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Status of the Fishery for White Hake (*Urophycis tenuis*, Mitchill) in the Southern Gulf of St. Lawrence (NAFO Division 4T) in 1992 and 1993

by

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Abstract

The fishery for white hake in NAFO division 4T is at its lowest level since the first quota was put in place in 1982. Low prices and reduced effort contributed to the record low landings of 1,465 t in 1993 (75% below the average for the period 1960-93). In 1993, 47% of the landings were taken by longlines and less than 20% were taken by mobile gears. Since 1988, the majority (90%) of the white hake landings in the Gulf of St. Lawrence has been taken from statistical unit areas occupied by the 'Strait' component of the stock (i.e., 4Tg, 4Th, 4Tj, 4Tl, 4Tm and 4Tn). NAFO 4T landings (1980-93) were consistently greater (frequently several times greater) than the combined landings in adjacent NAFO divisions and subareas (i.e., 4R, 4S, 3Pn, 3Ps and 4Vn).

Fewer older white hake (i.e., age 6 and over) have been caught since 1989 and the fishery is now dependent on only three age groups, compared to five to six in the years before 1989.

Results from the 1993 research vessel survey indicate that the abundance and biomass of white hake in NAFO division 4T are at very low levels. The research vessel abundance index has declined by about 50% since 1992, and is the lowest observed since 1983. An examination of the length composition of white hake caught during the 1993 survey did not indicate significant improvement in recruitment. The research vessel survey also revealed that the number of large hake has decreased and that the distribution of hake along the Laurentian Channel may be shrinking.

Index fishers have reported that hake were "smaller" and "scarcer" in recent years and other comments from industry indicate that the abundance of white hake has declined. Continued closure of the cod fishery and the possibility of competitive prices for hake in 1994 could result in increased effort directed at white hake and a higher rate of exploitation. Considering the low abundance and indications of weak incoming recruitment, rebuilding of this stock will probably occur slowly.

Résumé

La pêche à la merluche blanche dans la division 4T de l'OPANO est à son plus bas niveau depuis la mise en place des premiers quotas en 1982. La faiblesse des prix et la réduction de l'effort de pêche sont en partie responsables des débarquements de 1465 t en 1993, un niveau jamais enregistré (75 % de moins que la moyenne de la période allant de 1960 à 1993). En 1993, 47 % des débarquements provenaient de palangres et moins de 20 % provenaient d'engins mobiles. Depuis 1988, la majorité (soit 90 %) des débarquements de merluche blanche dans le golfe du Saint-Laurent proviennent des unités statistiques couvrant la composante «Détroit» du stock (c.-à-d. 4Tg, 4Th, 4Tj, 4Tl, 4Tm et 4Tn). Les débarquements réalisés dans la division 4T de l'OPANO (de 1980 à 1993) sont systématiquement plus élevés (et souvent de plusieurs fois) que le total de tous les débarquements réalisés dans les divisions et les sous-zones 4R, 4S, 3Pn, 3Ps et 4Vn de l'OPANO.

Depuis 1989, on capture moins de merluches blanches âgées (6 ans ou plus), et la pêche repose maintenant sur seulement trois groupes d'âge, comparativement à cinq ou six avant 1989.

Les résultats du relevé de recherche de 1993 indiquent que l'abondance et la biomasse des merluches blanches dans la division 4T de l'OPANO sont actuellement à de très faibles niveaux. L'indice d'abondance obtenu par le navire de recherche a diminué d'environ 50 % par rapport à 1992, et il est actuellement au plus faible niveau enregistré depuis 1983. Un examen de la composition des prises de merluches blanches selon la longueur, effectué au cours du relevé de 1993, n'a pas laissé voir d'importante amélioration dans le recrutement. Les chercheurs ont également appris que la quantité de grosses merluches a diminué et que la répartition des merluches le long du chenal Laurentien pourrait être en train de rétrécir.

Les participants au Programme des pêcheurs-repères affirment depuis quelques années que les merluches sont «plus petites» et «plus rares». D'autres pêcheurs de l'industrie se plaignent également d'une baisse de l'abondance des merluches blanches. Si l'interdiction de pêcher la morue se maintient et si les pêcheurs obtiennent des prix compétitifs pour la merluche en 1994, il pourrait y avoir une hausse de l'effort dirigé sur la merluche blanche et une hausse du taux d'exploitation.

Compte tenu de la faible abondance et des signes de faible recrutement, il est probable que le rétablissement de se stock se fasse lentement.

Introduction

The fishery for white hake (*Urophycis tenuis*, Mitchill) in the southern Gulf of St. Lawrence (NAFO division 4T - Figure 1) has historically been the third or fourth most important groundfish resource in the southern Gulf of St. Lawrence.

Since 1960, the average annual catch of white hake in NAFO division 4T has been about 5,800 t (Table 1). This resource was not managed by a TAC (Total Allowable Catch) until the precautionary quota of 12,000 tonnes was imposed in 1981, for the 1982 season. Subsequent assessments (Clay et al. 1986; Clay 1987; Clay and Hurlbut 1988) suggested long term yields in the range of 5,000 to 6,000 tonnes. The TAC for 1987 was reduced to 9,400 tonnes and for 1988 to 5,500 tonnes. This is the only fishery for this species within the NAFO convention area that is regulated by a TAC.

This fishery usually does not commence until May when the last of the ice has dispersed. Landings usually peak between July and September and decline through October and November. The hake fishery is carried out mainly by small inshore vessels, and is strongly affected by weather and local market conditions. Both fixed (gillnets and longlines) and mobile gears (small otter trawlers (< 20 m) and larger seiners) are used in the hake fishery. The majority of the fishery is conducted in Northumberland Strait, on the western end of P.E.I., and between P.E.I. and Cape Breton Island.

Previously, the hake fishery in the southern Gulf was considered to be a by-catch fishery; however, a recent analysis (Clay and Hurlbut 1990) indicated that it tends to be a directed fishery, traditionally pursued during periods between other, more economically lucrative fisheries (i.e., lobster, scallop, tuna, etc.).

The combined evidence from a discriminant function analysis of morphometric and meristic characters (Hurlbut 1990; Hurlbut and Clay 1990a), seasonal and annual distributional studies (Clay 1991; Clay and Hurlbut 1989) and a tagging study (Kohler 1971) indicates that the management unit for white hake in NAFO division 4T is composed of two different stock components:

(1) fish from the shallow inshore southern Gulf (depths <= 200 m), principally the Northumberland Strait area (the 'Strait' component) and

(2) fish from along the Laurentian Channel in depths in excess of 200 m (the 'Channel' component).

The research vessel data for these two components have tended to be highly variable, and thus of little use in assessment calibration. Furthermore, recent analyses of groundfish survey data indicate that the distribution of southern Gulf white hake extends beyond the limits of the NAFO division 4T management unit in winter (Morin and Hurlbut 1994). As a result of these uncertainties concerning stock definition and the adequacy of the NAFO division 4T management unit, a formal analytical

assessment (SPA based) has not been conducted since 1989. The present document reviews the status of the fishery in 1992 and 1993.

Description of the Fishery in 1992 and 1993

A) *Landings and Description of the Fishery*

With only a few exceptions, the annual landings of white hake in NAFO division 4T have declined every year from the high of 14,039 t in 1981 (Table 1 and Figure 2a).

The TAC for 1992 was 5,500 t and the provisional landings in 1992 (Table 2a - Figure 2a) were 3,814 t, a decrease of 15% from the 4,510 t landed in 1991, and a difference of -34% from the average landings for the period 1960-93 (Table 1).

The TAC was reduced from 5,500 t to 3,600 t for the 1993 fishing season. The provisional landings in 1993 were 1,465 t (Table 2b - Figure 2a), the lowest level in recorded landings for this resource (a difference of -75% from the average landings for the period 1960-93 (Table 1)).

Clay and Hurlbut (1990) investigated the magnitude of the landings of white hake in adjacent NAFO divisions and subareas. They showed that the landings from NAFO division 4T (1965 - 1986) were an order of magnitude greater than the sum of the landings in 4R, 4S, 3Pn and 4Vn. When NAFO 3Ps landings were included in a comparison, the NAFO 4T landings (fixed and mobile) were found to be consistently greater (frequently several times greater) than the combined landings in the adjacent NAFO divisions and subareas, however, this difference has diminished since 1990, especially for fixed gear catches (Figure 3a). This comparison also revealed that the majority of the landings of white hake in adjacent NAFO divisions and subareas are taken by fixed gear in NAFO 3Ps. The NAFO 3Ps fixed gear landings have been variable since 1980 and do not exhibit a trend similar to that observed for NAFO division 4T (Figure 3a).

Since 1991, the majority of the fixed and mobile gear landings in NAFO division 4T were taken between July and October (Figure 3b). In subarea 3Ps, the timing of the fishery was highly variable, with maximum fixed gear landings occurring in July in 1991, in May in 1992 and in July in 1993.

The seasonal nature of the fishery for white hake in NAFO division 4T reflects the annual migration of hake to and from the overwintering grounds in the Laurentian Channel, with the 'Strait' component gaining access to the shallow southern Gulf via the Cape Breton Trough (Clay and Hurlbut 1989; Clay 1991). We allocated the NAFO division 4T landings (1988 - 1993) to the 'Strait' and 'Channel' stock components by the lowest level of geographical disaggregation available (i.e., statistical unit area) using the depth criteria (depths <= 200 m Vs. depths > 200 m) defined by Hurlbut (1990) and Hurlbut and Clay (1990a). Excluding those landings that could not be attributed to a specific unit area (i.e., those designated as 4Tu), 79% of the total white hake landings have come from unit areas 4Tg, 4Tj, and 4Tl (Table 3, Figures 4, 5 and 6). These three unit areas comprise the majority of the NAFO division 4T management unit that is occupied by the 'Strait' component. Landings from unit areas 4Th, 4Tm and 4Tn have been minor and constant. Since 1988, the majority (90%) of the white hake landings in the Gulf of St. Lawrence have been from the 'Strait' component of the stock.

Over the same period (1988 - 93), annual landings from the unit areas that encompass the 'Channel' component (i.e., > 200 m depth - unit areas 4Tf, 4Tk, 4To, 4Tp and 4Tq) have averaged 10% of the total landings (Table 3, Figures 4, 5 and 6); however, the landings for unit areas 4Tf and possibly 4Tk, probably include hake from the 'Strait' component that were caught while migrating through these unit areas, or were produced in the shallower parts (i.e., < 200 m depth) of these unit areas.

In 1993, the most significant reduction in landings occurred in two unit areas: 4Tg ('Strait' component) and 4Tf (the 'Channel' component).

Since 1960, gillnets have accounted for 30% of the landings of white hake, followed by bottom trawls (26%) (Table 1 and Figure 2b). Over the same time period, longlines and seines have accounted for 16% and 11%, respectively. In 1993, however, 47% of the landings were taken by longlines and less than 20% of the landings were taken by mobile gears.

B) *Management Measures Relevant to the Hake Fishery*

Since the early 1980's, the minimum mesh size for mobile gears involved in the hake fishery was 108 mm (diamond mesh). Early in 1993, DFO (Department of Fisheries and Oceans) introduced Conservation Harvesting Plans as a strategy meant to involve industry in the development of conservation measures that would help rebuild fish stocks. Several changes to the regulations were subsequently announced that had impacts on the white hake fishery, including:

- increase in the minimum mesh size from 108 to 120 mm (square mesh) for mobile gears (<14 m (45 feet)) fishing in the Northumberland Strait area
- the minimum mesh size for mobile gears used outside the Northumberland Strait was increased to 130 mm (square mesh)
- a regulation to control excessive dumping/discarding of groundfish at sea was introduced requiring fishing vessels to land all groundfish caught
- criteria were established for the closure of groundfish fisheries, particularly those involving cod by-catch (All groundfish fisheries were closed in sectors where the cod by-catch exceeded 10% by weight, of the total catch - It was felt that closures had a minimal impact on the white hake fishery in 1993)
- the TAC was reduced from 5,500 t to 3,600t

Following the closure of the cod directed fishery (1/09/93), the minimum mesh size for mobile gears (<14 m (45 feet)) targeting hake in the Northumberland Strait was increased to 130 mm (square mesh). At the same time, the minimum mesh size for mobile gears fishing hake outside the Northumberland Strait, was increased to 145 mm (square mesh).

C) *Information from Department of Fisheries and Oceans (DFO) Sources*

Field staff from the Gulf Nova Scotia area reported the following:

- fishers complained that hake were not very abundant in that area in 1993 (there was speculation that there were fewer 'runs' of hake last year)
- most fishers from Gulf Nova Scotia agreed with the conservation measure of increased mesh sizes; however, many indicated concern that the increase to 130 mm (square mesh) this year, will allow most of the hake to escape
- longliners that used the larger #12 circle hooks were apparently satisfied with their performance and some fishers expressed interest in #13 hooks
- the low prices paid for hake in 1993 were the result of a large quantity of hake that was purchased from Soviet vessels by Nova Scotia processors
- participation by fixed and mobile gear hake fishers was reduced in all areas of Gulf Nova Scotia in 1993 due mainly to low prices (estimates of reduced participation were as high as 20% in some areas)
- local processors reported that the size of hake has been declining each year (the percentage of "large" hake processed in 1993 was approximately only 10%)
- both mobile and fixed gear fishers reported an abundance of very small hake

throughout the area
- several fishers switched from mobile to fixed gears in 1993

A port sampler from the Gulf Nova Scotia area confirmed that participation (fixed and mobile) in the hake fishery was considerably reduced in 1993. In contrast, more effort than usual was directed at hake in 1992, including six seiners from the Cheticamp area and two longliners from western Newfoundland that fished intensively for several weeks in St. Georges Bay, N.S. She also mentioned that several seiners complained about the preponderance of small hake in 1992.

D) *Information from Fishers*

In 1992, 57 groundfish fishers volunteered to participate in the Gulf Region's Groundfish Index Fisher Program (G.I.F.P.). Eighteen of the 29 index fishers that submitted log records indicated that they directed for white hake (main species). The anecdotal comments of these 18 fishers can be summarized as follows:

- 12 (67%) indicated that hake were scarce in 1992
- 8 (44%) indicated that hake were small(er) in 1992
- 3 (17%) indicated that they switched to another fishery (i.e., tuna, herring, etc.) or switched gears and continued fishing for groundfish (i.e., switched from longline to handline)
- 11 (61%) complained that dogfish interfered with their fishing operations

Fifty-six fishers volunteered to participate in the G.I.F.P. in 1993, and of this group, 32 fishers (57%) actually fished and submitted log records. The main comments of the 17 index fishers from this group, that directed for white hake, can be summarized as follows:

- 13 (76%) indicated that hake were scarce in 1993
- 7 (41%) indicated that hake were small(er) in 1993
- 6 (35%) indicated that they switched to another fishery (i.e., tuna, herring, scallops, etc.) instead of continuing to fish for groundfish
- 2 (12%) indicated that they were limited by closures of the fishery (i.e., cod by-catch).
- 3 (18%) complained that dogfish interfered with their fishing operations
- 1 (6%) complained about low prices for their catch

The 7 participants that would normally have directed for hake but did not submit any log records in 1993, made the following comments:

- 5 (71%) indicated that hake were scarce
- 5 (71%) indicated that they switched to another fishery instead of fishing for groundfish

During public hearings of the Fisheries Resource Conservation Council (FRCC) held in Gaspé, Que. (27/9/93), Shippegan, N.B. (28/09/93) and Charlottetown, P.E.I. (29/09/93) there was a consensus that the abundance of hake has declined everywhere. Some fishers also expressed the opinion that the 4T hake fishery is in as bad a state as the 4T-Vn cod fishery.

In a news release (29/11/93), the FRCC made the following recommendations:

- as a precautionary measure, the 1994 TAC for NAFO 4T hake should be reduced to 2,000 t.
- measures such as those instituted in 1993 (increased mesh sizes) to protect small fish should

be continued
- key areas and times of spawning activity for NAFO 4T hake should be delineated and that, if feasible, measures should be taken to establish closures during spawning areas/periods

Participants at the Gulf Groundfish Advisory Committee meeting held in Moncton, N.B. (02/12/93) made the following recommendations:

- introduction of a minimum fish size regulation
- examination of sexual maturity at the proposed minimum size
- investigation of the by-catch of small hake in smelt fisheries
- work on the management unit for white hake in the Gulf of St. Lawrence

Commercial Fishery Data

A) *Commercial Samples and Age Determination*

Commercial port samples of NAFO division 4T white hake were obtained according to previously established protocols (Clay et al. 1985; Clay and Hurlbut 1989; Clay and Clay 1991). In 1992, DFO port samplers collected 44 length frequency samples (7,565 fish measured) and 1,524 otoliths, of which 1,416 provided acceptable age estimates. In 1993, port samplers collected 37 length frequency samples (5,827 fish measured) and 743 otoliths, of which 708 provided acceptable age estimates. In 1992 and 1993, the majority (> 92%) of the commercial white hake samples from NAFO division 4T were obtained from unit areas occupied by the 'Strait' component (Samples from the 'Channel' component consisted of the following: 259 fish measured for length and 63 otoliths in 1992 and 404 fish measured for length and 77 otoliths in 1993).

Quality control tests were conducted during the entire period of age determination, after every 200 to 250 otoliths that were read. In 1992, agreement with the reference ager ranged from 77 to 83% with a mean of 80%, when two trays from the reference collection (minimum 100 otoliths) were aged.

A new ager was trained during the fall of 1993 and winter of 1994 (the training was conducted over 12 weeks). His agreement with the reference reader in 1993, ranged from 59 to 92% with a mean of 71%.

B) *Catch, Weight and Length at Age (1992 and 1993)*

Low sampling intensity in 1992 and 1993 allowed for separation of aged samples into only two gear groupings for both years (Table 4 a and b). As with previous assessments of this resource, otter trawls and seines were combined because they were considered comparable, as were gillnets and longlines.

Eight combinations of time and gear were selected for the length frequency data from the available samples for 1992 and six combinations were selected for the 1993 samples (Tables 4 a and b). The appropriate age-at-length keys were used to determine the age composition of the length frequencies from the landings.

The catch-at-age, weight-at-age and length-at-age were calculated for each key for 1992 and 1993 (Tables 5, 6 and 7 a and b) using the AGELEN program (ver 3.21) for sexes combined. As well, the catch-at-age, weight-at-age and length-at-age were re-calculated for the years 1984-91, to comply with revisions to the NAFO landings statistics for these years. These data were added together for the final catch numbers-at-age and a weighted average (by numbers in each age group) was calculated for

the weights- and lengths-at-age.

The mean length-at-age in 1992 and 1993 (Table 7 a and b) was compared with the mean length-at-age for 1990 and 1991 (Table 7 c and d). The largest fish at-age were those obtained from gillnet samples, however, the mean length- and weight-at-age of fish caught by longline has tended to be smaller/lesser, and more similar to the mean length-/weight-at-age for the two mobile gears. It is likely that this similarity in length- and weight-at-age is attributable to the limited number of samples obtained from longlines. There was a considerable reduction in the mean age of hake in the otter trawl and gillnet keys in 1993. The weight-at-age for white hake aged 8 years and older in 1993 was considerably less than for white hake of the same age in 1992, which in turn were lighter at age than those in 1991. This probably reflects the reduction in the numbers of age 8^{+} white hake.

Comparing the catch-at-age for 1992 and 1993 with that for previous years (Table 8 and Figure 7), it is evident that fewer older fish (i.e., age 6+ and 8+) have been caught since 1989. The modal age has shifted from age 6 in 1988 and 1989 to age 5 in the years since. This fishery is now dependent on only 3 year-classes (ages 4 - 6) and, as a result, it will be sensitive to annual fluctuations in recruitment.

C) *Catch Rates From Index Fishers*

A commercial catch rate series was used in past assessments of this resource, when it was assumed that each purchase slip represented one unit of fishing effort (day). This approach has not been used since 1989 because the model explained only a small percentage (< 25%) of the variation in previous years and because of errors encountered in the coding of inshore otter trawlers.

As a long term solution to this problem, the Groundfish Index Fisher Program was established in 1990. Since its start, 50 to 58 fishers have volunteered to participate in this program each year, about one quarter of which are considered to fish at least part-time for white hake. Six participants that direct for white hake have submitted log record information since 1990 (Figure 8).

Although the trends are variable for 1990 to 1992, the catch rates for all six of these fishers show a marked decrease between 1990 and 1993, confirming their comments and those of their fellow participants in the program.

Research Vessel Data

A) *Fall Groundfish Surveys of 1992 and 1993*

Research vessel surveys have been conducted every autumn since 1971 in the southern Gulf of St. Lawrence, to provide an index of groundfish stock abundance. A stratified random survey design was initially adopted and has been maintained, except for the period 1984-87, when randomly chosen fixed stations were surveyed. The surveys are conducted in the month of September before groundfish commence their migration out of the Gulf. Survey procedures and protocols are standardized and are documented in Hurlbut and Clay (1990b).

In 1992, the Alfred Needler replaced the Lady Hammond as the survey vessel for the annual resource survey. In early August 1992, before the replacement, a comparative fishing experiment was conducted between the two vessels. Results from this analysis indicated that there was no significant difference in the efficiencies of the two vessels for catching white hake (Nielsen 1994).

During the 1992 survey (N178), 176 valid sets were made and 197 valid sets were made during the 1993 survey (N192).

i) Geographic Distribution

The distribution of white hake catches during the 1992 and 1993 surveys was similar to the pattern observed in previous years (Figure 9) with concentrations of hake in areas east and west of PEI, off northwestern Cape Breton, and on slope water of the Laurentian Channel between Quebec and Cape Breton, south of the 4T-4S boundary. White hake were seldom caught in the shallow, central zone adjacent to the Magdalen Islands. However, the area of distribution appears to be shrinking.

ii) Length Frequency Distribution of Survey Catches

Length frequencies were produced for the series of abundance surveys of the southern Gulf conducted since 1986 (Figure 10). With the exception of 1990, when the modal length was only 33 cm, the modal length (1986-93) has varied between 39-44 cm.

The length frequency of white hake caught during the 1993 survey does not indicate significant improvement in recruitment (the first fully recruited age group was estimated at age 6 - 7 years (Clay and Hurlbut 1989) which corresponds to a size between 60 - 90 cm). The abundance of larger fish has continued to decline.

iii) Size at Age

The weight-at-age for white hake age 1 to 6 years old was comparable to that observed during the Lady Hammond surveys (1986-91; Table 9c). The mean length and weight of all white hake sampled during the research vessel surveys in 1992 and 1993 was again low, as it has been since 1987, which is consistent with fisher's opinions about this stock (Figure 11).

iv) Abundance Indices and Biomass Estimates

The research vessel mean catch (numbers) per tow, and C.V.'s of the mean catch per tow (Tables 9 a and b) were estimated using the RVAN analysis programs. The mean number of white hake caught per tow during the 1993 September groundfish survey declined by about 50% from the 1992 level and was the lowest observed since 1983 (Figure 12). There were fewer 1, 2, 3 and 4 year old's caught than in 1992 (Table 9a). The estimates of population abundance and biomass for 1993 decreased by just less than 50% from 1992 (Table 10).

As previously mentioned, two stock components have been identified for hake in the southern Gulf, a 'Strait' component with a September distribution in shallow inshore areas at either end of the Northumberland Strait and a 'Channel' component that occupies deeper water along the edge of the Laurentian Channel in September (Hurlbut 1990; Hurlbut and Clay 1990a). We calculated separate abundance indices for these two components for the period 1984-1993. Earlier surveys were not included in this analysis because we judged sample sizes in these earlier surveys to be insufficient to support separate analyses by region and because earlier surveys did not include stratum 403, an important area for hake. We selected strata 403, 420-422, 432 and 433 for analyses of the 'Strait' component and strata 415, 425 and 437-439 for analyses of the 'Channel' component (Figure 13).

An assumption of this analysis is that there has been no significant expansion of hake range to strata outside of these "preferred" subsets during periods of high hake abundance. Because the selected strata contained 95% of the hake caught in the 1984-1993 surveys (Figure 14), we believe that this assumption is reasonable.

Hake catches (all ages and both sexes combined) were analyzed using a multiplicative model with year, stratum and their interaction as effects:

$$\ln(Y_{ijk}+0.5)=\alpha_j+\beta_k+\gamma_{jk}+\epsilon$$

where Y_{ijk} is the number of hake (standardized to a 1.75 nautical mile tow) caught in tow i in stratum j in year k. The interaction term was dropped from the model if not significant (P>0.05). To respect the stratified random design of the survey, the data were weighted by A_j/n_{jk}, where A_j is the area of stratum j and n_{jk} is the number of tows in stratum j in year k. Analyses used the GLM procedure of SAS (SAS Institute 1990). Weighted means were calculated for each year to provide indices of relative abundance for each of the two stock components.

Stratum effects were highly significant (P<0.0001) in all analyses. The year*stratum interaction was highly significant for the 'Channel' component (F=1.95 df=36,138 P=0.003) but was not significant for the 'Strait' component (F=1.08 df=44,249 P=0.34). The year effect was significant for the 'Channel' component (F=2.69 df=9,138 P=0.007) but only approached significance for the 'Strait' component (after dropping the interaction term: F=1.89 df=9,293 P=0.053). Catch rates for hake in the shallow 'Strait' strata were low in 1984 and 1993; the 1993 catch rate was the lowest in the 10-yr time series (Figure 15). Catch rates in the deeper 'Channel' strata were relatively high in 1984-1988 and low in 1989-1993; the 1992 and 1993 catch rates were the lowest in the 10-yr time series.

The different annual patterns in catch rate between the shallow and deep strata (Figure 15) support the hypothesis that the hake occupying these two areas represent different stock components (cf. Hurlbut 1990). Density-dependent range expansion and contraction could also produce regional differences in annual variation in catch rate (cf. Swain and Wade 1993). However, this alternate explanation is not supported by the earlier decline in catch rates in the region with the higher annual average catch rate (i.e., the deep strata).

We examined annual variation in catch rate by stratum for the 'Channel' component (which exhibited a significant year*stratum interaction). Catch rates declined in the shallower strata (37 and 38) in the late 1980's but have remained high in the deeper strata, except for a recent decline in stratum 15 (Figure 16). This suggests a recent contraction of range into the eastern deep strata 25 and 39 for the 'Channel' stock component.

v) Stock Area

The theory of density-dependent habitat selection predicts that population range should contract into the area of optimal habitat as population size decreases (MacCall 1990). We examined annual variation in population range for each stock component using the index of distribution described by Swain and Sinclair (1994). This index estimates the minimum area over which a specified percentage of the population is spread. First, we calculated the cumulative distribution functions (cdf's) for the hake catch for each year and region, as follows:

$$F(c) = 100\frac{\sum_{h=1}^{L}\sum_{i=1}^{n_h}\frac{A_h}{n_h}X_{hi}I}{\sum_{h=1}^{L}\sum_{i=1}^{n_h}\frac{A_h}{n_h}X_{hi}} \qquad \text{where } I=\begin{cases}1 & \text{if } X_{hi}\le c\\ 0 & \text{otherwise}\end{cases}$$

where A_h is the area of stratum h, n_h is the number of trawl tows in stratum h, X_{hi} is the number of hake caught in tow i in stratum h (standardized to a tow length of 1.75 nautical miles), L is the number of strata, and c is a level of hake density (i.e., number per standard tow). We also calculated cumulative area in relation to hake catch:

$$G(c) = \sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{A_h}{n_h} I \qquad where\ I = \begin{cases} 1 & if\ X_{hi} \le c \\ 0 & otherwise \end{cases}$$

We evaluated F at intervals of 1.0, and calculated the 5th, 10th, 25th, and 50th percentiles of hake catch (Sokal and Rohlf 1981 p.46). We calculated the area associated with each of these levels of hake catch from G, and an index of distribution D_X as

$$D_X = A_T - G(c_{100-X})$$

where A_T is the total area surveyed and c_{100-X} is the 100-X^{th} percentile of hake catch. For example,

$$D_{95} = A_T - G(c_{05})$$

where c_{05} is the 5th percentile of hake catch and $G(c_{05})$ is the area over which hake density is at or below the 5th percentile level. D_{95} can be thought of as an estimate of the minimum area over which 95% of the population is distributed. A_T was 8,277 km^2 for the 'Channel' component and 13,564 km^2 for the 'Strait' component, except in 1988 when only 12,434 km^2 were surveyed for the 'Strait' component. For this year, when not all strata were sampled, the calculated values of D_X were standardized to a total area of 13,564 km^2. We calculated D_X for X equal to 95, 90, 75 and 50.

Stock area has tended to decrease over the 1984-1993 time period (Figure 17), but this tendency was not significant for either stock component (Table 11). Likewise, the area over which hake densities were relatively high (D_{50} and D_{75}) was not significantly correlated with indices of abundance for either stock component (Table 11). On the other hand, the area containing most of the hake stock (D_{90} and D_{95}) was significantly correlated with the index of abundance for the 'Channel' component but not for the 'Strait' component (Table 11). This indicates that population range has contracted as abundance decreased for the 'Channel' component but not for the 'Strait' component. This suggests that competition for density-dependent resources (e.g., food) has been significant for the 'Channel' component but not for the 'Strait' component, when abundance has been relatively high. This difference between the 'Channel' and 'Strait' stock components, is consistent with higher food resources in shallow inshore areas than in deeper water along the edge of the Laurentian Channel.

vi) Temperature Distribution

We examined relationships between hake density (fish per standard tow) and temperature using cumulative distribution functions (cdf's) following Perry and Smith (1994). The cdf (in percent) for temperature was calculated from the 1993 survey data as follows:

$$f(t) = 100 \frac{\sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{A_h}{n_h} I}{\sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{A_h}{n_h}} \qquad where\ I = \begin{cases} 1, & if\ x_{hi} \le t \\ 0, & otherwise \end{cases}$$

where t is a level of temperature, A_h is the area of stratum h, n_h is the number of tows in stratum h, x_{hi} is the bottom temperature at the end of tow i in stratum h, and L is the number of strata. For each sex and each age from 3 to 6, the cdf for hake catch in relation to temperature was calculated similarly:

$$g(t) = 100 \frac{\sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{A_h}{n_h} y_{hi} I}{\sum_{h=1}^{L} \sum_{i=1}^{n_h} \frac{A_h}{n_h} y_{hi}} \qquad \text{where } I = \begin{cases} 1, & \text{if } x_{hi} \le t \\ 0, & \text{otherwise} \end{cases}$$

where y_{hi} is the number of hake caught in tow *i* in stratum *h*. The significance of temperature selection by hake was tested by randomization tests based on the maximum absolute difference between the cdf's of temperature and of hake catch in relation to temperature (Perry and Smith 1994).

The September temperature distribution in 1993 is summarized in Figures 18 and 19. Hake of both sexes and all ages tended to select warm temperatures in relation to those available. Temperature selection was statistically significant for all cases except age-6 females (Table 12). Temperature distribution appeared to be somewhat broader (i.e, extended into cooler water) for older hake of both sexes (age 5 vs age 3 in Figure 19). Temperature preferences appeared to be strongest for temperatures between 4 and 7°C and 13 and 15°C (age 6 female hake). If this apparent preference for warm water is not related to selection of some other correlated variable, then much of the southern Gulf is unavailable to hake in September, especially in recent years of cold bottom temperatures (Chouinard and Swain
1994).

B) *January 94 Survey of Cabot Strait*

A groundfish survey was conducted in the Cabot Strait (NAFO divisions 4T to 4Vsb) from January 13-25, 1994 using the Alfred Needler and standard Gulf survey protocols (i.e., stratified random design, etc.). The primary objective of this survey was to determine the distribution and relative abundance of groundfish species in the Cabot Strait area during winter (Chouinard 1994).

During the survey, 71 valid sets were completed. White hake catches were almost entirely made in areas 4Vn and 4Vs in waters deeper than 200 m (Figure 20). Catches in the northern part of Cabot Strait were also limited to depths deeper than 200 m and only small catches were realized within the Gulf.

C) *Distribution in Adjacent NAFO Divisions and Subareas*

An analysis of the distribution of white hake from survey data for the northern and southern Gulf (fall and winter) was conducted to assess the adequacy of the 4T management unit for white hake (Morin and Hurlbut 1994). Data for this study originated from groundfish surveys conducted by the Québec and Gulf Regions.

In all of the summer surveys examined, the majority of white hake were caught in the NAFO division 4T management unit (Figure 21). Results from the winter surveys (Figure 22) indicated that hake increasingly occupy the deeper, eastern portion of the Gulf in winter and their distribution appears to be continuous with divisions outside of the Gulf, including 3Pn and 4Vn.

The observation that white hake in the Gulf of St. Lawrence select deeper water in winter is consistent with other studies. Clay (1991) inferred the annual migration of white hake in the southern Gulf from a series of seasonal surveys which indicated that as the shallow waters of the southern Gulf cool in the fall, the inshore ('Strait') group, which had been acclimated to warmer waters, migrates to the deep (> 200 m), relatively warm water of the Laurentian Channel. He suggested that this is the probable overwintering area for three groups of white hake: inshore and offshore components of the

southern Gulf (i.e., 'Strait' and 'Channel' groups) and hake from the northern Gulf (NAFO divisions 4R and 4S).

The results of this analysis and the Jan. 94 survey of Cabot Strait suggest that the NAFO division 4T management does not circumscribe the seasonal distribution of white hake and therefore may not account for all catches from this resource.

Estimation of Mortality Rates

Sinclair et al. (1993) described a method for estimating trends in fishing mortality at length, using commercial and research vessel survey length frequency data. With this method, the ratio of catch at length (C_l) to the RV estimate (A_l) is used as a direct estimate of relative fishing mortality at length (R_l).

$$R_l = C_l/A_l$$

A variation of this method was used to estimate trends in fishing mortality at age (R_a) from the ratio of catch at age (C_a) to the RV estimate (A_a).

$$R_a = C_a/A_a$$

The results (Figure 23) indicate a trend of increasing fishing mortality on the year-classes that supported the fishery (ages 4-6) from 1988-92, followed by a reduction in 1993, consistent with the reduction in fishing effort. These results are consistent with an analysis of instantaneous mortality rates (Paloheimo Z's), calculated from research surveys (Hurlbut and Chouinard 1992), which indicated that the fishing mortality was high (approximately 1.0) in the late 1980's and early 1990's (to 1992).

Multispecies Considerations

Small hake are taken as by-catch in estuarine smelt fisheries in some areas of the southern Gulf. One smelt fisher who fishes in the Miramichi estuary, maintained a daily logbook of his catch of smelt, tomcod and white hake (Figure 24). His records indicated that he caught 822 kg of small white hake during a one month period in 1992 (average size 23 cm). Assuming an average weight of 100 g per hake, the reported catch for this fisher could represent 8,220 small hake. The magnitude and extent of this type of mortality is currently unquantified.

Prognosis

The fishery for white hake in NAFO division 4T is at its lowest level since the first quota was put in place in 1982. Low prices and reduced effort contributed to the record low catch in 1993. Fewer older (i.e., age 6 and over) white hake have been caught since 1989 and the fishery is now dependent on only three to four age groups, compared to five to six in the years before 1989. Recovery of this resource will depend on the occurrence of favourable recruitment.

Results from the 1993 research vessel survey indicate that the abundance and biomass of white hake in NAFO division 4T are at very low levels. The research vessel abundance index has declined by about 50% since 1992, and is the lowest since 1983. An examination of the length composition of white hake caught during the 1993 survey did not indicate significant improvement in

recruitment. The research vessel survey also revealed that the number of large hake has decreased and that the distribution of hake along the Laurentian Channel may be shrinking.

Index fishers have reported that hake were "smaller" and "scarcer" in recent years and other comments from industry indicate that the abundance of white hake has declined. Continued closure of the cod fishery and the possibility of competitive prices for hake in 1994, could result in increased effort directed at white hake and a higher rate of exploitation.

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Table 1. Nominal landings (tonnes) of white hake from NAFO division 4T by gear, year and TAC (total allowable catch). All data from 1991 to 1993 are provisional.

YEAR	TRAWL	SEINE	GILLNET	LINE	OTHER	TOTAL	TAC
1960	479	21	3	1172	333	2008	
1961	1430	79	309	3498	7	5323	
1962	1141	97	889	4542	574	7244	
1963	1444	71	48	N/S	4987	6550	
1964	1508	82	N/S	1	4615	6206	
1965	N/S	N/S	N/S	N/S	N/S	4706	
1966	2267	205	375	1870	2307	7024	
1967	2295	128	809	948	2370	6550	
1968	795	84	1734	466	1182	4261	
1969	1030	50	1802	498	828	4208	
1970	1463	382	2149	385	1289	5668	
1971	1523	632	1622	702	1228	5707	
1972	1139	863	1190	1605	960	5757	
1973	2468	211	1265	1045	713	5702	
1974	1454	305	1098	345	414	3616	
1975	1574	306	1279	324	642	4125	
1976	1429	398	1147	183	601	3758	
1977	1227	408	1300	231	818	3984	
1978	1303	737	1829	456	500	4825	
1979	2826	912	3189	479	704	8110	
1980	3430	1615	4831	832	1715	12423	
1981	4733	1922	6174	799	411	14039	
1982	2885	994	4625	1027	245	9776	12000
1983	2141	906	2959	753	546	7305	12000
1984	1734	588	3789	865	74	7050	12000
1985	1639	1008	2480	799	88	6014	12000
1986	1094	898	1884	1068	4	4948	12000
1987	820	1505	2200	1847	0	6372	9400
1988	388	817	1923	748	11	3887	5500
1989	868	1689	1830	943	24	5354	5500
1990	771	1216	2022	1118	48	5175	5500
*1991	1104	957	1299	1150	0	4510	5500
*1992	845	992	846	1089	41	3814	5500
*1993	172	101	454	694	45	1465	3600
			1960 to 1993				
AVERAGE	**1512**	**623**	**1746**	**955**	**833**	**5808**	
PERCENT	**26**	**11**	**30**	**16**	**14**		
			1993				
PERCENT	**12**	**7**	**31**	**47**	**3**		

N/S = Gear Type Not Specified
* = Provisional Statistics

Table 2 a. Nominal landings (tonnes) of white hake from NAFO division 4T in 1992 by gear and month. All data are provisional statistics.

MONTH	TRAWL	SEINE	LINE	GILLNET	OTHER	TOTAL
JANUARY	0.0	0.0	0.0	0.0	0.0	0.0
FEBRUARY	0.0	0.0	0.0	0.0	0.0	0.0
MARCH	0.0	0.0	0.0	0.0	0.0	0.0
APRIL	0.0	0.0	0.0	0.0	0.0	0.0
MAY	2.6	39.5	1.8	21.8	0.0	65.7
JUNE	53.4	339.7	51.3	122.5	0.6	567.5
JULY	188.7	142.6	135.6	249.5	11.4	727.8
AUGUST	298.7	59.6	495.2	170.2	13.8	1037.5
SEPTEMBER	133.4	33.6	262.1	125.9	7.3	562.3
OCTOBER	52.8	166.9	112.0	134.4	7.8	473.9
NOVEMBER	114.5	210.3	31.2	22.1	0.0	378.1
DECEMBER	0.9	0.0	0.0	0.0	0.0	0.9
TOTAL	**845.0**	**992.2**	**1089.2**	**846.4**	**40.9**	**3813.7**
PERCENT	**22.2**	**26.0**	**28.6**	**22.2**	**1.1**	**100.0**

Table 2 b. Nominal landings (tonnes) of white hake from NAFO division 4T in 1993 by gear and month. All data are provisional statistics.

MONTH	TRAWL	SEINE	LINE	GILLNET	OTHER	TOTAL
JANUARY	0.0	0.0	0.0	0.0	0.0	0.0
FEBRUARY	0.0	0.0	0.0	0.0	0.0	0.0
MARCH	0.0	0.0	0.0	0.0	0.0	0.0
APRIL	0.0	0.0	0.0	0.1	0.0	0.1
MAY	0.2	4.6	0.3	8.7	0.0	13.8
JUNE	1.4	59.0	16.4	45.8	0.2	122.8
JULY	71.5	14.7	96.3	177.8	2.8	363.1
AUGUST	44.2	8.0	224.3	132.4	7.7	416.6
SEPTEMBER	48.5	8.9	132.7	54.9	1.7	246.7
OCTOBER	5.5	2.0	223.6	33.9	32.4	297.4
NOVEMBER	0.3	3.6	0.3	0.0	0.0	4.2
DECEMBER	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**171.6**	**100.8**	**693.9**	**453.6**	**44.8**	**1464.7**
PERCENT	**11.7**	**6.9**	**47.4**	**31.0**	**3.1**	**100.0**

Table 3. Nominal landings (tonnes) of white hake from NAFO Division 4T from 1988 to 1993 by Canadian Statistical Unit Area. The data for the period 1988 to 1991 do not include landings from Supplemental 'A' and 'B' forms and thus will not sum to the statistics in Table 2 (See Figures 4, 5 and 6).

Statistical Unit area	1988	1989	1990	1991
4Tf - Magdalen Is.	238	242	437	323
4Tg - Souris/Cheticamp	1777	1959	2261	2294
4Th - Northumberland Str.	43	96	93	197
4Tj - North shore PEI	271	224	250	181
4Tk - Orphan Bank	79	13	33	92
4Tl - Miramichi	491	706	587	574
4Tm - Chaleur Bay	48	65	34	59
4Tn - Gaspe	170	430	256	302
4To - St. Lawrence River	32	20	49	22
4Tp - St. Lawrence River	0	0	0	0
4Tq - St. Lawrence River	2	7	10	5
4Tu - unknown	709	980	1117	462
Total purchase slip	**3860**	**4742**	**5125**	**4510**
Nominal catch	**3887**	**5354**	**5175**	**4510**

Statistical Unit area	1992	1993	Mean 1988-1993	% * 1988-1993
4Tf - Magdalen Is.	262	66	261	8
4Tg - Souris/Cheticamp	2358	814	1910	57
4Th - Northumberland Str.	138	32	100	3
4Tj - North shore PEI	147	69	190	6
4Tk - Orphan Bank	80	19	53	1
4Tl - Miramichi	492	363	536	16
4Tm - Chaleur Bay	22	13	40	1
4Tn - Gaspe	193	40	232	7
4To - St. Lawrence River	27	10	26	1
4Tp - St. Lawrence River	3	2	1	0
4Tq - St. Lawrence River	3	1	4	0
4Tu - unknown	89	37	566	*
Total purchase slip	**3814**	**1465**		
Nominal catch	**3814**	**1465**		

*** - Does Not Include Landings for Unit Area 4Tu (unknown)**

Table 4a. Keys selected for gear/time combinations and their groupings to produce age at length keys for 1992 with at least 400 fish ages (See below for explanation of abbreviations for gear types).
Lower table shows the keys and associated landings for catch composition applied to each of these age at length keys.

KEY	FISHERY/PERIOD	TYPE	SIZE	AGE/LENGTH KEY
1	OTB:Jan.- July	Length	139	
		Age	67	
2	OTB:Aug.- Dec.	Length	303	OTB/SNU: Jan.- Dec.
		Age	37	Lengths - 1967
3	SNU:Jan.- July	Length	1078	Aged - 448
		Age	260	
4	SNU:Aug.- Dec.	Length	447	
		Age	84	
5	GN:Jan.- July	Length	416	
		Age	101	
6	GN:Aug.- Dec.	Length	2125	GN/LL/MISC: Jan.- Dec.
		Age	275	Lengths - 5598
7	LL:Jan.- July	Length	876	Aged - 968
		Age	236	
8	LL:Aug.- Dec.	Length	2181	
		Age	356	

	....AL k e y.....		...LF c a t c h...		
KEY	DATE	GEAR	DATE	GEAR	TONNES
1	01/12	OTB/SNU	01/07	OTB	244.7
2	01/12	OTB/SNU	08/12	OTB	600.3
3	01/12	OTB/SNU	01/07	SNU	521.8
4	01/12	OTB/SNU	08/12	SNU	393.8
5	01/12	LL/GN	01/07	GN	452.6
6	01/12	LL/GN	08/12	GN	200.7
7	01/12	LL/GN	01/07	LL+MISC	929.4
8	01/12	LL/GN	08/12	LL+MISC	470.4
				Total	3813.7

Length/Weight Coefficients (sexes combined) from Mission N178 (Sept. 1992): a = 0.006400 b = 3.024680

Gear Type Abbreviations

OTB = Otter Trawl SNU = Seine GN = Gillnet
LL = Longline MISC = Miscellaneous

Table 4b. Keys selected for gear/time combinations and their groupings to produce age at length keys for 1993 with at least 400 fish ages (See below for explanation of abbreviations for gear types).

Lower table shows the keys and associated landings for catch composition applied to each of these age at length keys.

KEY	FISHERY/PERIOD	TYPE	SIZE	AGE/LENGTH KEY
1	OTB:Jan.- Dec.	Length	221	OTB/SNU/GN/LL/MISC
		Age	62	Jan.- Dec.
2	SNU:Jan.- Dec.	Length	137	Lengths - 5401
		Age	24	Aged - 708
3	GN:Jan.- July	Length	878	
		Age	150	GN/LL/MISC
4	GN:Aug.- Dec.	Length	631	Jan.- Dec.
		Age	84	Lengths - 5043
5	LL:Jan.- July	Length	107	Aged - 622
		Age	23	
6	LL:Aug.- Dec.	Length	3427	
		Age	365	

....AL k e y.....			...LF c a t c h...		
KEY	DATE	GEAR	DATE	GEAR	TONNES
1	01/12	OTB/SNU/GN/MISC	01/12	OTB	171.6
2	01/12	OTB/SNU/GN/MISC	01/12	SNU	100.8
3	01/12	LL/GN	01/07	GN	232.4
4	01/12	LL/GN	08/12	GN	221.2
5	01/12	LL/GN	01/07	LL+MISC	116.0
6	01/12	LL/GN	08/12	LL+MISC	622.7
				Total	1464.7

Length/Weight Coefficients (sexes combined) from Mission N192 (Sept. 1993): a = 0.006730 b = 3.015781

Gear Type Abbreviations

OTB = Otter Trawl SNU = Seine GN = Gillnet
LL = Longline MISC = Miscellaneous

Table 5a. Catch-at-age of white hake in NAFO division 4T as estimated from dockside sampling of the commercial fisheries in 1992. The eight keys refer to the keys of Table 4a.

White Hake: Catch-Numbers-at-Age (000's)

AGE	KEY 1 (OTB)	KEY 2 (OTB)	KEY 3 (SNU)	KEY 4 (SNU)	KEY 5 (GN)	KEY 6 (GN)	KEY 7 (LL)	KEY 8 (LL)	SUM	VAR
1-2	0	0	0	0	0	0	0	0	0	0
3	0	95	15	3	0	0	2	7	122	1057
4	7	400	169	98	1	5	43	266	988	21151
5	28	210	144	199	17	54	56	307	1016	11028
6	30	31	71	79	82	79	27	140	540	1457
7	33	6	30	15	66	50	14	43	256	407
8	9	1	5	1	12	17	3	7	56	30
9	5	2	3	2	2	6	1	2	24	3
10	2	0	4	0	0	2	0	2	11	2
11	1	0	0	0	0	1	0	1	4	0
12	0	0	0	0	0	0	0	0	0	0
13-16	0	0	0	0	0	0	0	0	1	0
TOTALS:	115	743	441	398	181	214	148	776	3016	
# IN L-F	139	303	1078	447	416	2125	876	2181		
# AGED	448	448	448	448	968	968	968	968		
MEAN AGE	6.31	4.28	4.96	5.05	6.43	6.26	5.20	4.99		

Table 5b. Catch-at-age of white hake in NAFO division 4T as estimated from dockside sampling of the commercial fisheries in 1993. The six keys refer to the keys of Table 4b.

White Hake: Catch-Numbers-at-Age (000's)

AGE	KEY 1 (OTB)	KEY 2 (SNU)	KEY 3 (GN)	KEY 4 (GN)	KEY 5 (LL)	KEY 6 (LL)	SUM	VAR
1-2	0	0	0	0	0	0	0	0
3	2	0	4	26	3	41	77	287
4	32	9	17	66	34	145	304	2509
5	60	25	32	58	42	174	390	3029
6	28	20	38	32	15	80	213	549
7	9	7	24	11	2	32	85	126
8	1	1	8	3	1	13	27	22
9	1	1	3	1	0	5	10	3
10	0	0	1	0	0	1	1	0
11	0	0	0	0	0	1	2	0
12	0	0	0	0	0	0	1	0
13-16	0	0	0	0	0	0	0	0
TOTALS:	133	64	126	197	99	491	1110	
# IN L-F	221	137	878	631	107	3427		
# AGED	708	708	622	622	622	622		
MEAN AGE	5.13	5.54	5.79	4.74	4.85	4.97		

Table 6a. Weight-at-age (kg) of white hake in NAFO division 4T estimated from dockside sampling of the commercial fisheries in 1992. The eight keys refer to the keys of Table 4a.

	White Hake: Weight-at-Age (kg)								WEIGHTED
AGE	KEY 1 (OTB)	KEY 2 (OTB)	KEY 3 (SNU)	KEY 4 (SNU)	KEY 5 (GN)	KEY 6 (GN)	KEY 7 (LL)	KEY 8 (LL)	AVE.WGT.
1									
2	0.17	0.38							
3	0.46	0.54	0.60	0.57		0.59	0.51	0.55	0.55
4	0.94	0.73	0.76	0.87	0.98	1.03	0.79	0.77	0.77
5	1.26	0.93	1.06	1.11	1.55	1.39	1.13	1.12	1.10
6	1.69	1.40	1.59	1.44	2.01	1.83	1.73	1.65	1.68
7	2.55	1.94	2.28	1.96	2.37	2.53	2.43	2.18	2.35
8	3.28	3.23	2.86	2.32	2.85	3.33	3.01	2.79	3.06
9	4.00	4.54	3.75	5.96	4.16	4.51	4.84	4.82	4.46
10	6.46		5.81		5.25	4.47	4.75	5.63	5.55
11	5.11		5.90		5.82	5.25	5.83	5.91	5.57
12						6.11	6.00	6.14	6.06
13						7.17		8.07	
14							10.38		
15									
16						10.94			
MEAN	2.12	0.81	1.18	1.18	2.18	2.11	1.36	1.2	
(From keys)									
# IN L-F	139	303	1078	447	416	2125	876	2181	
# AGED	448	448	448	448	968	968	968	968	
MEAN AGE	6.31	4.28	4.96	5.05	6.43	6.26	5.20	4.99	

Table 6b. Weight-at-age (kg) of white hake in NAFO division 4T estimated from dockside sampling of the commercial fisheries in 1993. The six keys refer to the keys of Table 4b.

	White Hake: Weight-at-Age (kg)						WEIGHTED
AGE	KEY 1 (OTB)	KEY 2 (SNU)	KEY 3 (GN)	KEY 4 (GN)	KEY 5 (LL)	KEY 6 (LL)	AVE.WGT.
1							
2							
3	0.85	1.13	0.57	0.55	0.74	0.52	0.55
4	1.04	1.24	0.90	0.79	0.93	0.89	0.90
5	1.19	1.38	1.49	1.19	1.10	1.15	1.20
6	1.56	1.66	2.09	1.69	1.38	1.75	1.74
7	1.88	1.98	2.27	1.95	1.48	2.18	2.11
8	2.53	2.51	2.89	2.73	5.98	3.13	3.12
9	2.16	2.56	3.14	2.41	1.75	3.41	3.06
10		2.47	3.56	2.47		3.49	3.37
11		3.53	3.50	3.69	6.40	3.76	4.35
12	3.29	3.29	3.29			4.36	4.03
13							
14							
15							
16						10.19	
MEAN	1.29	1.56	1.84	1.12	1.18	1.27	
(From keys)							
# IN L-F	221	137	878	631	107	3427	
# AGED	708	708	622	622	622	622	
MEAN AGE	5.13	5.54	5.79	4.74	4.85	4.97	

Table 7a. Length-at-age (cm) of white hake in NAFO division 4T estimated from dockside sampling of the commercial fisheries in 1992. The eight keys refer to the keys of Table 4a.

	White Hake: Length-at-Age (cm)								WEIGHTED
AGE	KEY 1 (OTB)	KEY 2 (OTB)	KEY 3 (SNU)	KEY 4 (SNU)	KEY 5 (GN)	KEY 6 (GN)	KEY 7 (LL)	KEY 8 (LL)	AVE.LT.
1									
2	29.00	38.00							
3	40.24	42.32	43.88	43.22		43.68	41.74	42.60	42.53
4	50.96	46.78	47.37	49.61	51.64	52.42	47.98	47.71	47.53
5	56.05	50.56	52.79	53.80	59.96	57.93	53.92	53.88	53.40
6	61.68	57.97	60.44	58.63	65.52	63.36	62.07	61.26	61.60
7	70.71	64.69	68.02	64.62	69.13	70.42	69.57	67.18	68.77
8	76.63	75.68	72.87	68.09	73.26	77.08	74.41	72.35	74.76
9	81.88	86.00	80.27	93.42	83.24	85.53	87.51	87.48	84.96
10	96.19		93.03		89.91	85.28	87.03	91.78	91.37
11	89.41		93.64		93.22	89.89	93.20	93.45	91.72
12						94.83	94.25	95.00	94.58
13						100.00		104.00	
14							113.00		
15									
16						115.00			
MEAN (from keys)	65.07	48.00	53.53	54.36	66.95	65.53	56.01	54.15	
# IN L-F	139	303	1078	447	416	2125	876	2181	
# AGED	448	448	448	448	968	968	968	968	
MEAN AGE	6.31	4.28	4.96	5.05	6.43	6.26	5.20	4.99	

Table 7b. Length-at-age (cm) of white hake in NAFO division 4T estimated from dockside sampling of the commercial fisheries in 1993. The six keys refer to the keys of Table 4b.

	White Hake: Length-at-Age (cm)						WEIGHTED
AGE	KEY 1 (OTB)	KEY 2 (SNU)	KEY 3 (GN)	KEY 4 (GN)	KEY 5 (LL)	KEY 6 (LL)	AVE.LT.
1							
2							
3	48.97	54.00	42.69	42.33	46.80	41.06	42.02
4	52.22	55.57	49.52	47.42	50.20	49.52	49.61
5	54.53	57.45	58.27	54.18	53.24	53.72	54.46
6	59.71	60.94	65.94	61.32	57.50	61.81	61.82
7	63.44	64.54	67.68	64.22	58.97	66.48	65.84
8	69.82	69.76	73.08	71.64	93.19	74.97	74.62
9	66.54	70.15	74.74	68.68	62.47	76.72	73.98
10		70.00	77.89	70.00		77.74	76.67
11		78.68	78.36	79.84	96.00	80.04	83.59
12	77.00	77.00	77.00			83.44	81.47
13							
14							
15							
16						112.00	
MEAN (from keys)	55.79	59.60	62.04	52.40	53.53	54.44	
# IN L-F	221	137	878	631	107	3427	
# AGED	708	708	622	622	622	622	
MEAN AGE	5.13	5.54	5.79	4.74	4.85	4.97	

Table 7c. Length-at-age (cm) of white hake in NAFO division 4T estimated from dockside sampling of the commercial fisheries in 1990.

White Hake: Length-at-Age (cm)

AGE	KEY 1 (OTB)	KEY 2 (OTB)	KEY 3 (SNU)	KEY 4 (GN)	KEY 5 (GN)	KEY 6 (LL)	KEY 7 (LL)	AVE.LT.
1								
2								
3	43.42	44.23	43.56	46.00		42.70	45.31	43.28
4	49.37	48.64	48.71	51.89	51.64	44.86	49.61	47.70
5	55.23	53.19	53.81	57.63	58.93	51.89	53.53	54.19
6	59.36	58.14	60.15	64.61	64.77	58.22	60.48	61.35
7	64.03	66.47	68.61	70.35	72.13	63.00	72.39	69.80
8	77.30	78.61	78.61	74.77	76.61	62.00	77.93	76.78
9		83.69	88.24	85.96	84.65		89.90	86.67
10	96.83	104.00	94.59	81.25	80.94		90.39	90.88
11			92.00	92.00	95.74		103.32	97.66
12					96.00		107.00	107.00
13			110.00	92.00	93.94		93.65	
14								
MEAN (FROM KEYS)	57.41	54.85	58.31	65.03	66.56	47.77*	55.37	
# IN L-F	589	1782	1173	274	1062	68	1749	
# AGED	405	405	405	333	333	333	333	
MEAN AGE	5.53	5.24	5.60	6.14	6.23	4.38*	5.08	

Table 7d. Length-at-age (cm) of white hake in NAFO division 4T estimated from dockside sampling of the commercial fisheries in 1991.

White Hake: Length-at-Age (cm)

AGE	KEY 1 (OTB)	KEY 2 (OTB)	KEY 3 (SNU)	KEY 4 (SNU)	KEY 5 (GN)	KEY 6 (GN)	KEY 7 (LL)	AVE.LT.
1								
2								
3	42.76	41.26	43.11	42.95				42.02
4	48.85	47.74	48.22	47.63	44.83		48.00	47.85
5	54.35	51.97	52.45	51.13	57.13	58.23	54.67	53.28
6	59.53	57.02	58.61	55.68	65.34	62.32	58.89	59.46
7	67.15	64.41	68.19	61.97	69.50	66.26	66.63	67.35
8	74.15	69.77	74.26	73.00	71.70	67.67	74.61	72.06
9	87.40		86.63		78.57	74.90	79.85	81.48
10	93.16	92.00	99.39		96.43			96.73
11	92.30	92.00	91.89					91.95
12	97.46		97.99					32.58
13	96.88		111.00		105.00		109.00	
14								
MEAN (FROM KEYS)	59.36	52.40	56.95	50.79*	67.69	63.51	58.60	
# IN L-F	2554	352	770	764	1236	621	161	
# AGED	305	305	305	305	221	221	221	
MEAN AGE	5.82	5.01	5.54	4.83*	6.67	6.34	5.75	

Table 8. Commercial fishery catch-at-age (1,000's) for white hake from NAFO division 4T.

	Catch-at-age: NAFO 4T hake											
Age	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**	**81**
3	86	84	91	80	49	56	81	86	79	90	91	66
4	708	715	633	499	250	214	298	332	354	470	452	427
5	798	798	747	664	380	390	433	471	579	833	1028	1075
6	456	448	485	461	297	344	333	361	545	972	1661	1976
7	373	378	403	454	313	380	291	302	345	672	1196	1391
8	144	144	165	191	136	171	132	136	172	315	540	604
9	74	77	84	108	78	99	67	66	61	101	137	154
10	42	43	44	50	33	42	28	29	26	47	75	94
11	12	14	12	13	8	8	5	5	4	8	7	4
12	7	8	8	9	5	7	9	8	8	11	6	1
13-14	3	3	4	4	3	3	2	2	2	4	5	8

Age	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**
3	5	57	58	64	2	30	0	11	34	29	122	77
4	113	128	319	216	204	531	39	114	604	437	988	304
5	546	595	787	608	496	1357	476	574	1170	935	1016	390
6	1136	787	788	592	477	900	648	810	992	884	540	213
7	1104	609	542	391	330	411	513	689	427	554	256	85
8	551	398	275	227	233	149	109	224	80	86	56	27
9	149	233	142	108	77	68	15	76	18	16	24	10
10	79	71	69	51	45	18	6	11	8	6	11	1
11	21	5	22	16	21	4	2	13	2	2	4	2
12	9	4	16	18	14	2	1	5	1	1	0	1
13-14	9	1	7	12	9	3	1	6	1	1	1	0

Table 9a. Mean catch per tow (numbers) of white hake estimated from research vessel surveys in the southern Gulf of St.Lawrence (NAFO division 4T).

Mean catch per tow (Survey) White hake

E.E. Prince

Age	Year 1978	1979	1980	1981	1982	1983	1984	1985
0	.00	.00	.00	.00	.00	.00	.03	.00
1	.06	.00	.01	.00	.03	.10	.05	.11
2	2.14	.28	.29	.50	.26	.80	.58	.96
3	1.49	2.04	.96	1.10	.61	.80	1.36	2.47
4	2.49	2.06	1.77	2.50	.97	.80	1.74	2.06
5	1.98	1.82	2.29	3.10	.77	.40	1.59	.66
6	.91	1.28	.89	2.40	.71	.30	.75	.42
7	.28	.48	.44	1.40	.31	.10	.39	.30
8	.05	.13	.21	.50	.14	.10	.25	.15
9	.02	.02	.08	.20	.02	.10	.07	.13
10	.06	.02	.10	.00	.03	.00	.10	.08
11	.00	.02	.02	.00	.00	.00	.01	.02
12	.04	.06	.01	.00	.00	.00	.02	.05
13	.00	.00	.00	.00	.00	.00	.00	.01
total	9.53	8.21	7.10	11.80	3.85	3.50	6.95	7.46

Lady Hammond / Alfred Needler

Age	Year 1986	1987	1988	1989	1990	1991	1992	1993
0	.19	.00	.09	.41	.49	.08	.09	.23
1	.51	.06	.20	1.13	.67	.54	.34	.28
2	2.51	.68	1.76	2.16	2.34	2.04	1.37	.67
3	3.27	2.55	2.87	4.26	2.54	2.86	2.57	.58
4	5.03	2.83	3.49	2.33	1.61	1.80	2.18	.97
5	2.74	1.66	2.74	1.44	1.62	1.27	.64	.68
6	1.17	.83	.85	.76	.52	.59	.12	.18
7	.55	.34	.31	.21	.34	.19	.06	.05
8	.31	.12	.08	.03	.07	.06	.01	.03
9	.11	.03	.02	.02	.02	.01	.00	.02
10	.00	.04	.02	.01	.00	.02	.00	.01
11	.03	.00	.00	.01	.00	.02	.00	.00
12	.02	.05	.00	.00	.00	.00	.00	.00
13	.03	.00	.00	.01	.00	.00	.00	.00
total	16.48	9.20	12.44	12.78	10.23	9.49	7.36	3.68

Table 9b. Coefficients of variation (CV's) of mean catch per tow (numbers) of white hake estimated from research vessel surveys in the southern Gulf of St.Lawrence (NAFO division 4T).

Coefficient of variation of mean catch per tow (Survey) White hake

.....Lady Hammond.....

Age	1986	1987	1988	1989	1990	1991
0				83.16	53.46	48.10
1	22.49	36.25	29.93	54.61	43.24	36.35
2	34.99	25.46	23.68	23.56	32.73	46.16
3	31.17	38.30	25.00	18.40	33.09	47.02
4	39.28	35.08	20.41	18.35	19.98	40.59
5	28.91	26.05	16.40	17.12	18.25	23.13
6	20.81	13.54	16.30	21.55	15.47	21.98
7	22.15	21.82	17.19	28.54	23.81	32.01
8	20.67	29.53	29.42	37.17	39.79	38.39
9	49.34	100.00	54.64	51.05	71.04	99.99
10		58.24	55.98	70.72		58.68
11	98.82			73.34		79.67
12		73.56				
13	98.82			73.34		

.....Alfred Needler.....

Age	1992	1993
0	36.35	57.52
1	27.98	31.06
2	38.61	21.50
3	44.52	25.69
4	36.96	33.35
5	23.13	28.99
6	24.90	22.03
7	51.00	
8		
9		
10		
11		
12		
13		

Table 9c. Mean weight-at-age (kg) of white hake from research vessel surveys in the southern Gulf of St.Lawrence (NAFO division 4T).

Mean weight-at-age (Survey) White hake

E.E. Prince

Age	Year 1978	1979	1980	1981	1982	1983	1984	1985
0							.229	
1	.209		.216		.081	.131	.166	.101
2	.297	.338	.381	.242	.342	.318	.292	.194
3	.466	.478	.539	.464	.608	.616	.580	.334
4	1.011	.864	1.010	.873	1.024	1.100	.965	.763
5	1.567	1.456	1.408	1.327	1.338	1.837	1.496	1.246
6	1.964	1.895	1.878	1.744	1.759	2.051	2.117	1.901
7	2.327	2.272	2.499	2.110	2.194	3.057	2.693	2.440
8	4.106	3.196	2.956	2.693	2.882	3.806	3.431	3.100
9	2.456	3.219	3.288	2.990	2.787	3.872	2.870	3.725
10	2.117	2.775	5.414	3.276	2.682		6.220	3.309
11		5.201	4.129	10.906*			3.919	4.135
12	7.144	2.790	9.531	3.276			7.643	11.005*
13				9.195				8.908

Lady Hammond

Alfred Needler

Age	Year 1986	1987	1988	1989	1990	1991	1992	1993
0			.010	.047	.028	.058	.075	.047
1	.158	.091	.111	.085	.065	.179	.152	.140
2	.237	.193	.234	.209	.213	.254	.286	.266
3	.453	.426	.408	.423	.350	.464	.449	.404
4	.775	.656	.690	.595	.634	.672	.627	.628
5	1.303	1.183	.976	1.027	.985	1.055	.952	.856
6	1.944	2.072	1.688	1.571	1.450	1.557	1.538	1.379
7	3.149	3.122	2.521	2.336	2.043	2.164	2.016	1.187
8	3.717	4.106	3.462	3.338	3.804	3.711		1.392
9	3.836	6.032	6.594	5.234	4.103	4.338		4.225
10		6.402	7.836	6.657		6.593		5.074
11	7.726			8.927		7.149		
12	7.378	8.401						
13	10.304			8.927				

Table 10. Research vessel population and biomass estimates for NAFO division 4T white hake (R/V Lady Hammond surveys: 1986–91 and Alfred Needler surveys 1992–93).

Abundance ('000)

YEAR/AGE	All Ages
1986	28440
1987	17764
1988	22274
1989	22600
1990	18482
1991	16781
1992	13280
1993	7053

Biomass (t)

YEAR/AGE	All Ages
1986	28319
1987	17834
1988	17781
1989	13355
1990	10615
1991	11277
1992	7691
1993	4140

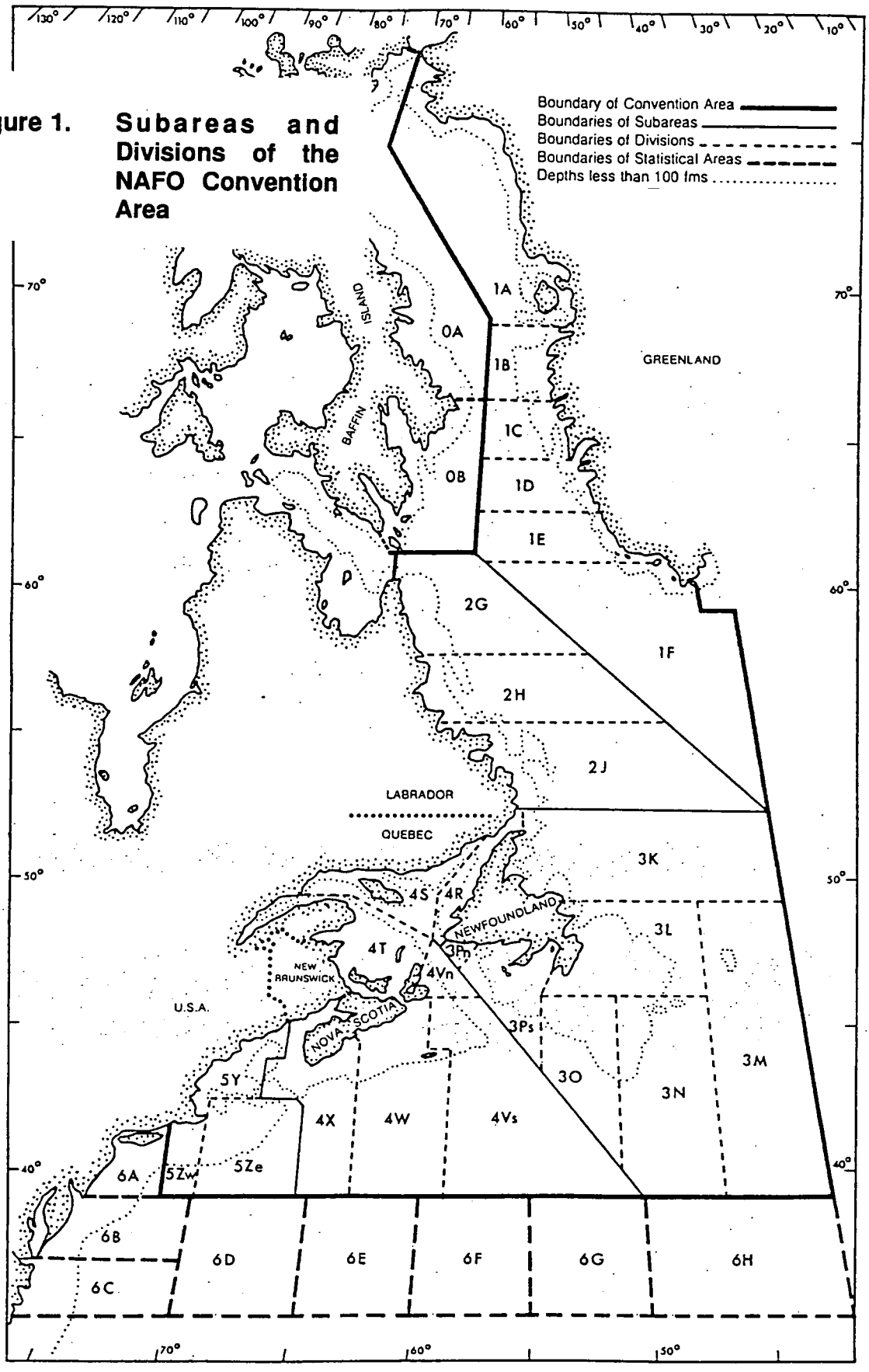
Table 11. Annual trends and density dependence of hake population range. D_X is the minimum area over which X% of the stock is distributed. I is the index of relative abundance from the September research survey. R is the correlation coefficient.

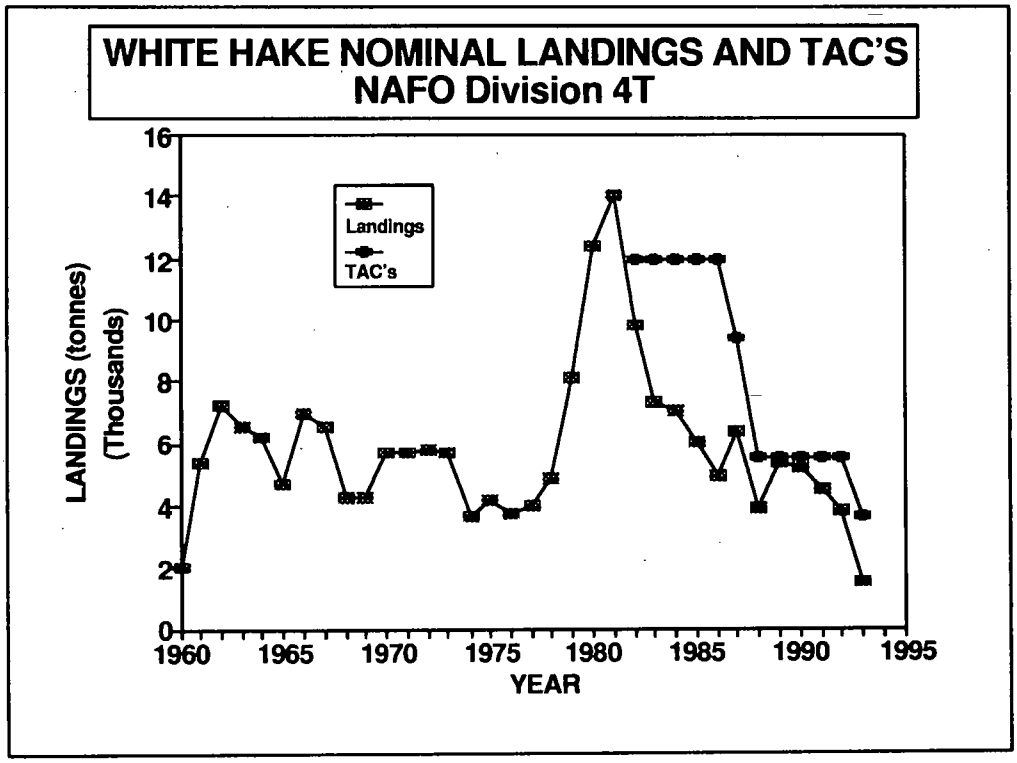
Stock Component	Covariate	Statistic	D_{95}	D_{90}	D_{75}	D_{50}
Strait	yr	R	-0.56	-0.52	-0.46	-0.34
		P	0.10	0.12	0.17	0.34
	I	R	-0.20	-0.25	0.15	0.33
		P	0.58	0.49	0.68	0.35
Channel	yr	R	-0.61	-0.46	-0.47	-0.40
		P	0.059	0.18	0.17	0.25
	I	R	0.77	0.71	0.61	0.31
		P	**0.0093**	**0.021**	0.062	0.38

Table 12. Randomization tests of temperature selection by white hake in the southern Gulf of St. Lawrence, September 1993. D_{max} is the observed maximum absolute difference between cumulative distribution functions for temperature and for hake catch in relation to temperature. N is the number of random permutations of the data that produce a D_{max} greater than or equal to the observed value (out of 2999 random permutations). P is the probability that hake are randomly distributed with respect to temperature ($P = (N+1)/3000$).

	Females			Males		
age	D_{max}	N	P	D_{max}	N	P
3	70.30	0	0.0003	63.46	0	0.0003
4	61.48	15	0.0053	52.40	31	0.011
5	47.97	59	0.020	47.73	40	0.014
6	45.49	385	0.13	47.53	7	0.0027

Figure 1. Subareas and Divisions of the NAFO Convention Area





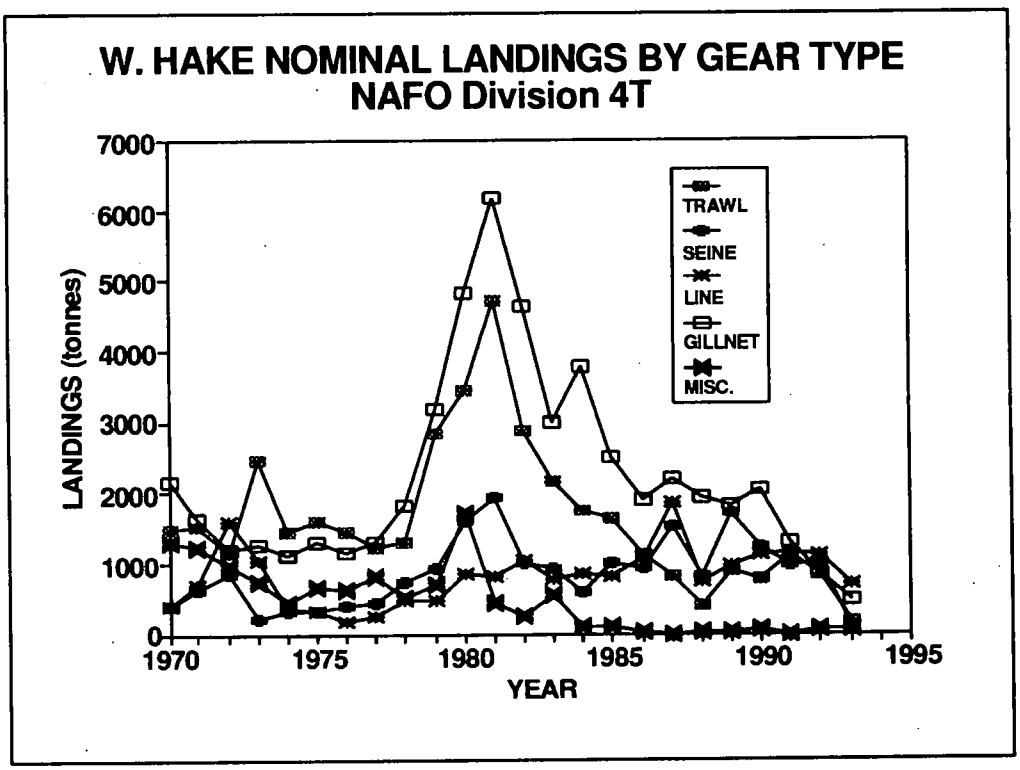
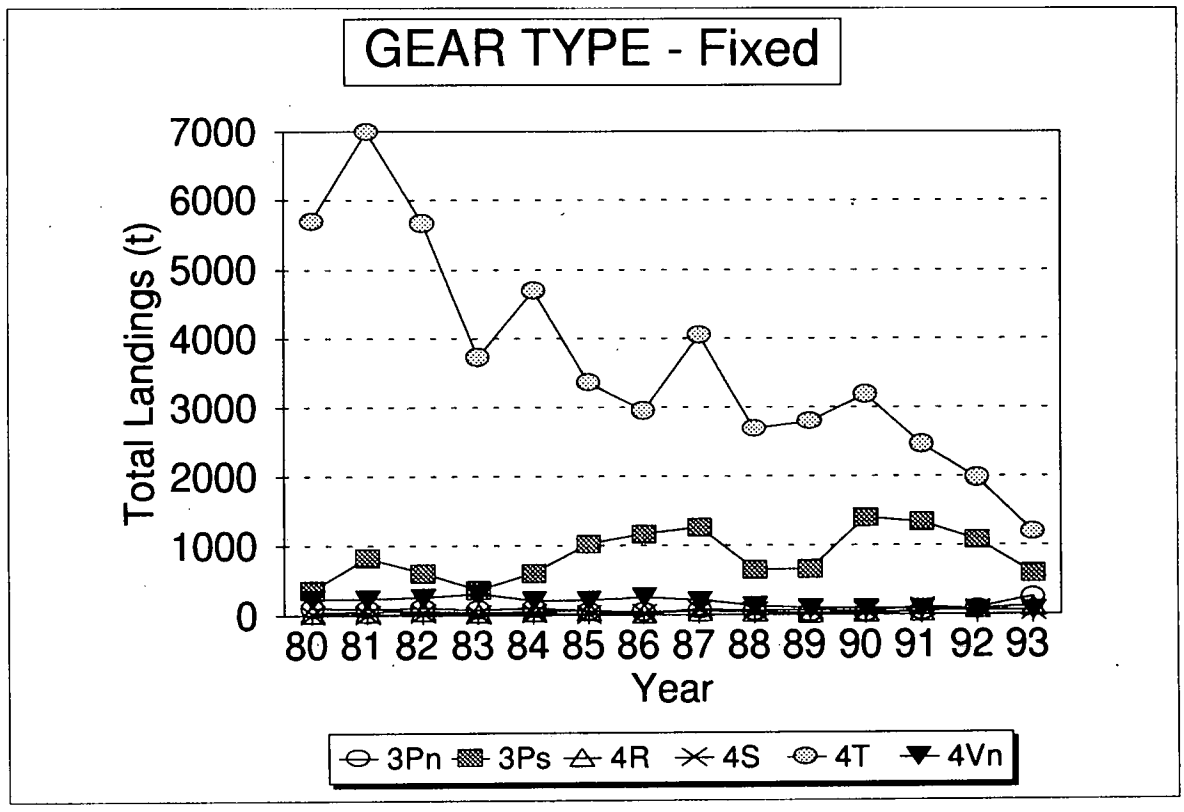


Figure 2 a. Nominal landings and TAC's for white hake in NAFO Division 4T.
b. Nominal landings by gear category for white hake in NAFO Division 4T.



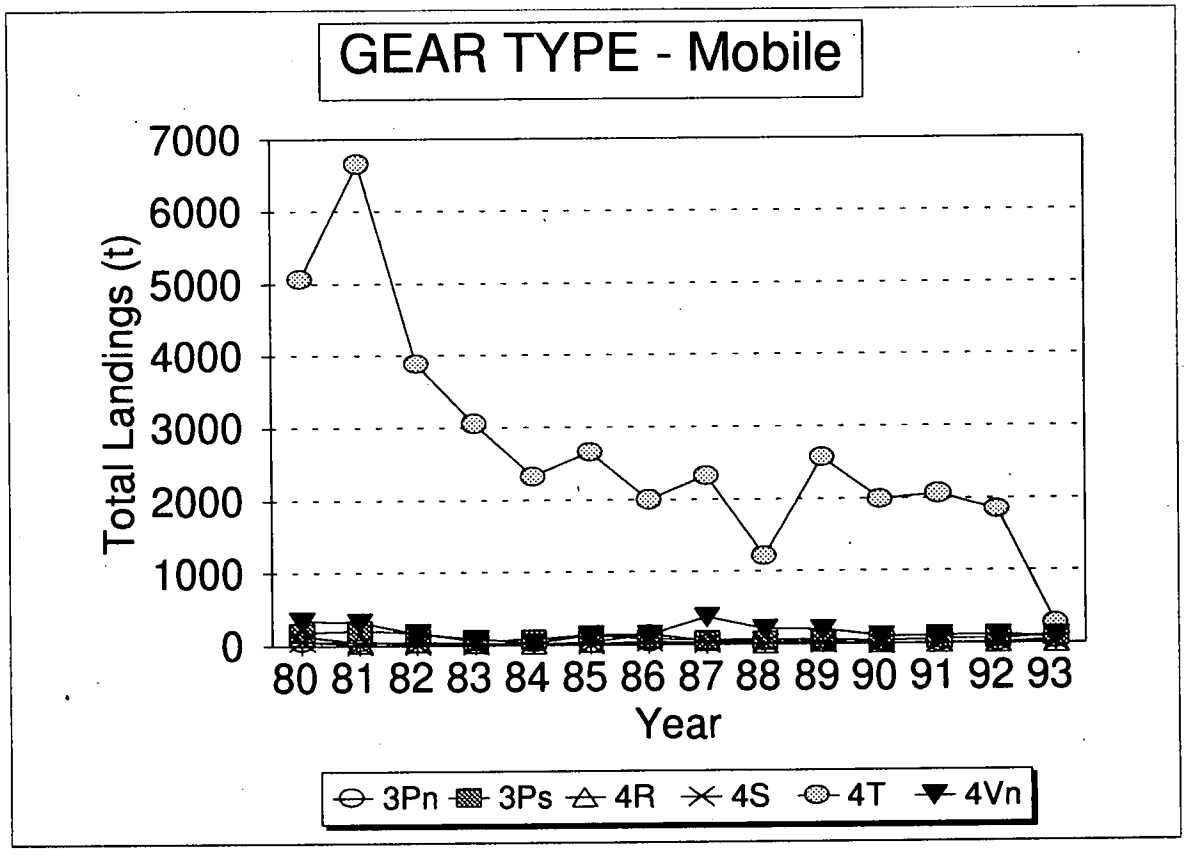
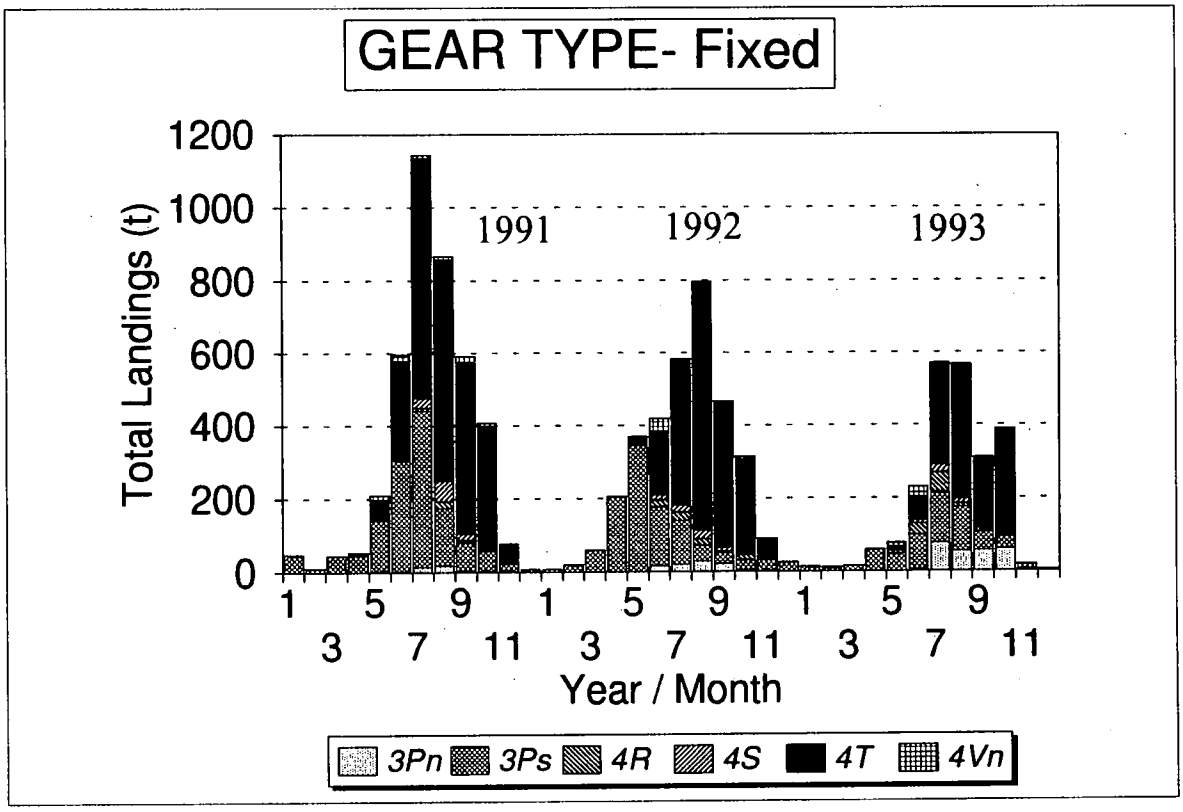


Figure 3a Landings (tonnes) of white hake (Fixed vs Mobile) from NAFO Div.'s 4R, S, T and Subareas 3Pn, 3Ps, and 4Vn for 1980-93 .



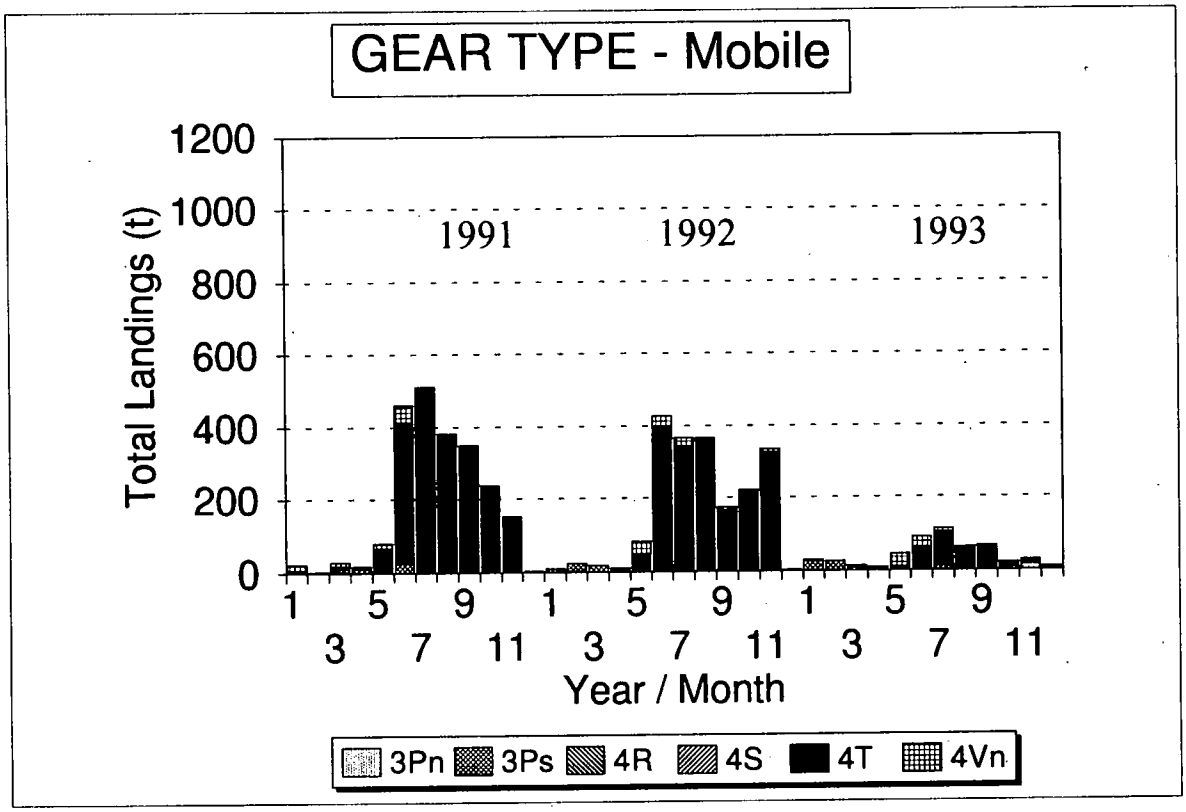


Figure 3b. Monthly landings (tonnes) of white hake (Fixed vs. Mobile) from NAFO Divisions 4R, S, T and Subareas 3Pn, 3Ps and 4Vn for 1991 - 93.

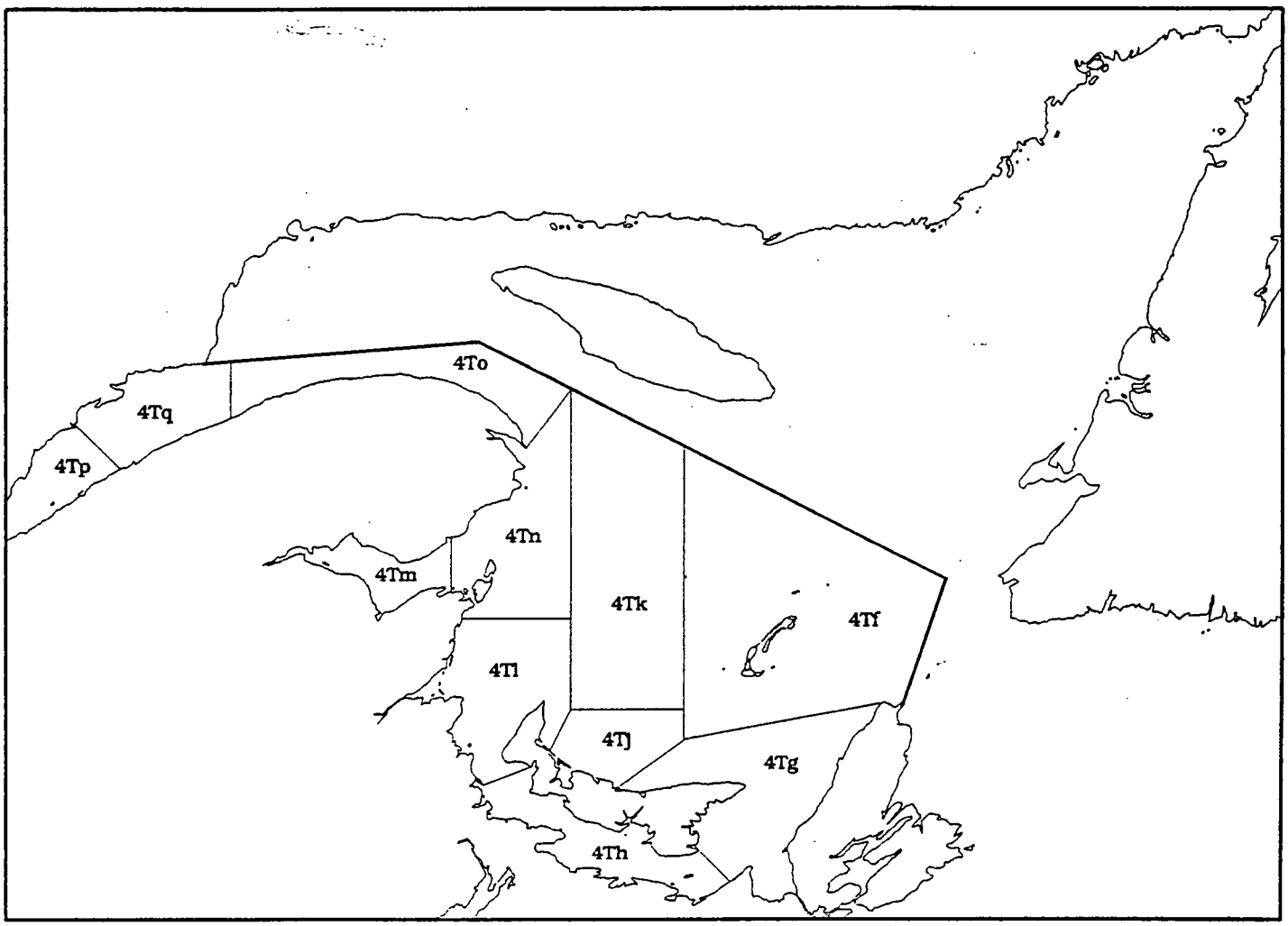
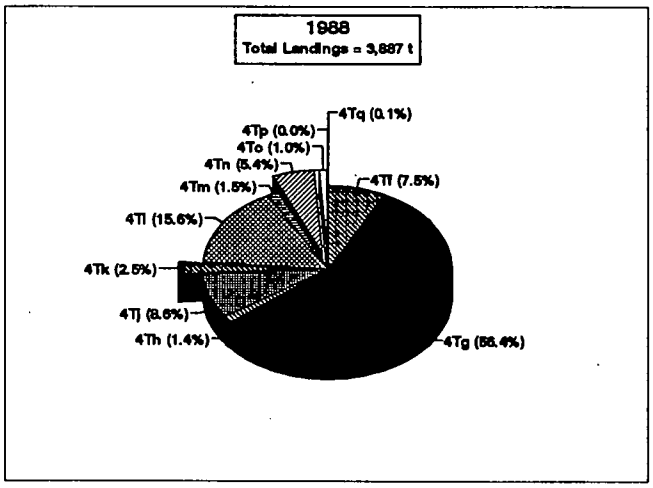
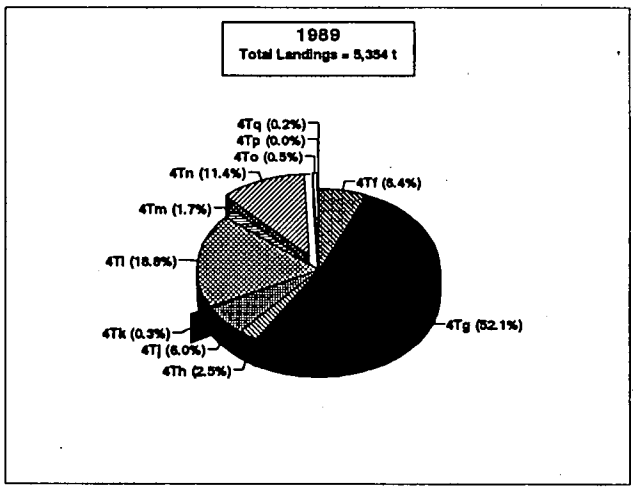
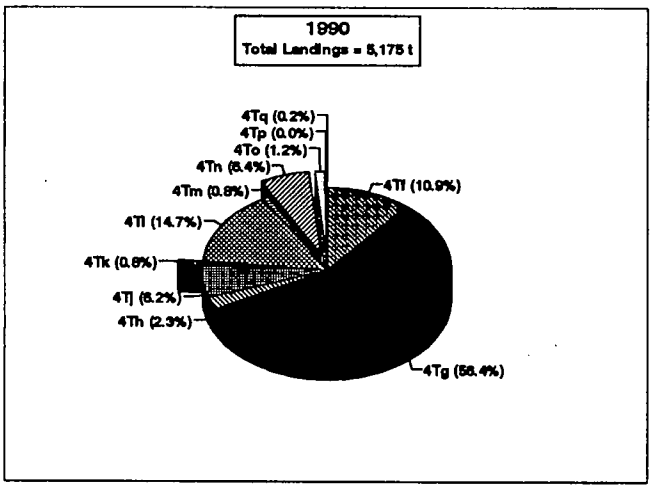
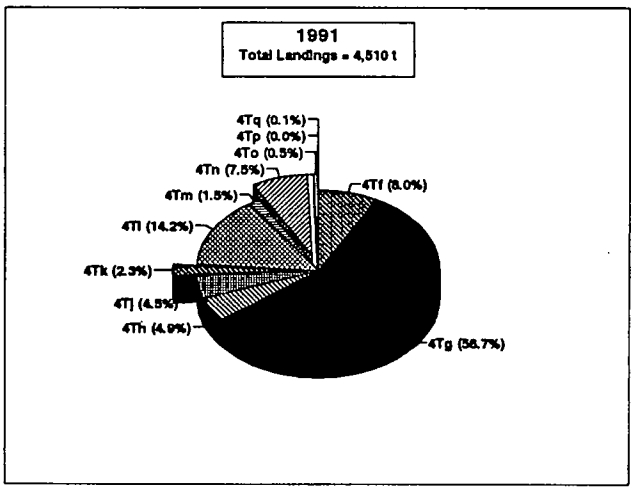


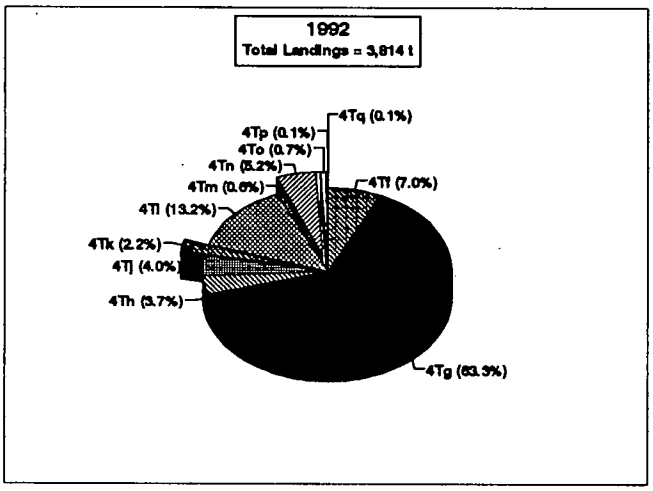
Figure 4. Canadian Statistical Unit Areas within NAFO Div. 4T











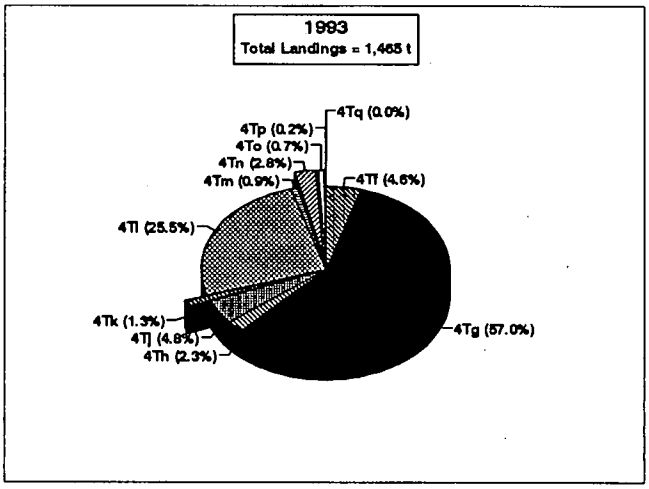
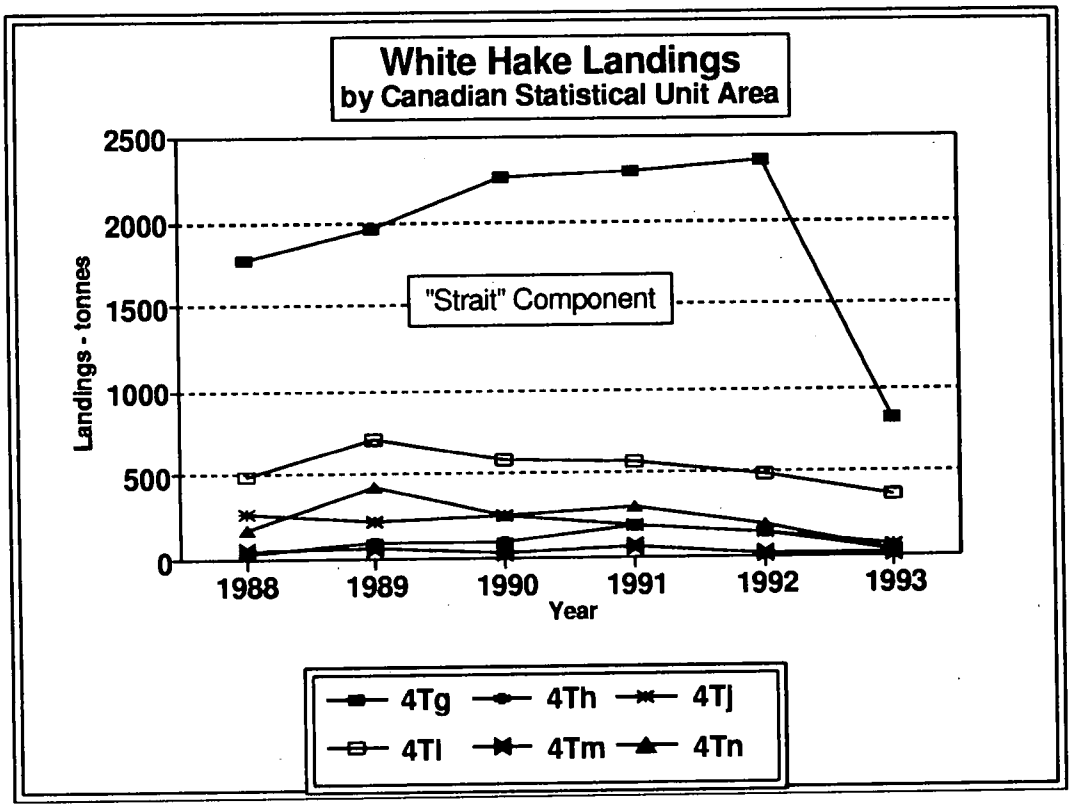


Figure 5. Landings of white hake by statistical unit area in NAFO Division 4T: 1988-93.



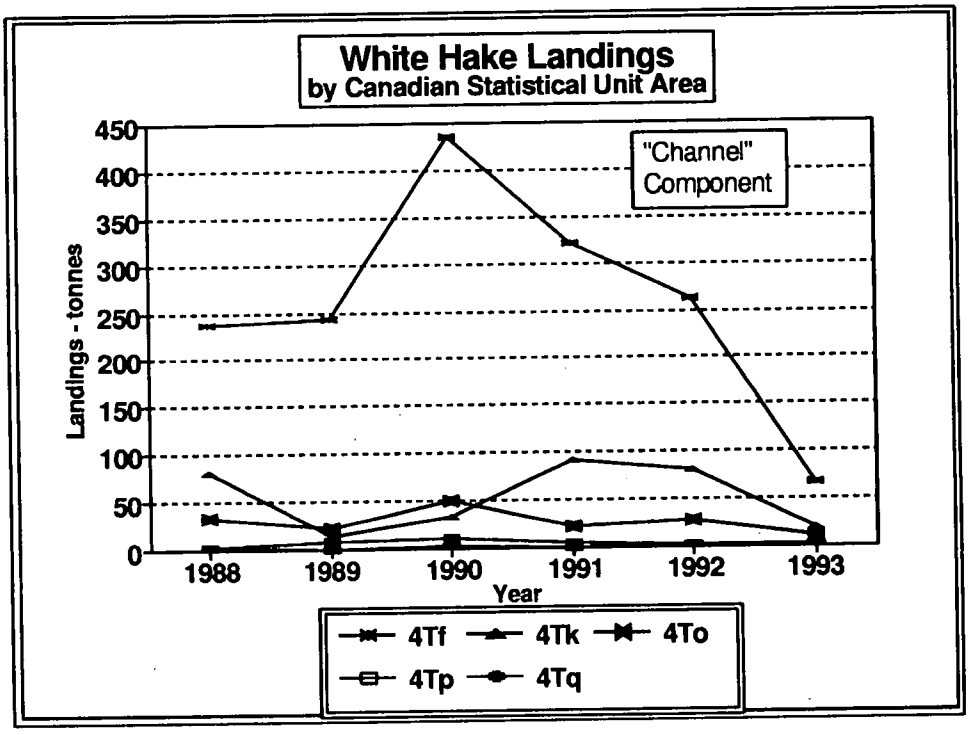


Figure 6. Landings of white hake by Canadian statistical unit area: 1988-93.

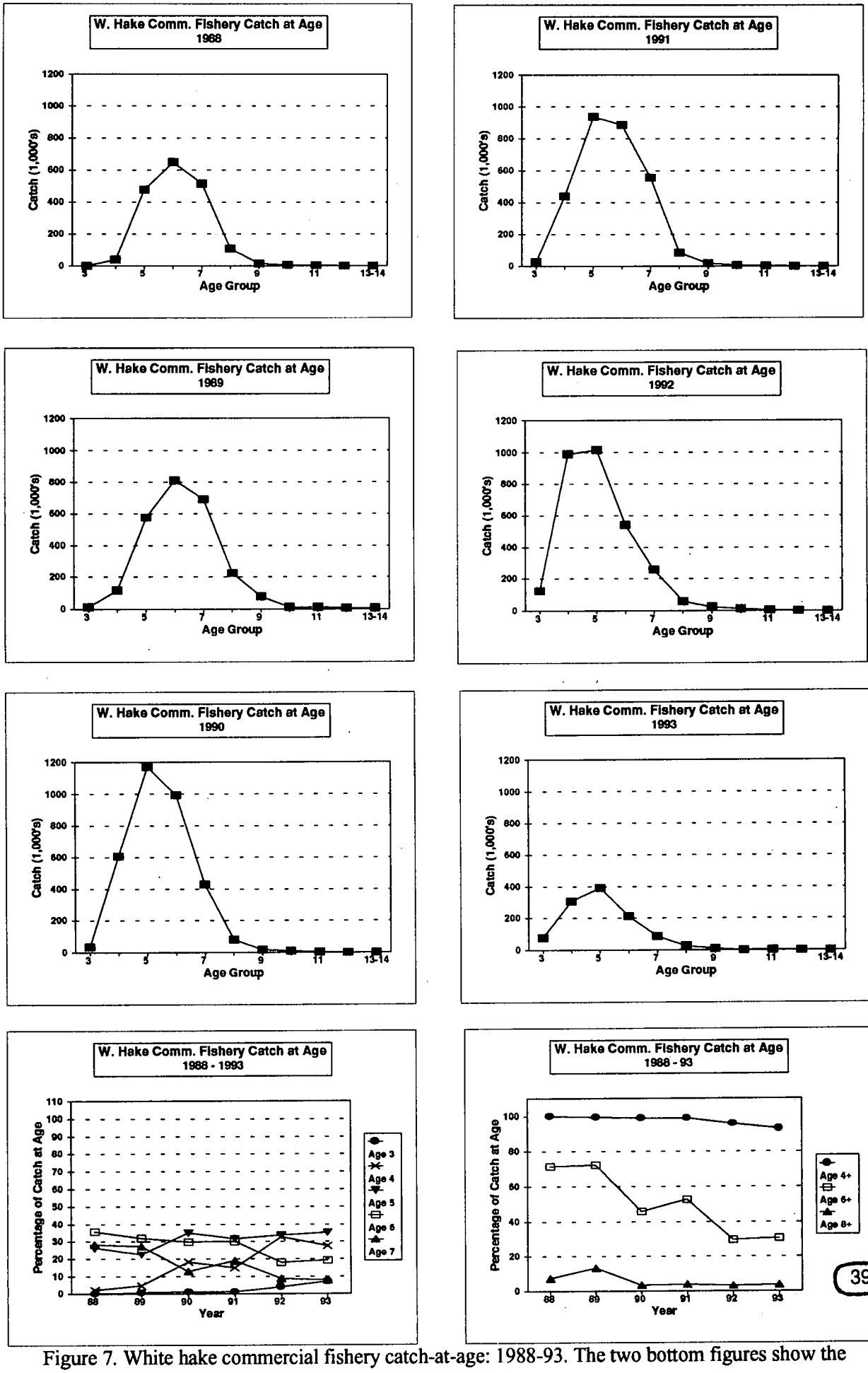
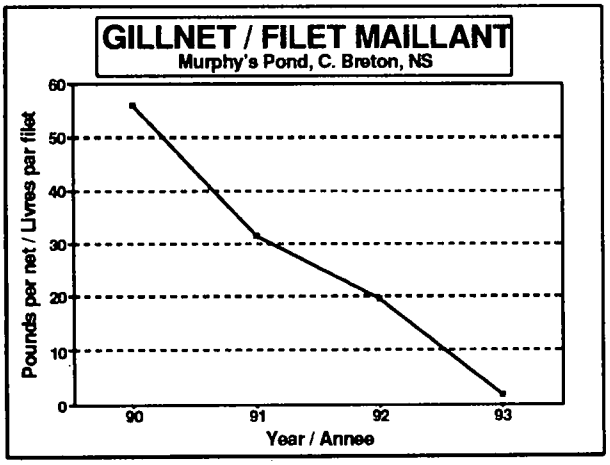
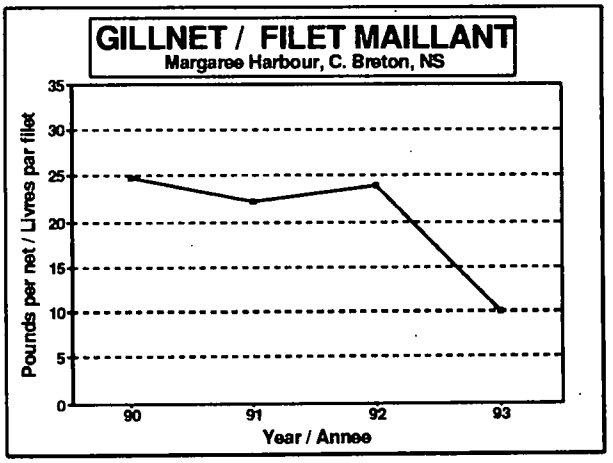
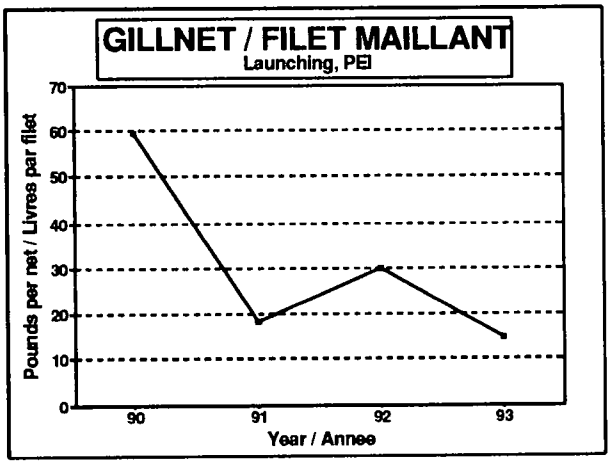
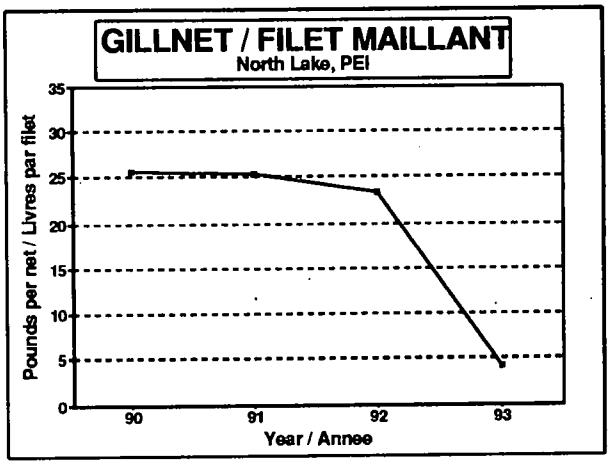


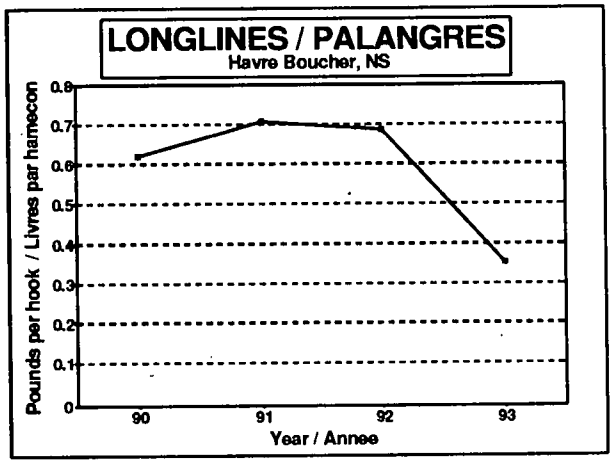
Figure 7. White hake commercial fishery catch-at-age: 1988-93. The two bottom figures show the age composition (%) for 1988-93.











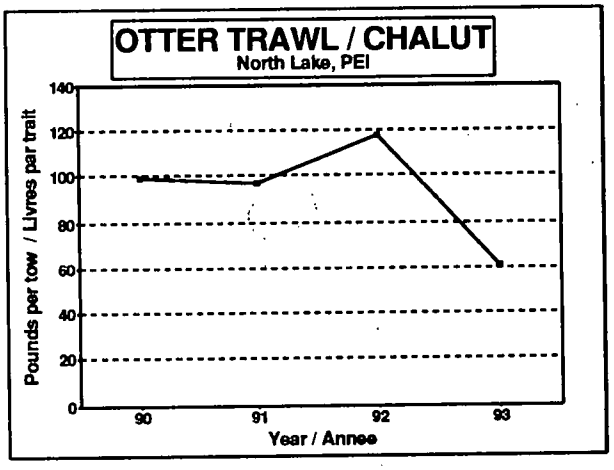


Figure 8. Catch rates for six index fishers that targetted white hake and submitted log records 1990-93.

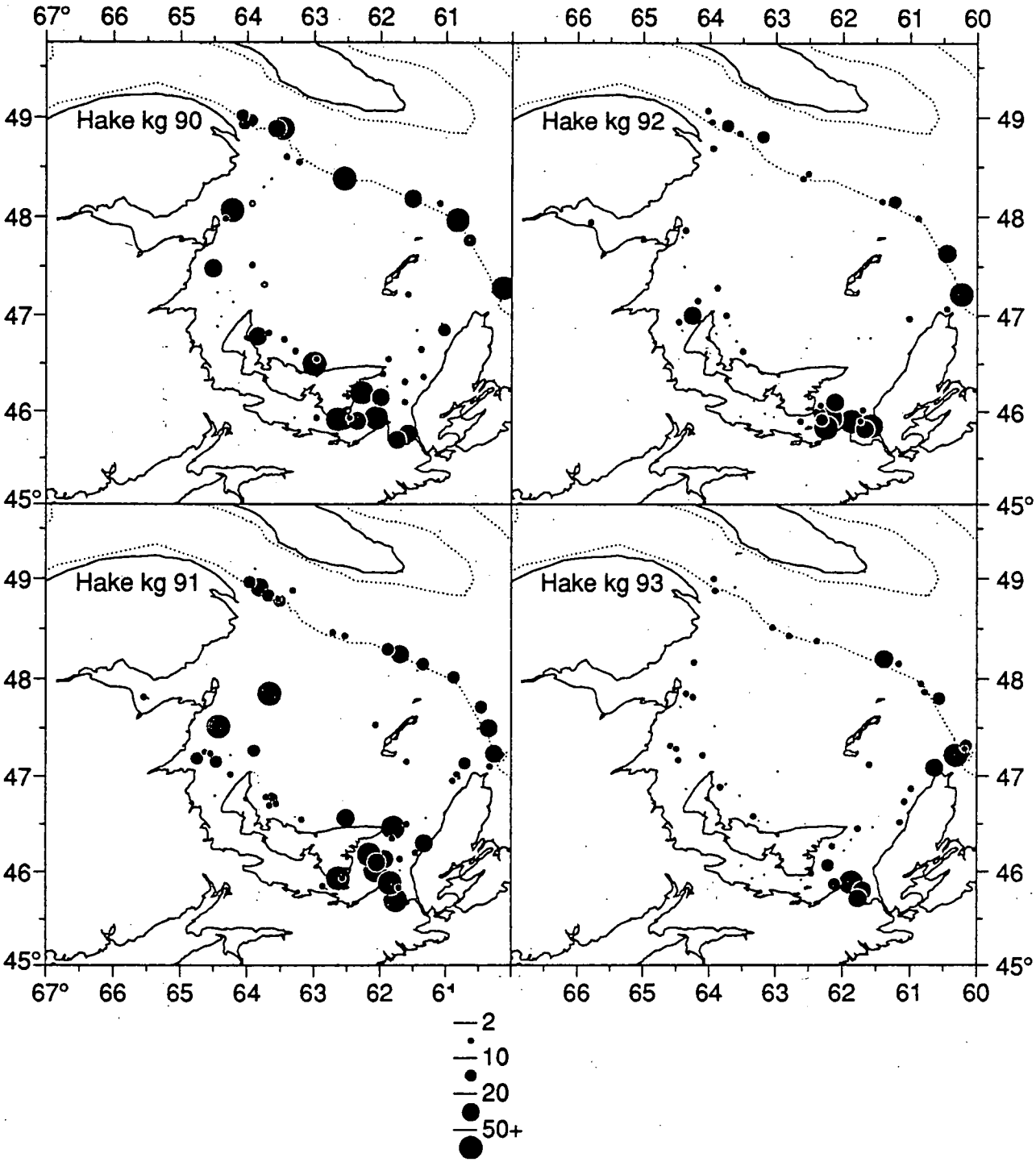


Figure 9. **Distribution of catches (kg) of white hake during annual groundfish surveys of the southern Gulf of St. Lawrence**

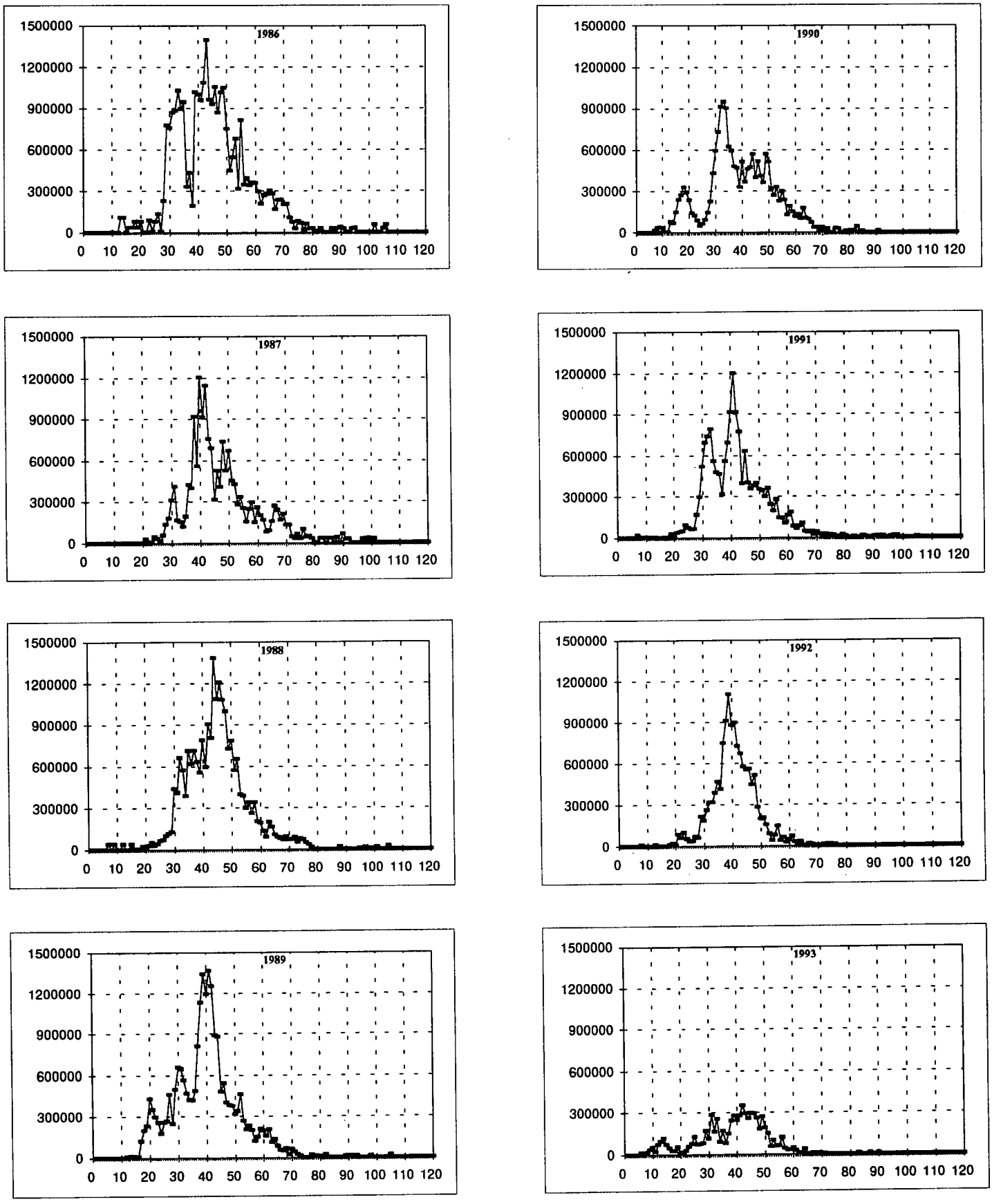


Figure 10. Length frequency (cm) distributions for white hake caught during surveys of the southern Gulf of St. Lawrence: 1986-1993.

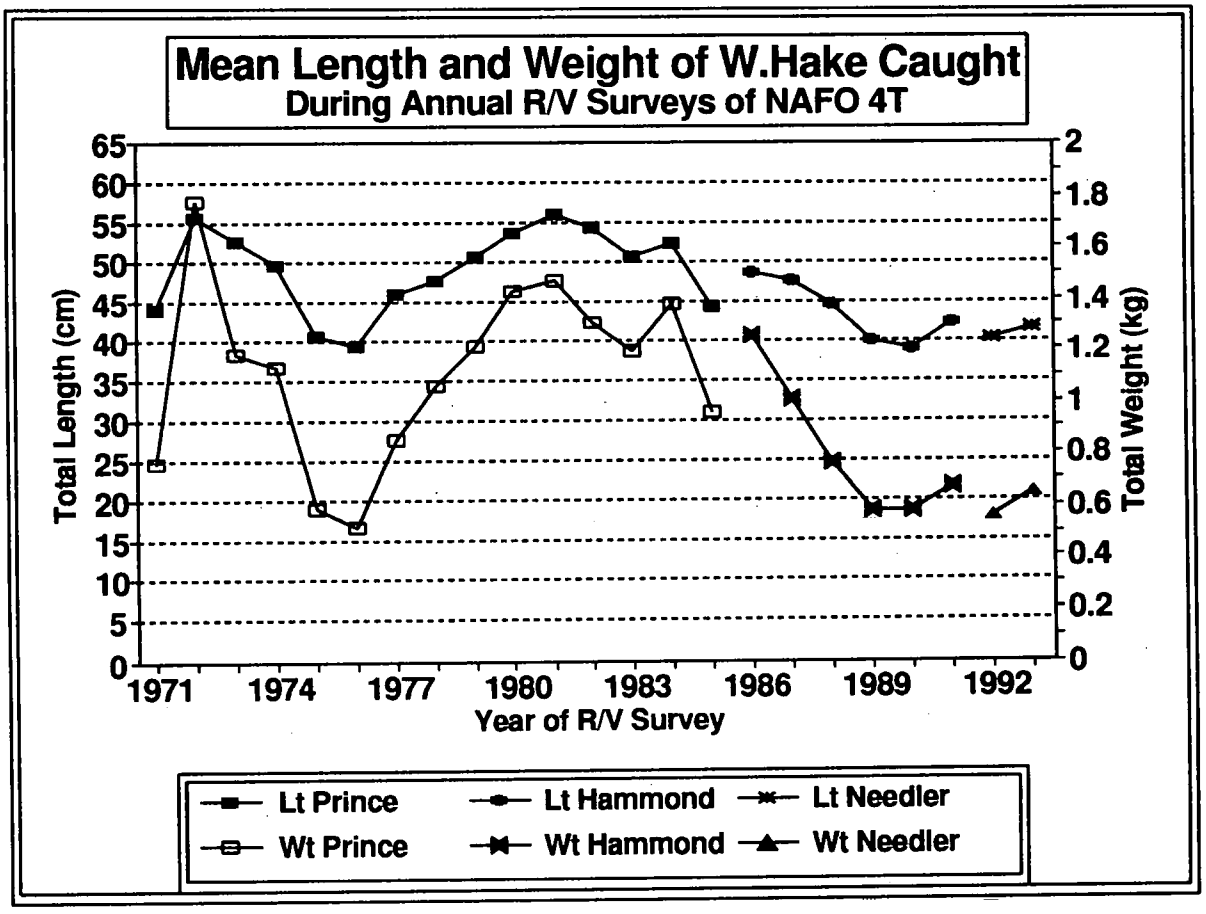


Figure 11. Mean length and weight of white hake sampled during R/V surveys of NAFO division 4T

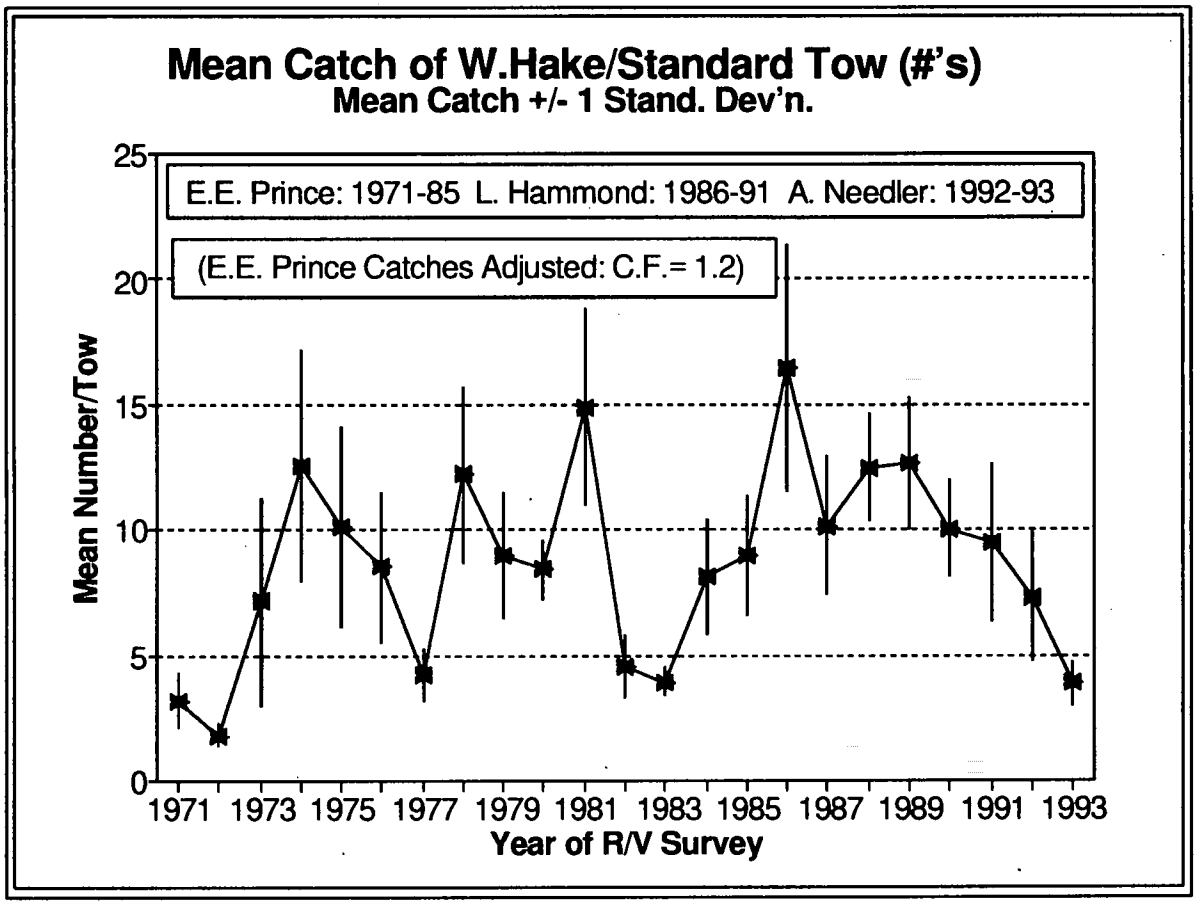
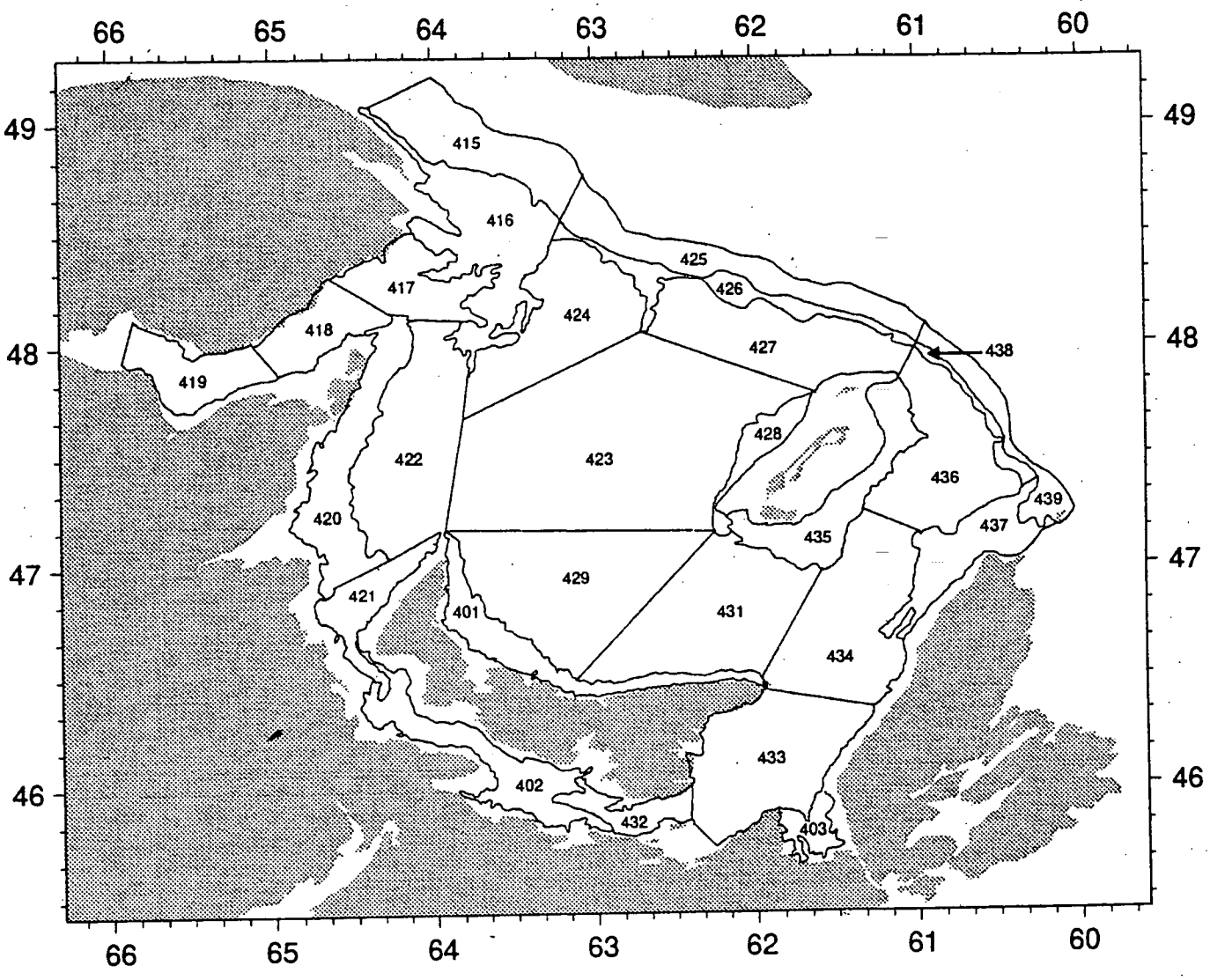


Figure 12. Research vessel survey mean numbers per tow for 4T White Hake, 1971-93.

Figure 13. Survey strata for the the southern Gulf of St. Lawrence annual groundfish survey



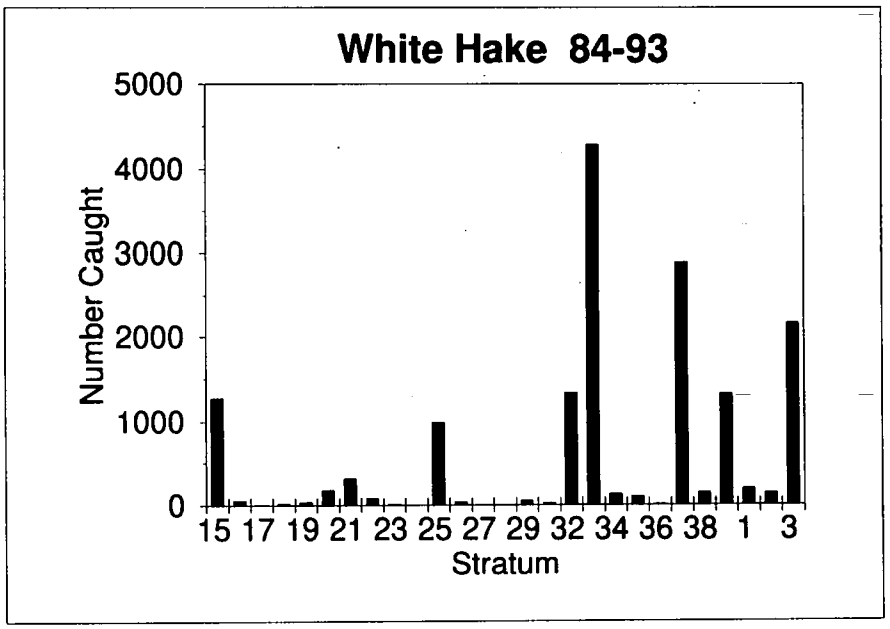
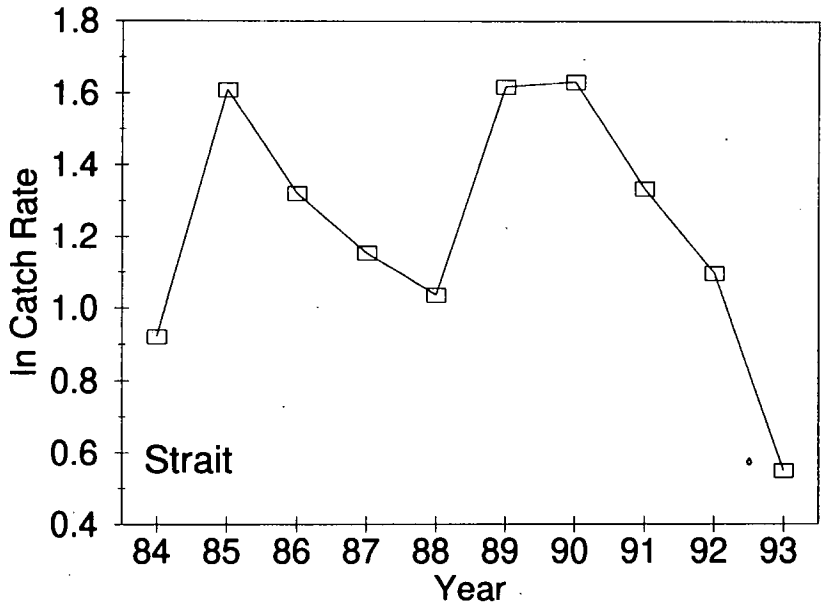


Fig. 14. Total catches of white hake by stratum in the 1984-1993 bottom trawl surveys of the southern Gulf of St. Lawrence.



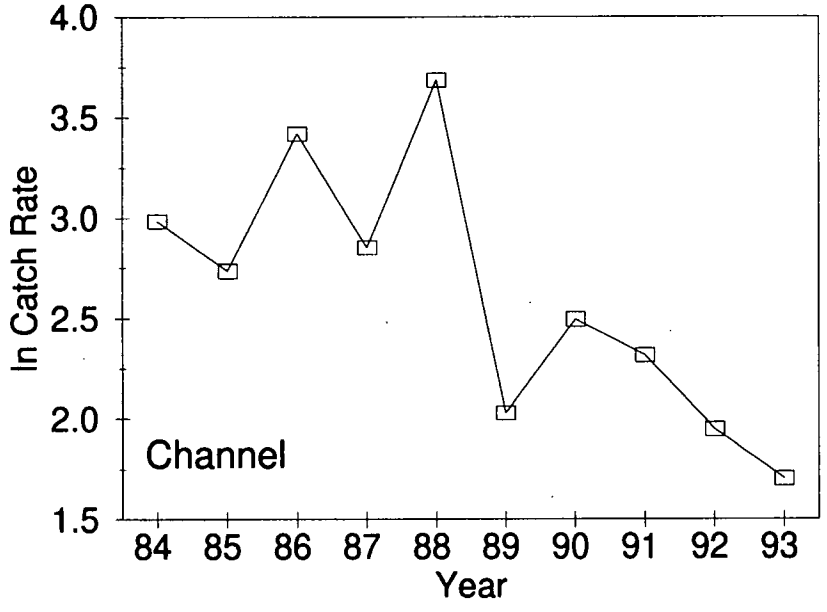


Fig. 15. Weighted mean catch rates of white hake in shallow and deep strata of the September survey of the southern Gulf of St. Lawrence.

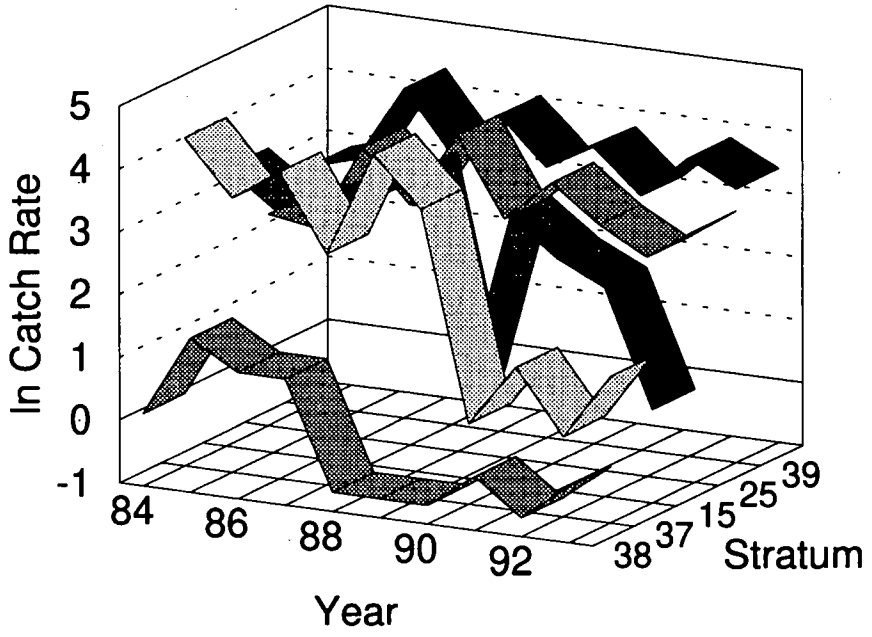


Fig. 16. Catch rates of white hake in deep strata of the September bottom trawl survey of the southern Gulf of St. Lawrence.

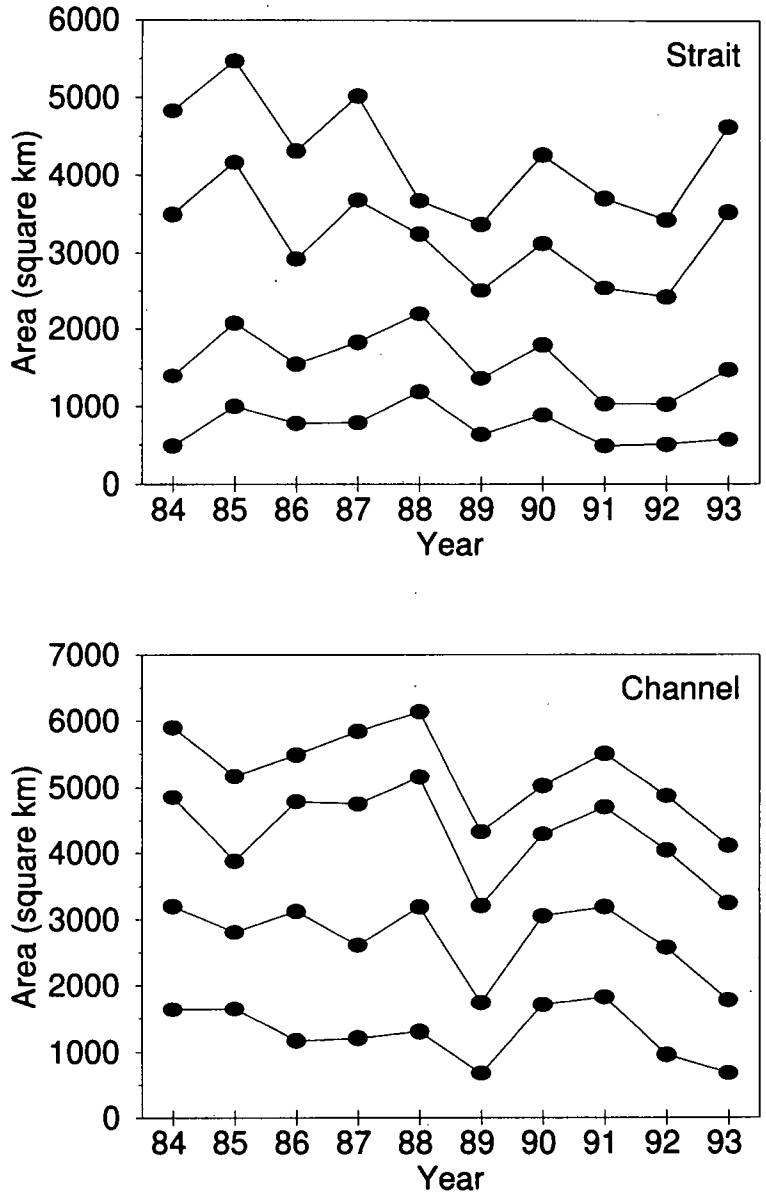


Fig. 17. Stock areas of white hake in shallow and deep strata of the southern Gulf of St. Lawrence. Areas are the minimum areas over which 50% (bottom line) , 75%, 90% or 95% (top line) of the stock in each region is spread.

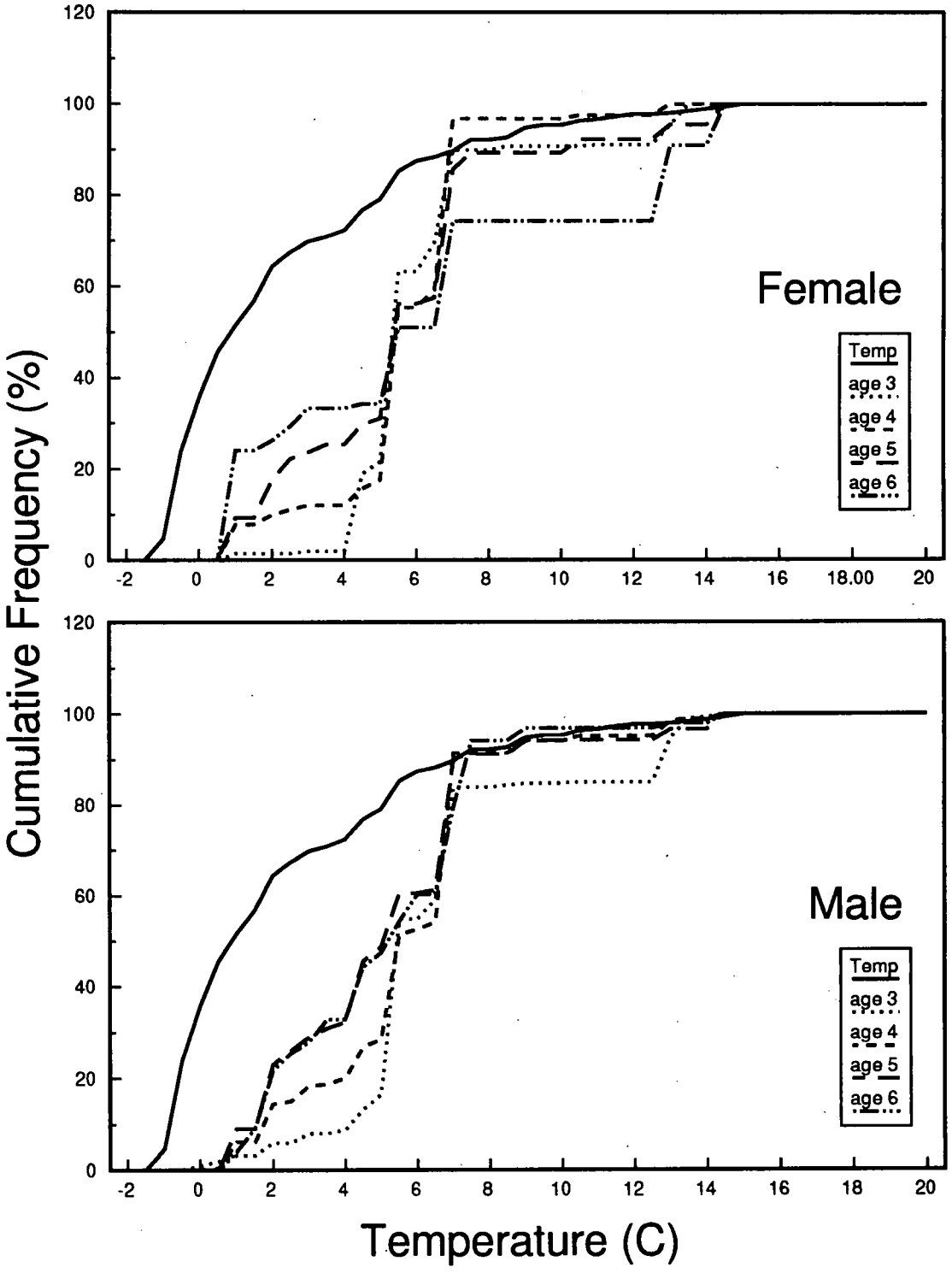


Fig. 18. Cumulative frequencey distributions of bottom temperature and of hake catch in relation to bottom temperature, September 1993.

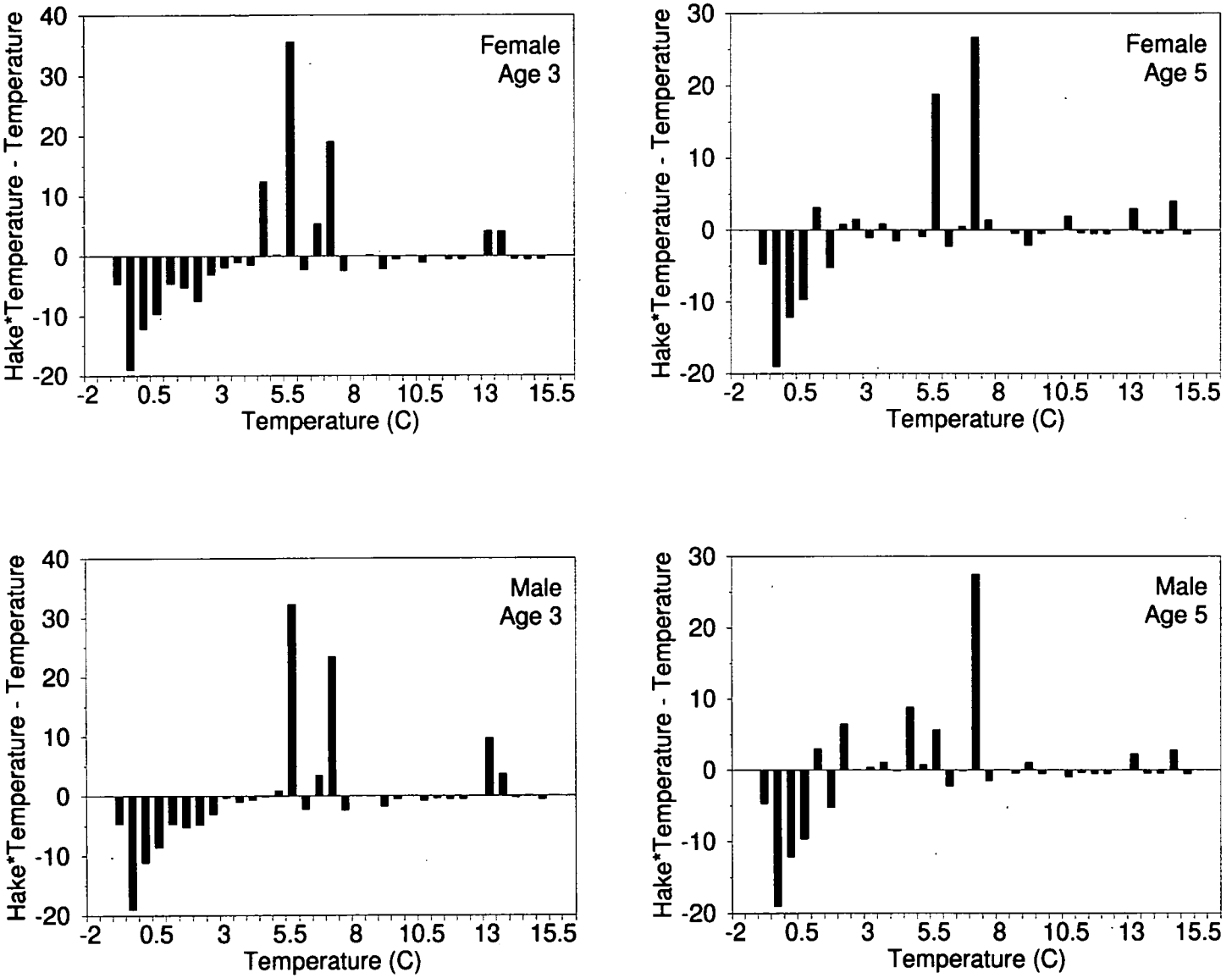


Fig. 19. Temperature selection by white hake in the southern Gulf of St. Lawrence, Sept 1993. Bars are the percent of the hake population occupying a particular temperature minus the percent of the survey area at that bottom temperature.

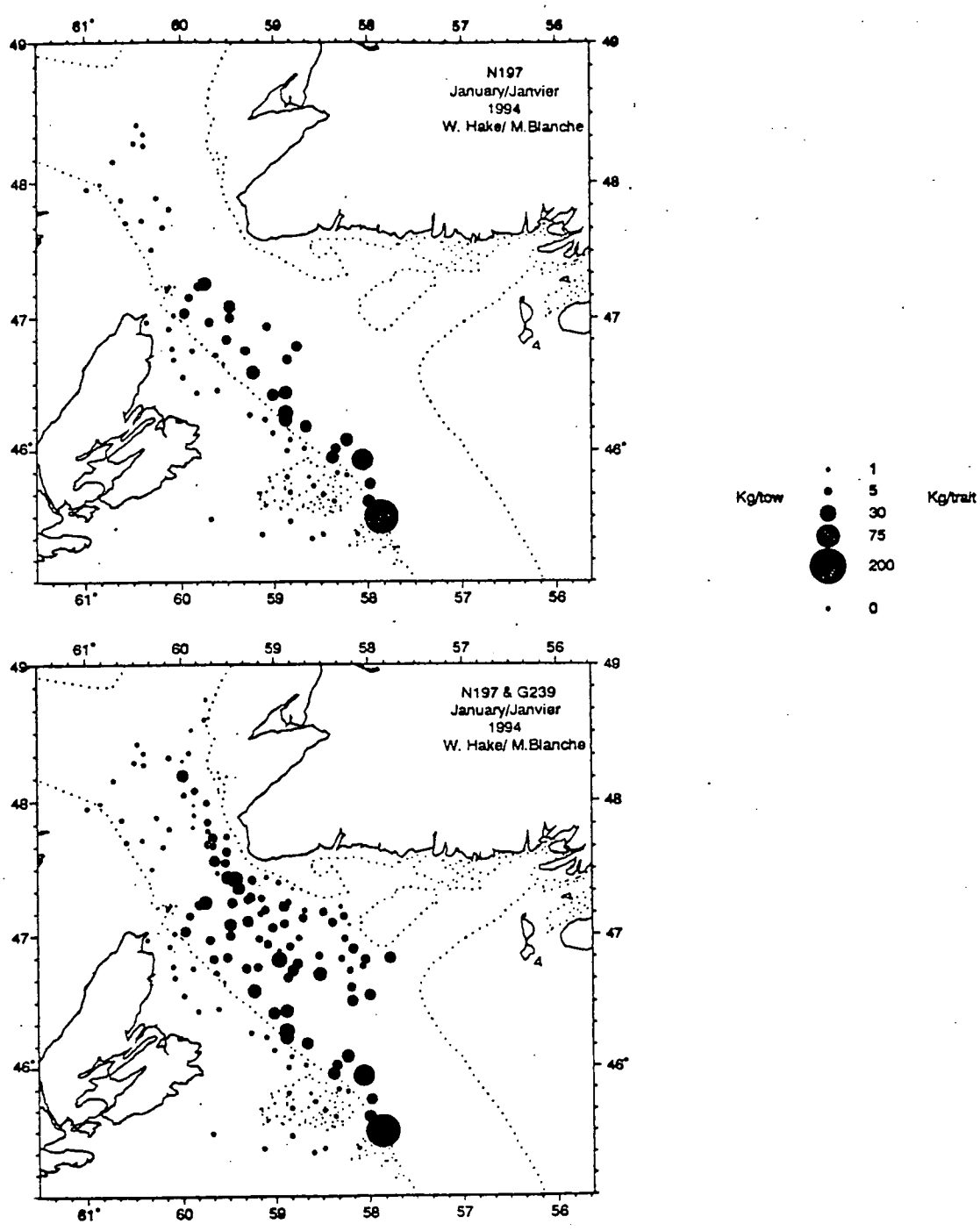


Figure 20. **Distribution of catches (kg/standard tow) of white hake during the January 13-25, 1994 survey of the Cabot Strait area (Gulf Region data). The bottom panel includes distributional data from the January 1994 survey conducted by the Québec Region.**

Figure 21. **Distribution of catches (kg/standard tow) of white hake during annual (August and September) surveys of the northern and southern Gulf of St. Lawrence (Québec and Gulf Region data).**

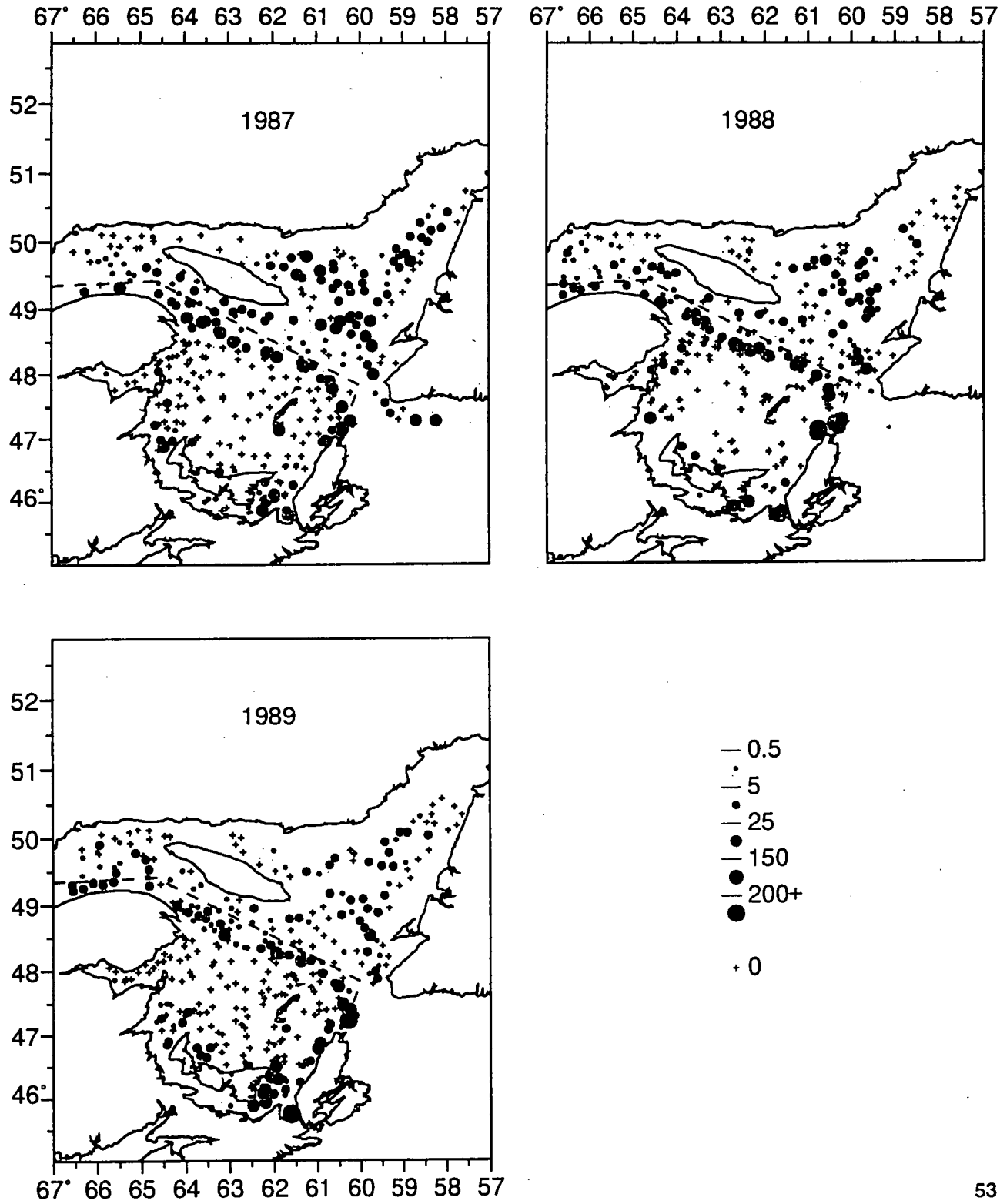
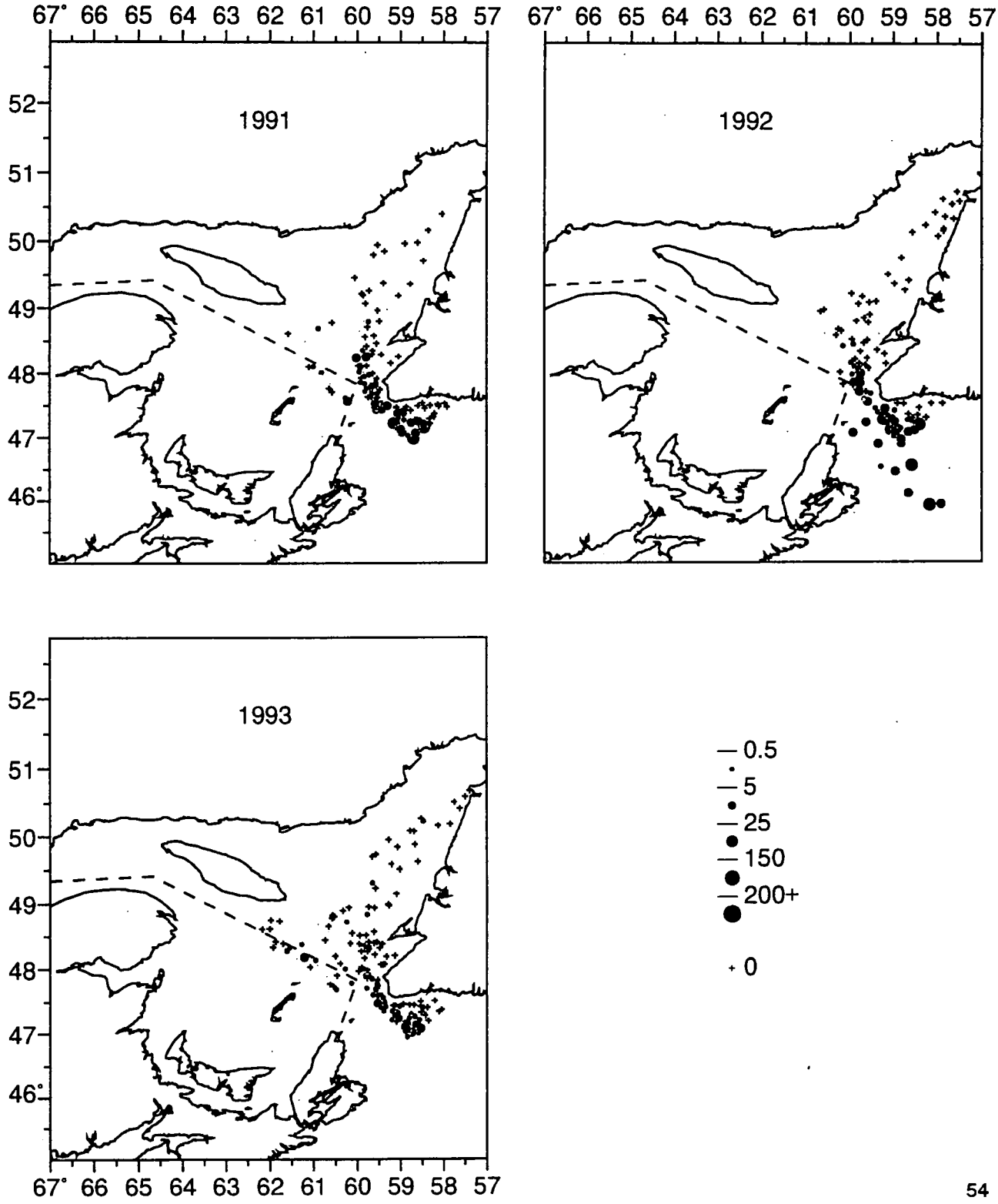


Figure 22. **Distribution of catches (kg/standard tow) of white hake during annual (January) surveys of the northern Gulf of St. Lawrence. (Québec Region data).**



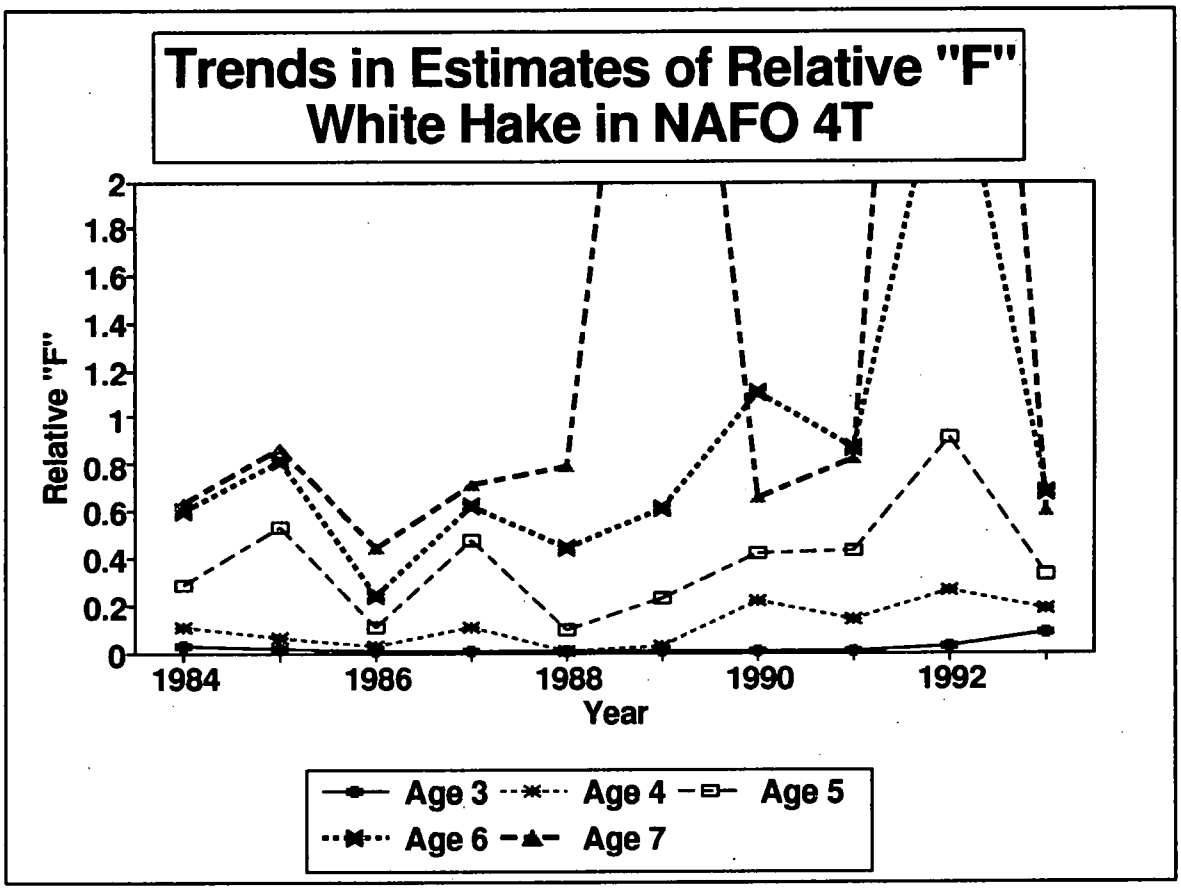


Figure 23. Trends in estimates of relative fishing mortality (F): 1984-93

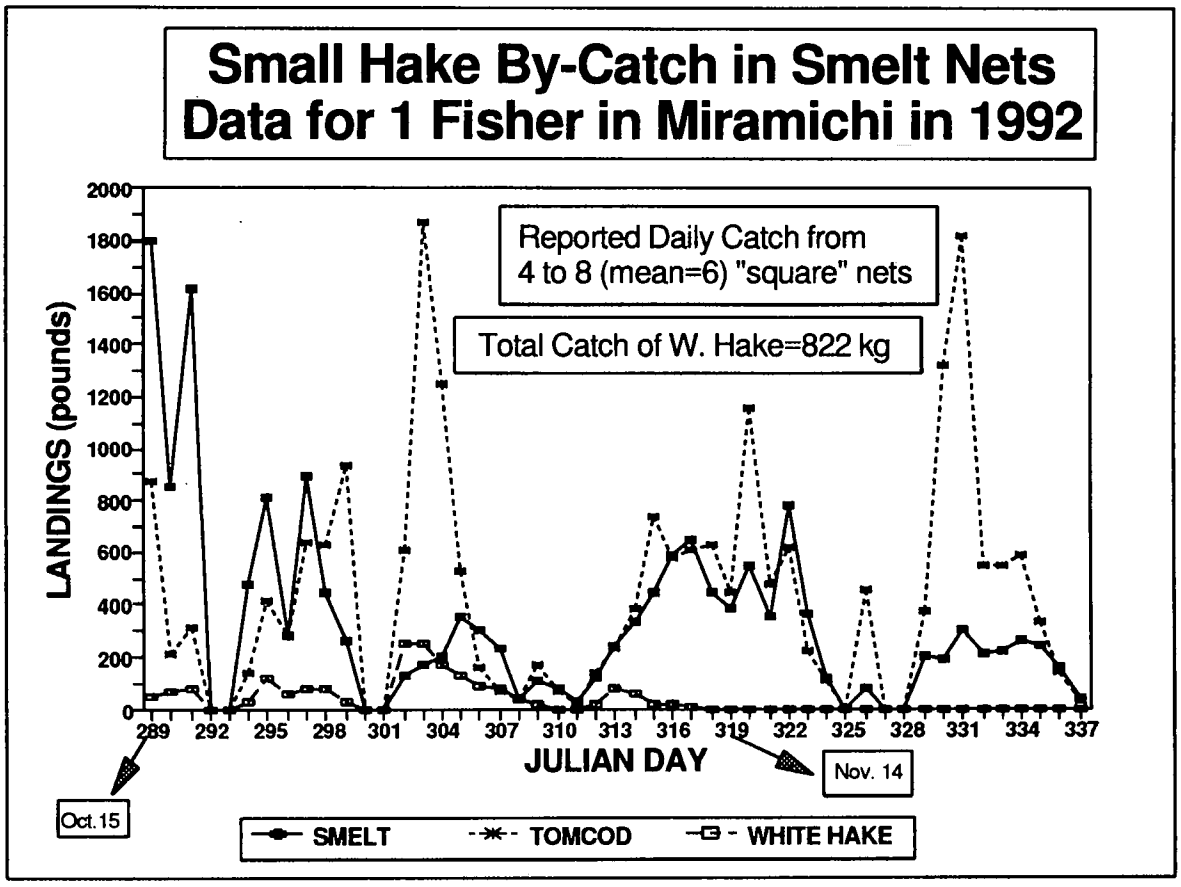


Figure 24. Reported (logbook) catch of small (Mean Lt.=23cm) white hake by one smelt fishermen that fished "square nets" in the Miramichi estuary in 1992.