70	23.64	12.67	3.37	1.43	0.47	3.14	32.23	2.97
817	8.72	17.60	18.43	16.75	11.17	7.85	11.13	42.78	29.43	1.32	4.21	2.22	7.00	1.05
818	16.71	3.70	29.01	19.99	9.26	9.88	4.84	3.98	1.87	0.85	2.24	2.78	5.44	5.25
819	1.21	4.48	7.06	5.38	4.10	1.36	0.65	2.78	2.89	0.81	0.58	2.45	21.00	4.38
820	0.00	2.42	10.10	9.78	18.51	0.68	1.94	4.70	13.37	0.00	0.00	4.30	1.12	0.93
821	0.97	1.16	6.84	0.97	1.99	3.89	2.29	1.17	0.65	0.00	0.00	1.35	1.94	8.75
822	8.94	4.63	5.26	6.13	5.53	5.38	7.39	2.33	1.17	2.69	0.00	5.58	0.97	0.73
823	15.25	11.77	12.88	52.50	29.85	25.28	0.00	2.53	1.17	0.00	0.00	0.00	1.46	3.40
824	6.67	3.55	8.17	44.82	5.65	4.80	3.05	0.00	0.00	0.00	1.46	1.58	0.00	0.78
827		16.93	3.07	3.76	4.92			0.00	0.00	0.00	0.49	2.12		8.75
828		4.08	2.21	0.49	13.78	12.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78
829		3.13	11.67	0.00	6.03	6.61	5.31	9.58	1.17	0.00	0.78	1.17	0.00	
830	1.54	1.53	6.65	0.24	3.40	2.04	7.13	0.00	2.43	0.00	0.00	0.00	3.79	0.00
831		1.91	0.92	9.72	18.02	7.88	1.94		2.92	0.00	0.97	0.58	1.06	0.00
832		52.44	44.38	38.87	40.89	45.34	66.50	29.44	0.00	6.82	9.92	0.89	0.73	0.29

Table 7. Data used in models to estimate missing stratum means in the August surveys of the northern Gulf of St. Lawrence.

	Missing Cells		Data used	
Model	Year	Strata	Years	Strata
1	1984	409-414,831,832	1984-1989	409-414
	1985	409-414		805,817
	1986	409,411-414		831,832
2	1987	410	1987-1989	409-414
	1989	411-414		805,817
3	1984	827-829	1984-1989	827-830
	1989	827		
4	1991	831	1990-1997	817,818,831
5	1994	409	1990-1997	409,817
6	1994	413	1990-1997	411,413
7	1995	814	1990-1997	801,813,814

Table 8. Options for replacing missing values in calculations of stratified mean catch rates of witch flounder in the August surveys of the northern Gulf of St. Lawrence. Modelled values are those obtained with parameter estimates from Poisson models using the years and strata indicated in Table 7. Stratum means are for 1984-1989 or 1990-1997 (i.e., means are calculated within vessels and gears).

		All Lengths			Length ≥ 24cm		
Year	Stratum	Modelled	Stratum Mean	Year Mean	Modelled	Stratum Mean	Year Mean
1984	409	39.91	42.79	7.53			
1984	410	14.54	16.10	7.53			
1984	411	40.02	48.64	7.53			
1984	412	41.97	50.09	7.53			
1984	413	33.85	42.67	7.53			
1984	414	23.31	23.38	7.53			
1984	827	3.15	7.17	7.53			
1984	828	3.42	6.58	7.53			
1984	829	2.18	5.49	7.53			
1984	831	5.59	6.41	7.53			
1984	832	34.33	36.99	7.53			
1985	409	77.98	42.79	11.89			
1985	410	28.41	16.10	11.89			
1985	411	78.20	48.64	11.89			
1985	412	82.00	50.09	11.89			
1985	413	66.13	42.67	11.89			
1985	414	45.54	23.38	11.89			
1986	409	60.39	42.79	14.16			
1986	411	60.56	48.64	14.16			
1986	412	63.50	50.09	14.16			
1986	413	51.21	42.67	14.16			
1986	414	35.27	23.38	14.16			
1987	410	28.28	16.10	13.00	29.25	13.28	11.41
1989	411	21.52	48.64	7.24	19.58	44.70	6.27
1989	412	22.56	50.09	7.24	19.68	43.82	6.27
1989	413	18.20	42.67	7.24	16.21	37.95	6.27
1989	414	12.53	23.38	7.24	9.40	17.61	6.27
1989	827	8.90	7.17	7.24	7.43	4.05	6.27
1990	827		1.89	11.60		1.89	7.04
1991	831	5.20	1.07	11.76	1.50	0.74	4.91
1994	409	9.00	31.03	7.03	10.15	23.65	3.72
1994	413	31.25	29.43	7.03	15.44	10.92	3.72
1995	814	4.47	2.29	5.72	0.77	0.70	2.74
1996	827		1.89	7.60		1.89	3.07
1997	829		2.57	5.28		1.18	2.58

Table 9. 4RST witch flounder population size at length (thousands of fish) estimated from the August and September RV surveys of the Gulf of St. Lawrence. Estimated from survey catch rates adjusted to a standard night tow of 1.75 nautical miles by the *Lady Hammond* using a Western IIA trawl.

Length (cm)	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
24.5	846.79	1312.55	570.13	3062.18	3150.76	4936.90	2434.66	4524.92	2869.65	3332.42	1584.24
26.5	1491.67	1210.08	743.17	3477.60	3635.69	2207.12	1467.67	4439.04	2893.40	3115.73	3444.20
28.5	2947.53	1787.12	814.66	1636.49	2683.92	2117.16	739.60	4208.85	2208.88	2962.99	1785.46
30.5	4448.69	2356.31	1195.49	2741.30	1146.36	2064.09	545.29	1508.30	2179.99	2081.50	2003.81
32.5	4437.68	3428.65	1998.09	3915.75	2167.70	739.25	589.53	1382.03	814.76	1999.81	1629.76
34.5	3550.74	4169.49	2628.02	4189.05	2364.96	1309.39	688.09	1195.48	1192.30	1865.73	1472.50
36.5	3039.84	3535.95	2316.17	5921.22	2633.19	1830.82	435.49	1231.69	914.70	2299.45	928.78
38.5	1694.60	2959.59	2155.76	3290.63	2330.20	5006.50	625.01	828.33	975.01	1001.27	513.39
40.5	1246.03	1814.79	1716.92	2032.03	1240.19	962.16	409.12	572.01	757.40	916.50	423.97
42.5	1296.77	1288.33	1293.90	1608.30	801.73	629.79	176.49	750.19	378.55	505.02	308.16
44.5	1081.11	1236.24	1081.01	1193.87	706.65	252.50	118.15	154.87	189.98	279.67	187.36
46.5	1010.33	1375.05	994.85	924.61	494.63	318.32	97.89	367.43	76.73	142.04	188.14
48.5	945.72	858.07	491.71	449.95	447.37	179.40	76.46	204.72	104.22	79.17	16.39
50.5	434.59	469.96	244.75	532.99	215.70	11.17	131.64	64.60	16.01	42.03	24.09
52.5	195.94	218.14	204.78	91.50	149.08	20.99	17.40	62.76	17.61	14.23	12.29
54.5	138.97	175.65	221.93	0.00	52.54	14.96	12.54	8.13	0.00	13.21	9.08
56.5	46.81	81.51	62.74	170.55	43.18	16.51	0.00	7.09	6.62	7.12	4.08
58.5	0.00	9.98	32.87	0.00	119.35	6.37	6.23	0.00	6.62	6.09	0.00
60.5	0.00	0.00	30.22	0.00	0.00	0.00	0.00	0.00	0.00	12.18	0.00
62.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64.5	0.00	0.00	0.00	0.00	9.50	0.00	0.00	0.00	0.00	0.00	0.00
Total	28853.82	28287.46	18797.17	35238.04	24392.69	22623.41	8571.26	21510.44	15602.44	20676.15	14535.70

Table 10. Estimates of relative fishing mortality at length for 4RST witch flounder, obtained directly from the ratio of estimated catch-at-length and RV estimates of trawlable population numbers at length.

Length	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
24.5	0.0000	0.0116	0.0000	0.0000	0.0001	0.0007	0.0000	0.0000	0.0000	0.0000
26.5	0.0343	0.0000	0.0000	0.0000	0.0044	0.0056	0.0000	0.0005	0.0003	0.0000
28.5	0.0693	0.0313	0.0001	0.0049	0.0120	0.0446	0.0016	0.0021	0.0054	0.0049
30.5	0.1125	0.1299	0.0186	0.0207	0.0373	0.1545	0.0170	0.0108	0.0212	0.0211
32.5	0.1919	0.2606	0.0547	0.0424	0.2012	0.2098	0.0367	0.0572	0.0430	0.0505
34.5	0.2171	0.2731	0.0842	0.0894	0.2109	0.3647	0.0865	0.0835	0.1025	0.1054
36.5	0.3126	0.4084	0.0659	0.1055	0.1756	0.8000	0.1210	0.1476	0.1237	0.2352
38.5	0.2808	0.3828	0.0946	0.1231	0.0791	0.5276	0.2094	0.1549	0.2456	0.5103
40.5	0.3332	0.3553	0.1670	0.1770	0.3515	0.6807	0.2382	0.1723	0.1939	0.4842
42.5	0.3192	0.3486	0.1892	0.2759	0.3652	1.4014	0.1485	0.1979	0.1922	0.4082
44.5	0.3128	0.3182	0.1764	0.2081	0.6472	1.3744	0.4592	0.1641	0.2357	0.3340
46.5	0.1922	0.3058	0.1760	0.2049	0.2895	0.9942	0.1219	0.4460	0.2758	0.3294
48.5	0.2182	0.2509	0.2358	0.1050	0.3018	0.6465	0.1427	0.2362	0.2861	1.3700
50.5	0.2018	0.3894	0.0930	0.3249	2.7987	0.3058	0.2166	1.1388	0.1299	0.4533
52.5	0.2208	0.2212	0.2262	0.2163	0.7165	0.9208	0.2045	0.1045	0.3225	0.2742
54+	0.2912	0.0816	0.2694	0.3340	0.4129	0.9664	1.1514	0.1027	0.2088	0.3244

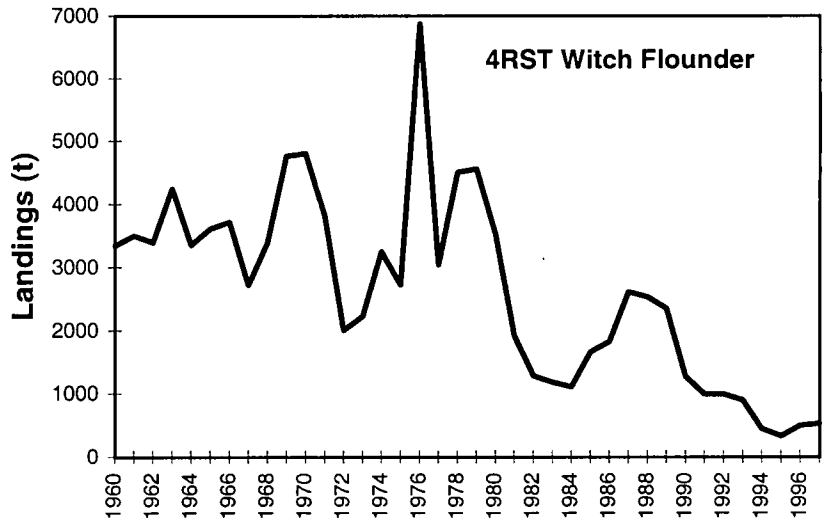


Figure 1. Landings of witch flounder in NAFO divisions 4RST.

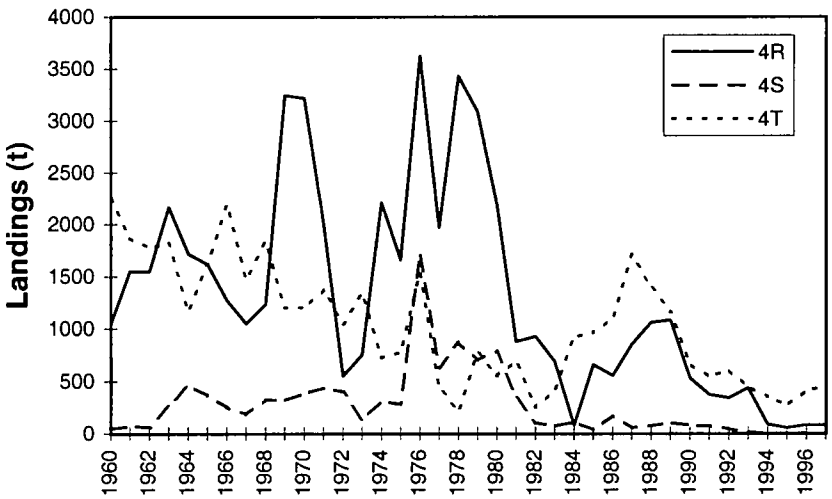


Figure 2. Landings of 4RST witch flounder by NAFO division.

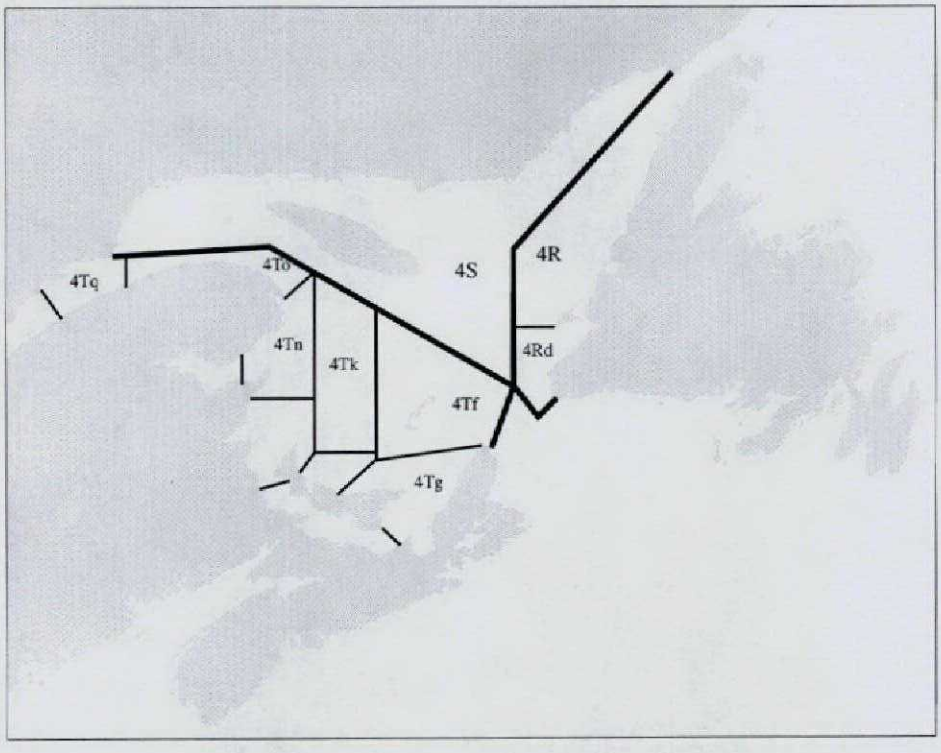


Figure 3. NAFO divisions 4R, 4S and 4T (bordered by heavy lines). Unit areas where most witch flounder are caught in commercial fisheries are labelled in lower case.

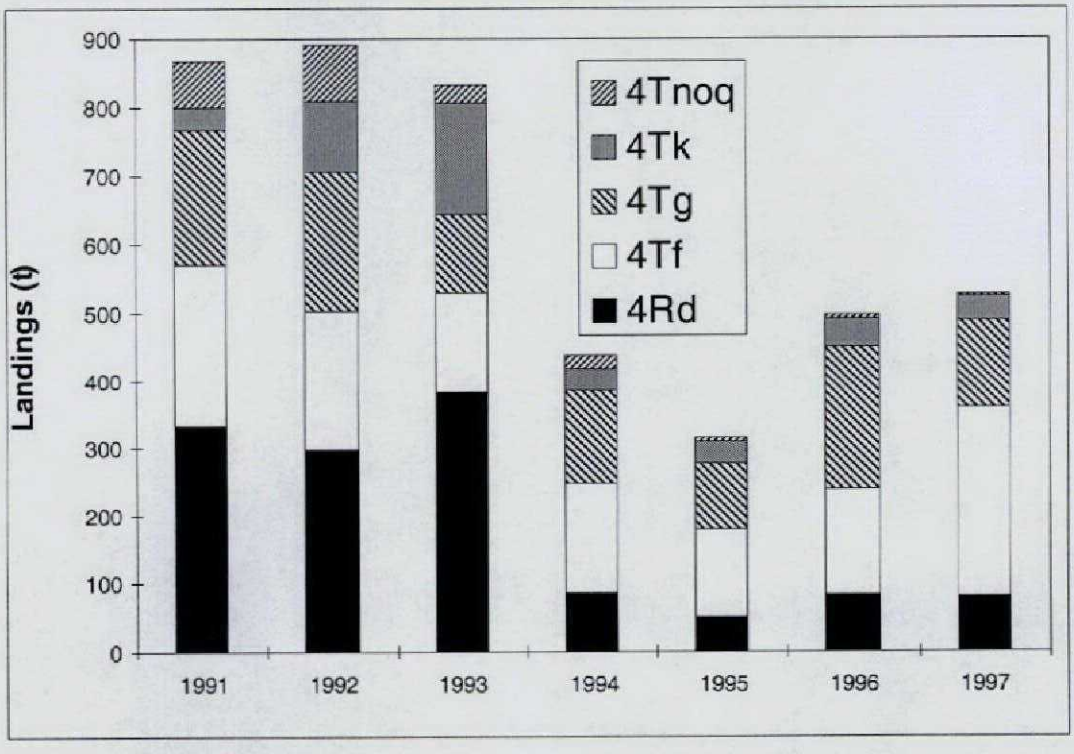


Figure 4. Landings of 4RST witch flounder by NAFO unit area. The unit areas shown account for 90-100% of the landings in each year.

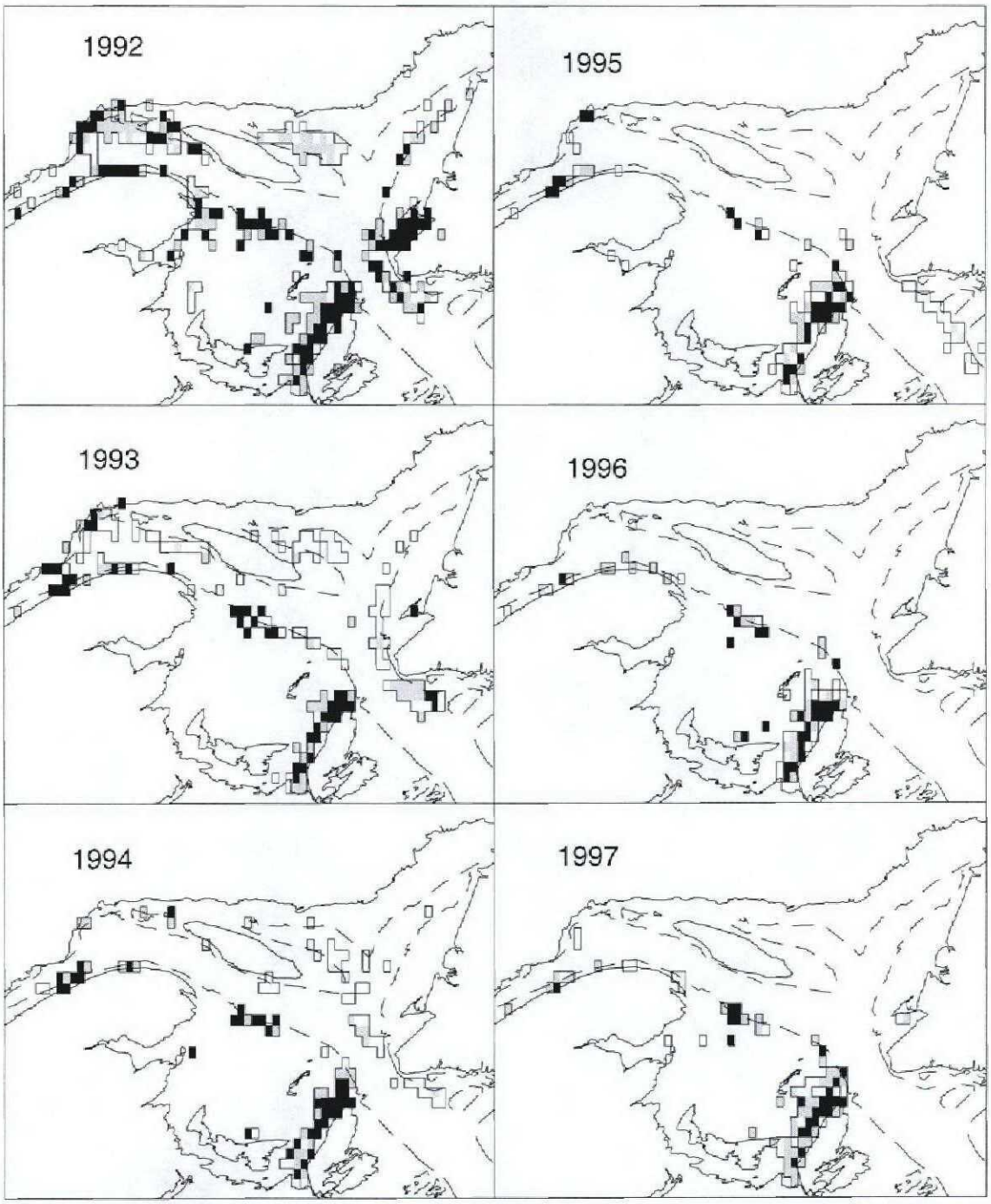


Figure 5. Distribution of commercial fishery catches of witch flounder in 10-minute blocks, 1992-1997. Three levels of catch are distinguished: average 33rd percentile and lower (0.001-0.1 tonne, white blocks), 33rd-67th percentile (0.11-0.6 tonne, gray blocks), greater than 67th percentile (>0.6 tonne, blck blocks). Coordinates of catches landed in Newfoundland ports are not available since 1994.

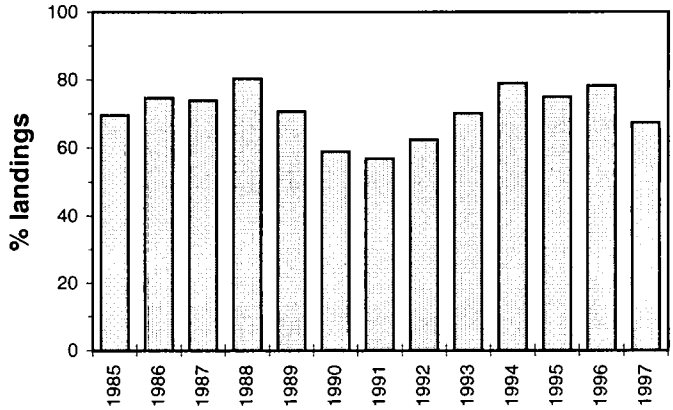


Figure 6. Percent of mobile-gear landings of 4RST witch flounder with witch as the directed species.

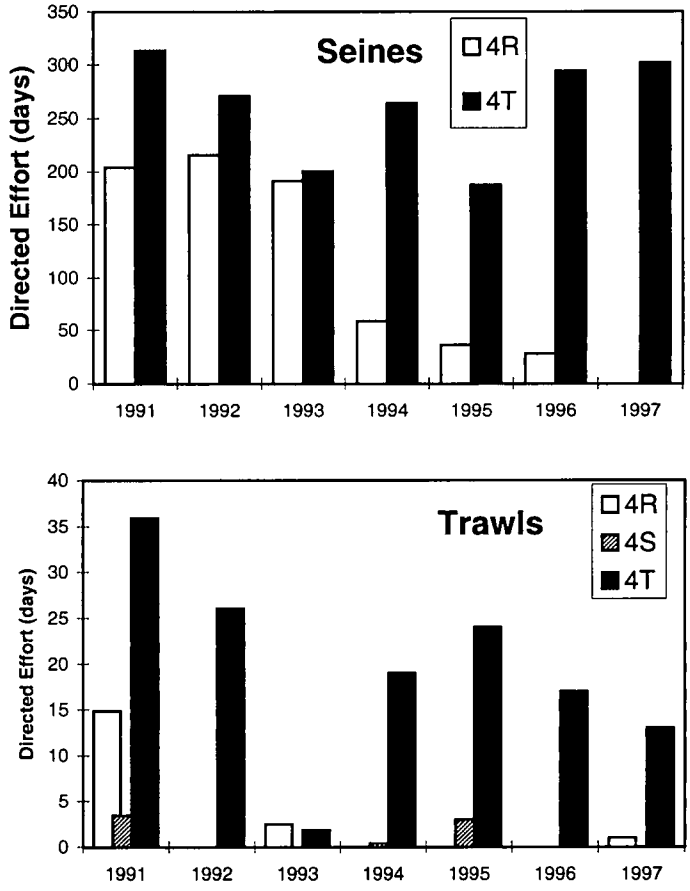


Figure 7. Fishing effort of seines and trawls directing for witch flounder by NAFO division.

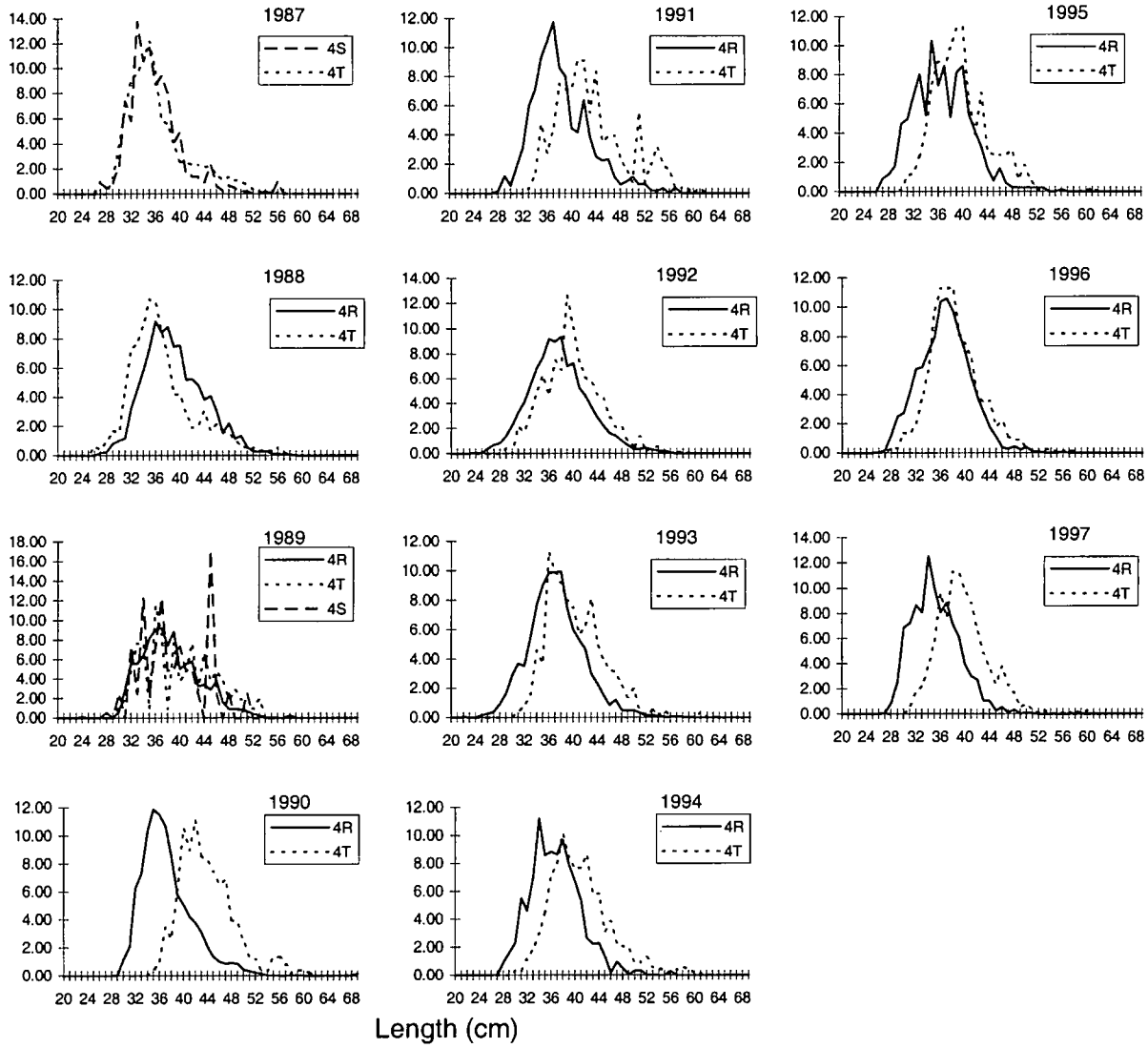


Figure 8. Length frequencies (%) of witch flounder sampled from mobile-gear landings in NAFO divisions 4RST, 1987-1997.

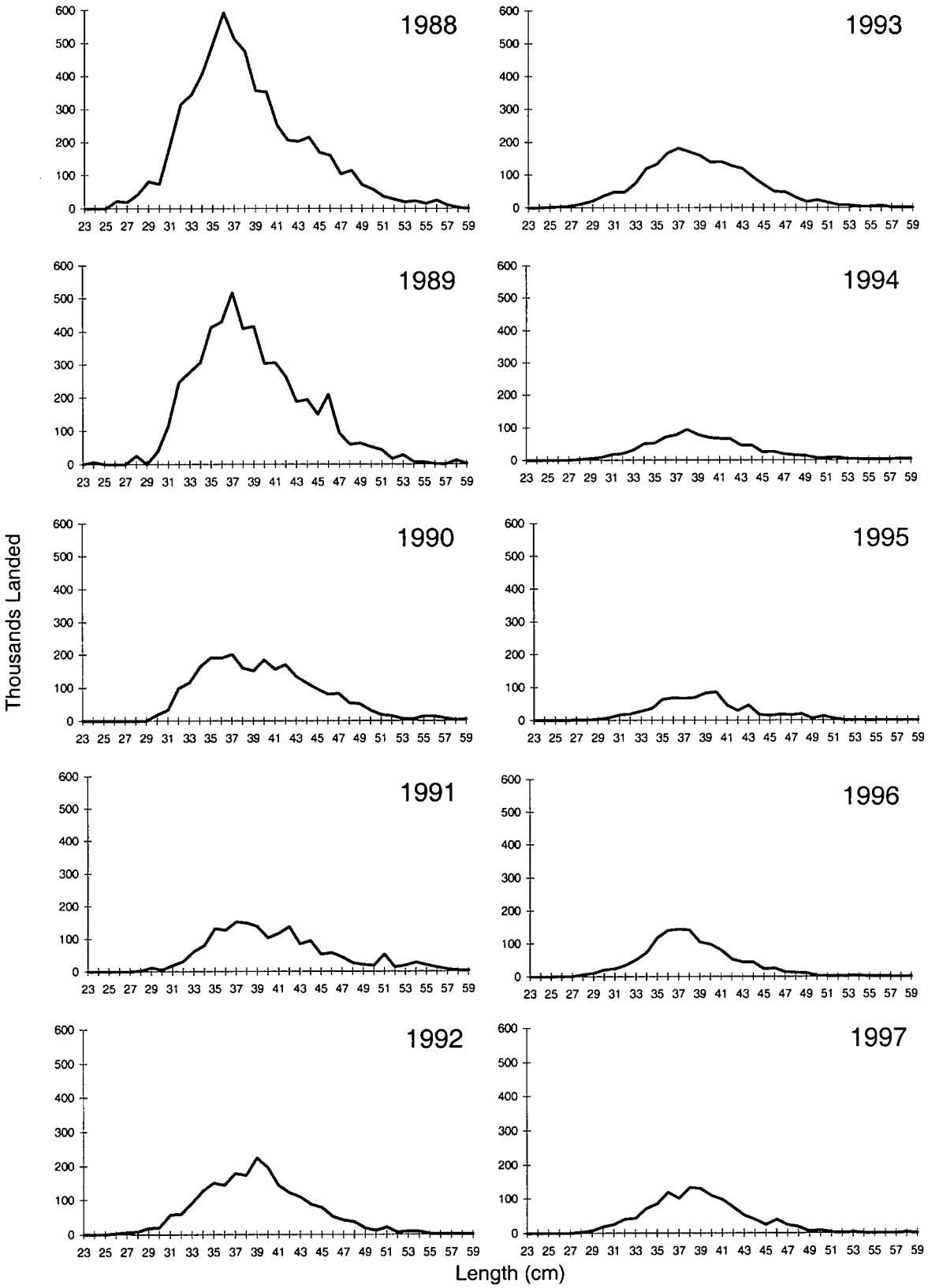


Figure 9. Estimated catch-at-length for mobile-gear landings of witch flounder in NAFO divisions 4RST, 1988-1997.

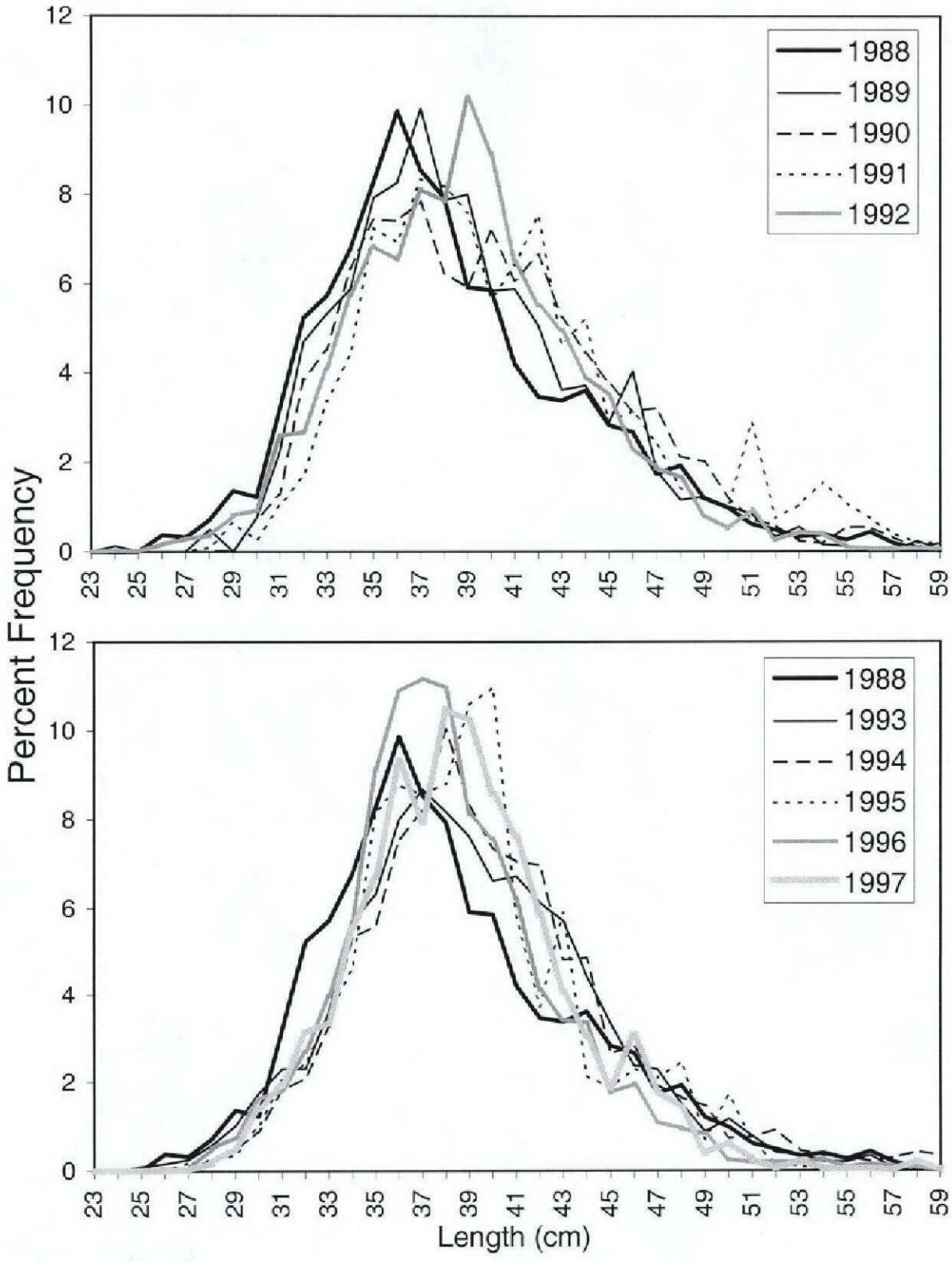


Figure 10. Percent length composition of mobile gear landings of 4RST witch flounder.

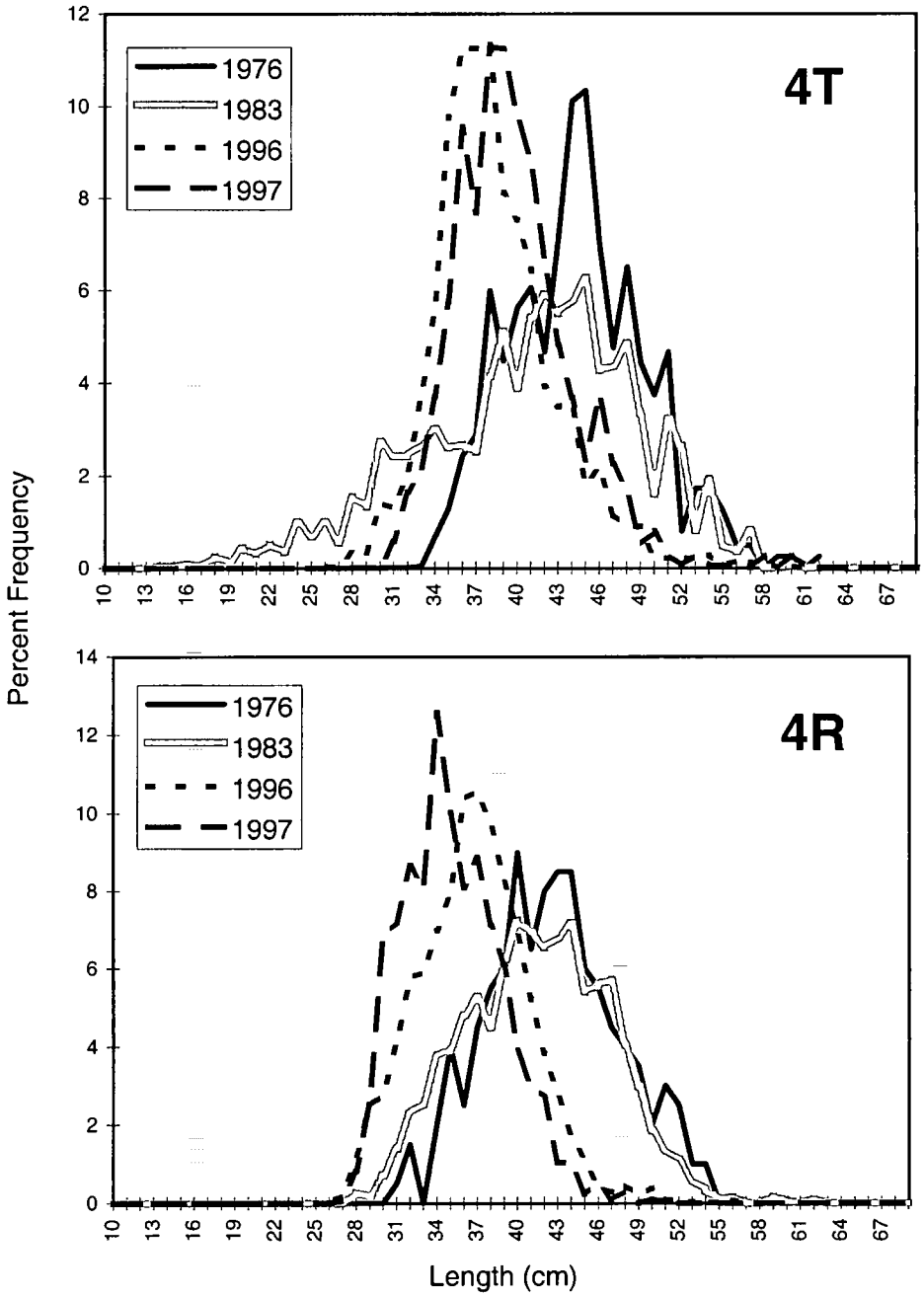


Figure 11. Comparison of length frequencies of witch flounder landed by mobile gears in 4T and 4R in 1976, 1983, 1996 and 1997.

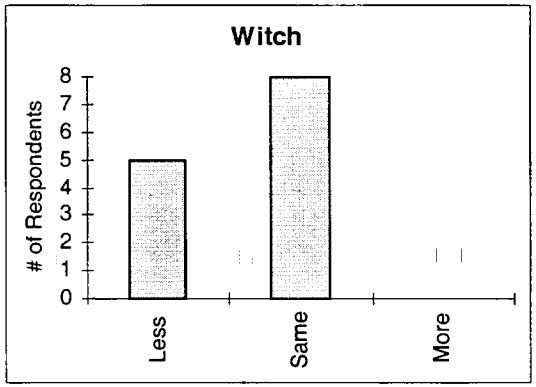


Figure 12. Comparison to previous years of the amount of fishing gear used in 1997 (Note: Witch flounder was their 'first, second, or third priority' in 1997).

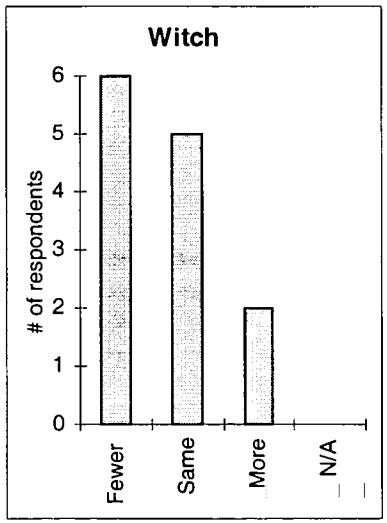


Figure 13. Comparison to 1996 of the number of days spent fishing for groundfish in 1997 (Note: Witch flounder was their 'first, second, or third priority' in 1997).

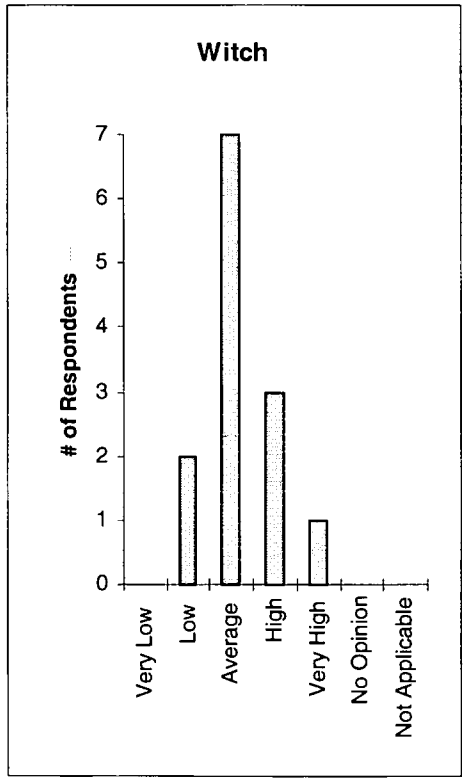


Figure 14. Opinions of respondents concerning the abundance of witch flounder in 1997.

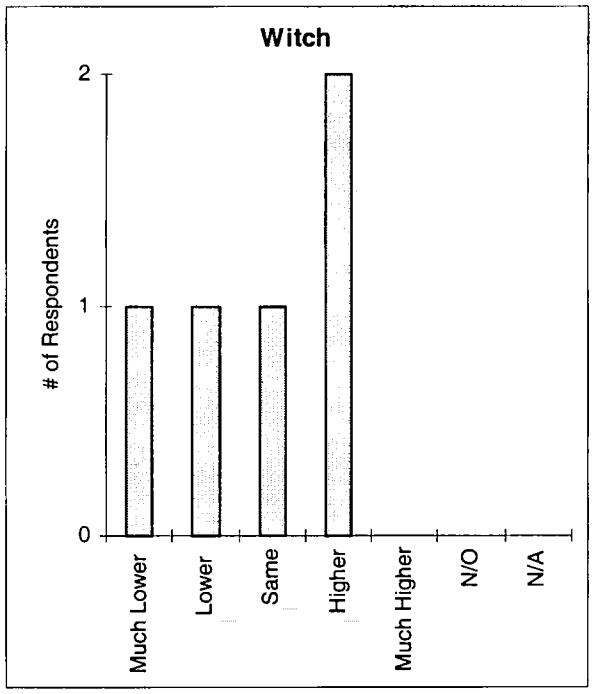


Figure 15a. Opinions of respondents asked to compare the abundance of witch flounder in 1997 with its abundance from 1992-1996.

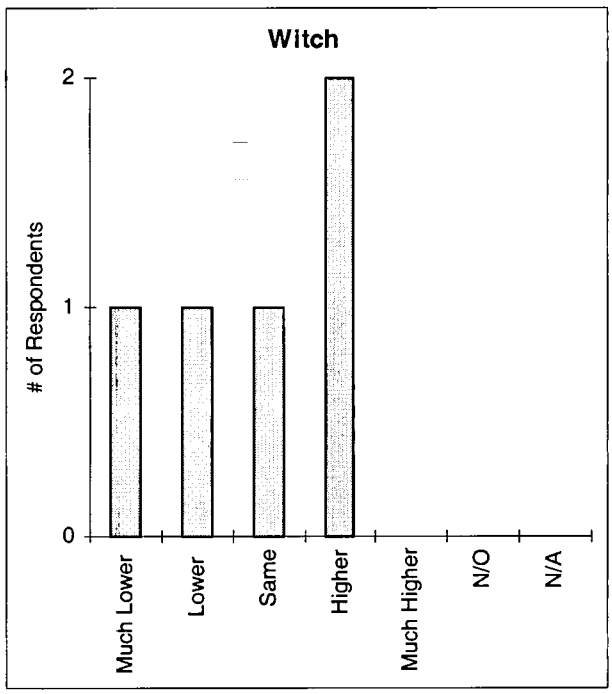


Figure 15b. Opinions of respondents asked to compare the abundance of witch flounder in 1997 with its abundance during all the years fishing for this species.

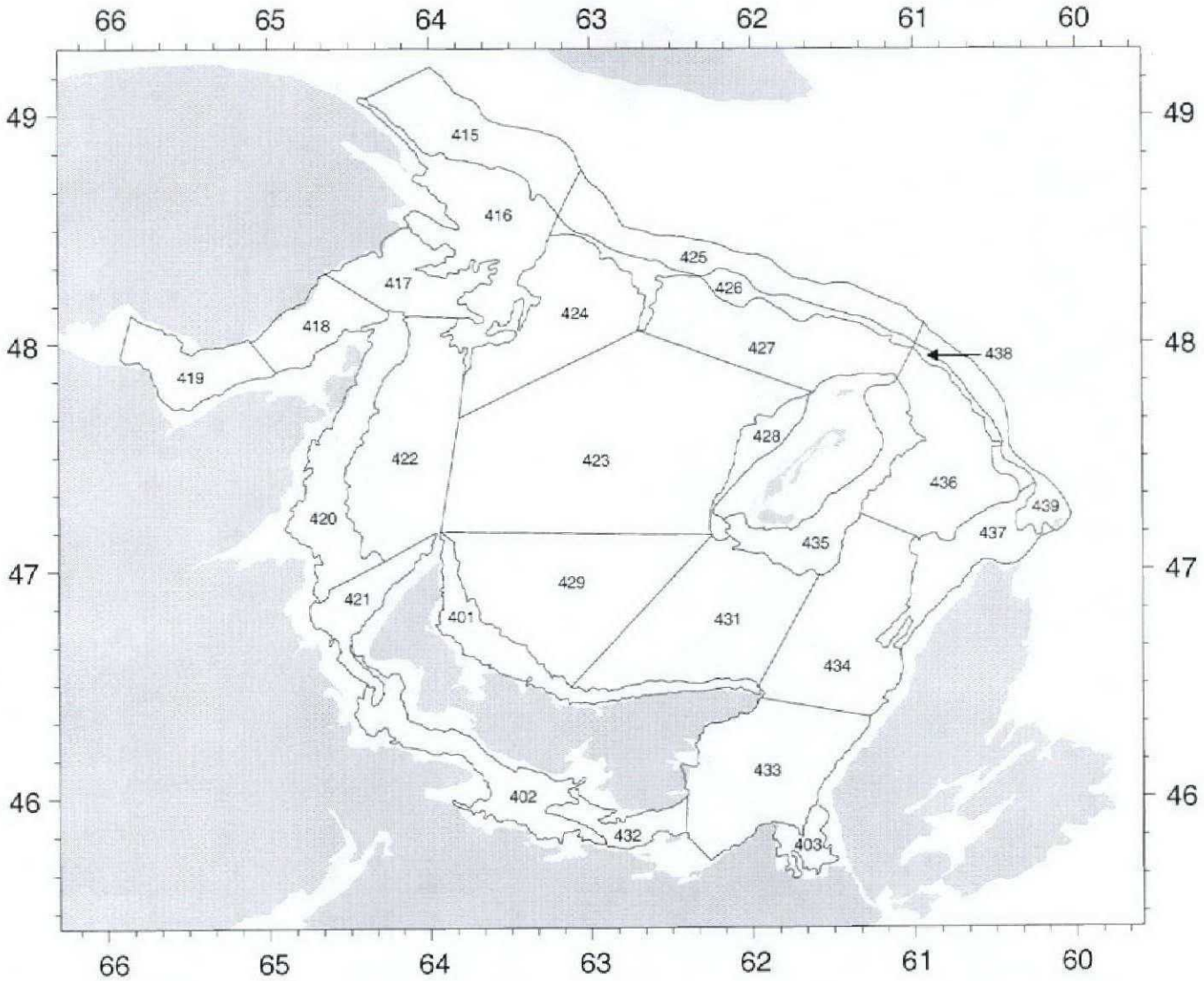


Figure 16. Stratification for the September groundfish abundance survey of the southern Gulf of St. Lawrence.

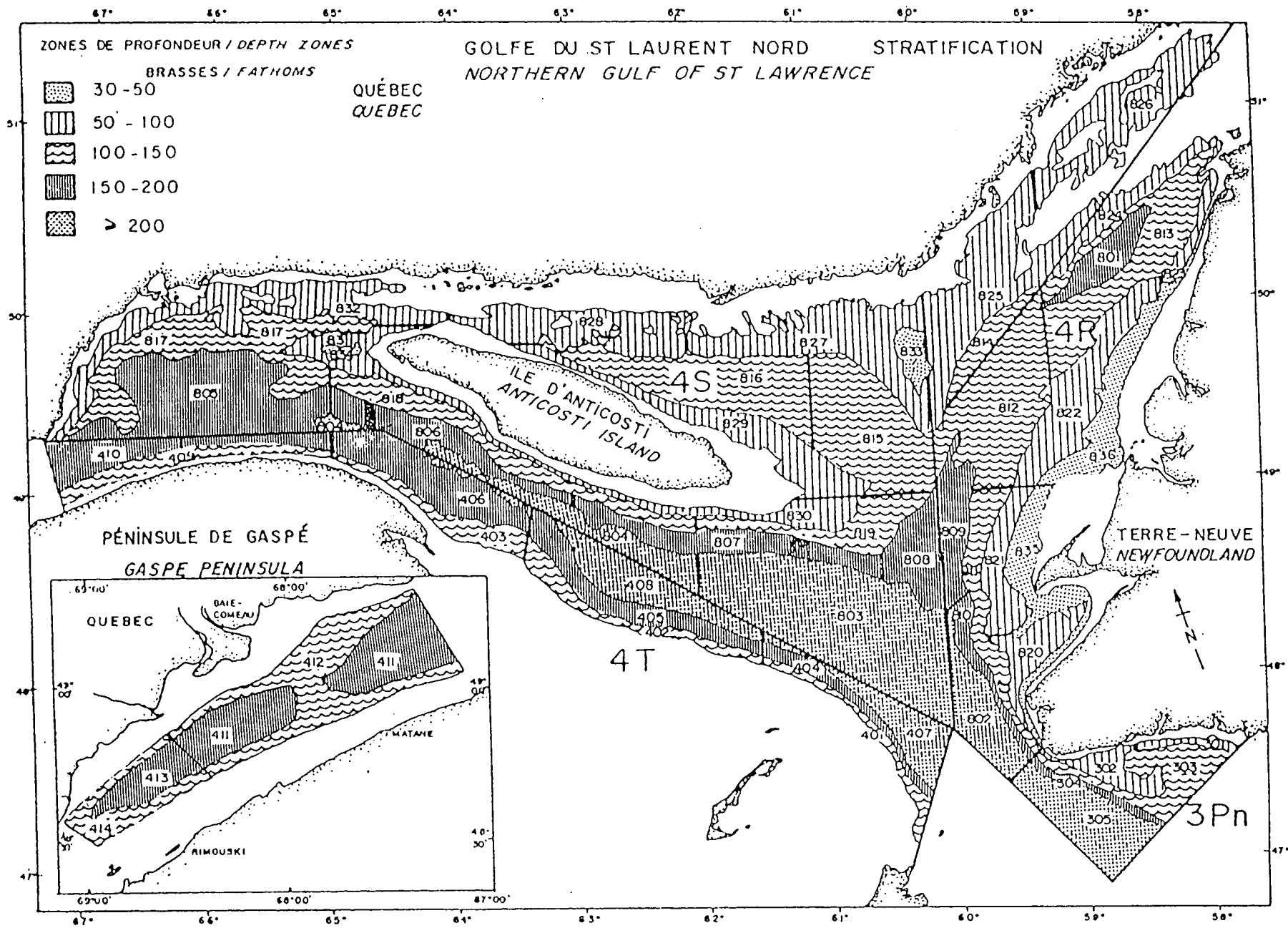
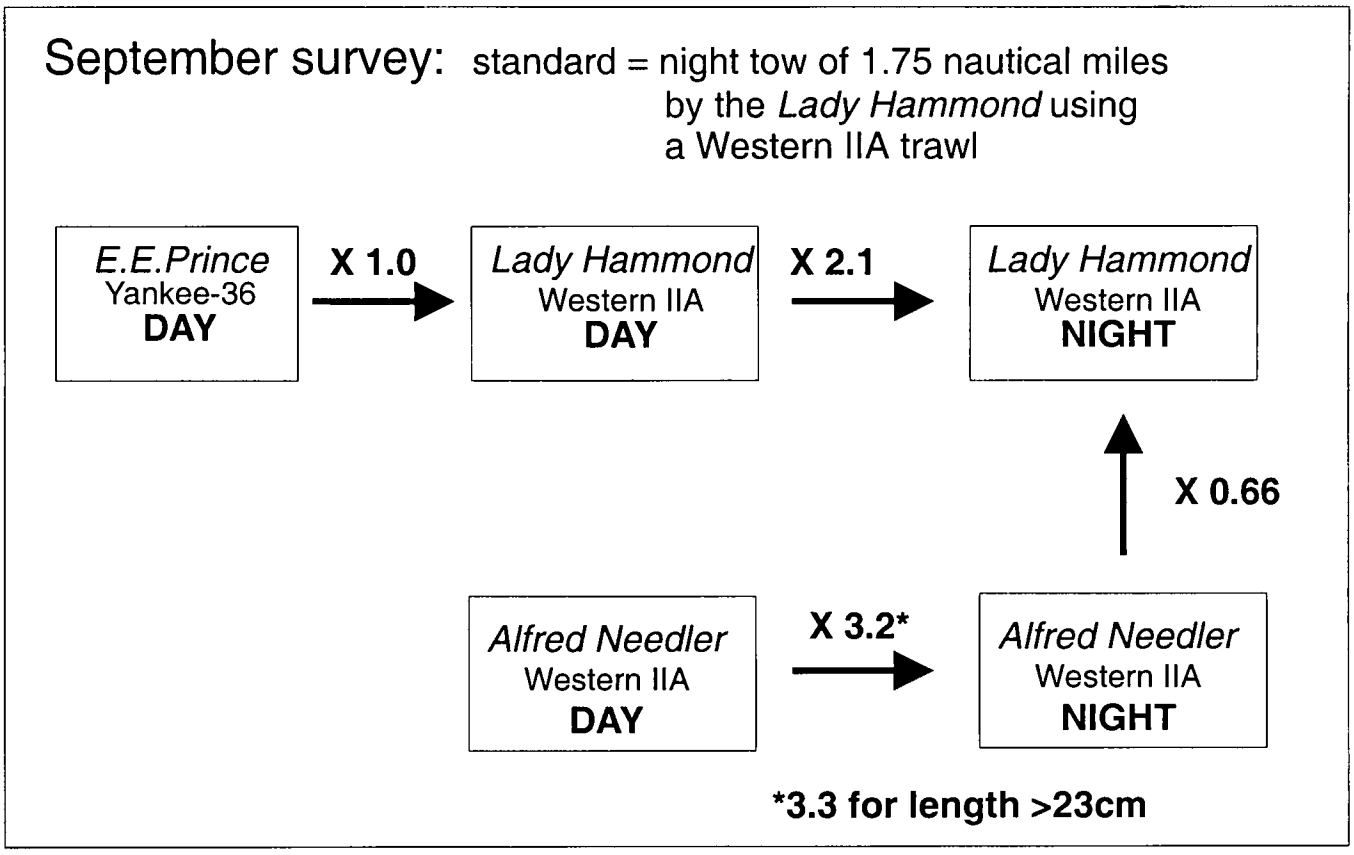


Figure 17. Stratification of northern Gulf surveys of the Laurention Region, DFO.



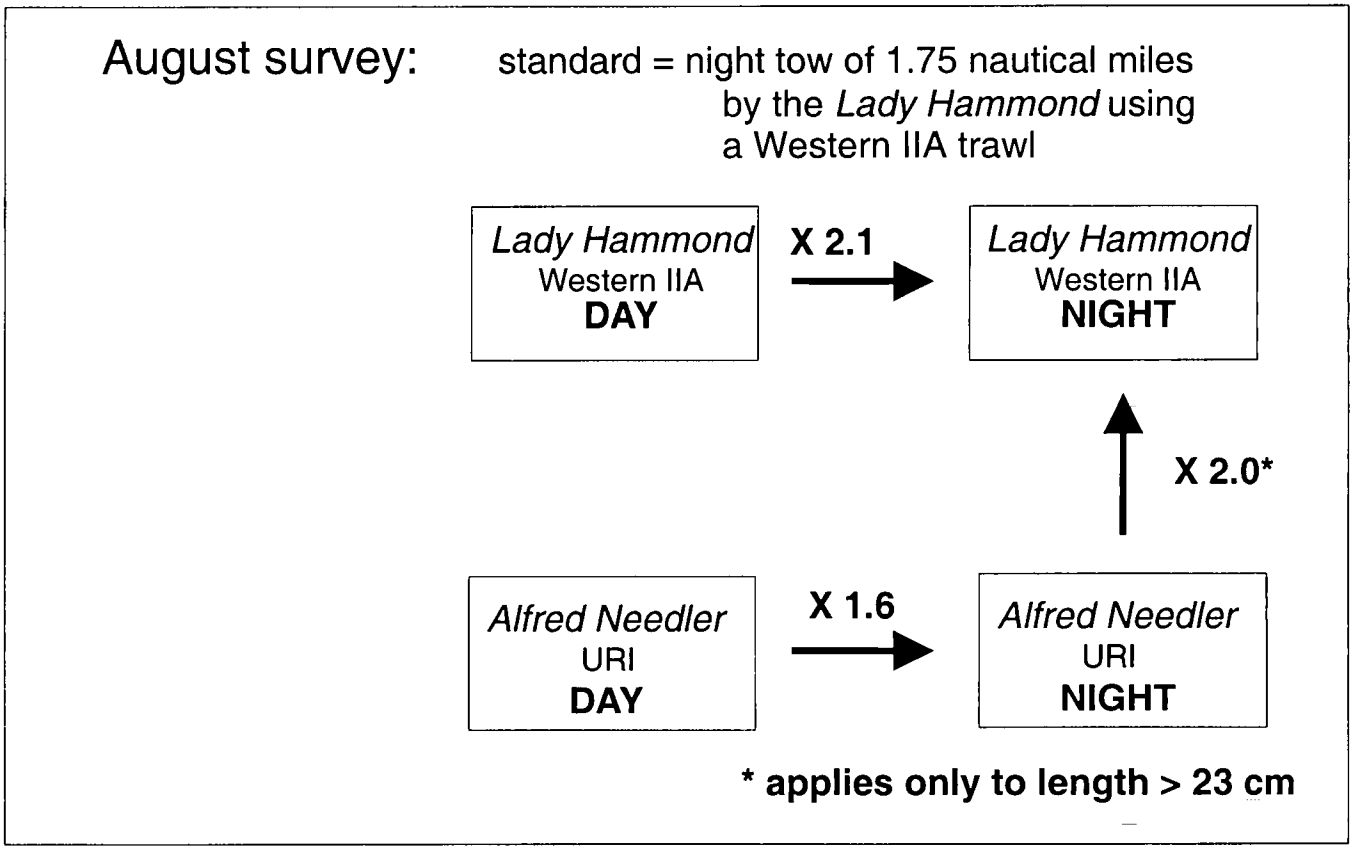


Figure 18. Construction of a consistent series of mean catch rates for witch flounder in the summer surveys of the Gulf of St. Lawrence. All catches are standardized to a tow of 1.75 nautical miles before applying conversion factors.

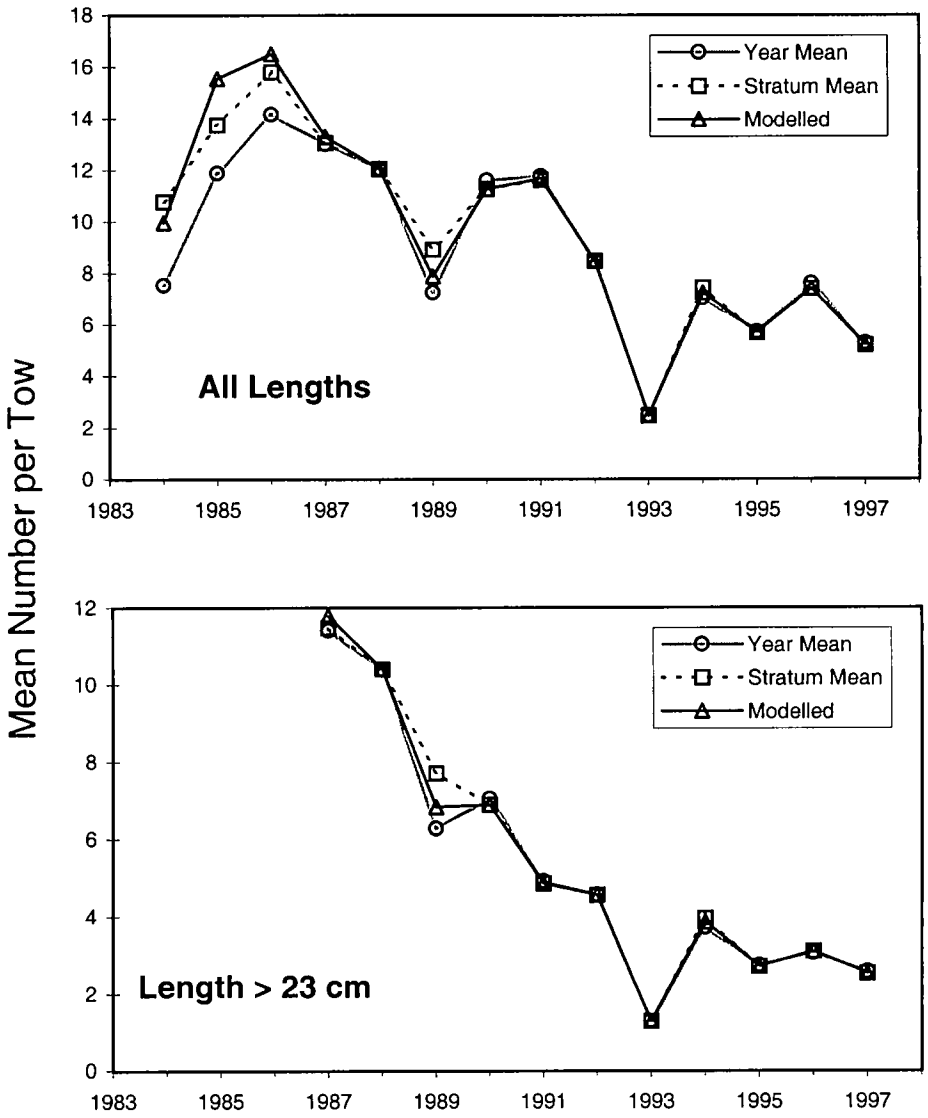


Figure 19. Comparison of mean catch rates of witch flounder in the August surveys of the northern Gulf of St. Lawrence using various methods to replace missing stratum means. Catches are adjusted to a standard night tow of 1.75 nautical miles but are not adjusted for the change in vessel and gear in 1990.

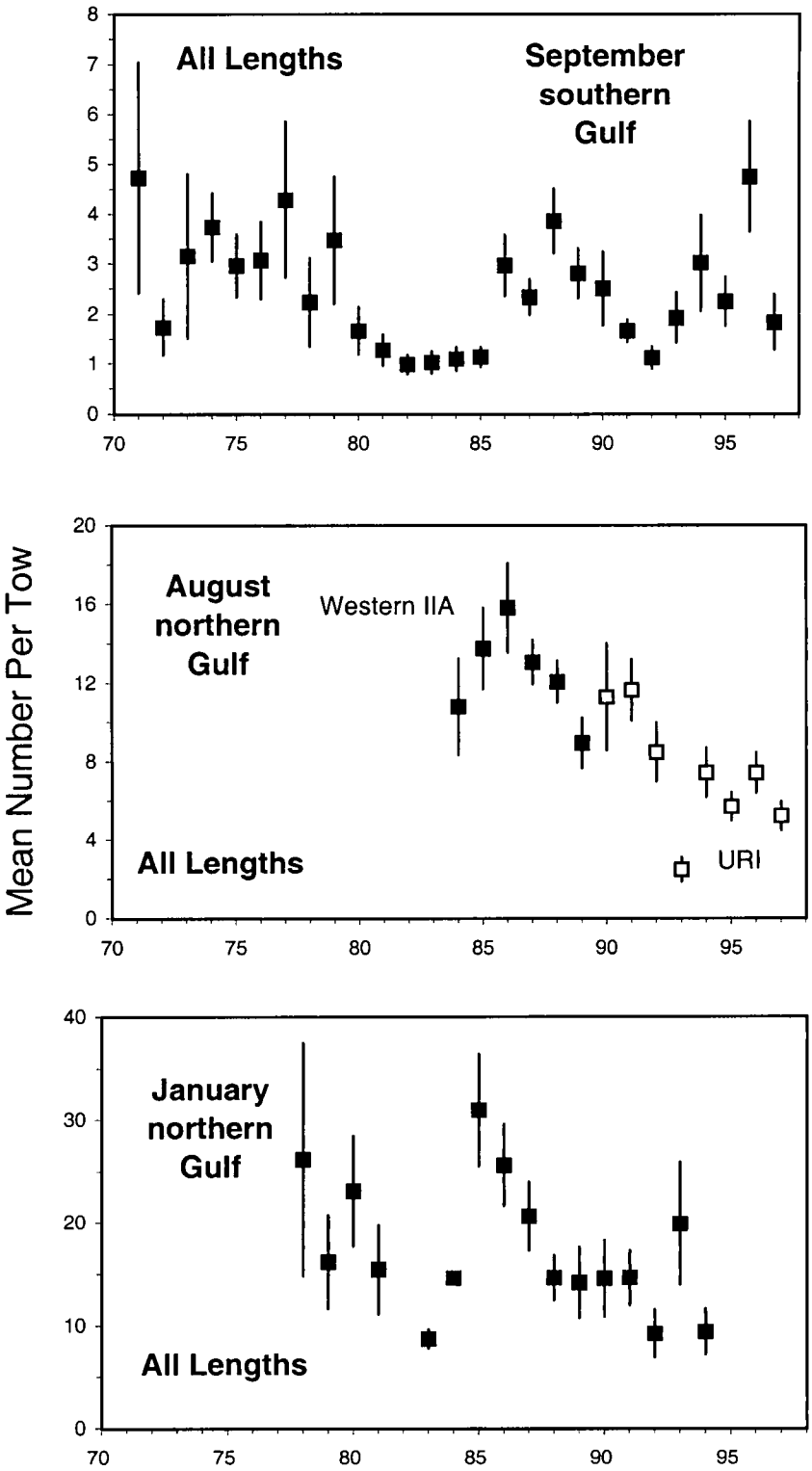


Figure 20. Mean catch rates of witch flounder in surveys of the Gulf of St. Lawrence. Vertical bars are approximate SE. Catches in the summer surveys are adjusted to a standard night tow of 1.75 nautical miles. No adjustment has been made for the change in vessel and gear in the August survey of the northern Gulf in 1990. Set 144 is omitted from the 1986 August survey (if included the mean for this survey is 34.1 with a SE of 18.4).

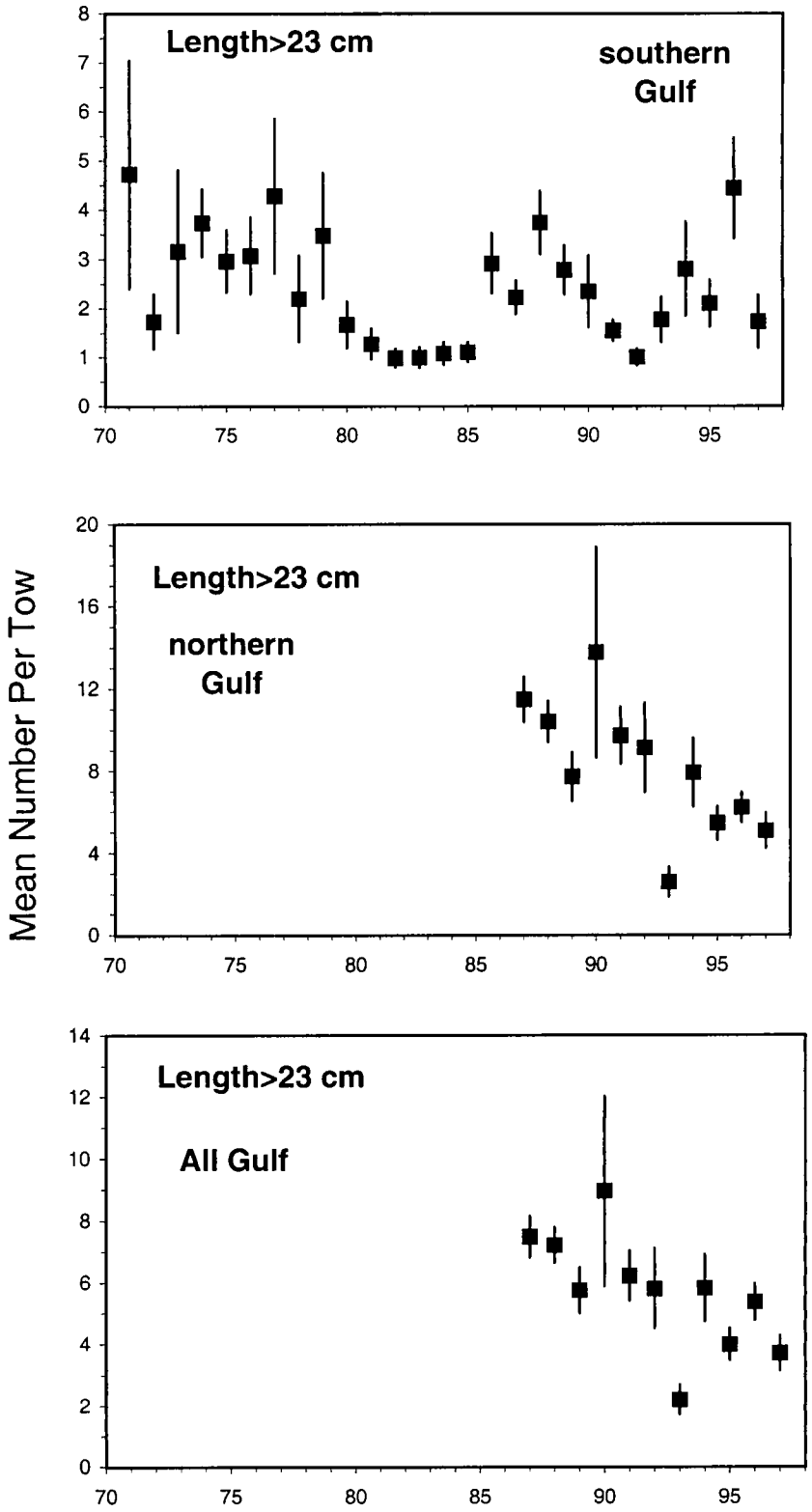


Figure 21. Mean catch rate of witch flounder 24 cm or greater in length in the summer surveys of the Gulf of St. Lawrence. Vertical bars are approximate SE. Catches are adjusted to a standard night tow of 1.75 nautical miles by the Lady Hammond using a Western IIA trawl.

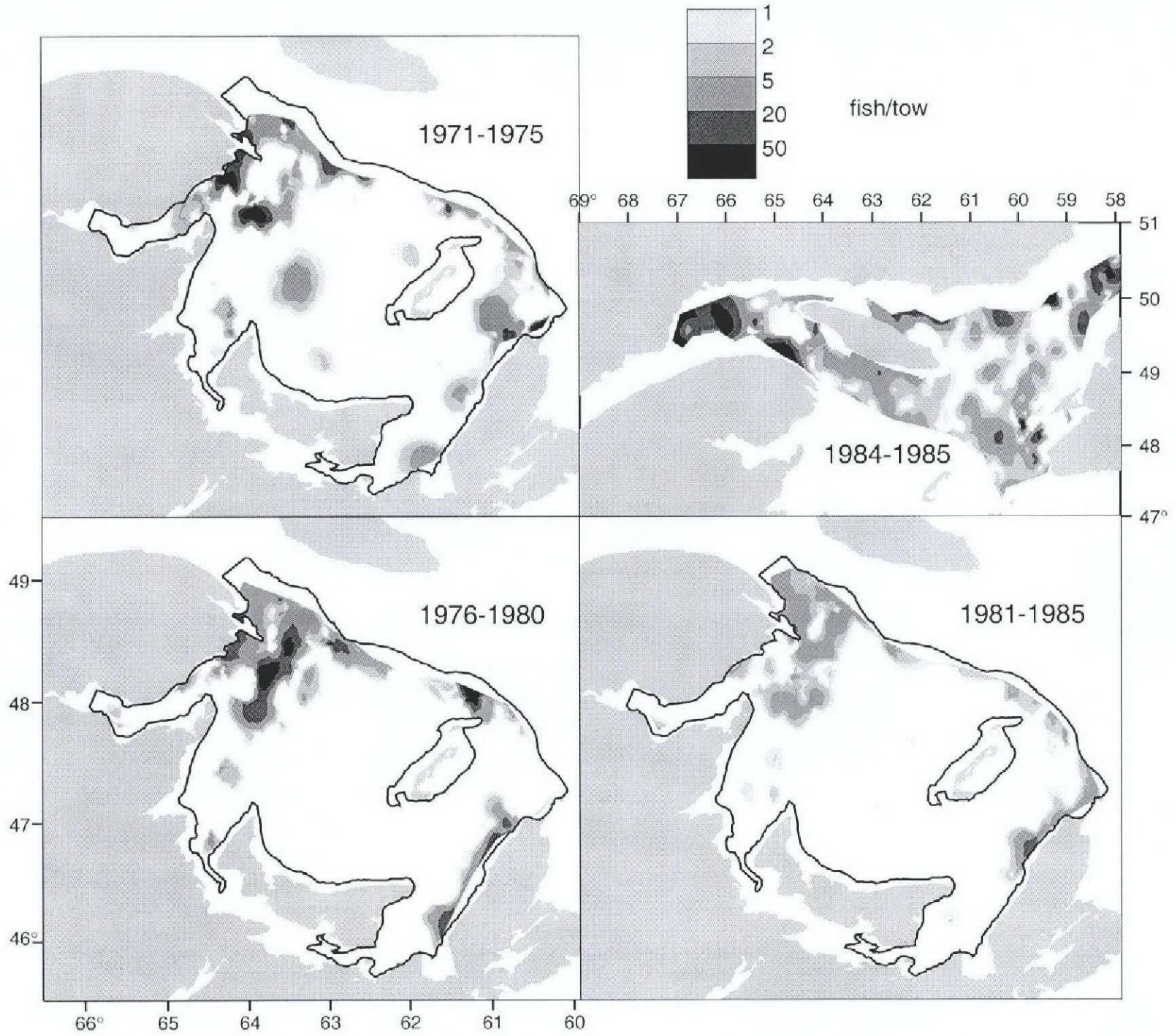


Fig. 22. Distribution of witch flounder catches during the summer surveys of the Gulf of St. Lawrence.

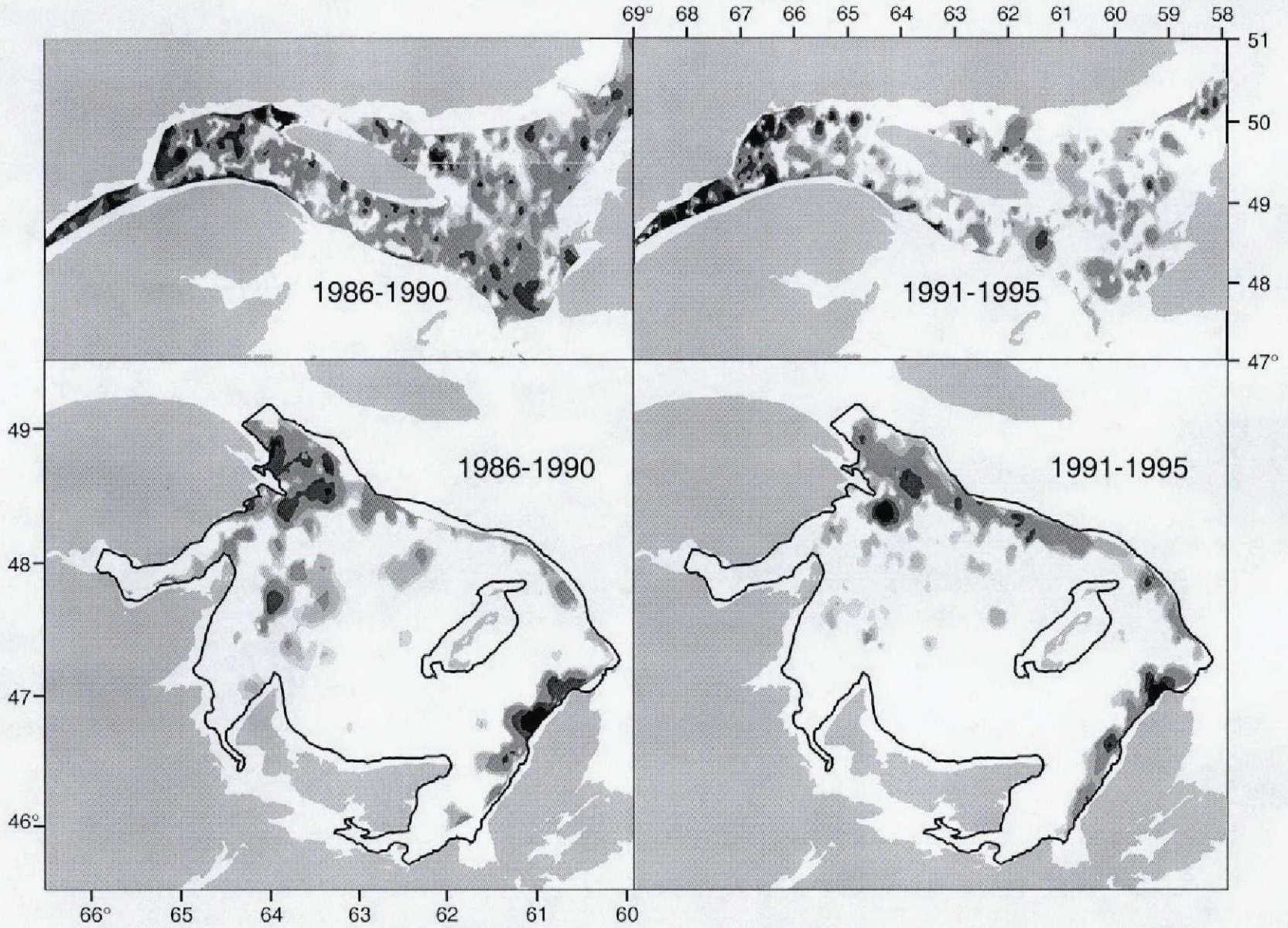


Fig. 22. cont'd. Note that gear and vessel changed in 1990 in the northern Gulf.

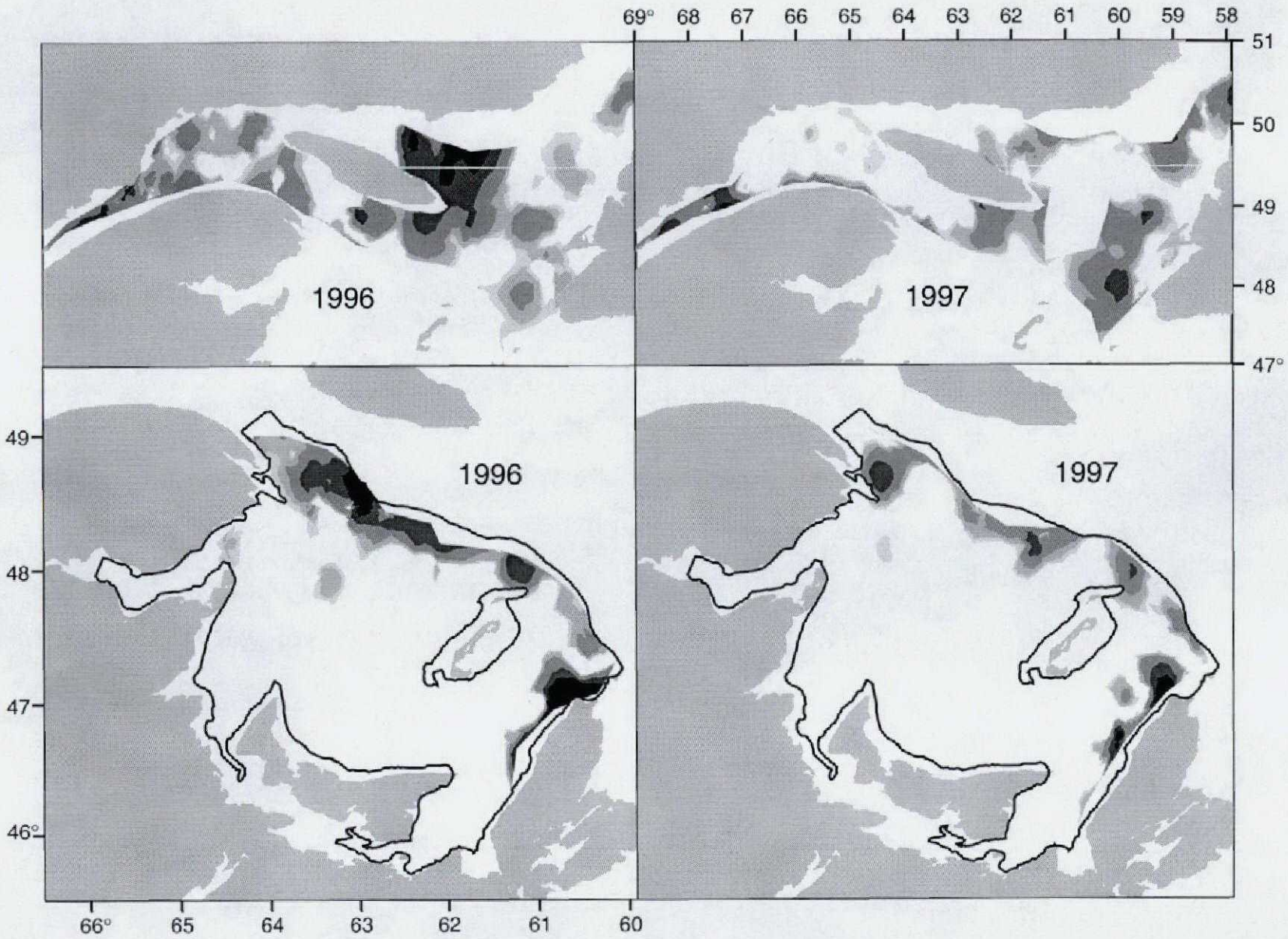


Fig. 22. cont'd. Catch standardization described in captions for Figures 25 and 26.

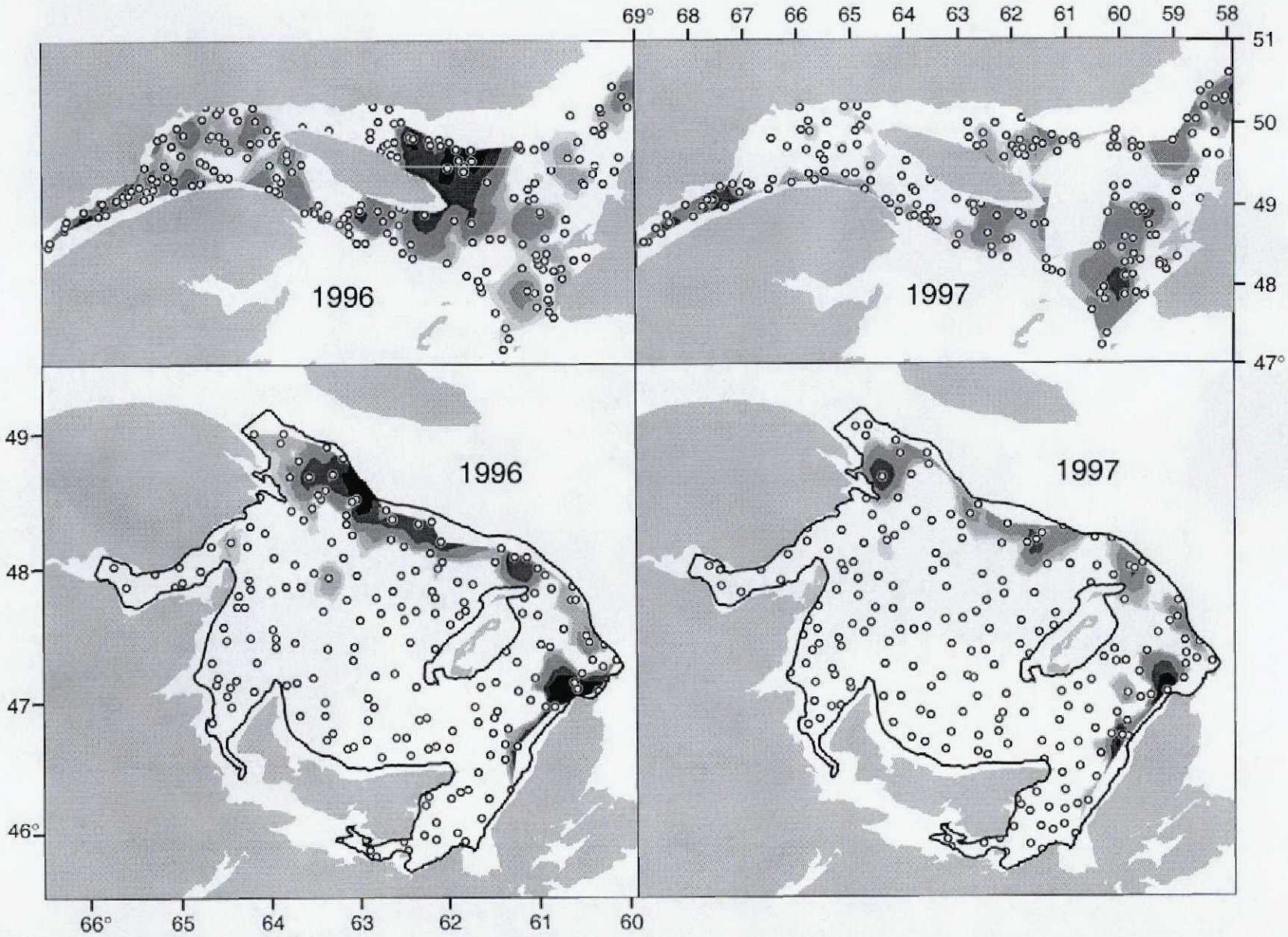


Fig. 22. cont'd. Location of tows in the 1996 and 1997 summer surveys.

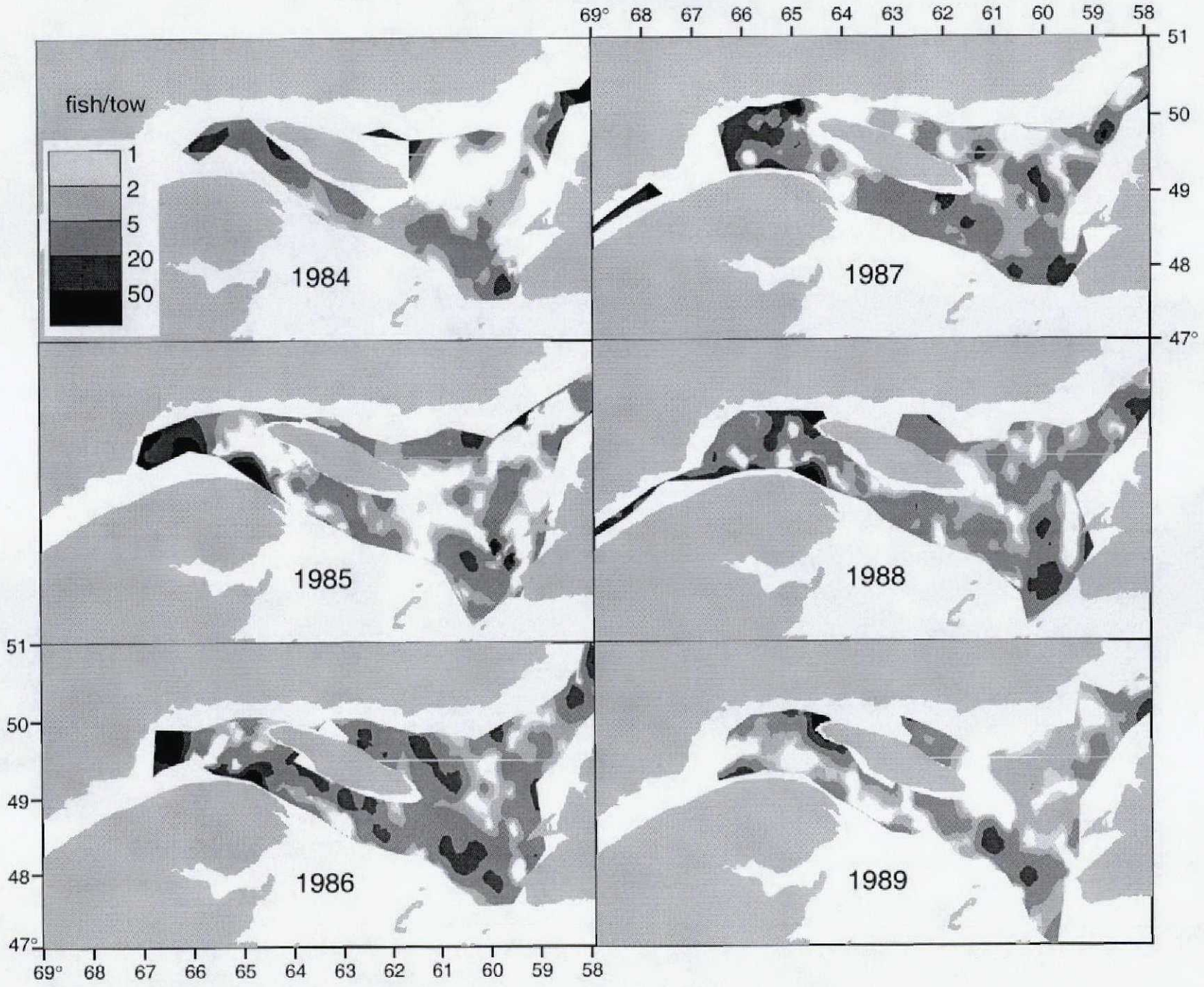


Fig. 23. Distribution of witch flounder catches in August surveys with the Western IIA trawl.

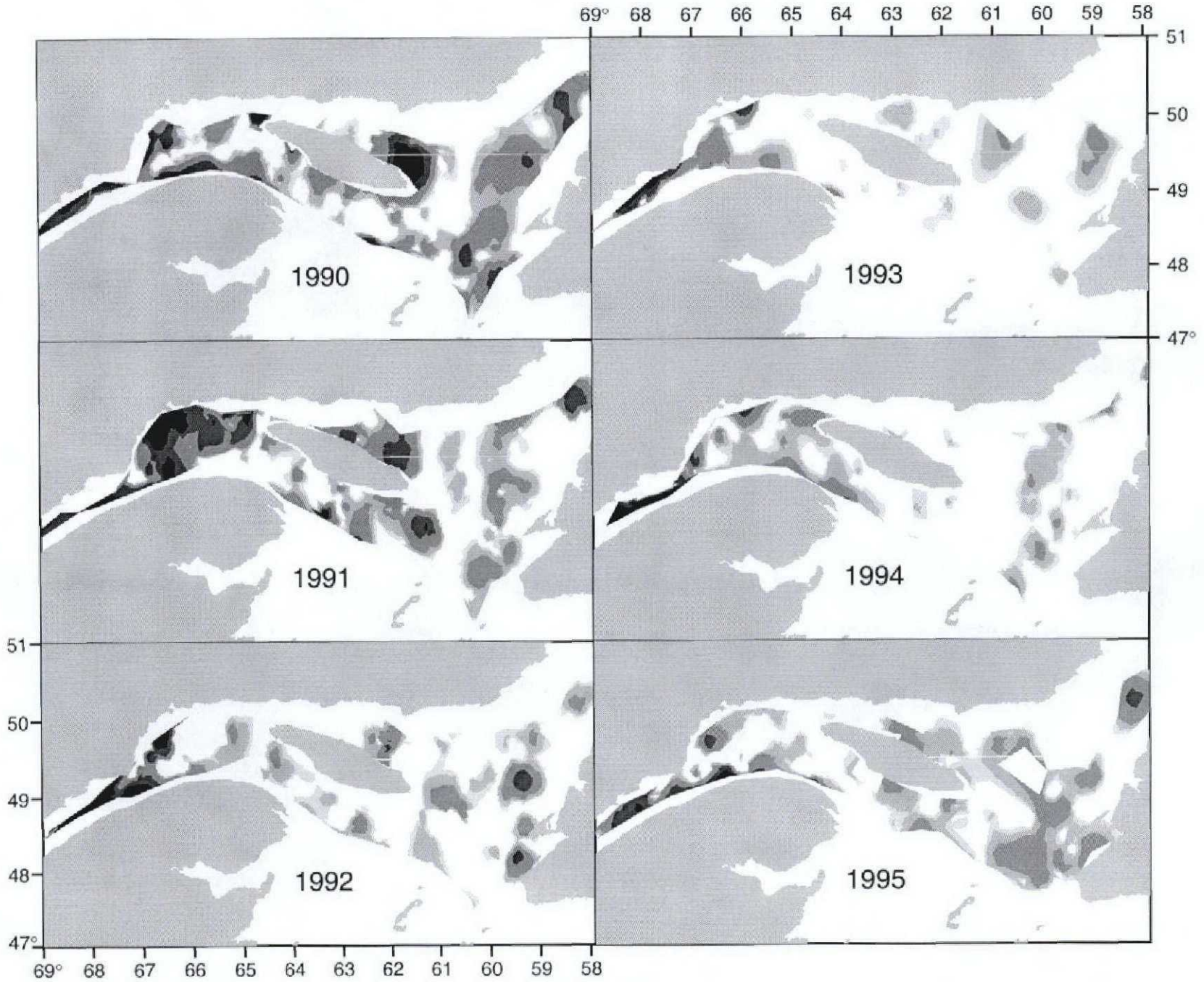


Fig. 24. Distribution of witch flounder catches in August surveys with the URI trawl. See Fig. 23 for legend.

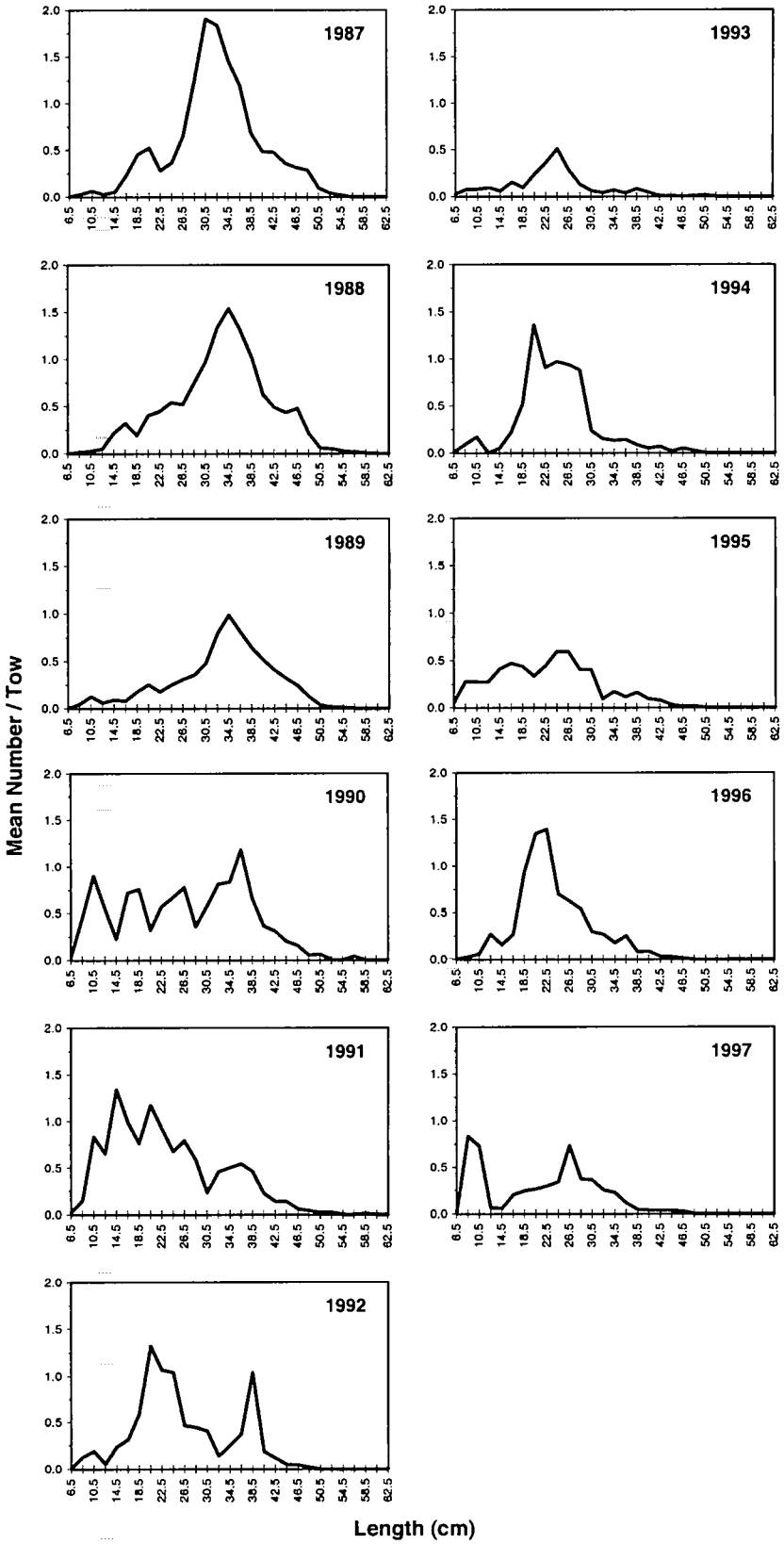


Figure 25. Stratified mean length frequencies of witch flounder caught in the August surveys of the northern Gulf of St. Lawrence. Catches are standardized to a night tow of 1.75 nautical miles by the Lady Hammond using a Western IIA trawl (1987-1989) or the Alfred Needler using a URI trawl (1990-1997).

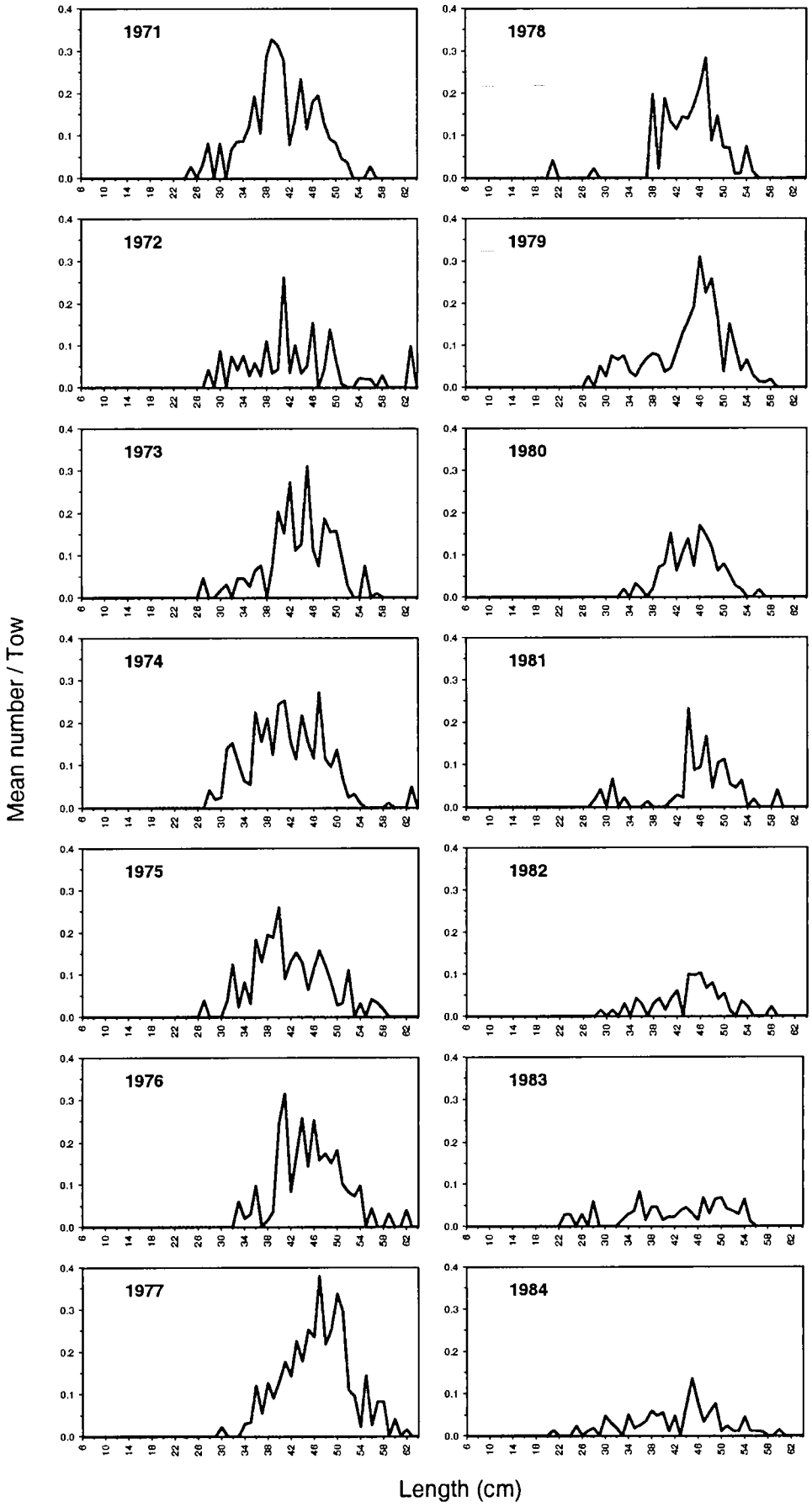


Figure 26. Stratifed mean length frequencies of witch flounder caught in the September surveys of the southern Gulf of St. Lawrence. Catches are adjusted to a standard night tow of 1.75 nautical miles by the Lady Hammond using a Western IIA trawl.

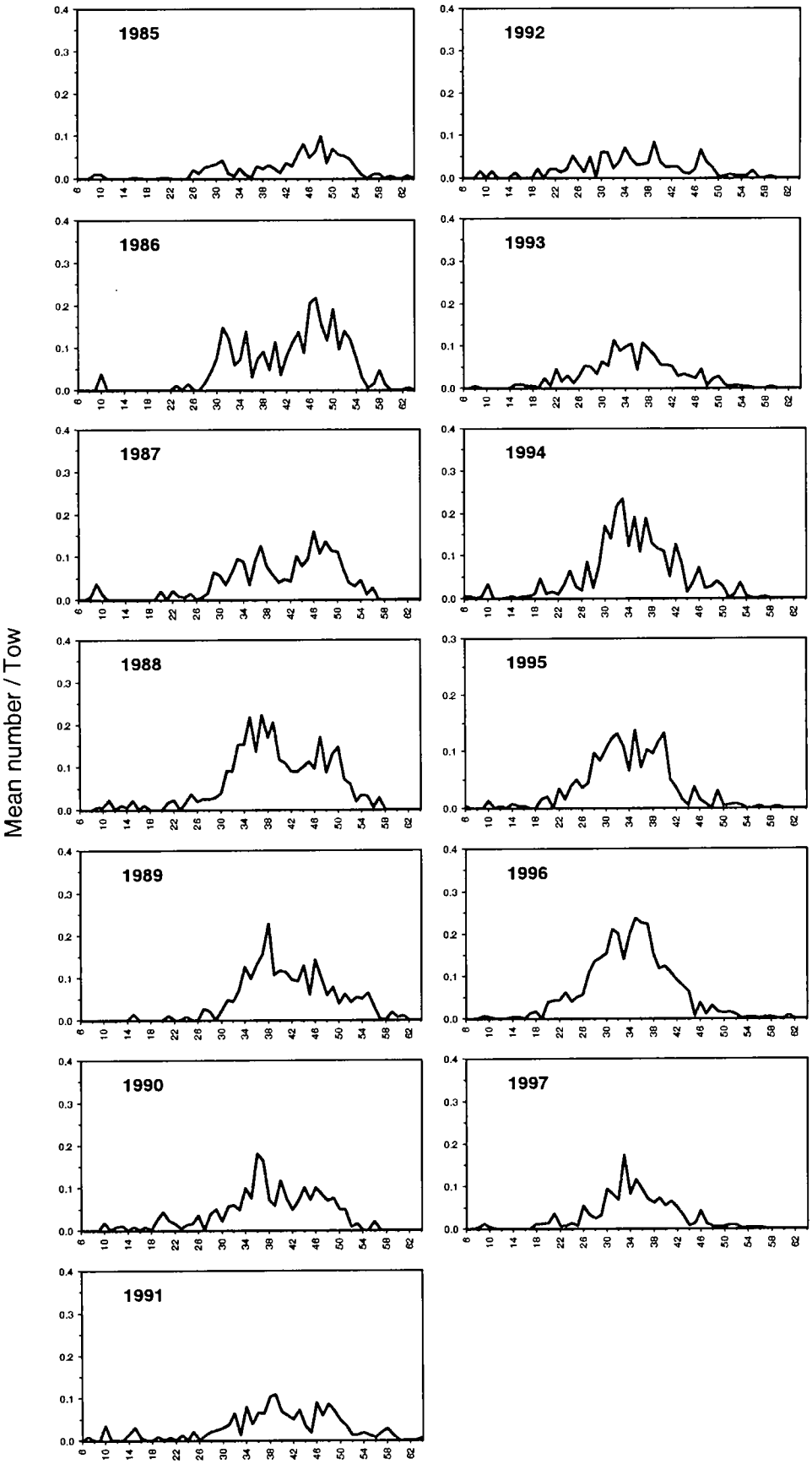
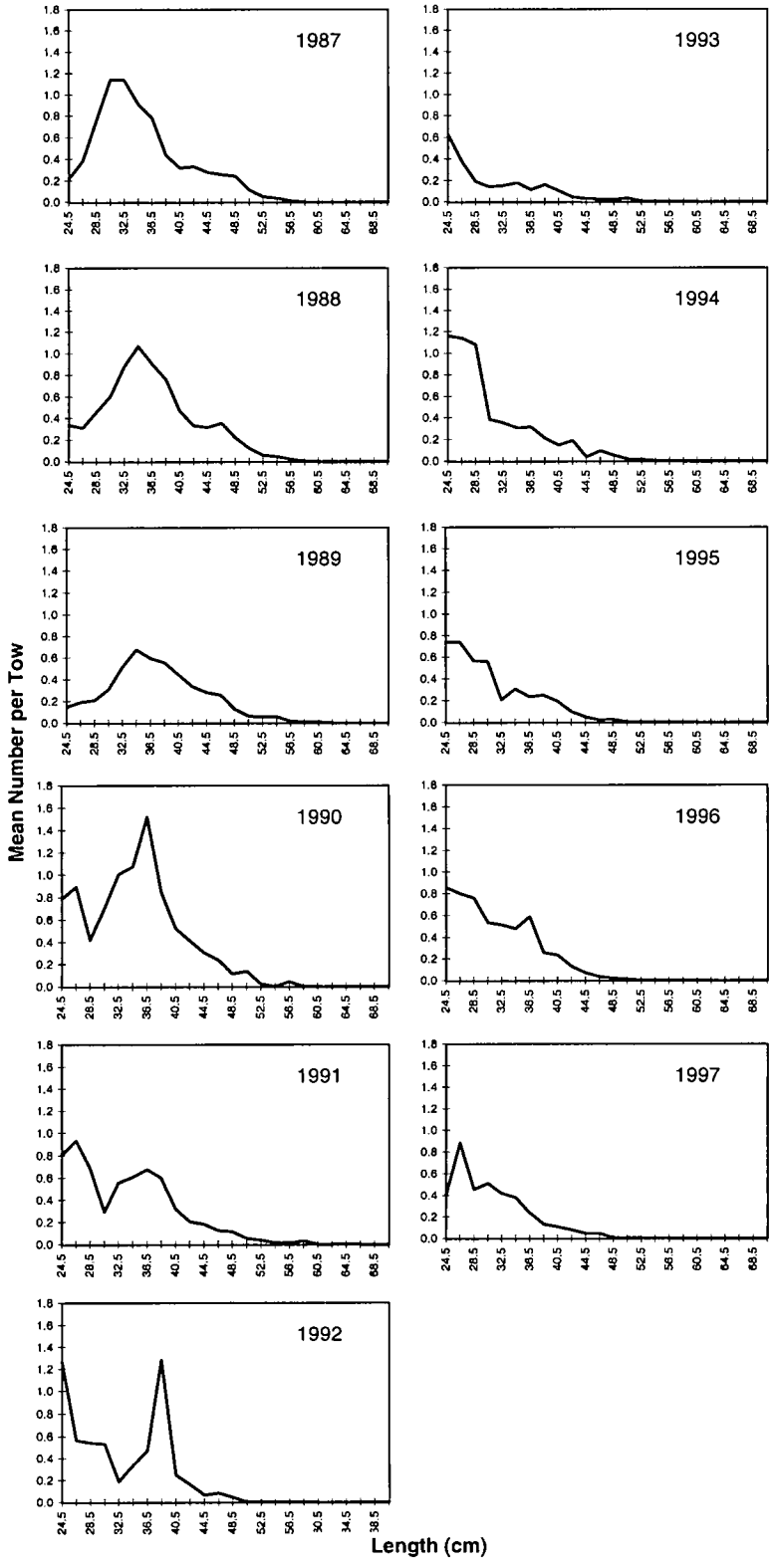

1985
1992
1986
1993
1987
1994
1988
1995
1989
1996
1990
1997
1991
Mean number / Tow
Length (cm)

Fig. 26. cont'd.



Percent greater than 30 cm in length

Year	%
1987	82
1988	85
1989	89
1990	77
1991	61
1992	59
1993	46
1994	39
1995	49
1996	54
1997	53

Figure 27. Stratified mean length frequencies of witch flounder 24 cm or greater in length caught in the summer surveys of the Gulf of St. Lawrence. Catches are adjusted to a standard night tow of 1.75 nautical miles by the Lady Hammond using a Western IIA trawl.

	Relative abundance by size class			
	24-29	30-39	40-49	>49
1987-90	4975	15993	5985	841
1994-97	9342	7005	1651	83
%change	88	-56	-72	-90

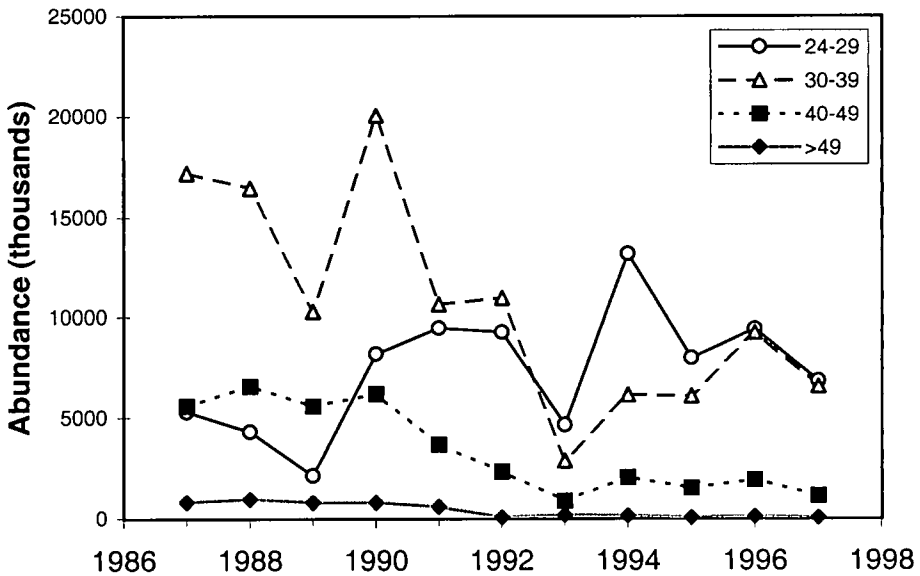


Figure 28. Relative abundance of 4RST witch flounder by size class, estimated from catch rates in the August and September surveys of the Gulf of St. Lawrence.

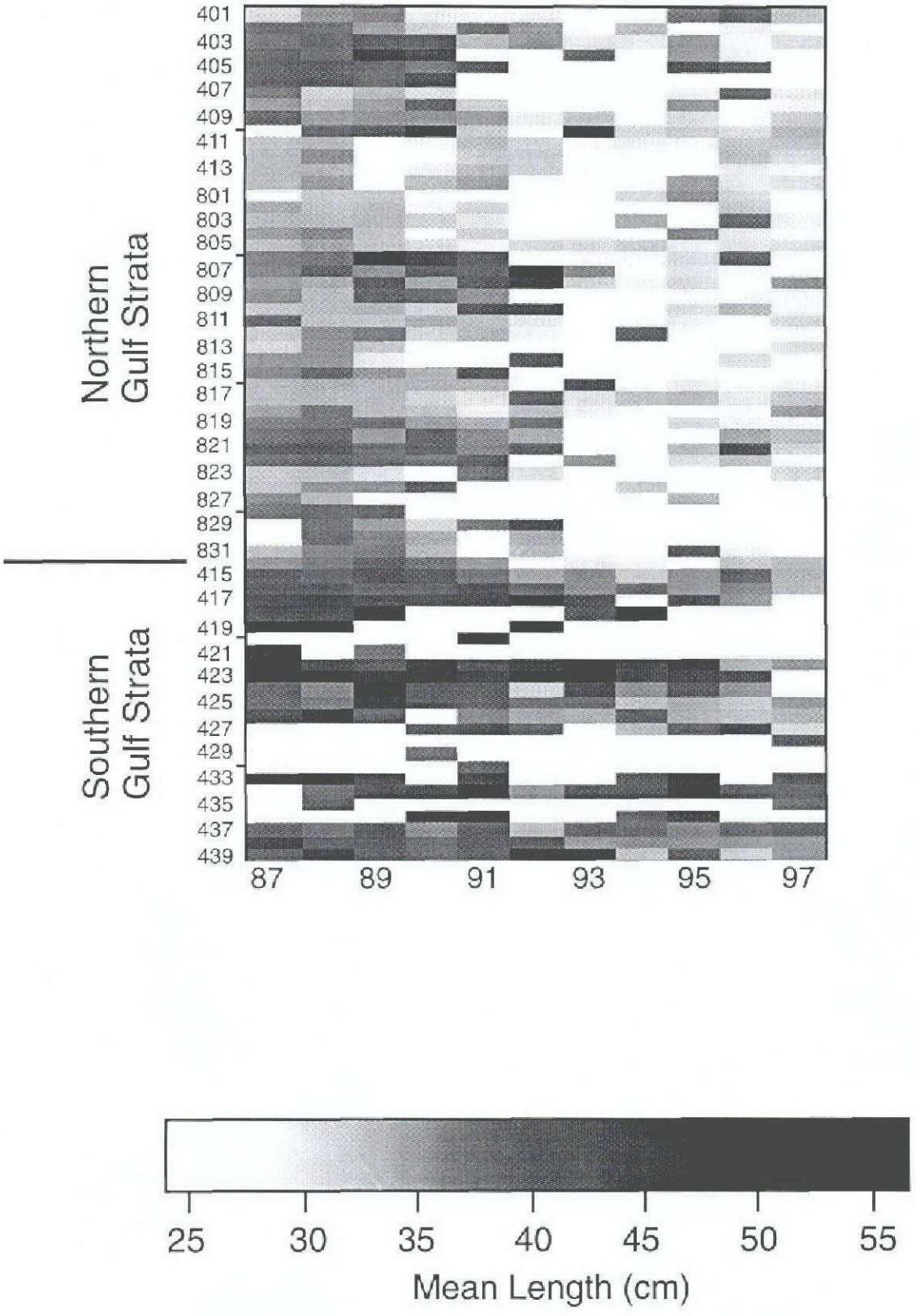


Figure 29. Mean lengths of witch flounder 24 cm or greater in length by stratum and year for the summer surveys of the Gulf of. St. Lawrence. White shading indicates that strata were not sampled or that no witch were caught.

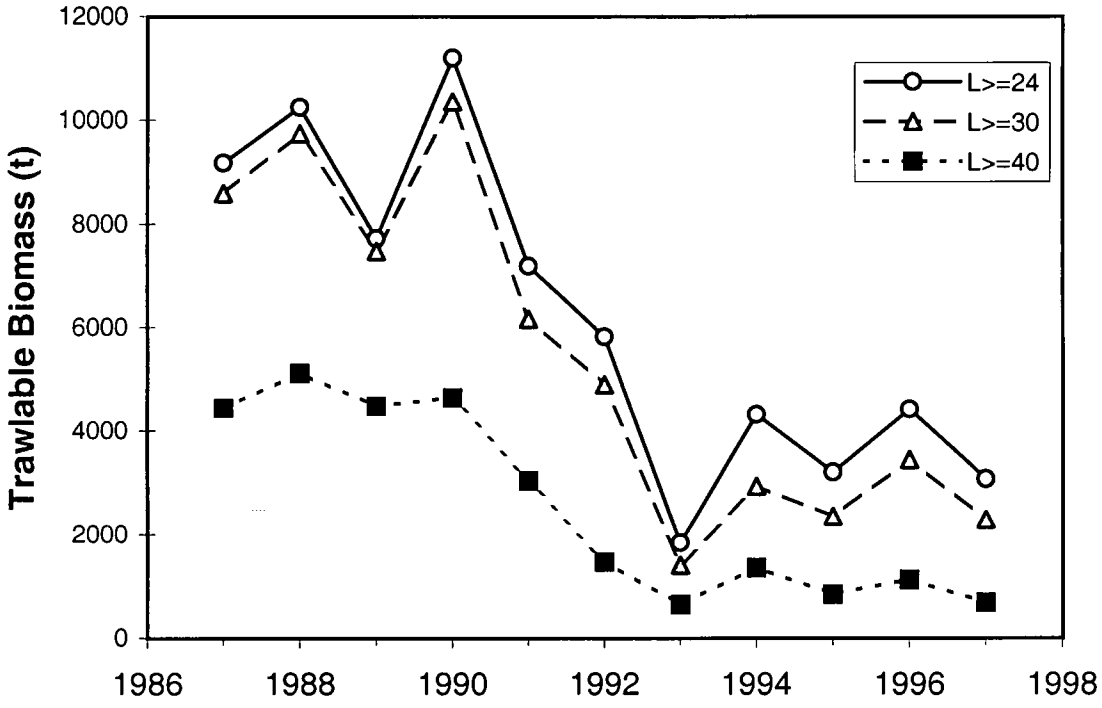


Figure 30. Trawlable biomass of witch flounder greater than or equal to 24, 30 or 40 cm in length, estimated from August and September surveys of the Gulf of St. Lawrence.

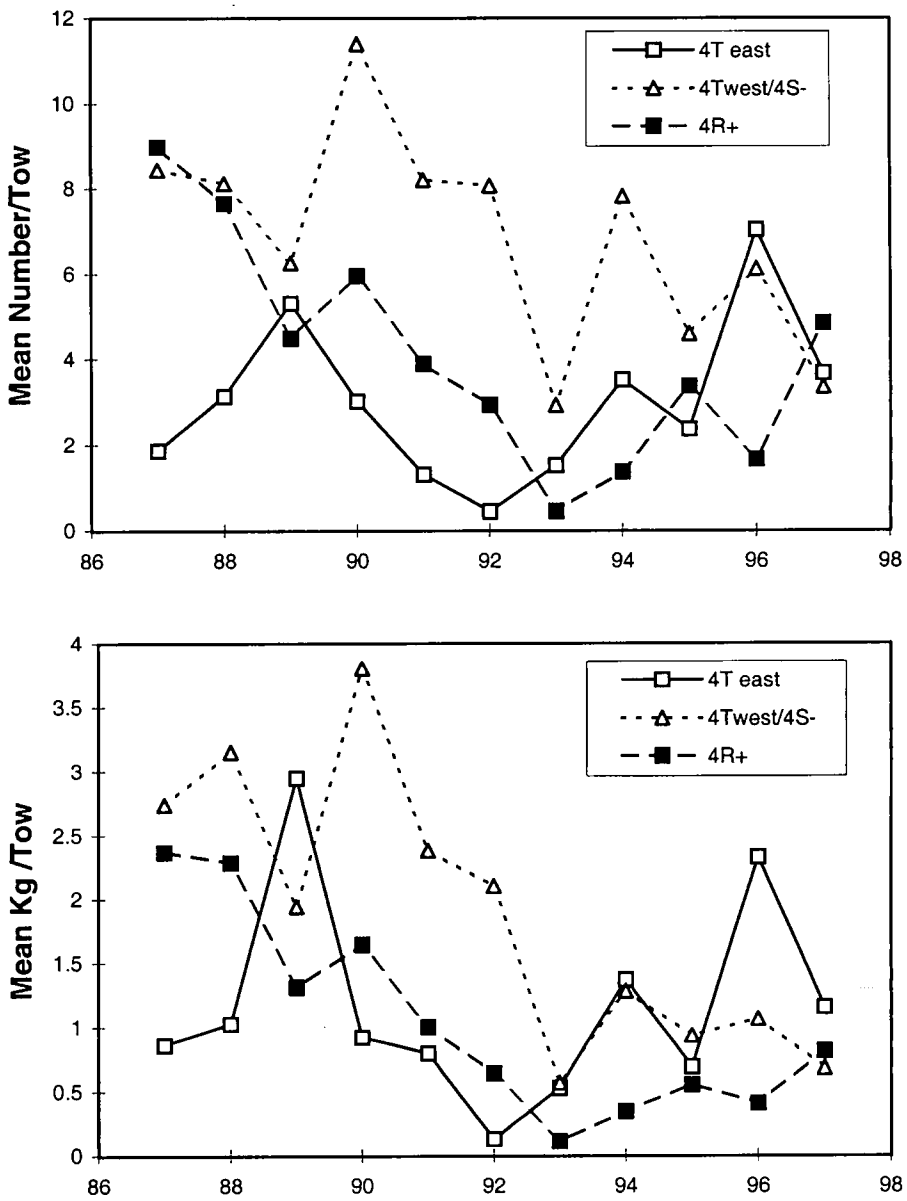


Figure 31. RV abundance indices for witch flounder by subregion: 4T east (401, 404,407,431-439), 4T west and 4S- (402,403,405,406,408-429, 4S strata except 803, 808, 814), and 4R+ (4R strata plus 803, 808 and 814).

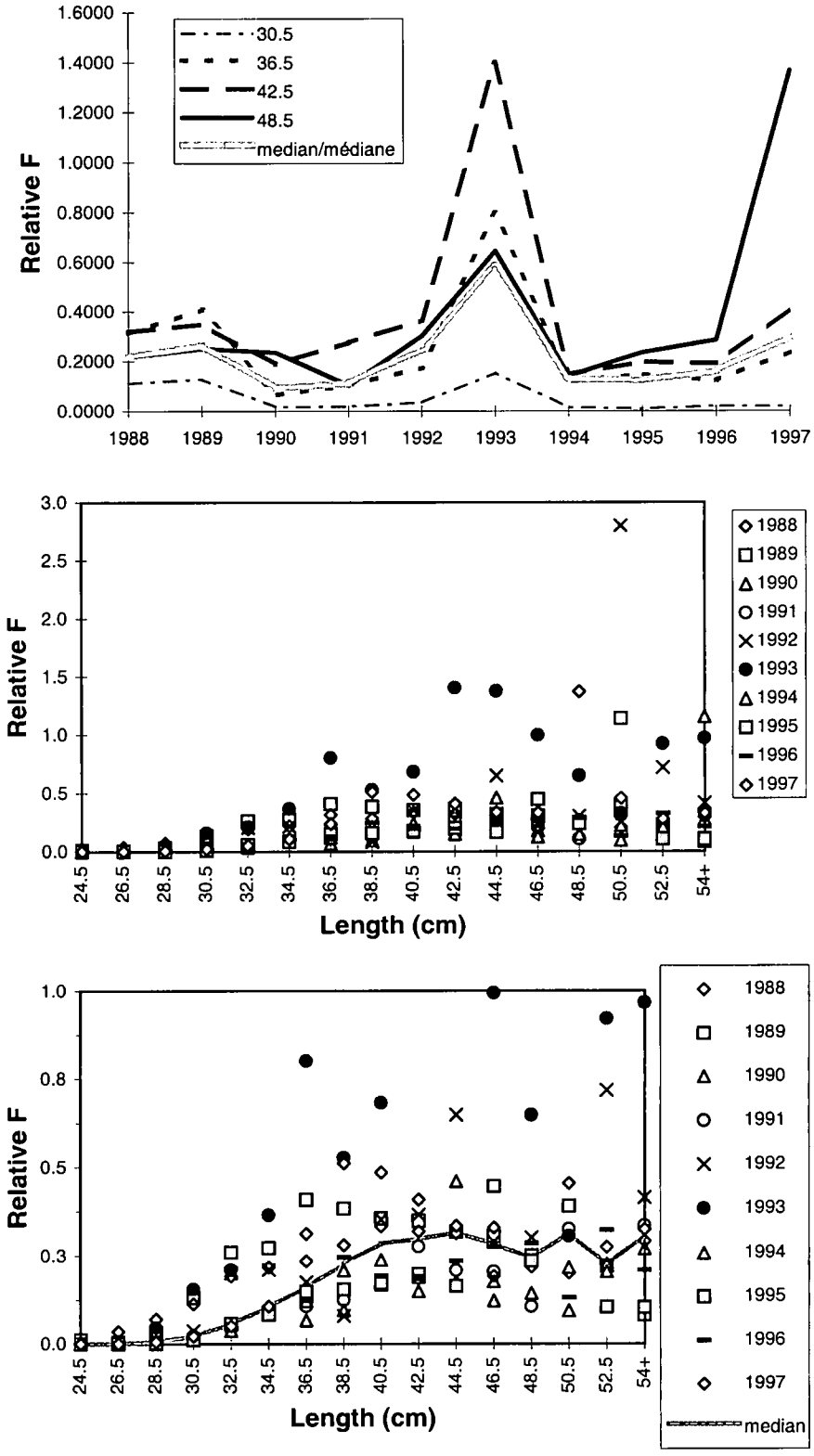


Figure 32. Estimates of relative fishing mortality of 4RST witch flounder, obtained from the ratio of the estimated catch-at-length divided by the RV estimate of trawlable population size.