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Status of witch flounder in NAFO divisions 4RST, February 2001

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Abstract

Throughout the 1990s and most of the 1980s, landings of witch flounder in NAFO Divisions 4RST have been mostly by seiners directing for witch flounder between May and October in St. George's Bay, Newfoundland (4Rd) and off the west coast of Cape Breton Island (4Tf and 4Tg). Landings declined in the 1990s, reaching historical lows between 1994 and 1997, but increased to the TAC (800-1000 t) in 1998-2000. The low landings in 1994-1997 reflected a sharp decline in effort in 4R during this period (when a high incidence of crab gear interfered with the fishery for witch flounder in 4R). A biomass index for witch flounder over the entire 4RST area was calculated by combining data from annual research vessel surveys conducted in the northern Gulf of St. Lawrence each August and in the southern Gulf each September. A sharp decline in the biomass of commercial sizes (¡Ý30 cm in length) occurred from 1990 to 1993. The biomass index remained at a low but steady level from 1993 to 1998. It increased sharply in 1999 and remained at this relatively high level in 2000. Changes in biomass were not uniform throughout the stock area. The decline in biomass occurred in 4R, 4S and western 4T, but was not evident in eastern 4T. The large increase in the biomass index in 1999 was confined to eastern 4T, but increases in survey catch rates in 4R, 4S and western 4T also contributed to the relatively high biomass index in 2000.Sentinel surveys conducted in the northern Gulf (mainly 4R and 4S) in July and October indicated that biomass in this area changed little from 1995 to 1999. The October sentinel survey indicated an increase in biomass in 2000 but the July survey did not. Pre-recruit abundance (witch flounder 16-29 cm in length) in the research surveys fluctuated without trend between 1990 and 1999 but increased markedly in 2000. This sharp increase in 2000 reflects a strong year-class, likely the 1995 year-class, that has been evident in the northern Gulf survey each year since 1997. Stock structure is a major source of uncertainty for this resource.

Résumé

Tout au long des années 90 et pendant la plupart des années 80, les débarquements de plie grise issus des divisions 4RST de l'OPANO étaient pour la plupart imputables aux senneurs ciblant l'espèce de mai à octobre dans la baie St. Georges, à Terre-Neuve (4Rd), et sur la côte ouest de l'île du Cap-Breton (4Tf et 4Tg). Les débarquements ont chuté dans les années 90, atteignant des creux historiques entre 1994 et 1997, pour ensuite augmenter au niveau du TAC (800 t-1000 t) pendant la période 1998-2000. Les creux observés de 1994 à 1997 reflètent une baisse marquée de l'effort dans 4R pendant cette période (le grand nombre d'engins de pêche du crabe entravant la pêche de la plie grise dans 4R). On a calculé un indice de la biomasse de plie grise dans l'ensemble des divisions 4RST en regroupant les données de relevés de recherche annuels menés dans le nord du golfe du Saint-Laurent en août et dans le sud du golfe en septembre. La biomasse de plie grise de taille commerciale (= 30 cm de longueur) a affiché une baisse marquée de 1990 à 1993. L'indice de la biomasse est demeuré faible mais stable de 1993 à 1998, pour ensuite grimper en flèche en 1999 et demeurer à ce niveau relativement élevé en 2000. Les changements observés dans la biomasse n'étaient pas uniformes à l'échelle de la zone du stock. La baisse de la biomasse s'est produite dans 4R, 4S et dans l'ouest de 4T, mais elle n'était pas évidente dans l'est de 4T. La hausse marquée de l'indice de la biomasse en 1999 ne s'est manifestée que dans l'est de 4T, quoique des augmentations des taux de capture des relevés de recherche dans 4R, 4S et l'ouest de 4T aient aussi contribué à l'indice de la biomasse relativement élevé en 2000. Les relevés par pêche sentinelle effectués dans le nord du golfe (principalement dans 4R et 4S) en juillet et octobre ont révélé que la biomasse dans cette région a peu varié de 1995 à 1999. Le relevé d'octobre par pêche sentinelle a révélé une augmentation de la biomasse en 2000, mais non le relevé de juillet. L'abondance des prérecrues (de 16 à 29 cm de longueur) dans les relevés de recherche a fluctué de 1990 à 1999, sans afficher une tendance, pour ensuite grimper en flèche en 2000. Cette hausse sensible en 2000 est signe d'une classe d'âge abondante, probablement celle de 1995, observée chaque année depuis 1997 dans le relevé effectué dans le nord du golfe. Une forte incertitude entoure cette ressource du fait que la structure du stock est mal comprise.

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. Juveniles tend to occupy deeper water than adults, especially during summer (e.g., Powles and Kohler 1970, Markle 1975, Morin and Hulbut 1994). Adults undertake seasonal migrations, moving into deeper water in winter and shallower water in summer (e.g., Powles and Kohler 1970). Powles and Kohler (1970) noted that the geographic extent of these migrations may be small, as little as 5-10 miles.

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. Landings in 4T were not subject to catch quotas, a concern given expected increases in effort for other groundfish species following the closure of the cod fisheries in the Gulf in 1993 (R. Morin, pers. comm.). 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 the management unit for witch flounder in the Gulf be redefined to include 4T (FRCC, 1994). This recommendation was implemented in 1995 and a 4RST stock unit was assumed in subsequent assessments of stock status.

In the last assessment of this stock, Swain et al. (1998*b*) noted that stock structure remains a major source of uncertainty for 4RST witch flounder. Based on spatial and temporal patterns in the fishery for witch flounder (McRuer and Swain 2001) and spatial variation in recruitment and abundance trends, Swain and McRuer (2001) proposed that the witch flounder moving into the Cape Breton Trough in eastern 4T each summer were more closely affiliated with witch flounder on the northeastern Scotian Shelf (NAFO Div. 4VW) than with those in other regions of the Gulf of St. Lawrence. This proposal was reviewed in January 2001 (O'Boyle 2001). This review acknowledged that the stock affiliations of witch flounder in eastern Div. 4T are uncertain but concluded that there is yet insufficient evidence to warrant a revision of the management units for witch flounder. Thus, this assessment of stock status is based on a 4RST management 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. 1). 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 a historical low of 320 t in 1995. Landings were near this low level from 1994 to 1997, when catches remained below the allocated quotas for all gear sectors. The decline in landings was particularly strong for 4R-based Danish seiners, whose landings reached only about one-quarter of their allocation during the 1994 to 1997 period. This decline in landings reflected a sharp decrease in fishing effort in 4R. In this period, a high incidence of crab gear interfered with the fishery for witch flounder in 4R in early summer, a period when fishing effort was traditionally high (see below). The fishery during the 1994-

1997 period was dominated by landings in 4T (Fig. 1). In 1996 and 1997, 4T-based vessels caught about 75-80% of the allocation. Restrictions on fishing practices may have contributed to landing shortfalls during this period. For example, delays in the opening of the fishery until June precluded traditional fisheries during spring movements of witch when catch rates tend to be high and may have contributed to the 1997 shortfall (R. Hébert, DFO Moncton, pers. comm.). Landings increased in the 1998-2000 period (Fig. 1) when quotas were caught or exceeded by the fleets directing for witch flounder in 4R and eastern 4T.

Monthly landings in 4R and 4T are shown in Figure 2 from 1989 to 2000. From 1989 to 1993, most landings in 4R were made between June and October, with the highest levels tending to be in June and July. Landings in 4R shifted to later months in the summer and early fall in the 1994-1998 period, when the highest values usually occurred in September and October. In 1999 and 2000, most landings in 4R occurred from June to August or September. Most landings in 4T occur between May and October, peaking in May-June and/or September-October. Landings tended to be highest in spring (May-June) in 1989-1993 and in fall in 1994-1997 (and 1999). Peak landings occurred in spring and fall in 1998 and 2000.

The fishery for witch flounder has been conducted almost entirely by mobile gears (Table 1). Danish seines have dominated 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 was highest from 4Rd until 1994 when landings in this unit area declined sharply (Fig. 4). Landings in 4Rd remained low from 1994 to 1997, returning to their earlier levels in 1998-2000. Landings have remained fairly steady in 4Tf and 4Tg. These areas dominated the fishery in the 1994-1997 period (Fig 4). In the 1998-2000 period, 4Rd and 4Tfg contributed roughly equal portions of the landings. Contributions from 4Tk and 4Tnoq are now fairly minor.

The fishery for witch flounder is primarily a directed fishery (Fig. 5). Trawls directing for witch are largely restricted to 4T. From 1994-1999, 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. 6). 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 remained low through 1997. Seine effort in 4R increased again in 1998 and 1999, to about 60% of the 1991-1993 levels. Directed effort by seines remained high in 4T throughout the 1991-2000 period.

2.2 Catch-at-length

We attempted to estimate mobile gear catch-at-length for 1987-2000, 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. 7). 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 Swain et al. 1998*b*). No samples were available from 4R in 1987, so we did not estimate catch at length for that year. Other details regarding methods and the samples available for 1988-1997 are given in Swain et al. (1998*b*). The number of length frequency samples and the landings that they were applied to are given in Table 2 for 1998-2000.

Length composition of the landings are given in Table 3 and Figures 8 and 9. The large drop in the landings from 1989 to 1990 (Fig. 8) was not accompanied by any decrease in the size of the fish landed (Fig. 8 and 9). For example, the modal size in the landings was 36 cm in 1988 and 39 cm in 1992 (Fig. 9). Modal lengths in 1999-2000 were 37-38 cm. Although there have been only slight changes in the modal length of landings over the past decade, length distributions have become less skewed to the right, with a smaller proportion of large fish in recent years than in the late 1980s. (Fig. 8, 9). The sizes of fish landed in recent years are considerably smaller than those landed in the mid 1970s and early 1980s (Fig. 10).

2.3 Fishery Catch Rates

Fishery catch rates are sometimes used as indices of fish abundance. However, inferences about population size from fishery catch rates are complicated by systematic variation in catchability, the proportion of the population captured by a unit of effort. Catchability to fisheries often increases over time due to improvements in fishing power or efficiency (e.g., Garrod 1964; Gulland 1964, 1983). Catchability also depends on fish distribution, increasing as fish become more aggregated. Catchability to fisheries is expected to be density-dependent, increasing as population size decreases and geographic range contracts (e.g., Paloheimo and Dickie 1964). Catch rates in the otter trawl fishery for northern cod increased as the stock collapsed and became 'hyperaggregated' in the southern extremities of its range (Rose and Kulka 1999).

We estimated separate catch rate indices for seines in 4R and 4T, standardizing for vessel and month. Analyses used 7 vessels fishing in 4R (n=690) and 17 vessels fishing in 4T (n=1700). Only trips where witch was the main species caught were included in analyses. Trips with landings under 5 kg or effort under 5 h were excluded. Catch rates were $\log_e$ transformed. Model factors were vessel, month and year. Years included in the analysis were 1990-1999 for 4R and 1985-2000 for 4T. Months included were March and May-December for 4R and April-November for 4T. Two models were fit for each area, one including interaction terms and one omitting these terms. Many empty cells occurred in the models with interaction terms, so Type IV sums of squares were used for these models. All interaction terms were significant except for the vessel × month term in the 4R model (Table 4). The models including interactions accounted for 63% of the variation in $\log_e$-transformed catch rates in 4R and 58% of the variation in 4T. In the 4R model, the interaction effects were relatively weak compared to the year effect; interaction mean squares (MS) were 7-20% of the year MS. In the 4T model, the vessel × year interaction effect was as strong as the year effect. Models omitting interactions accounted for only 39% of the variation in $\log_e$-transformed catch rates in 4R and 31% of the variation in 4T. Further research is required to interpret the interactions and identify the effects of empty cells on these results. Standardized catch rates were estimated for illustrative purposes using the main effects models. These are shown in Figure 11 after back-transformation and bias correction. Catch rate trends differed between 4R and 4T. In 4R, mean catch rates varied little between 1990 and 1995 and then increased threefold from 1995 to 1997, remaining at the higher level in 1998 and 1999. In 4T, mean catch rates showed little interannual variation, except for a high value in 1985 and a low value in 1990.

2.4 End-of-Season Telephone Survey

Fishers participating in the groundfishery in the southern Gulf have been surveyed by telephone following the fishing season each year since 1996 using the same questionnaire (e.g., Hurlbut and Daigle 2000). Opinions on witch flounder abundance are summarized in Table 5 for the few (3-7) fishers surveyed whose first priority was witch flounder. In all years, the majority of the 3-7 respondents considered witch flounder abundance to be the same or higher than in the previous year. Except in 1998, the most frequent response was that abundance was the same as in the previous year. Responses were scored from –2 (much lower) to 2 (much higher), with 0 indicating the same abundance as last year. In all years except 1997, the average score was positive, indicating an average view that abundance was higher than in the previous year. The cumulative average score indicates steadily increasing abundance since 1995 in the average opinion of the respondents. On average, respondents also considered abundance to be higher than in the previous 5 yr for each year except 1997. This opinion was especially strong in 1998-2000. On average, respondents considered abundance to be somewhat lower in 1996 and 1997 than the average in all previous years fished and higher in 1998-2000 than the average in all previous years fished.

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. 12), a survey of the northern Gulf conducted each August since 1984 (Fig. 13), 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 the last full assessment of this stock was to try to combine data from both surveys into a single index of abundance covering the entire stock area (Swain et al. 1998*b*). 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 proportion 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*a*). We adjusted September catches by the *Alfred Needler* since 1992 to be equivalent to *Lady Hammond* catches as described by Swain et al. (1998*a*). Comparative fishing between the *Alfred Needler* using a URI trawl and the *Lady Hammond* using a Western IIA trawl, conducted in August 1990 in the northern Gulf, indicated length-dependent differences in fishing efficiency for witch flounder between these two vessels and gears (Swain et al. 1998*a*, Swain 2001). At small sizes, fishing efficiency was greater for the URI trawl, whereas at large sizes, efficiency was greater for the Western IIA trawl. Swain et al. (1998*a*) estimated relative fishing efficiency between the Western IIA and URI trawls for witch flounder 24 cm or greater in length, a length range over which relative fishing efficiency changed little. This estimate was used 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. Using these conversion factors, consistent catch rate indices for witch flounder greater than 23 cm in length were calculated for the entire Gulf (Fig. 14). These indices are updated for 1998-2000 here. Swain (2001) estimated length-dependent relative fishing efficiencies between these two vessels and gears. These estimates are used here for analyses that include lengths below 24 cm.

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. A number of inconsistencies have been discovered in the data, and analyses of these data have been deferred until further editing of the data can 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 6. 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 very low over the Magdalen Shallows. In 1998, the mean catch rate was especially high in stratum 415 (off the Gaspé Peninsula), while in 1999 and 2000 mean catch rates were especially high in stratum 437 (the Cape Breton

Trough). Strata were not sampled on four occasions over the 30-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 7. These means include all lengths of witch, and no adjustments have yet been applied for the change in vessel and gear in 1990. Strata 825, 826 and 834 were rarely sampled because of lack of trawlable bottom and have now been dropped from the survey. Swain et al. (1998*b*) also omitted stratum 833 from abundance indices 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. Swain et al. (1998*b*) did not include these strata in abundance indices because they rarely contained witch (only a single witch was captured in strata 837-841 from 1991 to 1995) and were not sampled prior to 1991. We selected the same strata used by Swain et al. (1998*b*) to calculate abundance indices (strata 401-414, 801-824, 827-832). However, mean catch rates were relatively high in stratum 835 in 1999 and 2000 (and in 836 in 1994), so we also calculated stratified mean catch rates for the August survey in 1991-2000 including additional strata (833, 835-837, 839) for comparisons with the standard indices.

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 and recent 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 (the year mean), (2) the average value for that stratum over all sampled years (the stratum mean), or (3) the predicted value from a statistical model describing variation in catch rates among strata and years. Swain et al. (1998*b*) compared these three approaches. For most years, stratified means were very similar using all three approaches. Exceptions were 1984-1986, when most strata in the 409-414 group (where catch rates tend to be well above survey averages) 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 15 and 16. 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 period after 1986 when all three approaches produced similar results.

Abundance indices including all lengths of witch flounder are compared among surveys in Figure 15. 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. Mean catch rates were at the highest levels observed in this survey in 1996 and 1998-2000. In each of these years, several large catches contributed to these high means.

The index from the August survey suggests a gradual but steady decline in abundance from the mid 1980s to the mid 1990s, followed by increases in 1999 and 2000 to levels comparable to those of the mid 1980s. 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*a*), small fish will contribute more heavily to the index in the 1990-2000 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 15 (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 15. 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 16. For the southern Gulf, this index is almost identical to that including all lengths (Fig. 15), 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, followed by a high value in 2000. Catch rates in the two surveys are combined into a single index in the bottom panel of Figure 16. 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 from the late 1980s to the mid 1990s (though this decline is less steep than for the northern Gulf alone), followed by increases in abundance in 1999 and 2000.

Figure 17 compares mean catch rates for the August survey between the standard strata and these strata plus several strata added in 1991. Trends are virtually identical between the two series.

3.2 Geographic distribution

Geographic distribution in summer and early fall (August-September) is summarized in Figures 18-23 for three size classes of witch flounder between 1987 and 2000. Contouring was based on Delaunay triangles, calculated using the ACON program. Contour intervals are the 1st, 10th, 50th, 75th, and 90th percentiles of the non-zero 1987-2000 survey catch rates of witch flounder in the Gulf of St. Lawrence and the Scotian Shelf. Unlike other data presented here, catch rates used for these distribution maps have been standardized to a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl. This allows direct comparisons with distribution maps for witch flounder on the Scotian Shelf (e.g., Swain and McRuer 2001).

Small witch flounder (<14 cm in length) tend to be restricted to the deep waters of the Laurentian, Anticosti and Esquiman Channels. Large witch flounder tend to move into less deep waters, with concentrations in the Cape Breton Trough west of Cape Breton Island, the Chaleur Trough and Shediac Valley east of the Gaspé Peninsula and the St. George's Bay area off western Newfoundland. In the 1987-1990 period, large witch flounder penetrated deeply into the western Magdalen Shallows along the Chaleur Trough and Shediac Valley, a pattern also typical of earlier years in the 1970s and 1980s (Swain et al. 1998*b*). Penetration of large witch flounder into the western Magdalen Shallows was less strong in the 1991-1994 period and has been absent since then. Concentrations of large witch flounder on the shelf off western Newfoundland also declined considerably in the 1991-1997 period relative to the 1987-1990 period. However, strong concentrations of large witch flounder were evident in the St. George's Bay area in 1998-2000. Strong concentrations of large witch flounder occurred in the Cape Breton Trough in all time periods between 1987 and 2000. Medium-sized witch flounder were widely distributed throughout the Estuary and the Channels and their slopes in the 1987-1990 period. Densities of this size class generally diminished in all areas but the Estuary in the 1991-1994 period. In the 1995-1997 period, a strong concenration of this size class was evident northeast of Anticosti Island (this reflects high catch rates in this area in 1996 alone). High densities of medium-sized witch flounder occurred in the Estuary and throughout the Laurentian and Esquiman Channels in 2000.

3.3 Length Distributions

The length composition of witch flounder catches in the August surveys of the northern Gulf is shown in Figure 24, both with and without adjustment for the length-dependent differences in fishing efficiency between the URI and Western IIA trawls in 1990-2000. Modes are generally difficult to track in these length frequencies. A mode between about 30 and 40 cm occurs in the length frequencies from 1987 to 1992. This mode tends to occur at progressively larger sizes each year in this period. This could reflect the growth of a strong yearclass during this period, though the apparent growth rate would be slower than that reported by Bowering and Brodie (1984) for earlier years in the northern Gulf and by Bowering (1999) for the same years in the 3Ps population. In these latter cases, mean length at age progressed through this length range in 4-5 years compared to the 6 years in Figure 24. This mode vanished after 1992 and fish were very rare in the 30-40 cm range in the 1993-1995 surveys. Strong modes occur between 15 and 30 cm in many years in the early to mid 1990s but these generally do not progress beyond 30 cm (i.e., it appears that either growth approaches an asymptote near 30 cm or fish are lost before they grow to sizes over 30 cm during this period). In contrast to the earlier years, a strong yearclass can be followed through the length distributions of the 1997-2000 period. This yearclass (probably the 1995 yearclass) first appears as a mode near 10 cm in the unadjusted URI catches in 1997 and is evident at progressively larger sizes each subsequent year. In 2000, it is reflected in record-high catch rates in the 20-30 cm length range. The possibility that the record-high catch rates in the 2000 August survey reflect a year effect cannot yet be excluded, but there seems to be little doubt that a strong yearclass is recruiting into this area. The 1995 yearclass of witch flounder was also exceptionally strong on the Scotian Shelf (McRuer et al. 1997).

A sharp discontinuity in the length frequencies is evident between 1989 and 1990, even after adjustment for the length-dependent differences in fishing efficiency between the URI and Western IIA trawls. Abundance is relatively high in the 15-25 cm range in the 1990-1992 adjusted data in contrast to the low catch rates at these sizes in the 1987-1989 surveys. This suggests that the corrections for the differences in fishing efficiency between the URI and Western IIA trawls may not be entirely effective.

Catches from both the August and September surveys are combined into a single length frequency distribution for the entire Gulf in Figure 25. 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 8. Catches by the URI trawl are adjusted to be comparable to those by the Western IIA in this figure using the length-dependent adjustments. Estimated abundance of fish over 30 cm declined sharply from 1990 to 1993 but returned to relatively high levels in 1999 and 2000. Abundance of fish under 25 cm is generally greater in the 1990-2000 period than in the 1987-1989 period, but this may partly reflect ineffective adjustment for the change in trawl in the northern Gulf survey in 1990. Abundance of small fish in the 15-25 cm range appears to be exceptionally high in 2000, perhaps reflecting the recruitment of the strong yearclass evident since 1997 (Fig. 24) into the survey population.

Regional contributions to the Gulf-wide length distributions are shown in Figure 26. Eastern 4T (4Te) was defined as the area covered by August survey strata 401, 404, and 407, and September survey strata 415-439. The 4STw (4S and western 4T) area comprises strata 402, 403, 405, 406, 408-429, and the 4S strata excluding strata 803, 808 and 814. The '4R' area was defined as the 4R strata plus strata 803, 808 and 814. Witch occupying the 4Te area in summer are almost entirely over 30 cm in length. Abundance of these relatively large fish appears to have been high in this area since the mid 1990s. In most years from 1987 to the mid 1990s, the 4STw area (4S and western 4T) contributed the majority of fish at most sizes. This partly reflects the large size of this area (3-4 times the size of the other two areas). Since the mid 1990s, the proportion of fish contributed by the 4STw area has declined at the larger sizes, with 4Te dominating the contribution to these large sizes in several years. In recent years (1999 and 2000), the contribution of the 4R area to the small and medium size classes has increased substantially.

A longer term perspective on changes in witch flounder size distribution can be obtained for the southern Gulf from the September survey (Fig. 27). Although overall abundance appears to have been high in the southern Gulf since the mid 1990s, large fish over 45 cm in length have been rare in the 1990s compared to the 1970s and 1980s.

Figure 28 shows changes in relative abundance by size class for the entire Gulf. A sharp peak in the relative abundance of the smallest size class (0-15 cm) occurred in 1991, but this peak is not reflected at larger sizes in later years. Catch rates at these small sizes have been at a high level since 1998. No trends are evident in catch rates of the 16-29 cm size class. Catch rates of this size class were very high in 2000. Catch rates of the 30-39 cm size class tended to be relatively high from 1987-1990 and then declined to a low level in 1993. Catch rates of this size class remained relatively low from 1994 to 1998 but increased in 1999 and 2000 to a high level. Catch rates of large witch flounder (≥ 40 cm) were high from 1987 to 1990 and then declined sharply from 1990 to 1993. Catch rates at these large sizes remained low from 1993 to 1998 and then increased to intermediate levels in 1999 and 2000.

3.4 Biomass Trends

Biomass trends for commercial-sized witch flounder (30 cm and longer) were obtained for the entire Gulf from the length distribution of the survey 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.

Relative biomass declined sharply from the 1987-1990 period to the 1994-1998 period (Fig. 29). The decline occurred after 1990 and thus cannot be attributed to the change in gear in 1990. Relative biomass reached a minimum in 1993, reflecting the very low abundance estimate in that year. Biomass remained stable at a low level from 1994 to 1998. Biomass increased sharply to an intermediate level in 1999, and remained near that level in 2000.

Changes in biomass have not occurred uniformly throughout the 4RST area (Fig. 30). The decline in biomass in the early 1990s was restricted to the 4R and 4S/western 4T areas. No clear decline in biomass occurred in the eastern 4T area during this period. In recent years, biomass has been relatively high in eastern 4T. In contrast, biomass remained low in the 4STw area from 1993 to 1999, increasing somewhat in 2000. In 4R, biomass of commercial sizes slowly but steadily increased from the very low 1993 level to a moderately high level in 2000, comparable to the 1989/1990 level and about two-thirds of the 1987/1988 level. The sharp increase in survey biomass over the entire 4RST area in 1999 is due almost entirely to the large increase in the 4Te area in that year. Increases in 4STw and 4R also contribute to the moderately high value in 2000.

4. Sentinel Surveys

Two mobile-gear sentinel surveys have been conducted in the northern Gulf of St. Lawrence each year since 1995, one in early summer (usually mostly in July) and one in fall (late September and October). Each survey is conducted by 9 otter-trawlers, each equipped with the same trawl and rockhopper gear. Since 1997, a restrictor cable has been used to standardize the horizontal opening of the trawl. The survey follows a stratified random design using the same strata as the August research vessel (RV) survey. Additional discretionary tows conducted on observed fish concentrations were not included in this analysis. The target fishing procedure is a 30-min tow at 2.5 knots, giving a standard tow of 1.25 nautical miles. Tows in the 3Pn strata were omitted for these analyses.

4.1 Length Distributions

Length distributions of witch flounder catches are available for the 1999 and 2000 sentinel surveys. These are compared to the length composition of witch flounder catches in the August RV surveys in Figure 31. The sentinel survey catches have been adjusted to a standard tow of 1.75 nm for these comparisons. The gear used in the sentinel survey appears to be less efficient than both the URI and Western IIA trawls at catching smaller witch flounder. A strong mode near 30 cm is evident in the length compositions of all three surveys in 1999. This mode shifts slightly toward larger sizes from the Jun/Jul sentinel survey through the August RV survey to the Sep/Oct sentinel survey. An even stronger mode is evident in the August RV length distributions at smaller sizes around 20 cm. Catch rates in the sentinel surveys were low at these sizes. Results are similar for the surveys in 2000. Modes near 30 cm were evident in all three surveys. A very strong mode between 15 and 25 cm occurs in the RV survey catches. There are also suggestions of modes in this length range in the sentinel survey catches; however, in contrast to the RV survey, these modes are much weaker than those near 30 cm in the sentinel survey catches.

4.2 Geographic Distribution

The geographic distribution of witch flounder catches in the mobile-gear sentinel surveys is shown in Figures 32 and 33. Catch rates tended to be highest along the shelf off the west coast of Newfoundland, particularly in the St. George's Bay area. Catch rates in St. George's Bay were especially high in October 1998 and October 2000. Relatively high catches also tended to occur along the southern slope of the Laurentian Channel and in the Estuary along the Gaspé Peninsula. An exceptionally high catch occurred along the slope of the Laurentian Channel off the Magdalen Islands in July 1997. The distribution of witch flounder catches in the sentinel surveys is generally consistent with the distribution in the August RV surveys given the relatively large size of the witch caught by the trawl used in the sentinel surveys.

4.3 Abundance Indices

Stratified mean catch rates in the sentinel surveys are shown in Figure 34. No strong trends are evident in these catch rates between 1995 and 2000. Mean number per tow in the July surveys varied little over this time period, except for a high catch rate in 1996. Mean number per tow varied little between 1995 and 1998 in the October surveys but was low in 1999 and high in 2000. Mean weight per tow also varied little in the July surveys except for a very high value in 1997. This high value was due to a single tow, resulting in high uncertainty in the index for this year (the mean ±1SE includes 0). The mean omitting this single tow is at the same level as the 1998-2000 means. The mean weight per tow in the October surveys shows the same pattern as mean number per tow. The trend in the October surveys corresponds well with that in the RV surveys, which indicate little change in the biomass of commercial-sized witch flounder in the 4RS and western 4T area from 1995 to 1999 and an increase in 2000. In contrast, the July sentinel surveys do not indicate any increase in witch flounder biomass or abundance in 2000.

5. Surplus Production Models

Given the lack of age structure data for 4RST witch flounder, we attempted to estimate population parameters using a non-equilibrium surplus production model. We used the ASPIC software (Prager 1995) to fit these models. We fit the models using the landings data and the survey biomass index (kg/tow for witch flounder 30 cm and larger). Reasonable solutions could not be found. Fitting over the entire 4RST area, the model converged to one of two states (Table 9). One solution (e.g., run 10 in Table 9) gave estimates of 2418 t for MSY (maximum sustainable yield), 0.29 for the fraction of the biomass at MSY occurring in 2001, and 0.49 for the fraction of MSY available in 2001. However, the estimate of r, the intrinsic rate of increase, was 0.87 for this model. This is unrealistically high for a long-lived species with a late age at maturity (a value near 0.3 would be more reasonable). The second solution (e.g. run 13 in Table 9) yielded parameter estimates that were clearly nonsense. In this solution, estimated MSY, carrying capacity K, and biomass at MSY were huge values, and the estimated starting biomass in 1987 was over 4 times the carrying capacity. The model appeared to be having difficulty reconciling the increase in biomass in 1999 and 2000 with the increase in yield in 1998-2000. We tried fitting the model with the biomass index missing for 1999 and 2000. Again, two solutions were possible. In one (e.g., run e1, Table 9), estimated MSY was 3392 t and estimated r was a more reasonable 0.49. However, the observed yields in 1999 and 2000 drove the population to extinction by 2001. The second solution (run e4) resembled the nonsense solution described above. We also tried fitting models to the 4R and eastern 4T data separately. Again, solutions involved an unrealistically high estimate for r (Table 9).

6. 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). No trend over time was evident in R (Fig. 35). R declined from 1989 to 1990, coincident with a decline in landings. A sharp peak in R

occurred in 1993. However, the survey abundance index was unusually low in 1993 (Fig. 16), 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 1988-2000 period. The proportion of the landings made before August in the 1994-1998 period was about half the level of the 1988-1993 period, increasing to 60% of the earlier level in 1999 and 90% in 2000. Thus, values of *R* late in the time series (except 2000) 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 1994-1999.

7. 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.

The possibility that changes in catchability may contribute to the large increase in the survey biomass index for eastern 4T in 1999 and for the northern Gulf in 2000 cannot yet be discounted. Contradictory results between the July and October sentinel surveys in 2000, with the biomass index increasing in the October survey but not in the July survey, are an additional source of uncertainty.

Stock structure remains a major uncertainty. In contrast to the 4R and 4STw areas, survey catch rates of witch flounder in eastern 4T have been at record-high levels in recent years. The interpretation of these high catch rates depends on stock structure. If witch flounder in the entire 4RST area comprise a single stock, then these high survey catch rates in eastern 4T reflect a distribution change in a stock that appears to have been at a low level throughout much of the 1990s and at an intermediate level in recent years. An alternate hypothesis is that witch flounder in eastern 4T are more closely affiliated with those in the 4VW area. 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, Swain and McRuer 2001). Abundance of pre-recruit witch appears to have been exceptionally high in 4VW in recent years (McRuer et al. 1997, Swain and McRuer 2001). 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 4VW.

8. Conclusions

The survey biomass index for commercial sizes of witch flounder in 4RST declined sharply in the early 1990s. This decline was mostly confined to the 4R, 4S and western 4T areas. The biomass index has been at high levels in eastern 4T since the mid 1990s. Over the entire 4RST area, relative biomass increased sharply from a low level in 1998 to a relatively high level in 1999. This increase was mostly due to very high catch rates in the survey in eastern 4T. The survey biomass index remained at the same relatively high level in 2000. Increases in survey catch rates in both 4R and 4STw contributed to the relatively high 2000 catch rate. The possibility that the high survey catch rates of commercial sized witch flounder in 2000 are partly attributable to a year effect cannot yet be excluded. However, an increased catch rate was also observed in the October 2000 sentinel survey of the northern Gulf (though not in the July 2000 sentinel survey).

Large fish over 45 cm appear to remain rare relative to the abundance in the 1970s and 1980s, judging from length distributions in the September research surveys. The sizes of witch flounder in the landings in both 4R and 4T remain much smaller than those landed in the mid 1970s and the early 1980s.

A strong yearclass appears to be recruiting into the 4RST area. This yearclass has been evident in the August research surveys as clear modes at progressively larger sizes in each of the past 4 years. In 2000, this yearclass had grown to sizes well-recruited to the survey gear (20-30 cm). It was reflected by a wide distribution of high catch rates of this size class of witch flounder in the 2000 summer surveys. Fishable biomass should increase as this yearclass recruits to commercial sizes.

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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	73	494	3	0	0	570	1000
1998	0	0	49	816	1	0	0	866	800
1999	0	0	14	713	3	0	0	730	800
2000	0	0	111	876	1	0	0	988	1000
MEAN	264	444	455	1352	25	17	68	2625	

Table 2. Numbers of witch flounder sampled for length from mobile-gear landings in NAFO Divisions 4RST, 1998-2000 (4R samples were applied to 4RS landings).

Year	area	Landings (t)	Port samples	Observer trips	No. measured
1998	4R	336.9	4	3	2106
1998	4T	527.4	12	24	8194
1999	4R	339.0	3	7	3145
1999	4T	388.1	8	15	7665
2000	4R	435.5	4	7	3453
2000	4T	551.9	8	-	1533

Table 3. Estimated catch-at-length (thousands) for mobile-gear witch flounder landings in NAFO divisions 4RST, 1988-2000.

Length	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.62
24	0.00	6.61	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.31
25	0.00	0.00	0.00	0.00	0.17	1.82	0.00	0.00	0.00	0.00	0.27	0.18	2.35
26	22.29	0.00	0.00	0.00	3.51	3.19	0.00	0.00	0.56	0.00	2.92	1.86	0.00
27	19.22	0.00	0.00	0.00	6.16	5.08	0.07	1.38	0.48	0.17	10.19	2.87	1.15
28	42.44	25.53	0.00	1.59	7.72	11.92	2.37	1.85	6.41	2.11	24.60	4.76	1.35
29	81.36	0.00	0.23	11.52	17.68	21.06	4.27	2.76	9.64	6.68	30.54	6.09	7.83
30	73.33	38.85	18.46	4.76	20.17	36.29	8.47	7.85	20.70	17.76	49.54	20.22	18.18
31	191.85	116.44	32.63	18.95	56.75	47.97	17.13	15.79	23.36	24.56	78.52	30.60	37.71
32	314.16	244.20	98.77	30.73	58.62	48.07	19.78	19.01	34.77	39.48	116.67	59.54	63.25
33	343.89	276.45	115.46	61.19	90.09	75.59	30.97	27.62	51.25	42.77	146.80	88.97	97.14
34	407.52	305.76	162.50	79.76	126.10	118.91	50.31	35.84	73.29	70.50	173.86	126.36	166.11
35	497.68	412.06	190.15	131.77	150.03	132.06	53.05	63.72	117.91	84.71	209.66	163.72	215.12
36	592.52	429.63	189.54	126.01	143.26	167.04	71.50	68.28	140.25	118.06	246.89	188.83	248.05
37	512.91	516.23	200.90	151.74	178.17	181.37	77.52	66.73	144.15	100.38	262.72	212.98	284.56
38	475.98	409.22	159.83	148.65	172.24	170.68	94.85	68.64	141.29	132.52	216.05	211.52	303.49
39	355.19	416.03	151.38	138.16	223.71	159.06	78.58	82.40	104.64	129.44	205.64	180.19	280.02
40	352.05	303.92	183.88	102.93	195.79	138.20	69.62	85.44	97.59	108.68	155.36	150.89	211.40
41	252.58	306.12	155.56	116.61	142.41	140.29	66.63	45.08	80.15	96.60	131.98	128.99	163.29
42	208.10	262.83	170.03	137.00	121.20	127.88	65.88	29.00	52.98	74.36	97.17	97.77	127.01
43	203.12	188.29	134.24	84.22	108.80	119.46	45.49	45.91	44.10	51.42	68.86	75.47	98.46
44	216.66	193.41	114.02	94.35	86.57	92.59	45.95	16.64	43.32	38.82	54.48	49.04	72.43
45	170.00	150.55	96.54	52.67	76.84	69.79	25.17	14.54	22.60	23.75	34.50	32.67	49.12
46	160.28	209.83	80.47	57.32	51.05	49.59	26.55	17.91	25.18	39.06	31.57	29.46	34.69
47	104.03	94.35	82.29	44.06	41.09	47.74	18.25	16.31	14.00	22.91	17.51	12.73	20.44
48	115.61	59.94	54.53	26.02	36.24	31.23	15.51	19.15	12.15	17.57	11.39	8.60	10.65
49	71.63	63.43	51.58	20.97	17.90	18.20	13.69	5.47	10.50	4.88	12.50	5.97	7.66
50	58.43	52.10	31.38	17.49	11.01	24.16	6.88	13.13	3.15	7.94	7.09	6.33	5.15
51	36.43	43.22	18.21	52.58	20.25	16.10	7.11	5.10	2.31	2.98	5.12	3.12	3.31
52	28.64	16.96	14.77	13.40	5.61	8.44	8.61	1.05	2.50	0.50	2.98	1.08	3.68
53	19.52	28.34	5.93	18.85	9.43	7.59	4.23	0.79	2.09	2.87	2.45	0.90	3.54
54	22.88	7.44	4.37	28.15	8.66	4.16	3.17	0.20	3.30	0.46	1.28	1.52	4.48
55	15.44	5.88	13.96	19.77	2.04	3.88	2.71	0.29	0.80	0.44	2.14	1.08	0.00
56	25.59	1.63	13.43	13.28	1.31	6.94	1.91	0.47	1.83	0.54	0.98	0.13	2.92
57	10.71	0.00	7.67	7.16	1.13	0.72	2.71	0.17	1.12	0.02	0.53	0.64	0.00
58	2.89	11.81	2.15	3.32	1.51	1.71	3.83	0.04	0.96	2.81	0.46	0.15	0.22
59	0.27	1.63	4.37	3.32	0.97	0.74	3.20	0.19	0.05	0.00	0.16	0.16	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.51
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

Table 4. Catch rate analyses for seines in 4R and 4T. Vessel factor coded cfv, month factor coded mon.

A. 4R with interaction terms:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	128	303.6656733	2.3723881	7.37	<.0001
Error	561	180.6476326	0.3220100		
Corrected Total	689	484.3133059			

R-Square	Coeff Var	Root MSE	cpue Mean
0.627003	12.37880	0.567459	4.584124

Source	DF	Type IV SS	Mean Square	F Value	Pr > F
cfv	6*	13.01408481	2.16901414	6.74	<.0001
year	9*	47.85421899	5.31713544	16.51	<.0001
cfv*year	31	20.83281992	0.67202645	2.09	0.0006
mon	8*	8.09636770	1.01204596	3.14	0.0017
cfv*mon	31	10.37559532	0.33469662	1.04	0.4104
year*mon	41	42.20872574	1.02948112	3.20	<.0001

* NOTE: Other Type IV Testable Hypotheses exist which may yield different SS.

B. 4R omitting interactions

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	190.6978613	8.2912114	18.81	<.0001
Error	666	293.6154446	0.4408640		
Corrected Total	689	484.3133059			

R-Square	Coeff Var	Root MSE	cpue Mean
0.393749	14.48425	0.663976	4.584124

Source	DF	Type III SS	Mean Square	F Value	Pr > F
cfv	6	24.9107830	4.1517972	9.42	<.0001
year	9	118.7590432	13.1954492	29.93	<.0001
mon	8	36.0634710	4.5079339	10.23	<.0001

C. 4T with interaction terms:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	323	933.601524	2.890407	5.91	<.0001
Error	1376	672.969331	0.489077		
Corrected Total	1699	1606.570855			

R-Square	Coeff Var	Root MSE	cpue Mean
0.581114	16.31109	0.699340	4.287512

Source	DF	Type IV SS	Mean Square	F Value	Pr > F
cfv	16*	62.0751877	3.8796992	7.93	<.0001
year	15*	22.3663922	1.4910928	3.05	<.0001
cfv*year	132	195.3658447	1.4800443	3.03	<.0001
mon	7*	10.2746385	1.4678055	3.00	0.0039
cfv*mon	74	50.4584754	0.6818713	1.39	0.0170
year*mon	75	79.0556206	1.0540749	2.16	<.0001

* NOTE: Other Type IV Testable Hypotheses exist which may yield different SS.

D. 4T omitting interactions:

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	501.459128	13.196293	19.83	<.0001
Error	1661	1105.111727	0.665329		
Corrected Total	1699	1606.570855			

R-Square	Coeff Var	Root MSE	cpue Mean
0.312130	19.02449	0.815677	4.287512

Source	DF	Type III SS	Mean Square	F Value	Pr > F
cfv	16	278.8236017	17.4264751	26.19	<.0001
year	15	110.5074073	7.3671605	11.07	<.0001
mon	7	82.1207662	11.7315380	17.63	<.0001

Table 5. Opinions on witch flounder abundance of respondents in the end-of-season telephone survey of participants in the groundfishery in the southern Gulf of St. Lawrence. Opinions are tabulated for respondents who gave witch flounder as their first priority.

Score:	-2	-1	0	1	2			Cumulative
	Much				Much		Average	Average
Year	Lower	Lower	Same	Higher	Higher	N/A	Score	Score
Relative to previous year								
1996	0	0	4	3	0	0	0.43	0.43
1997	0	1	3	1	0	0	0.00	0.43
1998	0	0	1	2	0	0	0.67	1.10
1999	0	0	4	2	0	1	0.33	1.43
2000	0	0	2	1	1	0	0.75	2.18
Relative to previous five years								
1996	1	0	3	1	1	1	0.17	
1997	1	1	1	2	0	0	-0.20	
1998	0	0	0	2	0	1	1.00	
1999	0	1	2	2	2	0	0.71	
2000	0	0	1	2	1	0	1.00	
Relative to all years fished								
1996	0	2	3	1	0	1	-0.17	
1997	1	1	1	2	0	0	-0.20	
1998	0	1	0	1	0	1	1.00	
1999	0	2	1	2	2	0	0.57	
2000	0	0	0	4	0	0	1.00	

Table 6. 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.

Stratum	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
415	0.64	12.30	15.24	34.55	12.95	8.12	9.05	13.85	5.12	6.59	4.11	10.79	8.92	3.71	4.88
416	1.38	4.84	1.90	7.92	10.09	14.54	4.77	18.71	24.62	18.62	5.66	2.33	6.18	4.41	4.03
417	34.36	0.36	12.01	9.97	12.43	11.52	1.30	4.19	19.87	1.69	0.37	3.83	0.43	2.17	1.47
418	1.75	0.68	0.68	2.45	2.98	0.00	5.80	0.00	0.00	0.00	1.15	0.00	0.58	0.00	1.29
419	0.00	0.00	0.88	1.23	0.00	1.02	2.16	0.00	3.06	0.00	0.00	0.00	0.00	0.00	2.15
420	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
421	0.00	0.00	0.00	0.00	3.98	0.00	0.00	3.94	0.00	0.00	0.00	0.00	0.39	0.00	0.51
422	0.54	0.00	27.11	2.63	1.84	11.84	3.61	0.00	1.17	0.39	1.30	0.00	0.00	1.55	1.31
423	0.00	3.13	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.14
424	0.00	0.00	2.45	0.00	0.00	0.77	1.40	1.08	2.04	3.45	3.60	0.00	0.00	0.00	2.75
425	23.48	3.94	0.00	11.73	24.50	8.38	30.78	13.74	1.94	0.00	7.71	3.45	3.16	3.22	1.89
426	0.00	2.16	0.84	14.61	17.15	10.21	0.00	2.31	55.13	4.09	2.17	0.00	0.00	3.50	1.29
427	0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
428	0.00	0.00	2.16	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
429	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00
431	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
433	5.25	0.00	0.00	0.00	1.53	0.00	22.12	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.19
434	0.55	0.00	1.75	0.00	2.04	5.04	0.36	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.75
435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
436	1.15	0.00	0.00	3.45	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.37
437	95.54	3.75	6.12	21.64	1.75	7.19	32.27	0.00	3.20	3.20	2.45	6.56	9.11	10.36	4.71
438	3.68	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	7.09	0.00	2.16	1.94	5.68
439	12.31	11.24	0.97	6.43	3.35	0.00	4.76	2.17	3.25	2.10	1.02	0.97	0.00	8.01	3.53

Stratum	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
415	22.31	17.71	27.05	1.78	5.26	4.10	5.98	10.49	11.14	8.42	9.15	4.04	55.88	12.46	9.89
416	9.25	12.04	20.71	11.99	12.44	5.72	5.27	8.15	17.37	11.63	7.33	3.88	7.26	1.48	0.99
417	5.92	1.69	12.85	3.37	5.61	0.87	2.87	1.66	0.00	0.41	0.46	0.00	0.00	0.00	0.00
418	0.40	2.05	3.85	2.28	0.00	0.00	0.00	0.15	0.72	0.00	0.00	0.00	0.00	0.00	0.00
419	3.56	3.13	0.38	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
420	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
421	0.00	0.64	0.39	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
422	2.88	0.74	0.08	0.19	5.19	1.37	0.38	0.38	0.74	0.22	0.06	0.04	0.09	0.00	0.06
423	1.00	0.13	0.52	0.95	0.41	0.77	0.11	0.03	0.25	0.03	0.03	0.00	0.24	0.03	0.00
424	3.40	0.68	1.20	0.87	2.50	1.28	0.08	0.56	0.40	0.34	0.43	0.00	0.00	0.16	0.27
425	2.53	11.55	12.79	1.26	2.69	8.84	7.25	5.56	6.26	4.79	33.77	6.58	13.56	3.87	5.49
426	0.34	1.63	0.76	7.00	0.00	7.78	6.14	14.11	2.94	20.31	19.92	16.43	1.08	0.92	22.75
427	0.00	0.00	0.00	0.00	1.02	0.62	0.76	0.00	0.13	0.09	0.45	0.30	0.00	0.00	0.00
428	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
429	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
431	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
432	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
433	1.40	0.27	0.26	2.81	0.00	2.85	0.00	0.00	0.43	0.07	0.00	0.33	0.12	0.11	0.00
434	0.31	0.00	0.41	7.25	0.55	0.75	0.34	0.13	6.40	0.06	3.23	1.19	5.21	0.24	0.24
435	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00
436	0.36	0.00	0.00	0.00	0.26	0.22	0.00	0.00	0.55	0.24	0.00	0.00	0.32	0.00	0.00
437	26.62	13.44	27.76	38.16	25.76	3.64	1.98	19.24	32.34	25.77	92.75	30.42	47.06	272.18	126.53
438	4.32	2.45	0.28	0.99	2.10	4.69	3.57	9.79	2.82	1.93	9.25	7.60	30.91	1.39	3.70
439	1.08	1.45	3.55	3.81	10.23	5.40	1.17	0.54	4.63	4.40	1.07	2.50	2.21	0.94	9.18

Table 7. 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	1998	1999	2000
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	3.50	6.32	2.43
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	10.78	15.63	8.60
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	18.66	12.99	47.93
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	0.00	0.93	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	0.67	0.36	4.67
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	3.81	4.55	20.03
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	0.67	10.69	18.62
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	13.77	15.08	19.10
409				56.51	44.47	27.40	44.95	48.94	47.25	4.26		48.76	14.58	8.46	17.89	4.96	52.21
410			19.01		16.36	12.93	2.19	38.63	1.52	1.70	16.11	9.26	3.80	3.32	5.80	1.71	11.97
411				65.06	32.23		52.05	54.19	122.27	19.22	47.10	32.33	15.69	16.92	14.63	11.30	62.72
412				62.71	37.47		44.59	79.27	145.01	52.60	186.89	17.18	15.56	30.52	18.30	19.83	46.38
413				64.19	21.15		41.56	44.96	74.81	2.98		16.83	13.61	11.24	6.13	9.78	19.76
414				8.17	38.58		36.04	45.27	18.96	2.46	303.33	6.73	2.39	0.72	0.90	0.67	22.60
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	26.25	9.57	21.47
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	2.56	2.33	3.79
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	2.20	22.81	35.49
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	3.67	25.70	11.34
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	1.75	1.87	12.08
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	10.59	15.36	7.10
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	0.73	10.40	8.09
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	1.35	4.34	2.33
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	11.67	1.75	3.89
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	5.09	1.75	12.54
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	27.15	7.19	13.39
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	1.44	3.50	23.33
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	9.38	18.08	36.85
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	0.00	5.35	11.16
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	1.92	15.39	6.85
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	4.50	10.10	4.09
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	5.27	2.54	20.75
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	2.24	14.52	8.05
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	2.33	4.39	3.50
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	4.89	3.50	10.98
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	0.00	4.86	7.10
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	5.13	7.15	7.23
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	0.00	53.18	11.67
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	0.72	7.29	6.56
825	0.00	100.04	8.21														
826			3.89														
827		16.93	3.07	3.76	4.92			0.00	0.00	0.00	0.49	2.12		8.75	15.33	13.13	1.94
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	0.65	0.00	
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		0.72	2.82	0.73
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	1.46	0.00	0.78
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	0.00	0.36	1.26
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	0.00	0.00	20.90
833				0.46	1.03	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00
835								0.32	1.84	0.00	0.49	0.00	0.00	0.00	1.08	24.79	28.33
836								0.00	0.00	0.00	42.78	0.00	0.00	0.00	0.00	0.00	0.00
837								0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.00	0.00
838								0.00	0.00	0.00	0.00	0.00				0.00	
839								1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
840								0.00	0.00		0.00						
841									0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00

Table 8. Population length distribution (thousands of fish) of 4RST witch flounder, estimated from the August and September research surveys of the Gulf of St. Lawrence. Estimates are the mean catch rate at length multiplied by the number of trawlable units in the survey area.

Length	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
6.5	0.0	0.0	0.0	0.4	6.8	0.2	0.4	6.6	4.2	0.1	0.2	8.1	0.0	0.0
8.5	106.1	34.4	98.6	51.4	17.7	27.9	13.8	14.1	34.3	9.2	115.3	110.6	52.7	11.6
10.5	154.4	81.7	286.3	405.6	420.1	102.7	35.9	105.5	137.7	29.1	334.7	218.3	189.3	28.1
12.5	61.9	102.4	129.4	585.1	707.5	57.2	103.1	0.0	302.1	292.8	71.3	252.0	250.3	261.2
14.5	117.2	514.8	207.9	410.7	2514.6	460.5	117.6	95.8	773.7	292.6	100.8	1313.3	1332.3	1947.2
16.5	537.6	760.4	172.8	1881.9	2604.9	825.0	418.5	549.3	1236.1	701.3	516.7	1779.0	3022.1	3466.5
18.5	1044.7	426.5	401.3	2462.4	2497.8	1942.2	311.6	1726.5	1419.0	3051.2	798.0	695.1	4163.2	7598.5
20.5	1193.7	929.4	582.9	1246.3	4333.0	4918.6	925.1	5060.9	1180.5	5133.7	997.3	922.2	4520.1	7909.2
22.5	664.8	1072.8	371.1	2317.8	3793.2	4422.0	1539.9	3651.8	1861.8	5828.3	1189.7	948.9	2980.4	8135.9
24.5	845.5	1315.4	561.3	2861.7	2946.5	4602.5	2274.2	4237.8	2680.6	3146.1	1480.9	2381.8	1531.2	4210.6
26.5	1496.9	1213.7	737.1	3374.4	3514.0	2129.6	1422.4	4311.4	2799.1	3041.9	3304.3	2492.2	2052.1	3333.1
28.5	2961.3	1791.4	806.9	1624.0	2652.9	2087.9	733.0	4175.0	2177.7	2949.6	1765.8	2166.7	2825.1	5224.2
30.5	4472.4	2363.8	1199.6	2760.3	1149.3	2062.9	545.6	1505.8	2173.0	2083.4	1993.3	1590.0	2992.2	5783.0
32.5	4464.3	3445.8	2017.6	3958.6	2198.7	744.8	590.2	1374.8	812.3	2002.1	1633.1	2228.2	2194.5	4222.3
34.5	3571.1	4187.0	2653.5	4279.1	2407.6	1325.4	689.9	1195.5	1195.3	1868.4	1475.0	1809.4	2654.9	4100.6
36.5	3055.5	3557.2	2334.5	6070.2	2684.5	1863.6	437.2	1230.7	912.8	2287.9	932.7	1660.8	3170.9	3066.7
38.5	1705.7	2973.8	2149.9	3378.1	2382.3	5114.0	631.6	830.9	982.1	995.8	512.3	934.4	3198.6	1978.4
40.5	1253.2	1822.6	1725.6	2084.2	1269.3	980.8	414.6	572.8	762.4	919.5	418.6	571.4	1769.8	1510.3
42.5	1301.4	1299.1	1300.0	1653.9	817.4	642.3	177.1	746.1	383.0	502.4	310.9	403.7	1052.2	1054.4
44.5	1088.2	1244.9	1083.1	1224.8	722.3	258.0	118.8	155.4	190.8	280.6	188.9	221.3	712.6	275.8
46.5	1014.1	1383.9	1003.4	949.5	503.5	321.1	96.8	371.4	77.4	141.0	190.7	175.9	324.1	260.5
48.5	953.6	864.2	496.5	462.1	453.8	180.2	77.0	206.1	105.7	78.0	16.1	61.8	212.9	115.5
50.5	439.0	473.6	245.8	545.1	219.0	11.2	133.2	63.0	15.9	41.6	23.4	13.7	0.0	58.3
52.5	197.5	219.1	204.9	92.7	152.6	21.1	17.5	61.4	17.6	14.0	12.1	0.0	35.3	2.9
54.5	140.0	176.5	217.4	0.0	52.7	15.0	12.6	8.0	0.0	12.9	8.9	7.5	18.5	5.7
56.5	46.8	82.3	60.3	175.6	43.2	16.2	0.0	7.0	6.6	7.0	4.0	7.5	0.0	0.0
58.5	0.0	9.9	31.4	0.0	121.1	6.4	6.2	0.0	6.6	6.0	0.0	0.0	0.0	0.0
60.5	0.0	0.0	28.8	0.0	0.0	0.0	0.0	0.0	0.0	11.9	0.0	4.8	0.0	0.0
62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
64.5	0.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 9. Starting values, model fit and parameter estimates for selected surplus production models for witch flounder in the Gulf of St. Lawrence.

run	10	13	e1	e4	r1	t1	t4
area	4RST	4RST	4RST	4RST	4R	4Te	4Te
years	1987-2000	1987-2000	1987-1998	1987-1998	1987-2000	1987-2000	1987-2000
starting values							
B1 ratio	1	1	1	0.2	1	1	0.2
MSY	10000	10000	5000	10000	5000	5000	10000
r	0.4	0.2	0.4	0.2	0.4	0.4	0.2
q	3.00E-08	3.00E-08	3.00E-08	3.00E-09	3.00E-08	3.00E-08	3.00E-09
fit							
R^2 with abundance index	0.435	0.385	0.576	0.588	0.836	0.474	-0.102
objective function	1.94	3.14	1.58	1.75	2.16	6.71	1.24
estimates							
B1 ratio	0.67	9.3	0.36	49.5	1.04	0.34	0.9
MSY	2418	1.24E+05	3392	47470	672	2309	3.95E+05
r	0.87	0.17	0.49	0.2	0.76	0.64	2.458
q	9.81E-07	2.69E-10	6.45E-07	1.55E-11	1.26E-06	6.82E-07	1.84E-09
K	11140	2.90E+06	27560	9.49E+06	3523	14410	6.42E+05
Bmsy	5570	1.45E+06	13780	4.75E+06	1762	7205	3.21E+05
B(2001)/Bmsy	0.29	2.153	3.30E-05	7.279	0.47	1.05	1.999
Fraction of MSY available in 2001	0.49	-3.29E-01	6.61E-05	-3.84E+01	0.71	0.998	1.36E-03

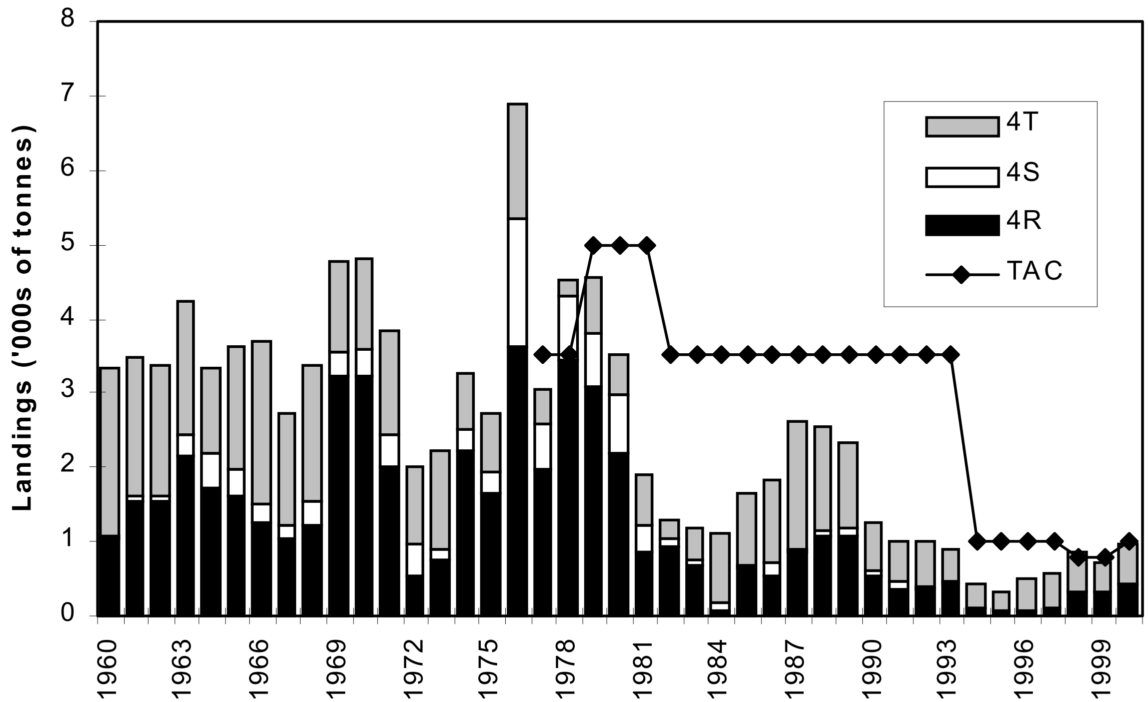


Figure 1. Landings of witch flounder in NAFO Divisions 4RST.

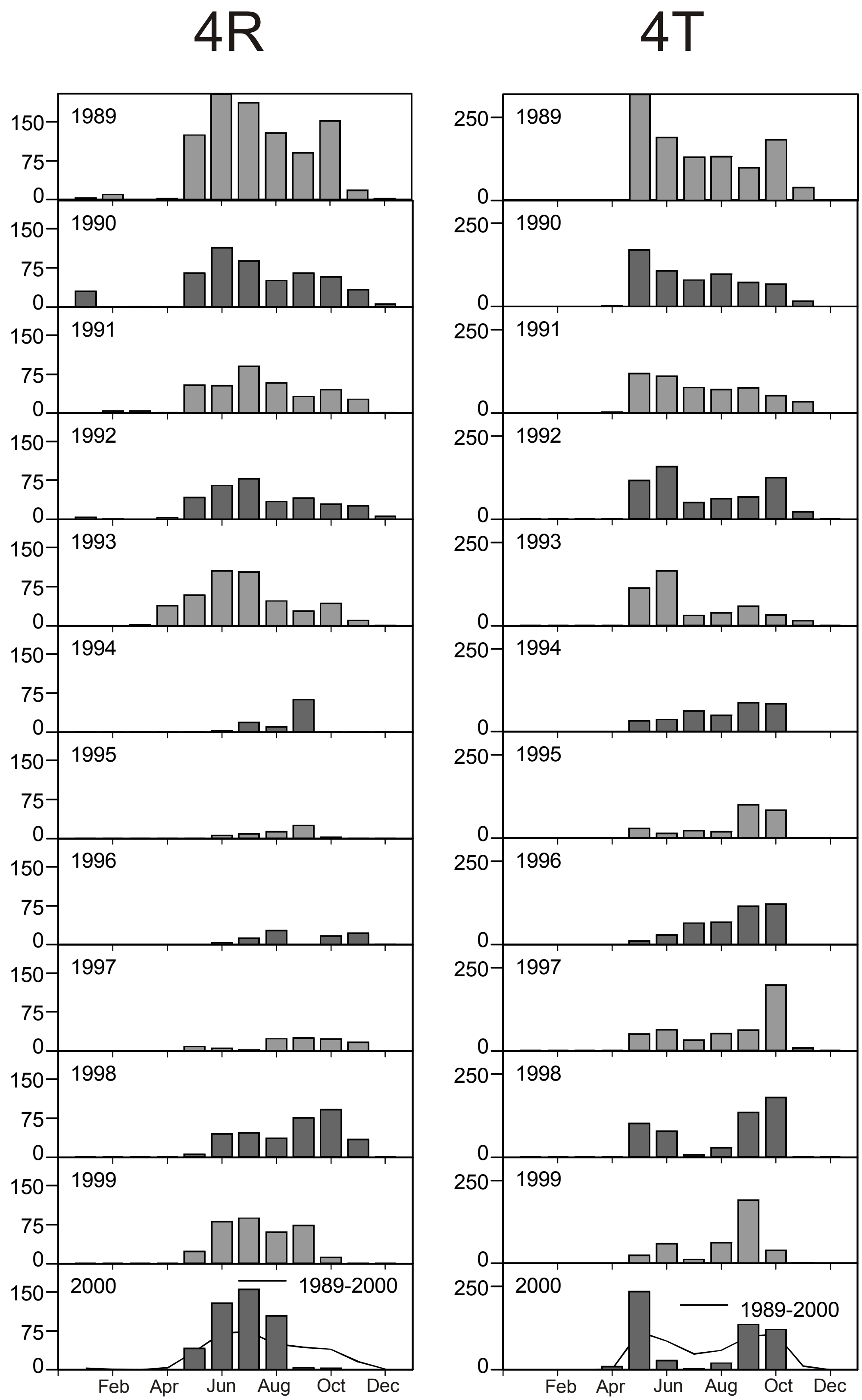


Figure 2. Monthly landings (t) of witch flounder in NAFO Divisions 4R and 4T. Lines show the average distribution for 1989-2000.

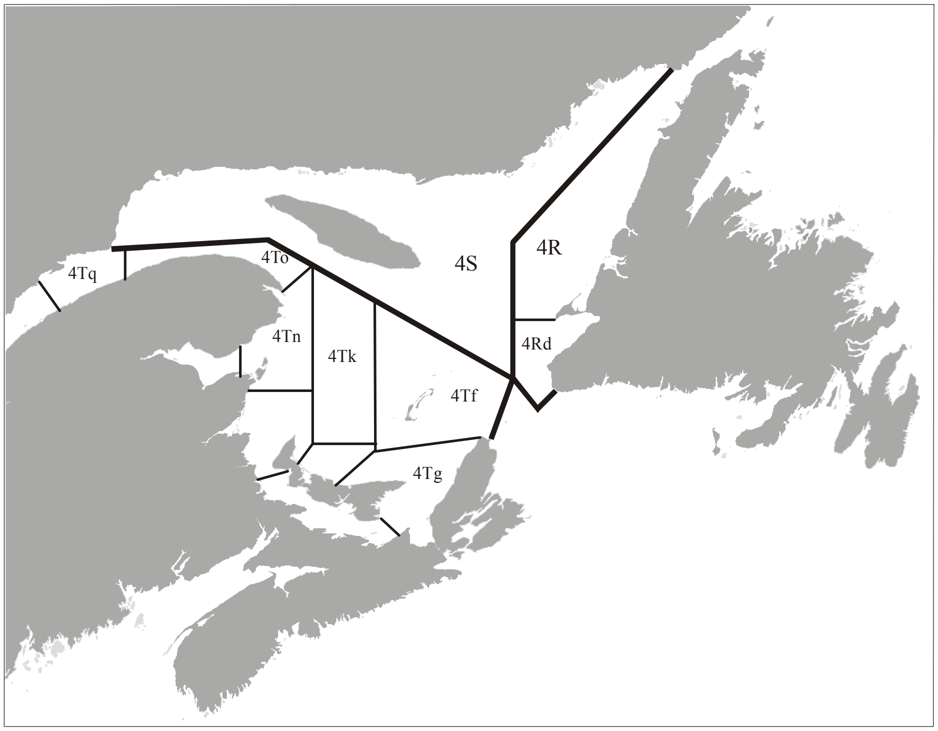


Figure 3. NAFO Divisions 4R, 4S and 4T (bordered by heavy lines). Unit areas where most witch flounder are caught in commercial fisheries are labelled in lower case.

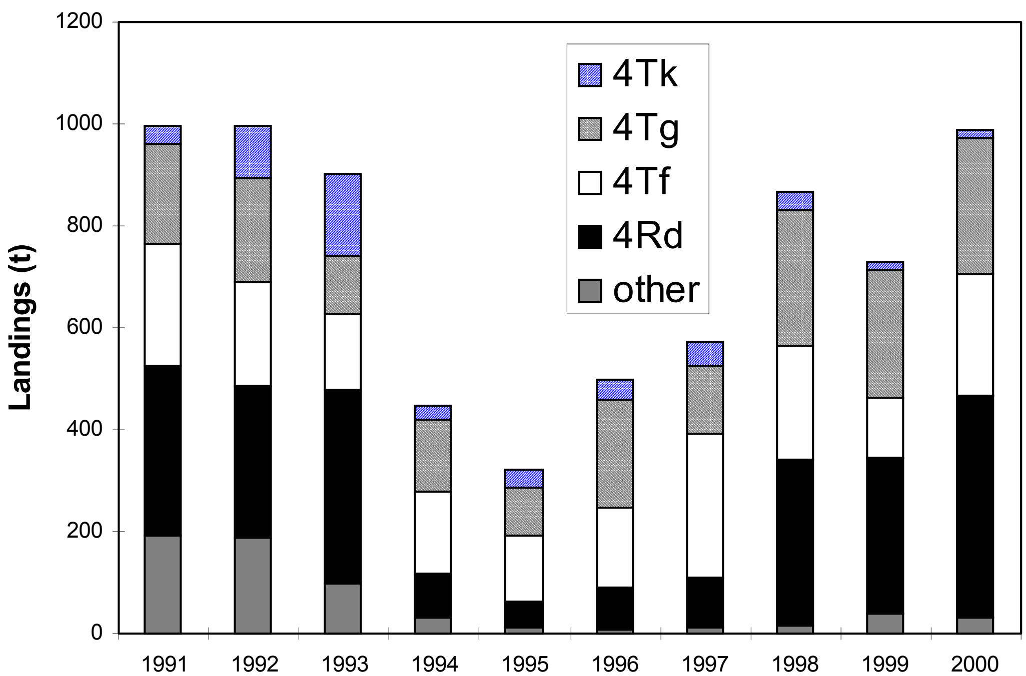


Figure 4. Landings of 4RST witch flounder by NAFO unit area.

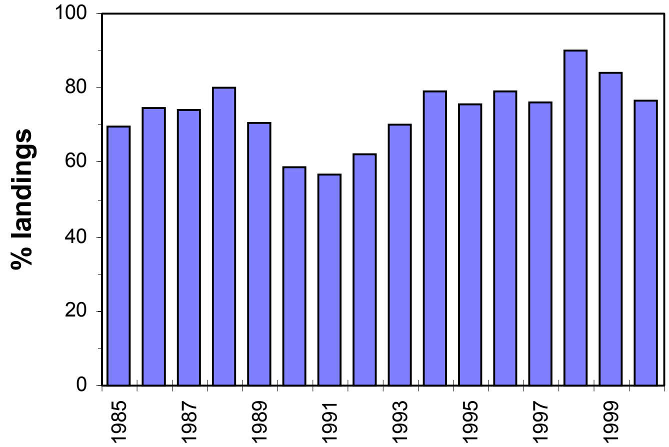
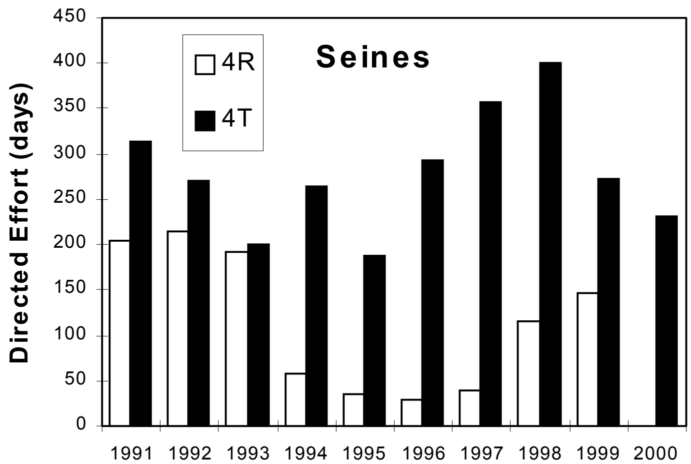


Figure 5. Percent of mobile-gear landings of 4RST witch flounder with witch as the main species caught.



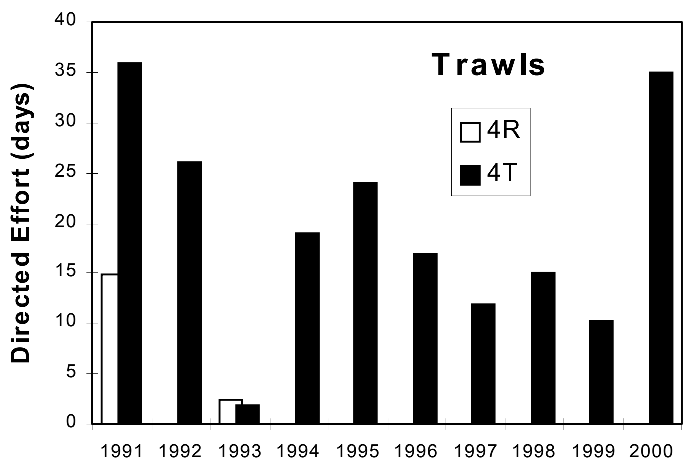


Figure 6. Fishing effort by seines and trawls directing for witch flounder in NAFO Divisions 4R and 4T. Effort data are not available for 4R in 2000.

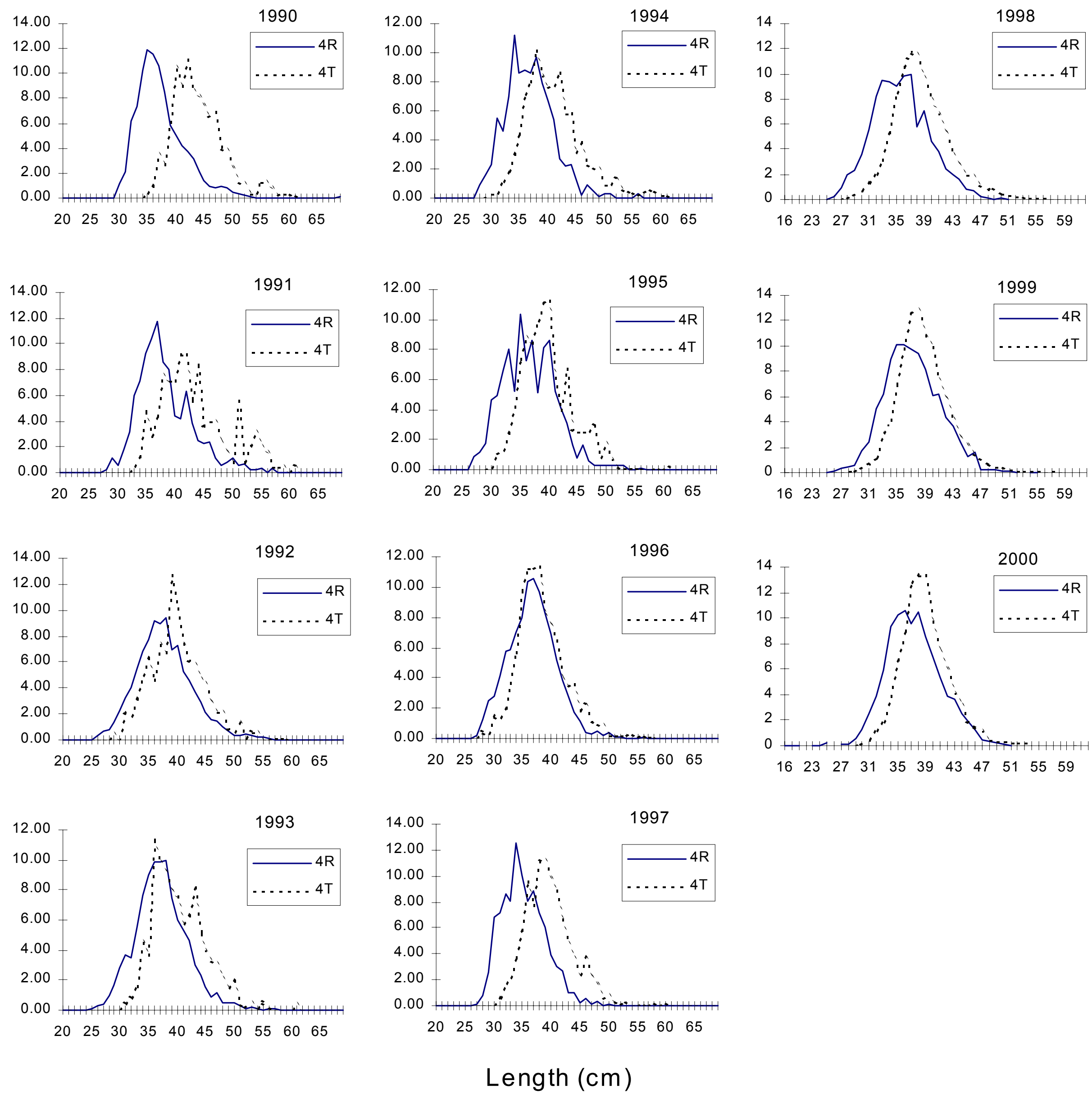


Figure 7. Weighted average length frequencies (%) of witch flounder sampled from mobile-gear landings in NAFO divisions 4RST, 1990-2000. Weighting is by the landing associated with each length frequency sample.

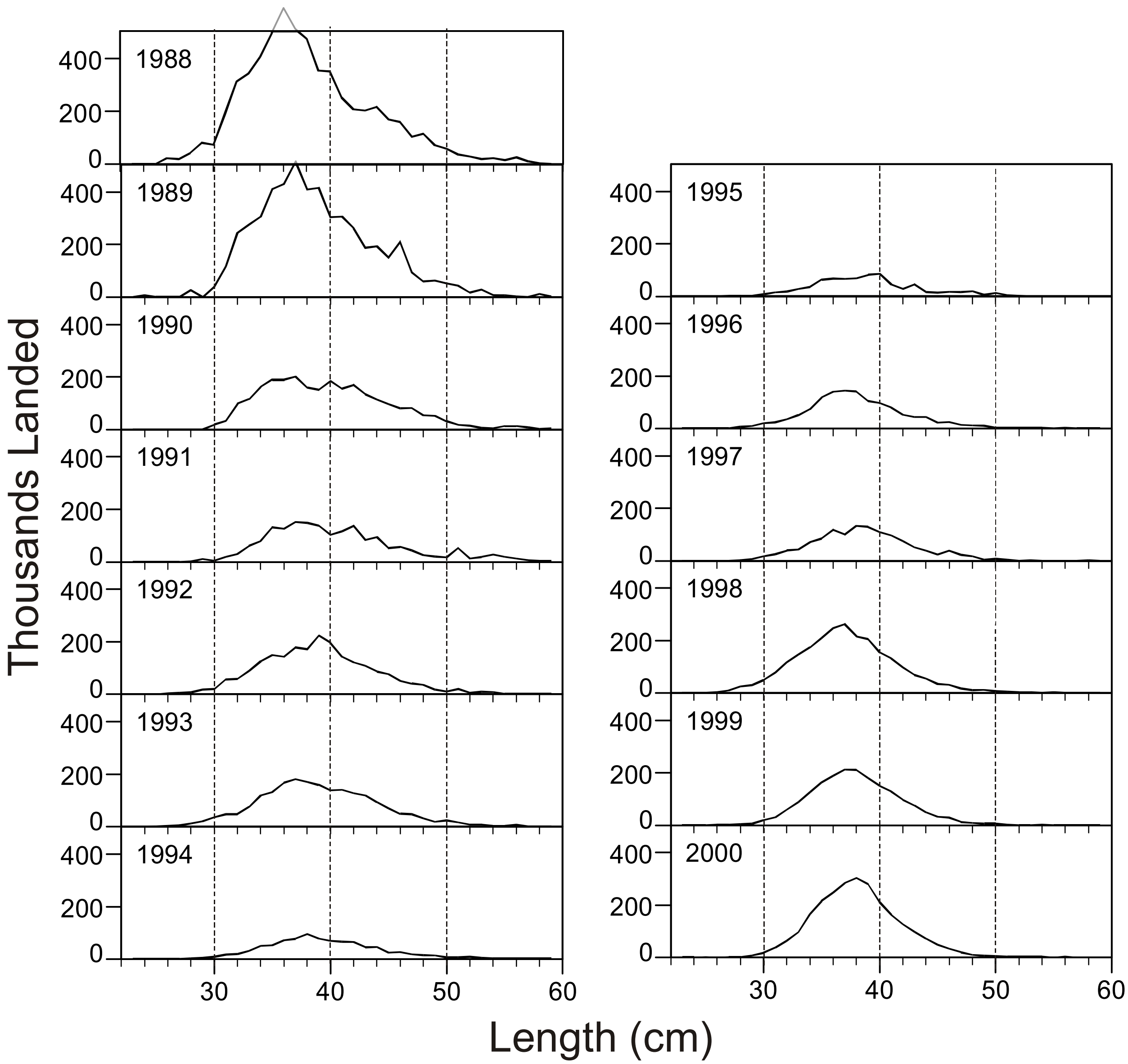


Figure 8. Estimated catch-at-length for mobile-gear landings of witch flounder in NAFO Divisions 4RST, 1988-2000.

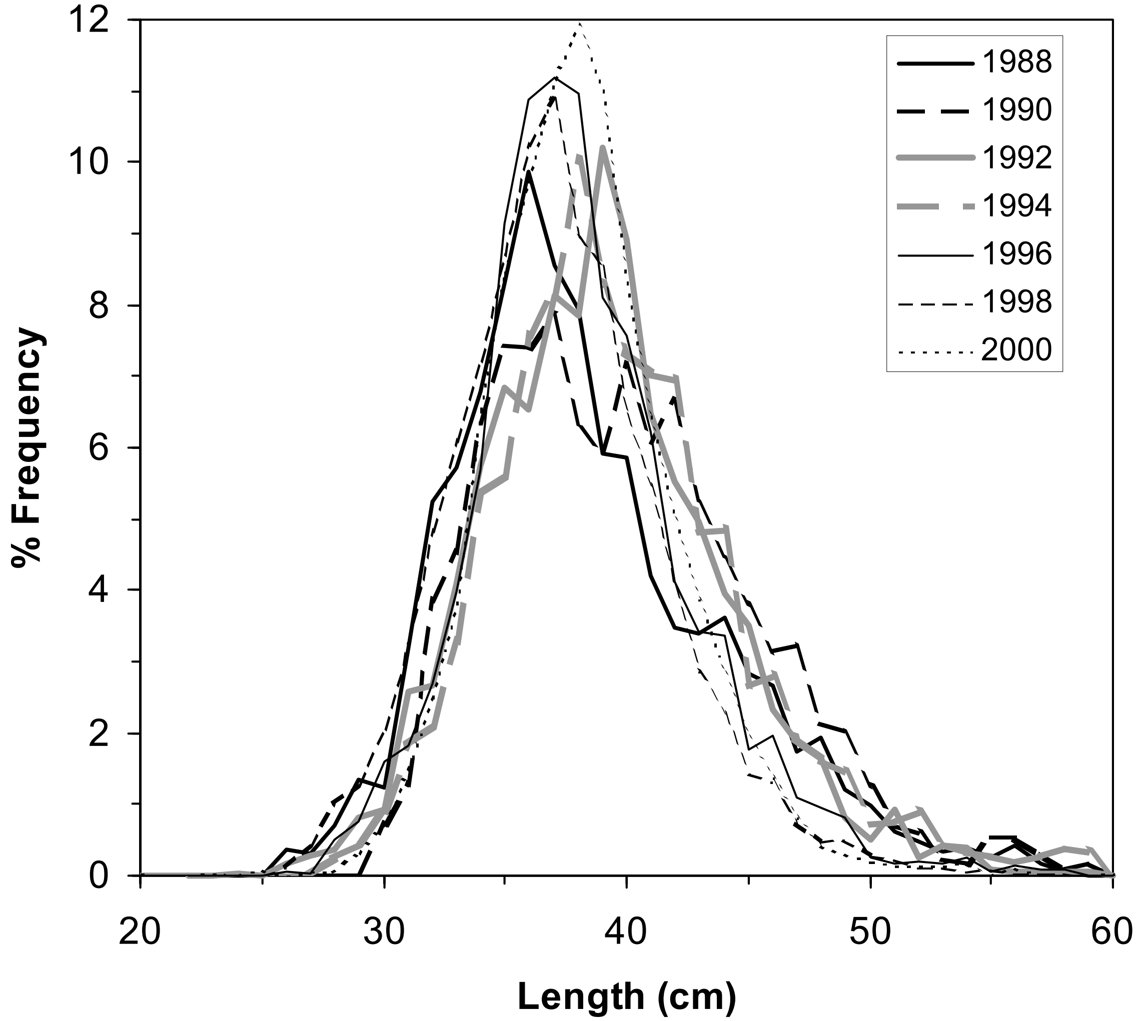


Figure 9. Percent length composition of mobile-gear landings of 4RST witch flounder.

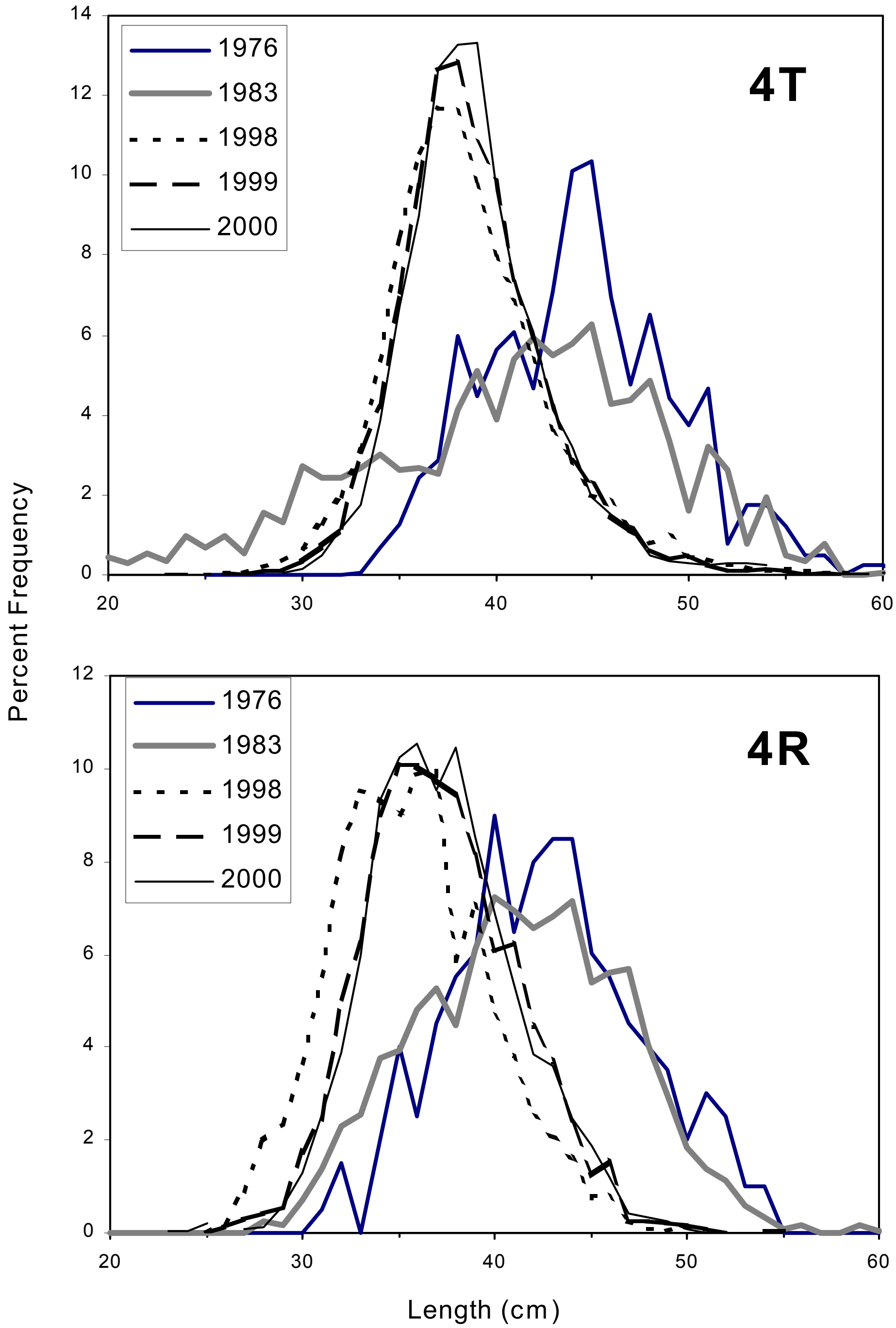


Figure 10. Comparison of length frequencies of witch flounder landed by mobile gear in 4T and 4R in 1976, 1983, 1998, 1999, and 2000.

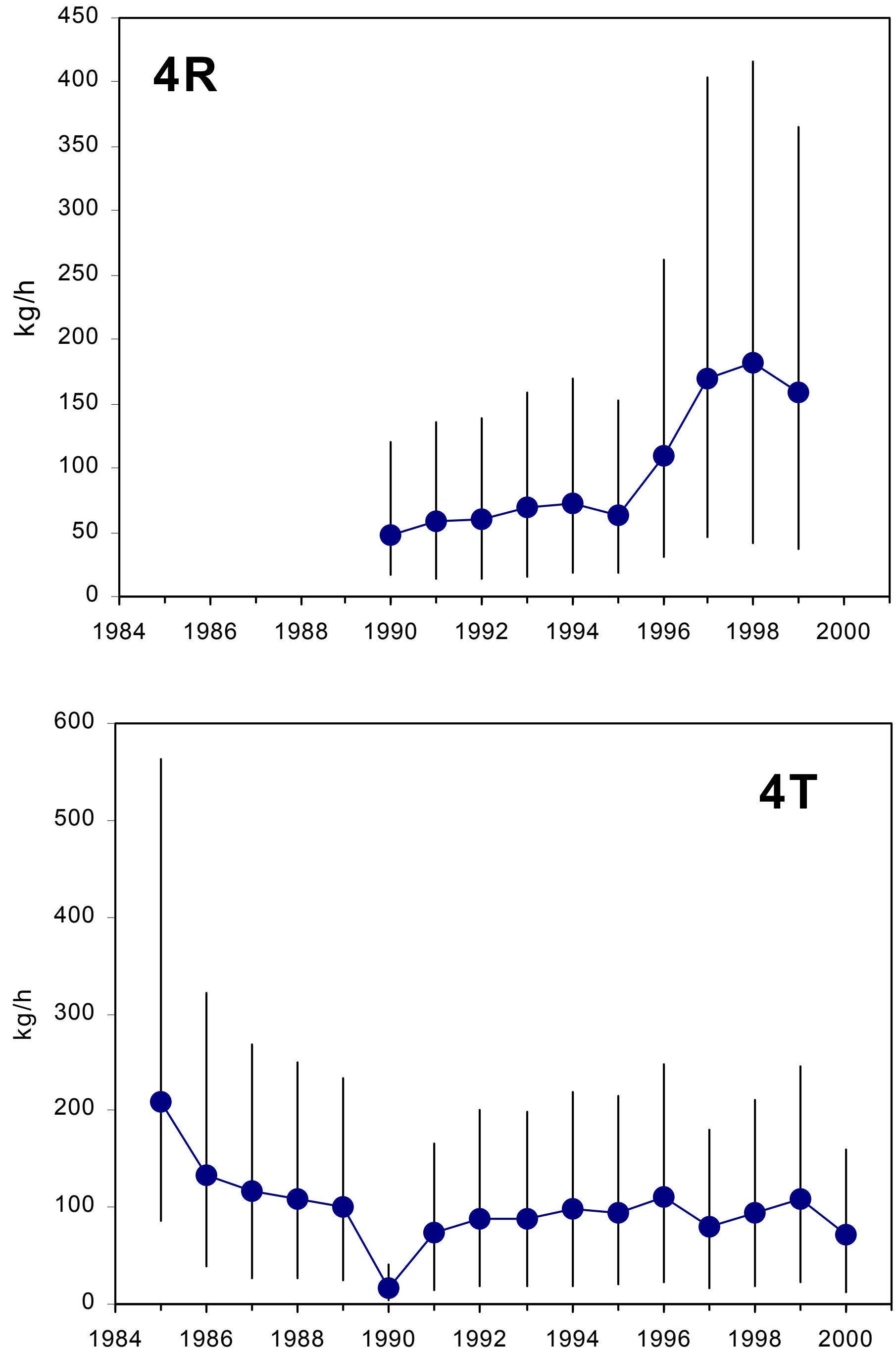


Figure 11. Catch rates of witch flounder by seines in NAFO Divisions 4R and 4T, standardized by vessel and month. Vertical lines are 95% confidence intervals.

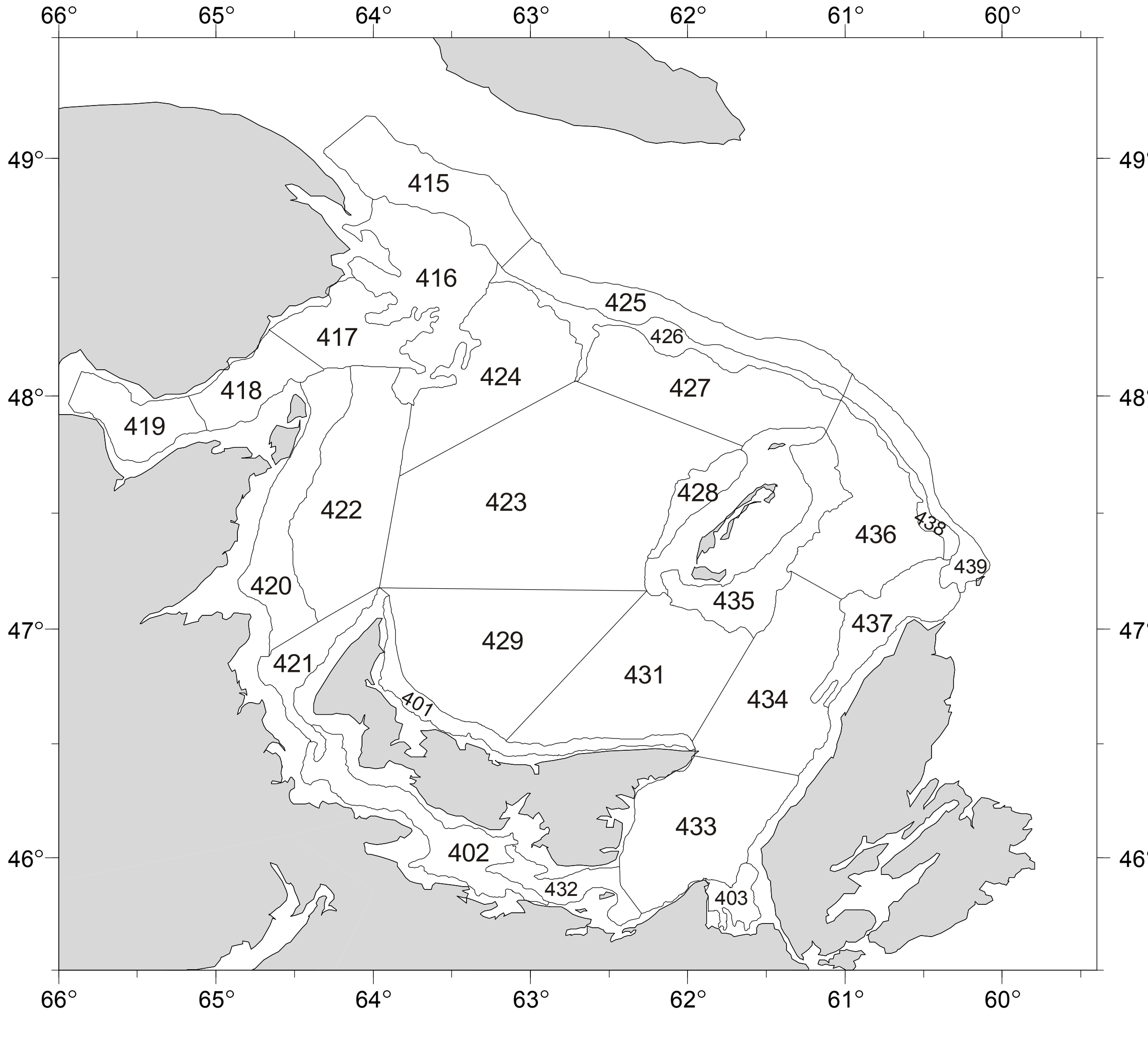


Figure 12. Stratum boundaries for the September bottom-trawl survey of the southern Gulf of St. Lawrence.

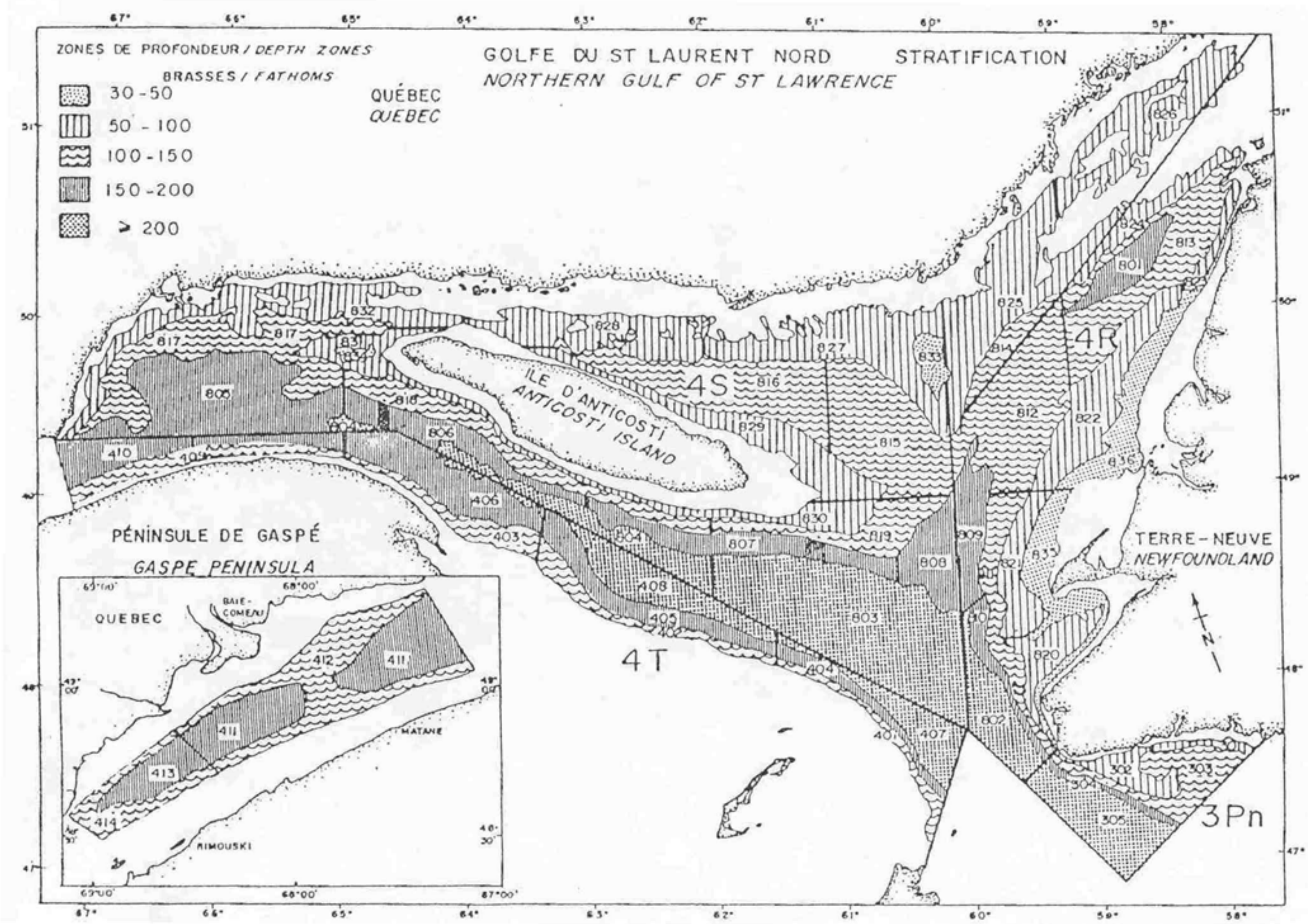


Figure 13. Stratum boundaries for the August bottom-trawl survey of the northern Gulf of St. Lawrence.

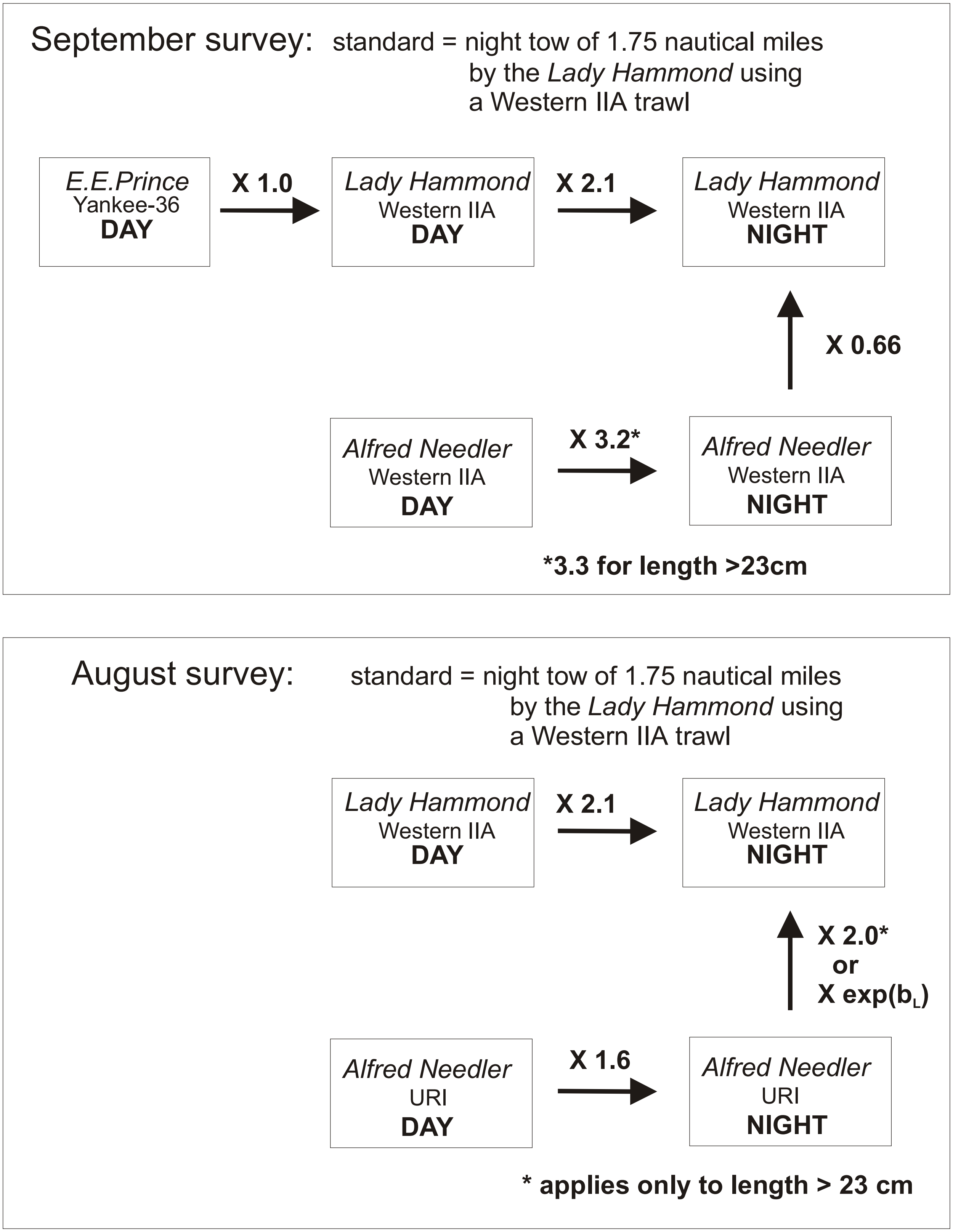


Figure 14. Construction of a consistent series of witch flounder catch rates in the summer surveys of the Gulf of St. Lawrence. All catches are standardized to a tow of 1.75 nautical miles before applying conversion factors. $\exp(b_L)$ is a length-dependent conversion factor.

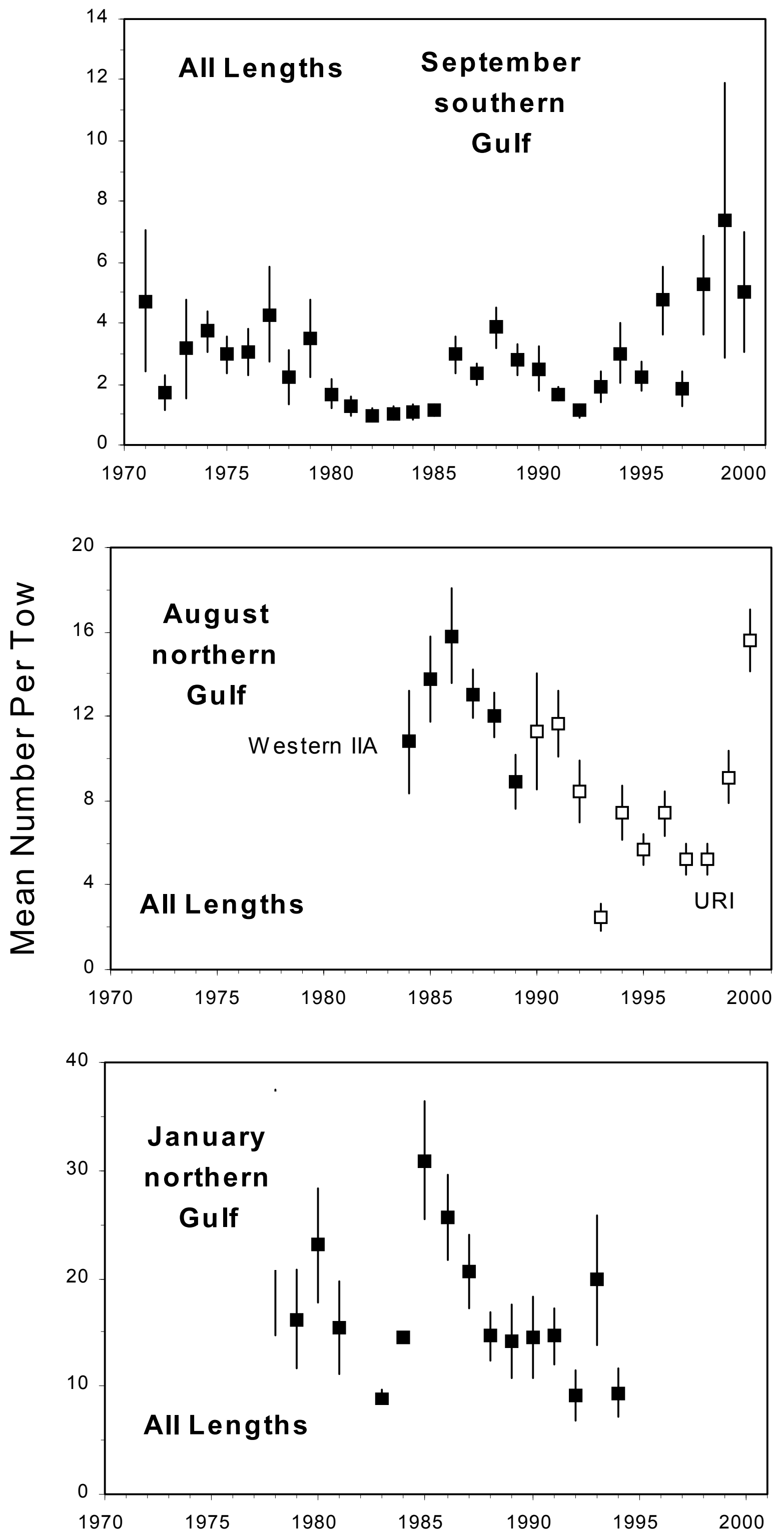


Figure 15. Mean catch rates of witch flounder in surveys of the Gulf of St. Lawrence. Vertical bars are approximate SE. Catches in the summer surveys are adjusted to a standard night tow of 1.75 nautical miles. No adjustment has been made for the change in vessel and gear in the August survey of the 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).

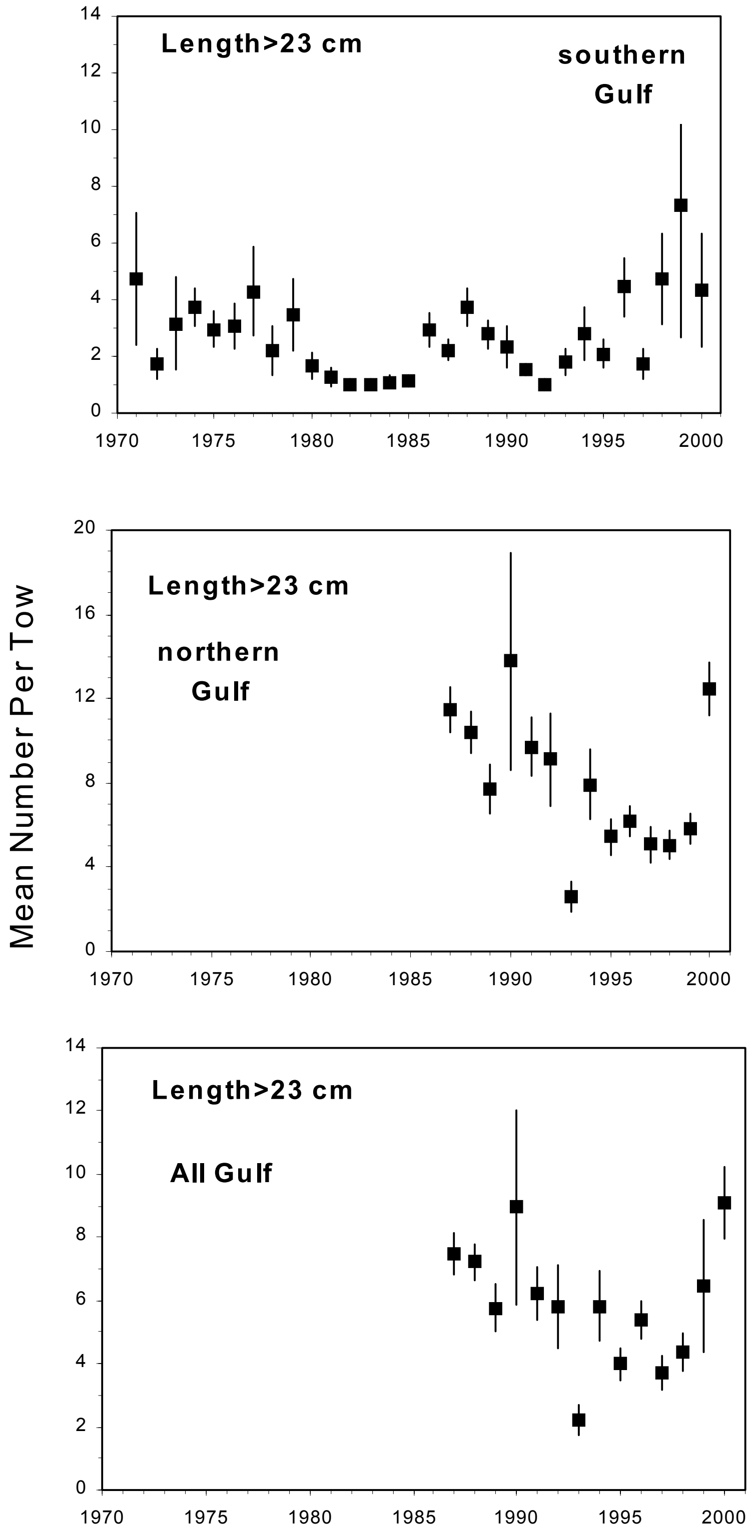


Figure 16. Mean catch rate of witch flounder 24 cm or greater in length in the summer surveys of the Gulf of St. Lawrence. Vertical bars are approximate SE. Catches are adjusted to a standard night tow of 1.75 nautical miles by the *Lady Hammond* using a Western IIA trawl.

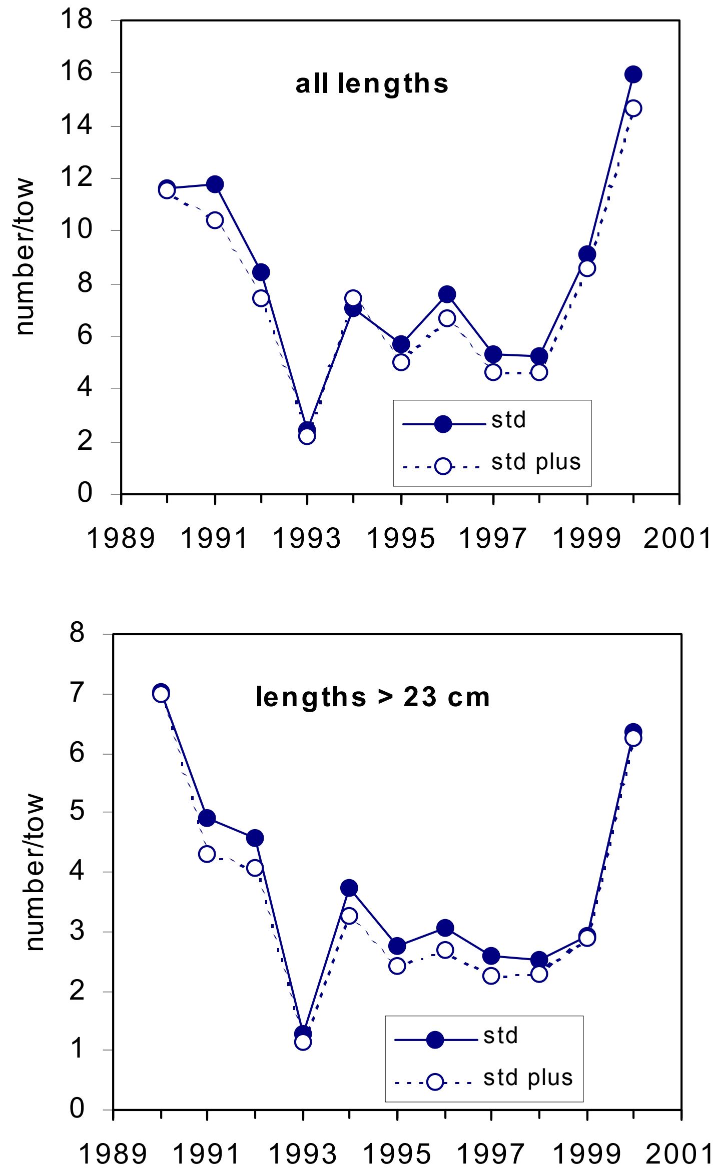


Figure 17. Comparison of stratified mean catch rates for the August survey of the northern Gulf using either the standard strata ("std": 401-414, 801-824, 827-832) or the standard plus additional strata ("std plus": 401-414, 801-824, 827-833, 835-837, 839). Catches are adjusted to a night tow of 1.75 nm by the *Alfred Needler* using a URI trawl. Missing cells are replaced by year means.

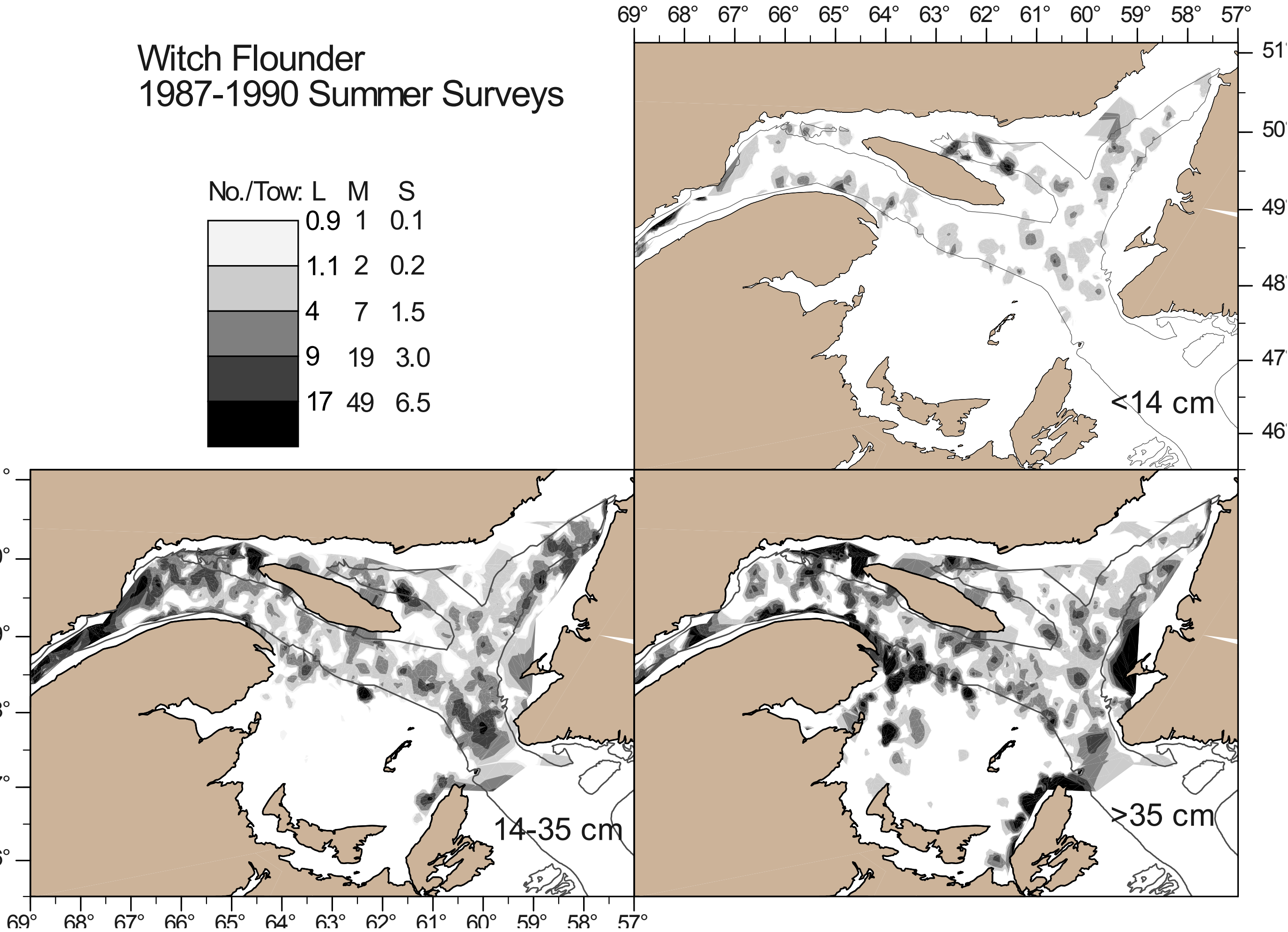


Figure 18. Distribution of three size classes of witch flounder in summer surveys of the Gulf of St. Lawrence, 1987-1990. S – length <14 cm, M – length 14-35 cm, L – length > 35 cm. Standard is a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl.

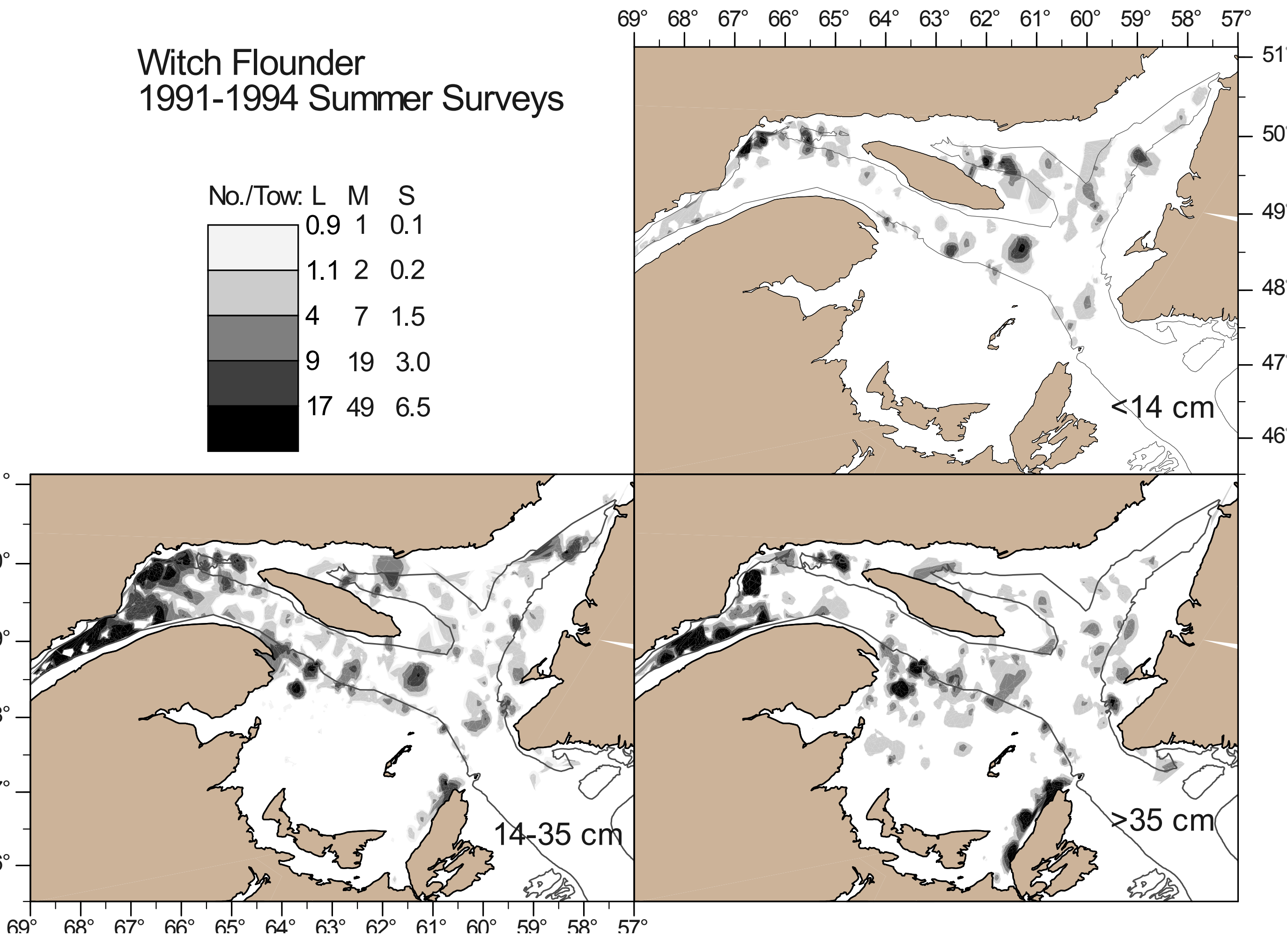


Figure 19. Distribution of three size classes of witch flounder in summer surveys of the Gulf of St. Lawrence, 1991-1994. S – length <14 cm, M – length 14-35 cm, L – length > 35 cm. Standard is a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl.

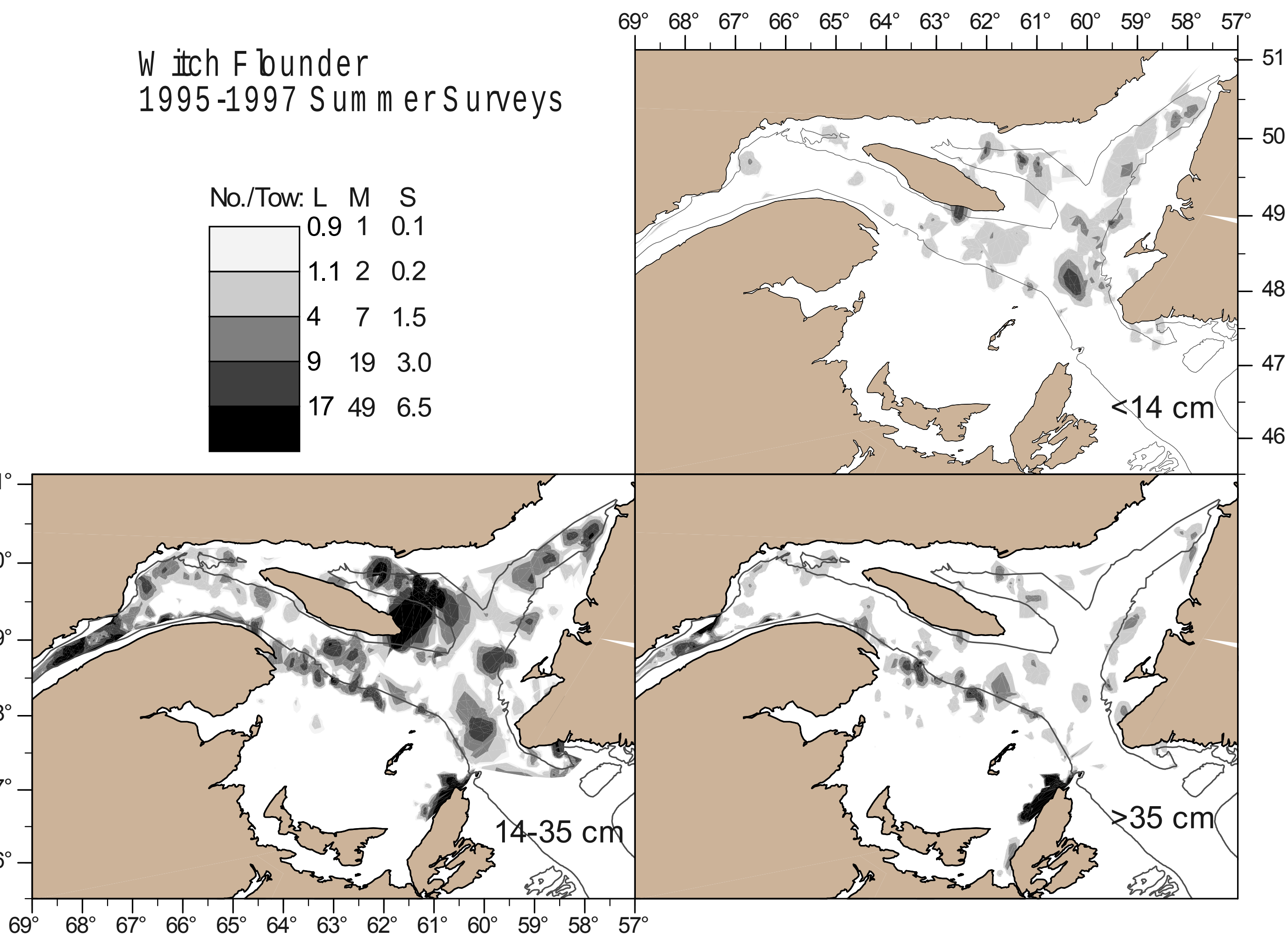


Figure 20. Distribution of three size classes of witch flounder in summer surveys of the Gulf of St. Lawrence, 1995-1997. S – length <14 cm, M – length 14-35 cm, L – length > 35 cm. Standard is a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl.

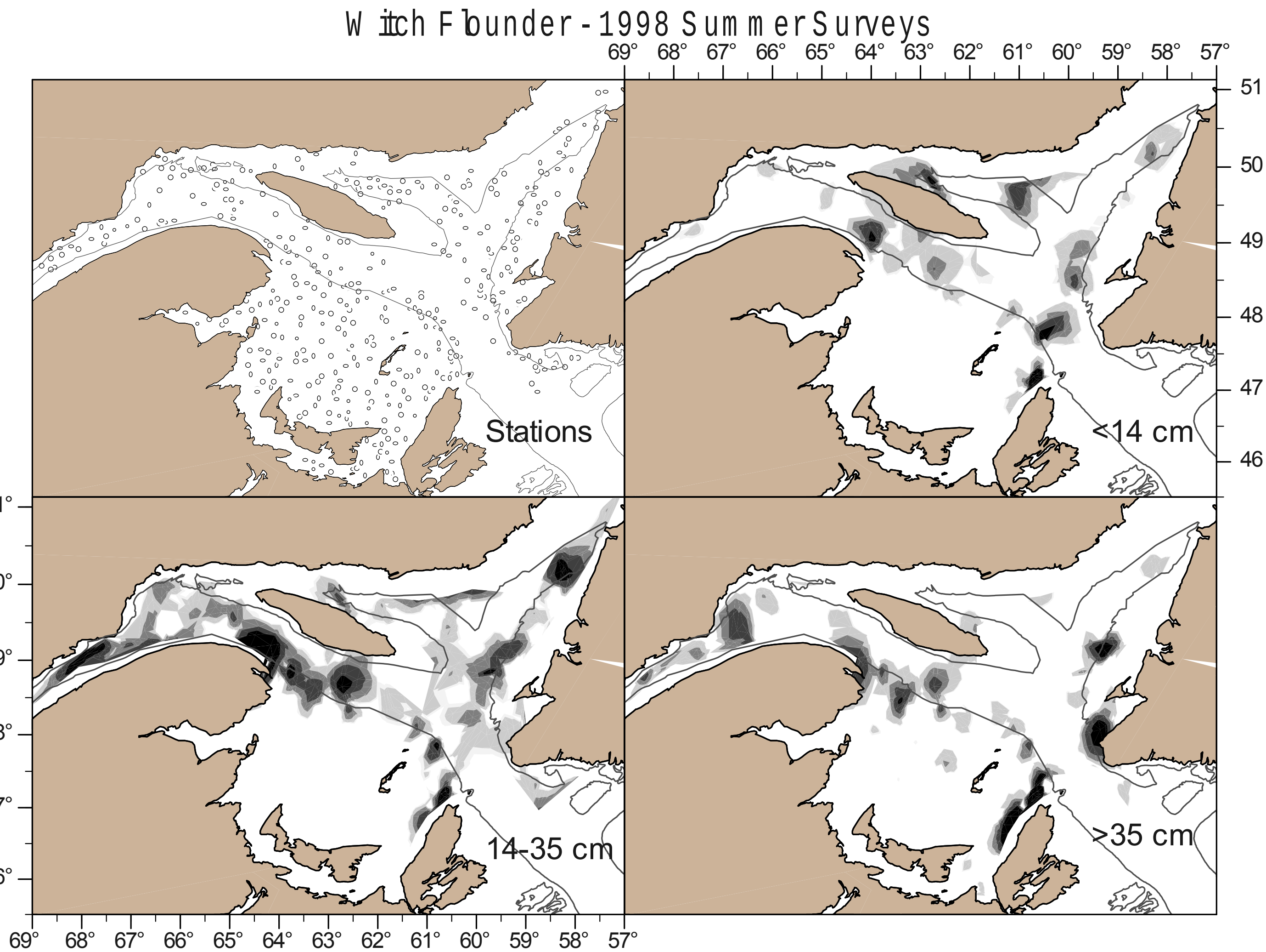


Figure 21. Distribution of three size classes of witch flounder in 1998 summer surveys of the Gulf of St. Lawrence. Standard is a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl. See Figure 20 for legend.

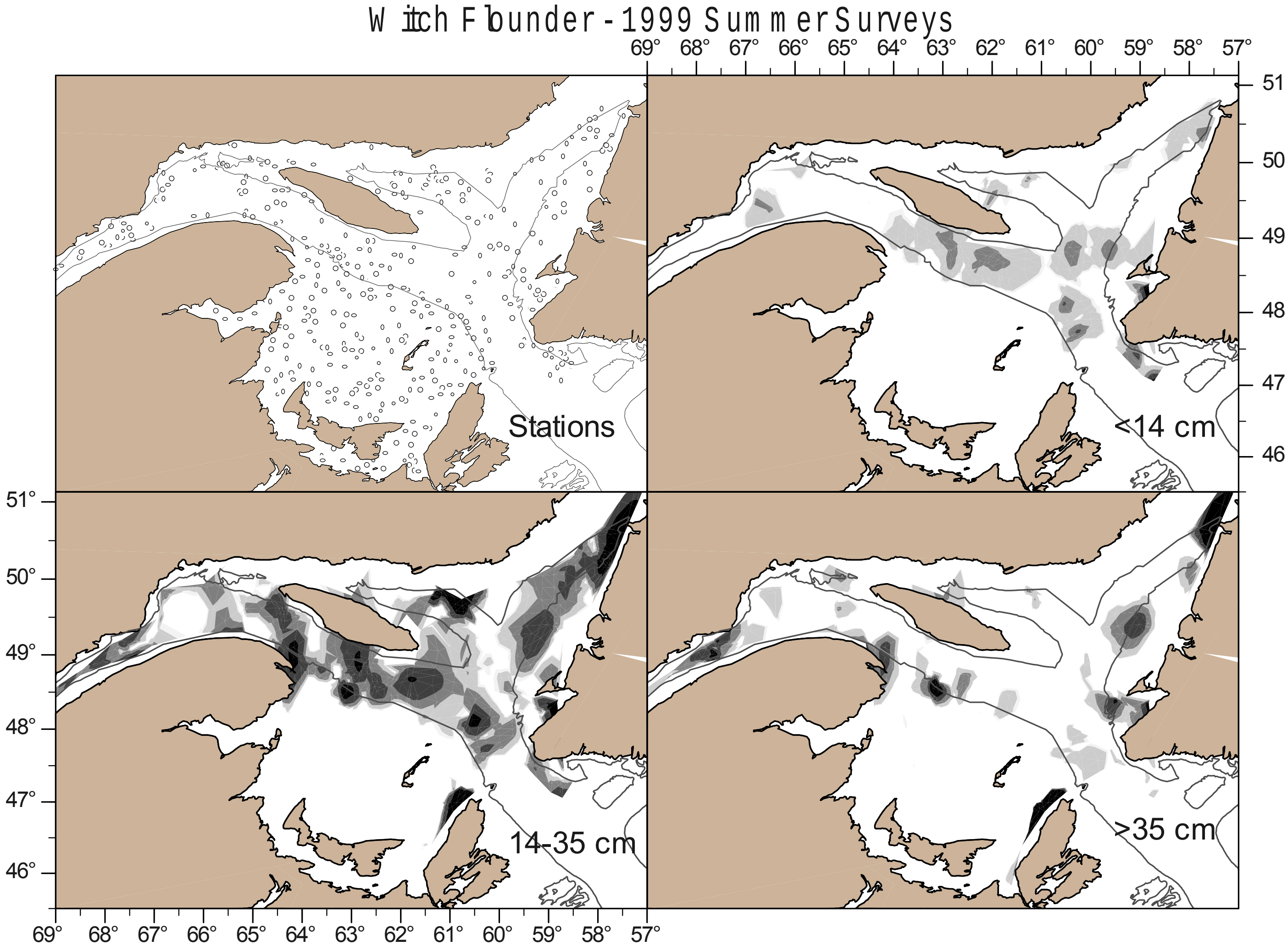


Figure 22. Distribution of three size classes of witch flounder in 1999 summer surveys of the Gulf of St. Lawrence. Standard is a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl. See Figure 20 for legend.

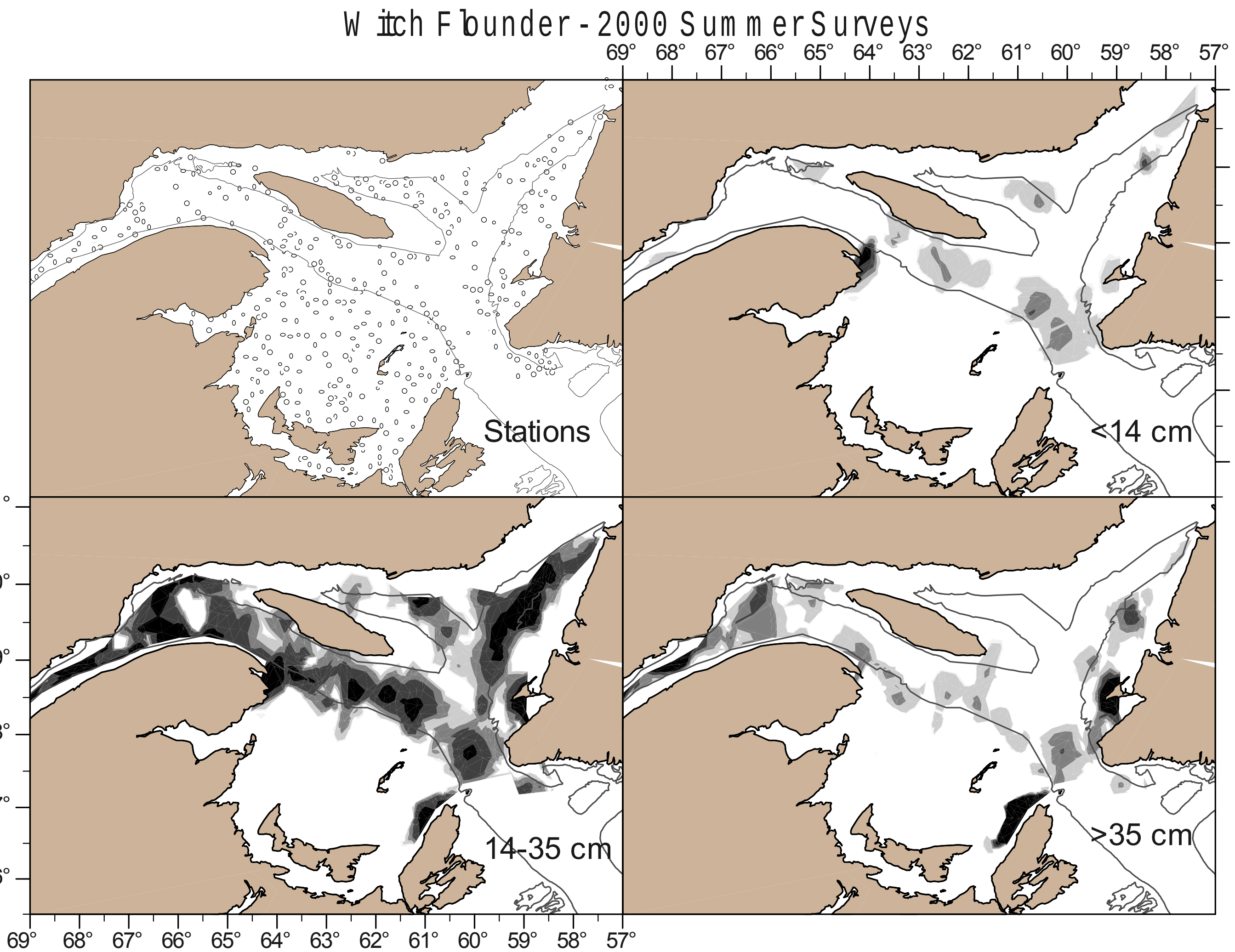


Figure 23. Distribution of three size classes of witch flounder in the summer surveys of the Gulf of St. Lawrence in 2000. Standard is a night tow of 1.75 nm by the *Alfred Needler* using a Western IIA trawl. See Figure 20 for legend.

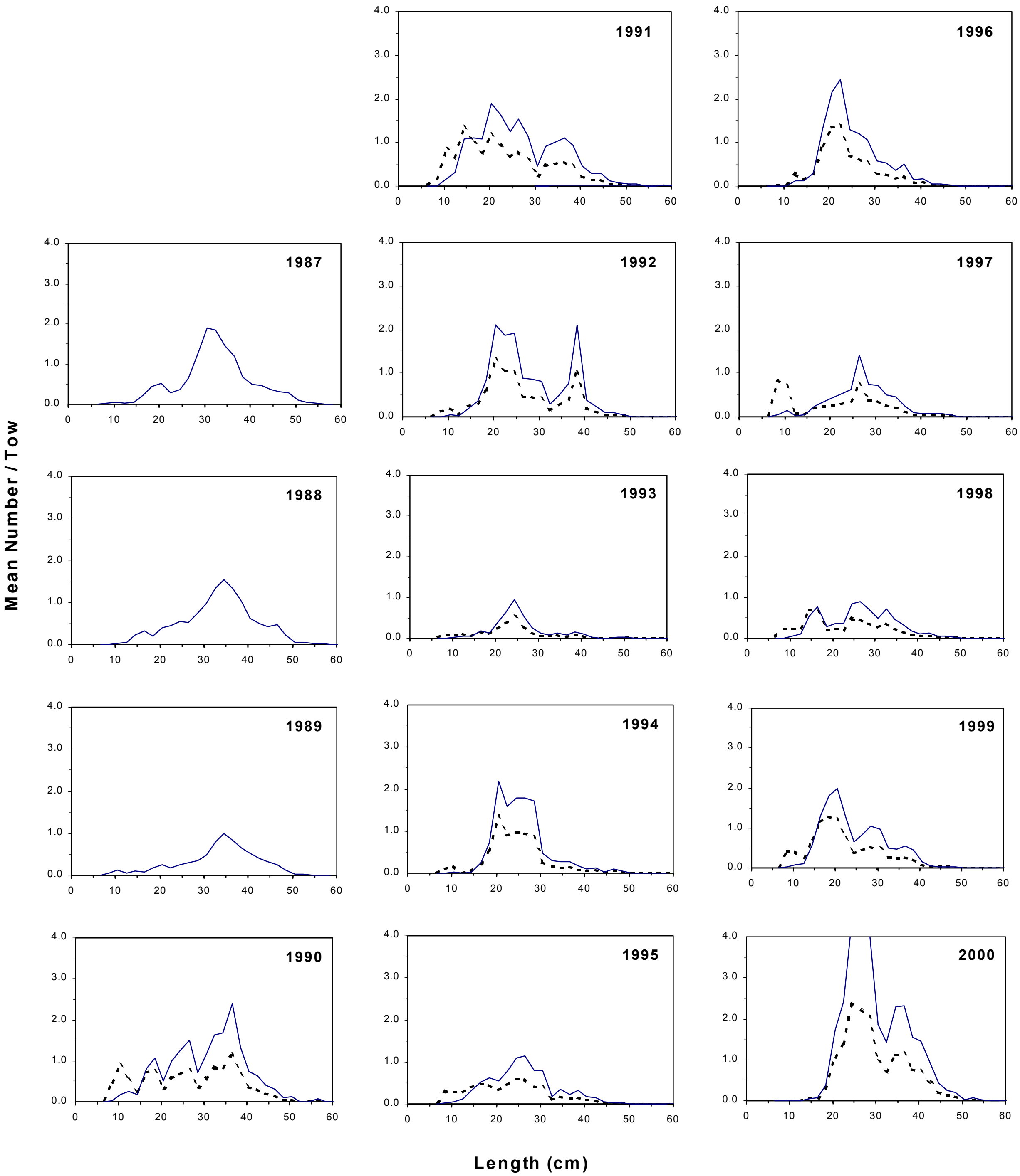


Figure 24. Stratified mean length frequencies of witch flounder caught in the August surveys of the northern Gulf of St. Lawrence. Catches are standardized to a night tow of 1.75 nautical miles. Surveys were conducted by the Lady Hammond using a Western IIA trawl (1987-1989) or the Alfred Needler using a URI trawl (1990-2000). Solid lines show catches adjusted to be equivalent to those by the Lady Hammond using a Western IIA trawl (1990-2000) and dashed lines show the unadjusted catches.

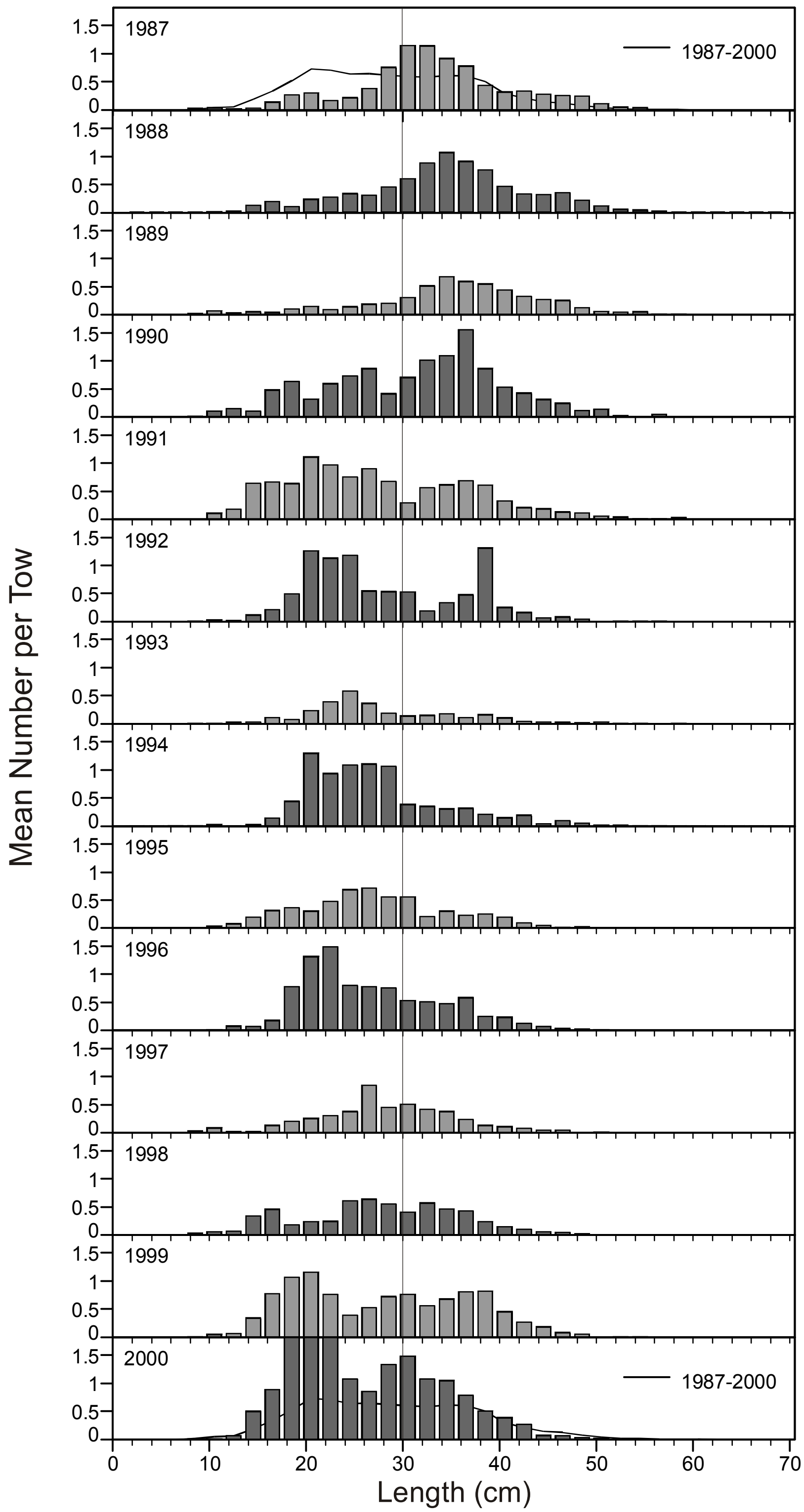


Figure 25. Length composition of witch flounder caught in the August/September surveys of the Gulf of St. Lawrence. Catches are adjusted to a night tow of 1.75 nm by the *Lady Hammond* using a Western IIA trawl. Lines show the average length composition for 1987-2000.

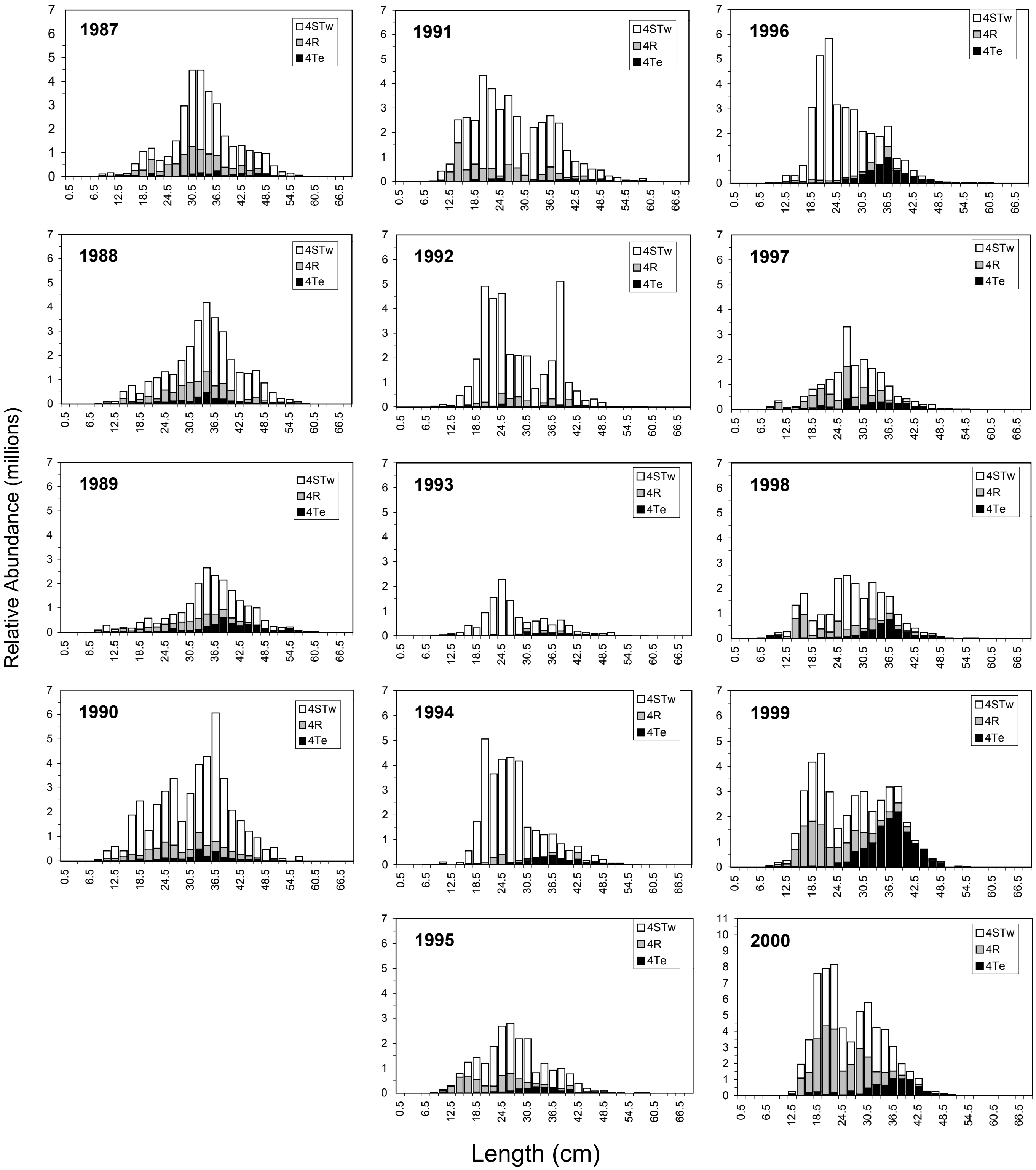


Figure 26. Regional contributions to the length composition of witch flounder caught in the summer surveys of the Gulf of St. Lawrence. Note the scale change in 2000 and that histograms are stacked.

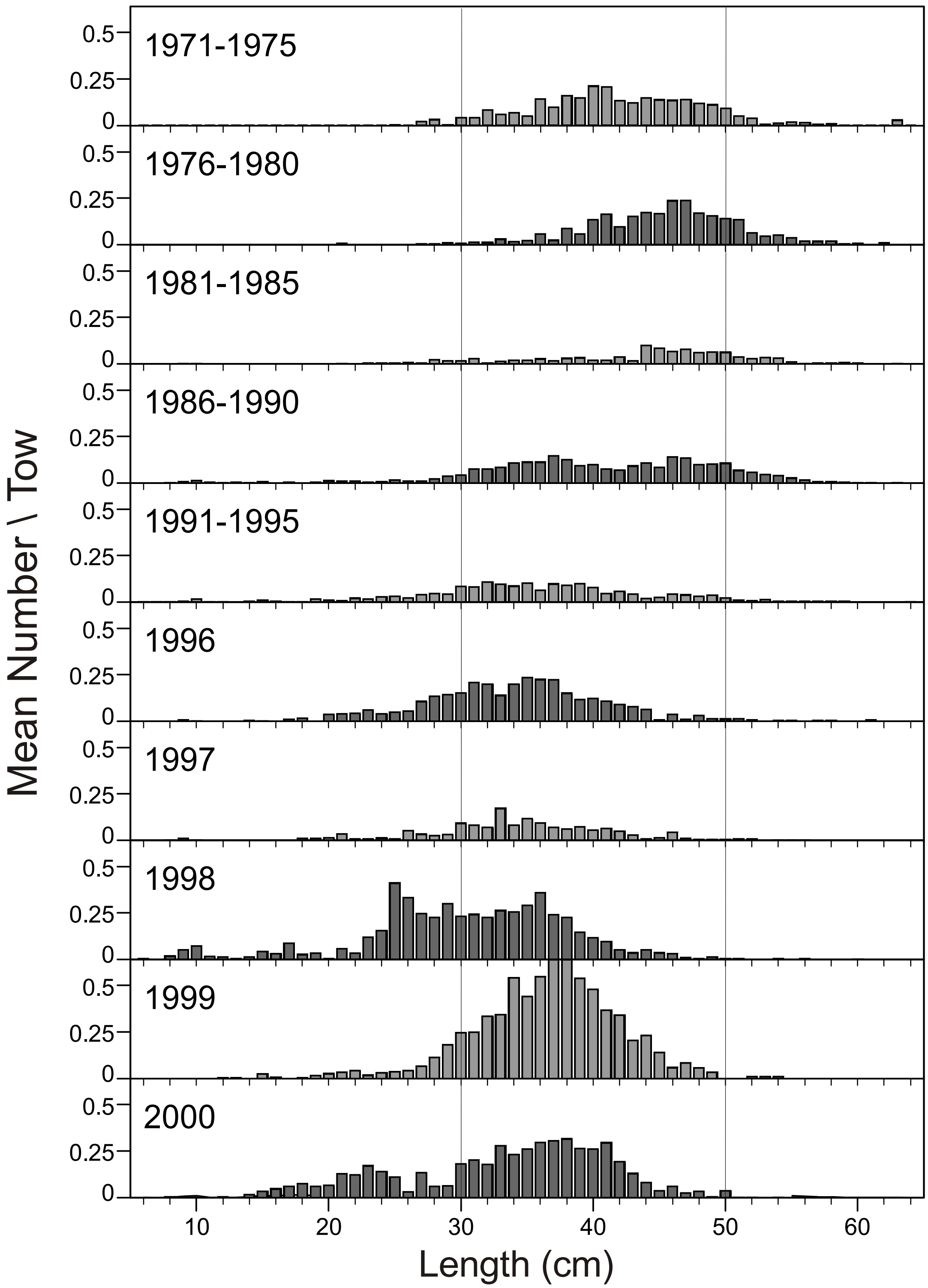


Figure 27. Length frequency distribution of witch flounder caught in the September surveys of the southern Gulf of St. Lawrence.

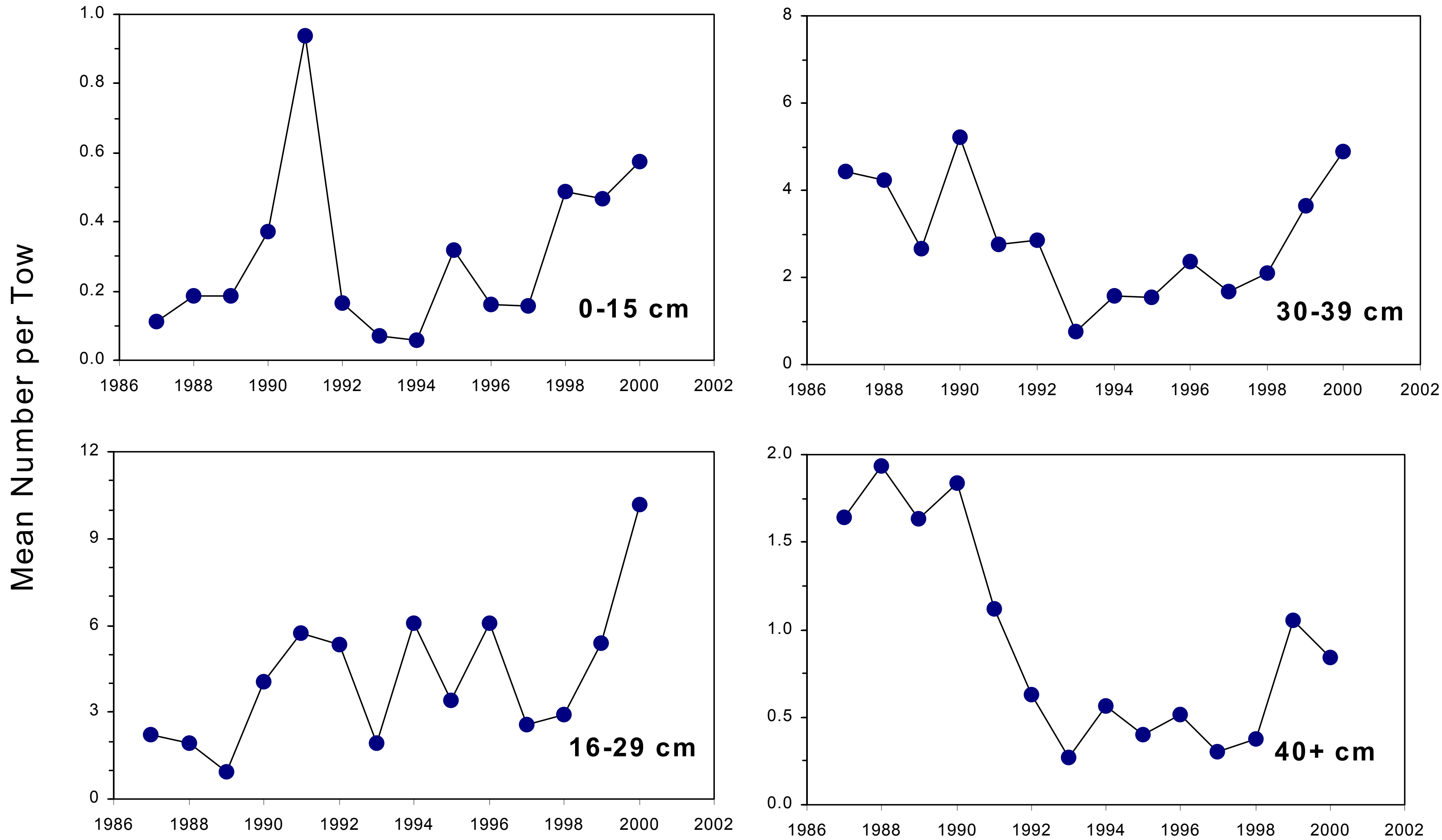


Figure 28. Relative abundance of witch flounder in the Gulf of St. Lawrence by length class.

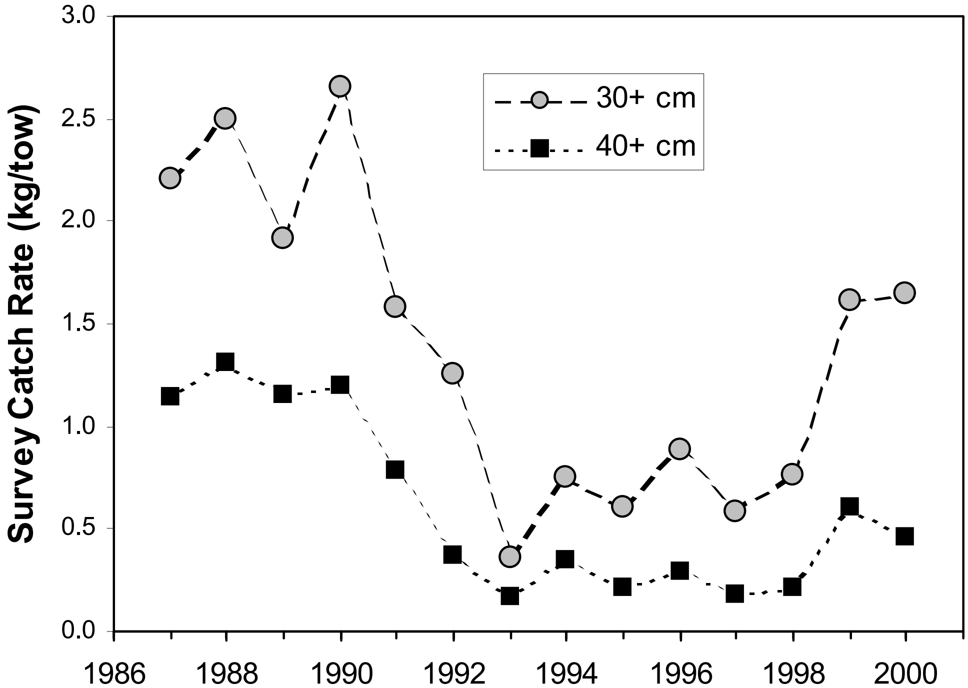


Figure 29. Biomass trends of witch flounder greater than or equal to 30 (30+) and greater than or equal to 40 (40+) cm in length in the August and September surveys of the Gulf of St. Lawrence.

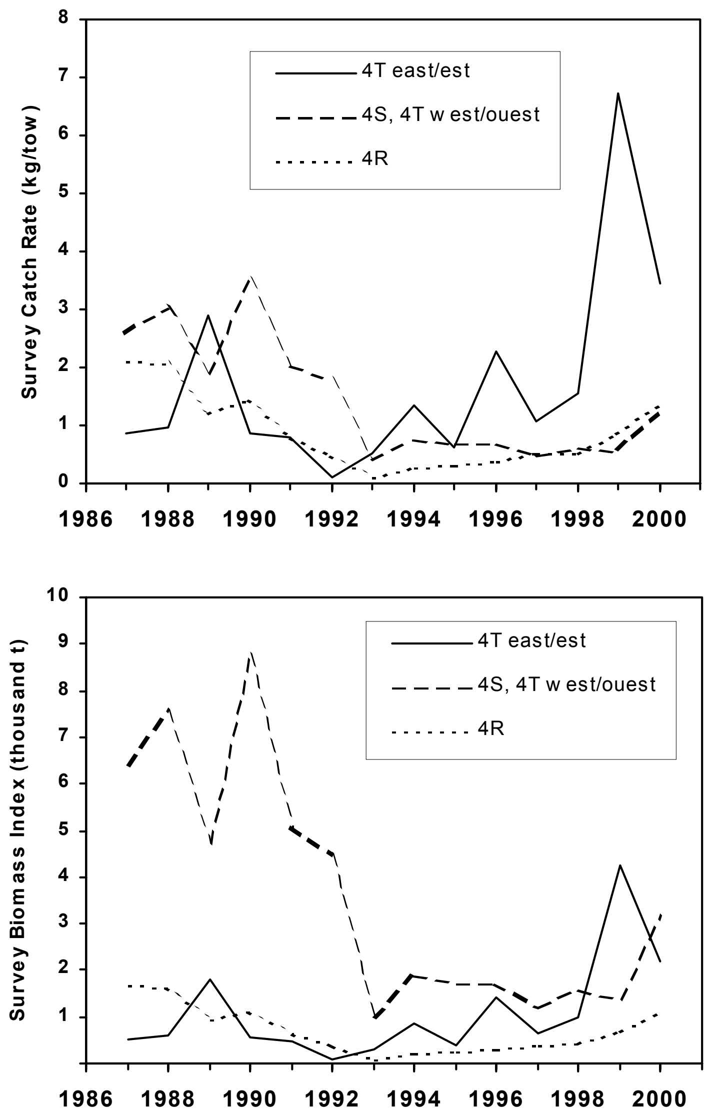


Figure 30. Survey biomass indices by subregion for witch flounder 30 cm in length or larger.

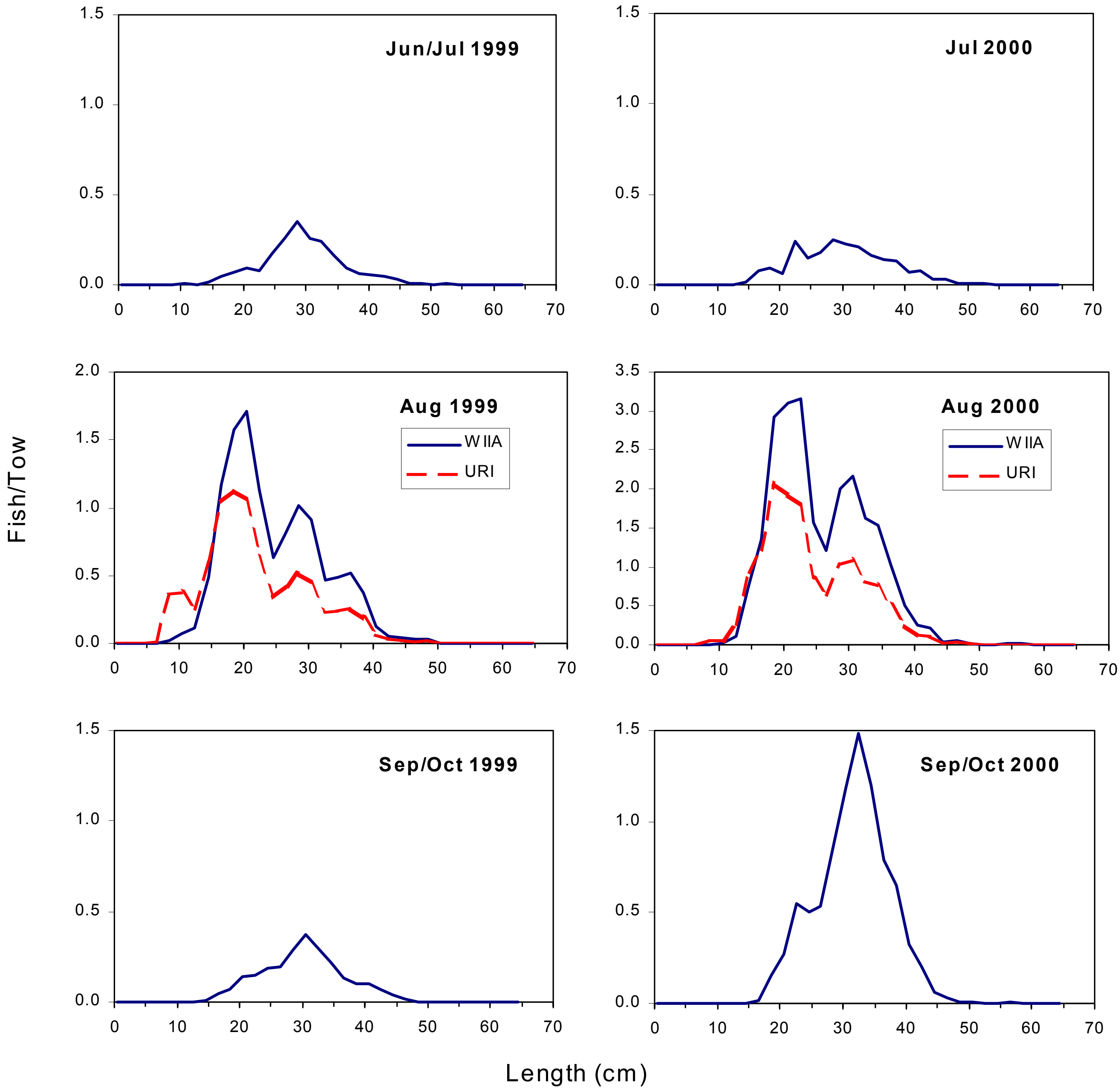


Figure 31. Stratified mean length frequency distributions of witch flounder caught in the 1999 and 2000 sentinel (Jun/Jul and Sep/Oct) and research (Aug) surveys of the northern Gulf of St. Lawrence. Catches are adjusted to a tow of 1.75 nm. For the August research surveys, day catches have been adjusted to night fishing efficiency, and distributions are shown both for the unadjusted (URI) catches and those adjusted to be equivalent to those by a Western IIA trawl (WIIA). Note the change in scale for Aug 2000.

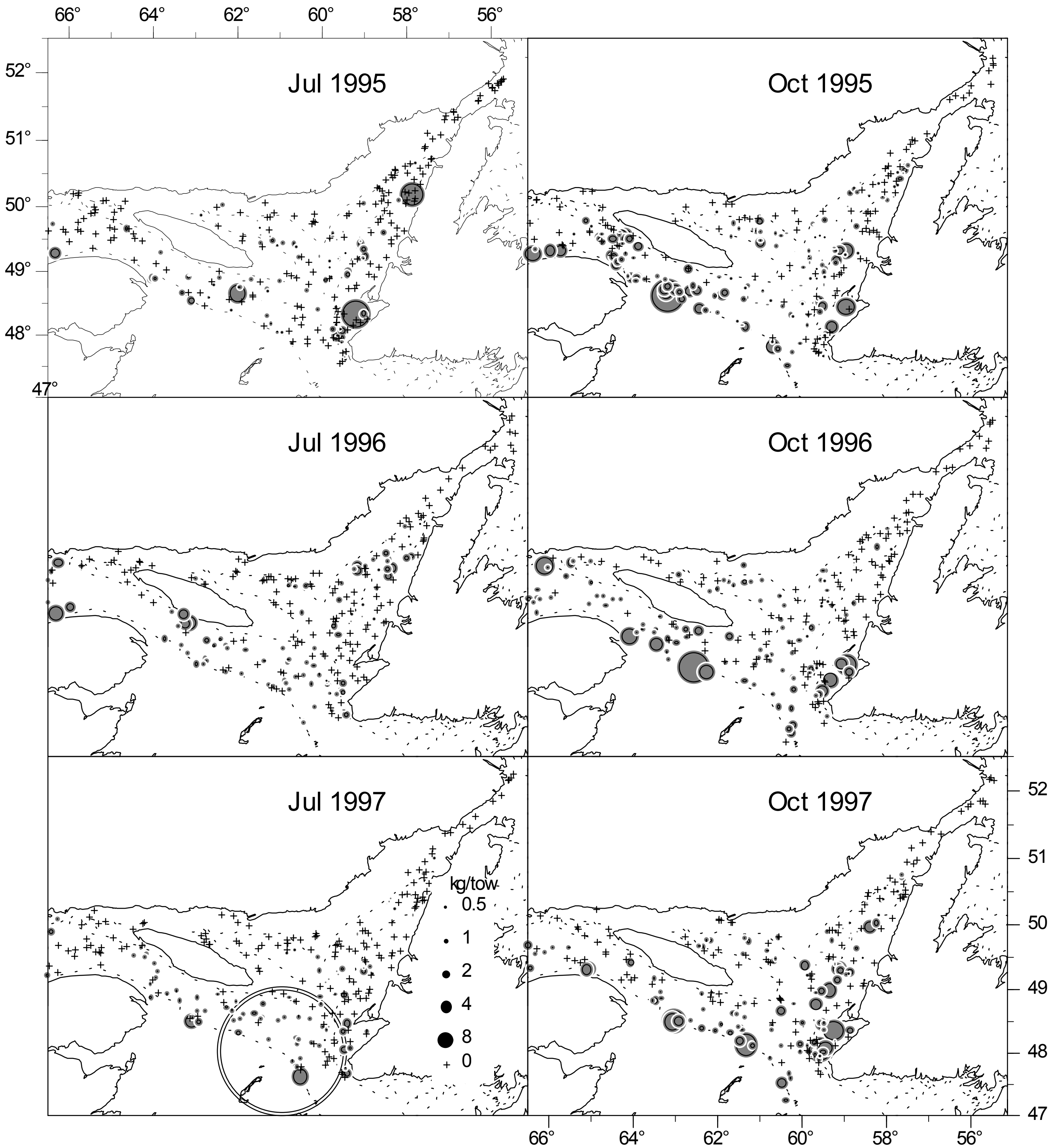


Figure 32. Distribution of witch flounder catches in the mobile-gear sentinel surveys of the northern Gulf of St. Lawrence, July 1995 – October 1997. Only tows in NAFO Div. 4RST are shown. Circle area is proportional to catch rate. Symbols for very large catches are not filled.

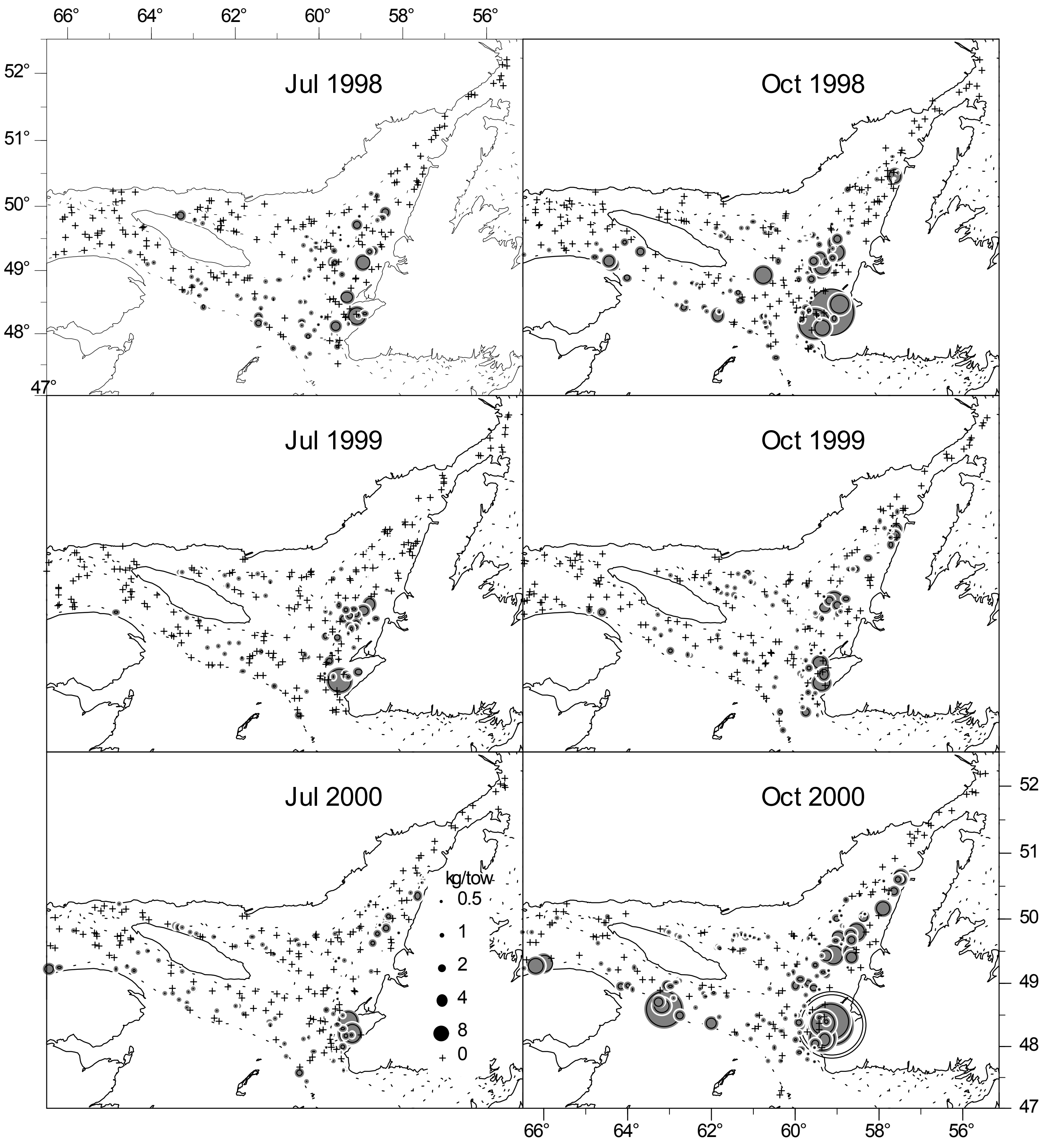


Figure 33. Distribution of witch flounder catches in the mobile-gear sentinel surveys of the northern Gulf of St. Lawrence, July 1998 – October 2000. Only tows in NAFO Div. 4RST are shown. Symbols for very large catches are not filled.

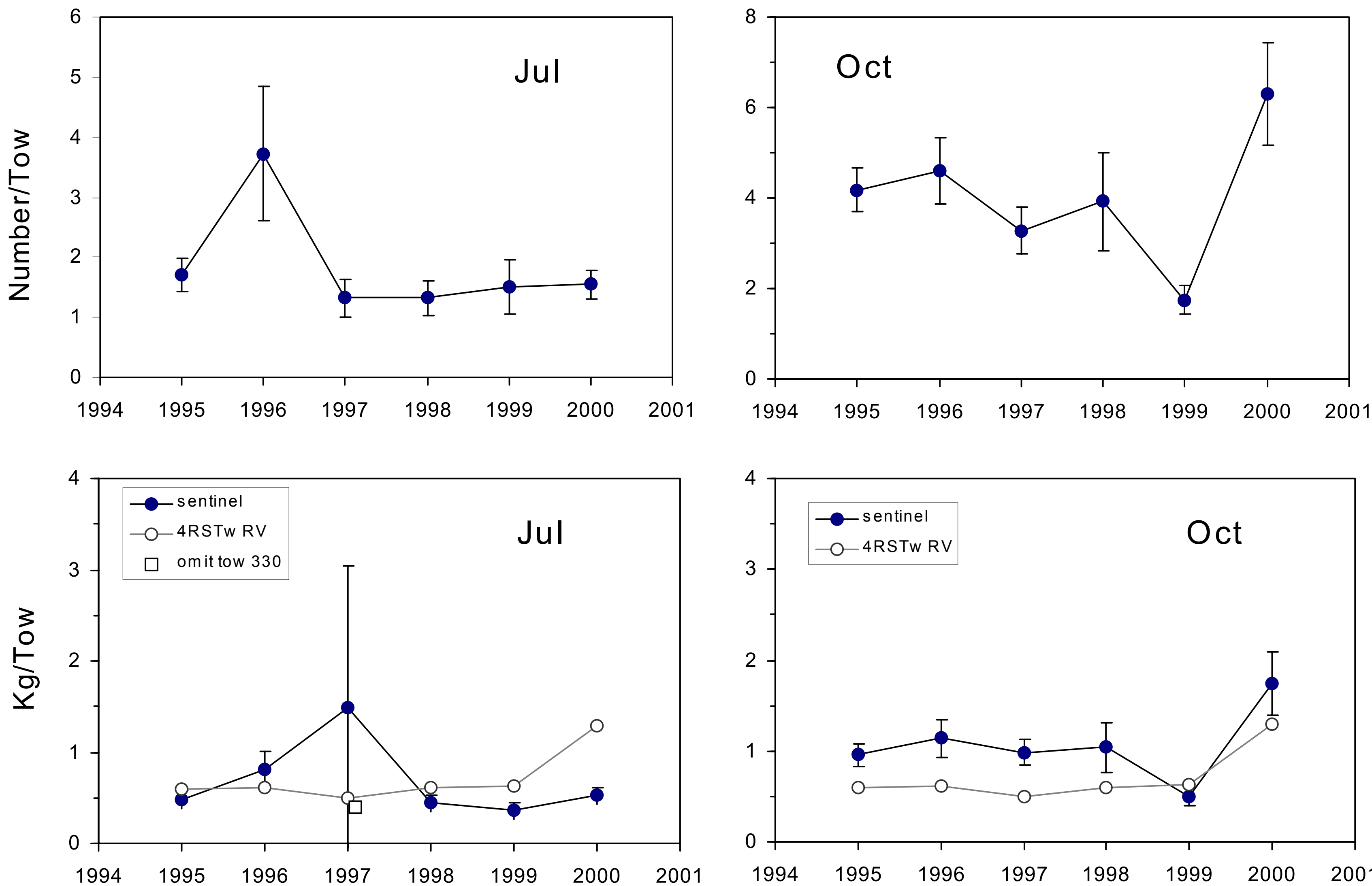


Figure 34. Mean catch rates of witch flounder in mobile-gear sentinel surveys of the northern Gulf of St. Lawrence. Vertical bars show approximate SE. Square shows catch rate (kg/tow) omitting one very large catch in July 1997 (this tow is missing for number caught). Catch rates (kg/tow) of witch flounder over 30 cm in length in the RV survey are shown for comparison.

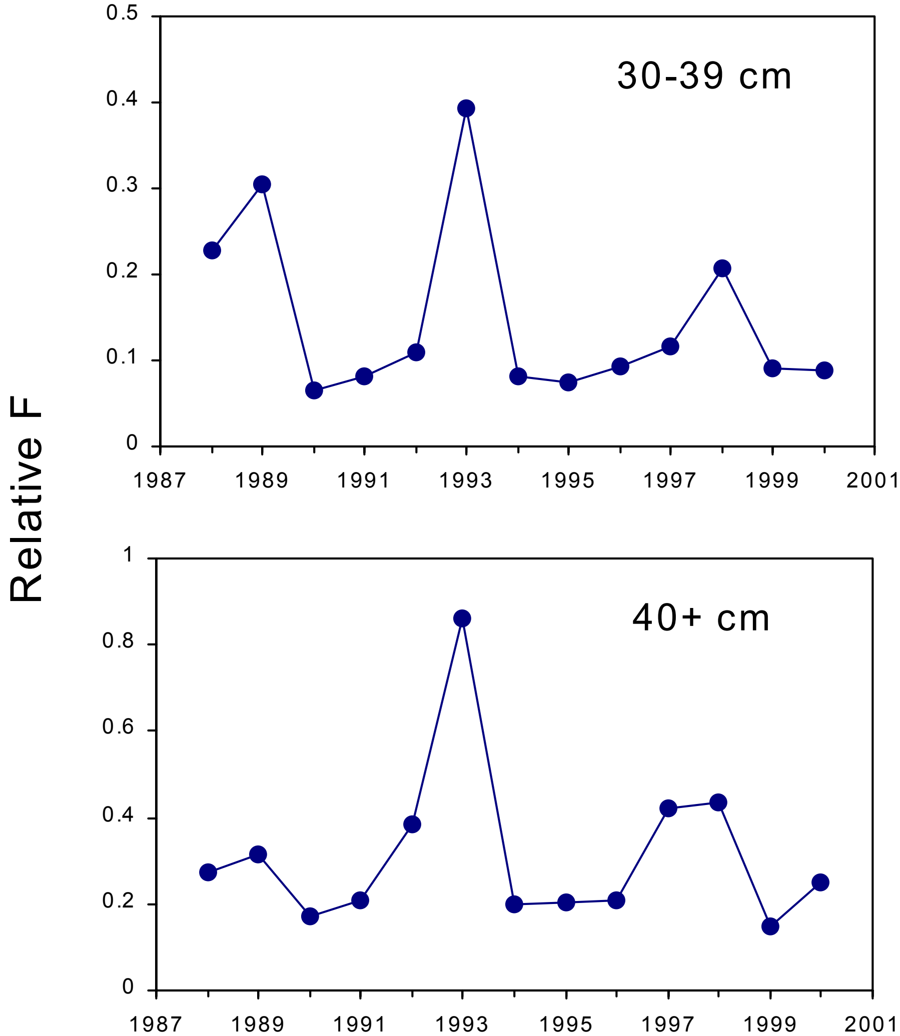


Figure 35. Estimates of relative fishing mortality of 4RST witch flounder, obtained from the ratio of the estimated catch in a size class divided by the survey estimate of the relative population size in that size class.