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Assessment of Atlantic herring in NAFO Division 4T, 1987

by

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Abstract

Reported herring landings in 1987 in the southern Gulf of St. Lawrence (NAFO Division 4T) were 76, 545 t; approximately two-thirds of the catch was taken in the fall gillnet fishery which had its largest catch since 1971 and probably the largest in history. The current assessment is predicting twice the mature biomass and much larger 1979, 1980, 1981, 1982 and 1983 year-classes than the previous assessment. This dramatic change in perception of the resource is largely because of a change in the abundance index. The new abundance index was calculated from gillnet catch rates using a multiplicative model. Catch rates in the spring and fall gillnet fisheries where the highest since 1974. Fishing mortality on fully recruited age groups was estimated to be 0.24 for fall spawners. It was not possible to calculate fishing mortality for spring spawners. Projected landings at $F_{0.1}$ = 0.3 for 1989, are 21,000 t for spring spawners and 53,700 t for fall spawners.

Résumé

Les relevés des prises débarquées de hareng en 1987 dans le sud du Golfe du Saint-Laurent (division 4T de l'OPANO) indiquent un nombre total de 76 545 t; environ les deux tiers de ces prises ont été le résultat de la pêche au filet maillant, qui a été la plus productive depuis 1971 et probablement la plus imposante jamais enregistrée. Selon l'évaluation actuelle, la biomasse des poissons à maturité serait le double de celle de l'évaluation précédente, et les populations des classes annuelles de 1979, 1980, 1981, 1982 et 1983 seraient beaucoup plus abondantes. Cette variation considérable de la perception de la ressource est largement attribuable à une modification de l'indice d'abondance. Le nouvel indice d'abondance a été calculé à partir de taux de prises au filet maillant au moyen d'un modèle multiplicatif. Les taux de prises des pêches au filet maillant du printemps et de l'automne ont été les plus élevés depuis 1974. La mortalité due à la pêche dans les groupes d'âge entièrement recrutés a été estimée à 0,24 dans le cas des géniteurs de l'automne. Il n'a pas été possible de calculer la mortalité due à la pêche pour les géniteurs du printemps. Les débarquements prévus, à $F_{0,1}$ = 0,3 pour 1989, sont de 21 000 t pour les géniteurs du printemps et de 53 700 t pour les géniteurs de l'automne.

1. INTRODUCTION

This assessment of the 1987 herring fishery marks the 12th year that CAFSAC has provided biological advice on 4T herring. There have been 12 previous assessments, including Winters et al. (1977), Winters (1978), Winters and Moores (1979, 1980), Cleary (1981, 1982, 1983), Ahrens and Nielsen (1984), Ahrens (1985a), Clay and Chouinard (1986), and Chadwick and Nielsen (1986, 1987).

There are two recognized spawning groups: spring and fall spawners. Prior to 1965 4T herring were exploited primarily by gillnetters on spawning grounds; average landings for 1949-1964 were 32,000 t. In the mid 1960's, purse seines were introduced which primarily harvested mixed stocks of spring and fall spawners. Landings by the seiner fleet peaked at 175,000 t in 1970. 4T herring were also fished on their wintering grounds in NAFO Division 3Pn from 1966-1972 (Figure 1). Purse seines were the major gear in the 1970's, but since 1981 over 80% of reported landings have been by gillnetters.

Total herring landings in 4T have followed a rising trend since 1981. In 1987 total reported landings were 76,545 t, an increase of 30% over the previous year (Table 1). The largest fishery is that of gillnetters in the fall, whose landings of 51,931 t accounted for 68% of total 4T harvest. Gillnets are primarily set on spawning grounds inshore, whereas the purse seine fishery since the early 1980's has been primarily prosecuted in October-December, after the fall spawning period. Most seine activity in 4T occurs in the Chaleur Bay area, principally on the north side of the bay in the general area of Shigawake-Chandler. 4T herring are also taken by seiners in winter in the Sydney Bight area of 4Vn.

Quotas or total allowable catches (TAC) have been established since 1972. From 1972-1981, the TAC ranged from 45,000 to 60,000 t, but was never achieved. From 1981 to 1984 TAC's ranged form 15,000 to 20,000 t, but were exceeded each year by at least 30%. In 1985 reported landings were slightly lower than the TAC of 32,500 t, but a substantial portion of the catch was unreported and the TAC may have been exceeded by about 30% (Chadwick and Nielsen 1986). The 1986 TAC was 43,375 t, which was exceeded by 36%. Advice from the 1986 assessment for the 1987 fishery was 6,600 t spring and 16,800 t fall spawners. Revised $F_{0.1}$ catches from the 1987 assessment were 12,900 and 31,300 t for spring and fall spawners.

In 1987, the total quota for 4T was 72,750. Reported landings (76,545 t, Table 1) exceeded this TAC by only 5%, although the actual overrun was likely greater because of under-reporting in the fall purse seine fishery. TAC's were allocated by season gear type, and area. The total spring gillnet TAC of 8,200 t was divided into: Escuminac in May (3,000 t), 4T other than Escuminac in May (4,500 t), and 4T in June (700 t). The total fall gillnet TAC of 50,000 t was divided into: Isle Verte and Magdalen Islands (500 t), the Chaleur Bay (28,500 t), Escuminac and Western P.E.I. (2,000 t), Fisherman's Bank (9,000 t), and Pictou (10,000 t). A summary of reported nominal catches and TAC's are in the table below:

	1980	1981	1982	1983	1984	1985	1986	1987	1988
TAC	55	16	15	20	19	32.3	43.4	72.8	72
Catch	40	21	24	26	27	31	59	76.5	--
CAFSAC									
Initial adv.	55	16	20	13	13	20	25	25	36.1
Revised adv.	55	--	0	--	18	30	32	44	--

In 1987, unreported landings were not considered to be a serious problem in the gillnet fishery. Based on anecdotal information from the fall purse seine fishery, however, it is possible that landings in this fishery have been under reported by 40% since 1981. In 1987, this problem was particularly acute because there was no on-site monitoring of the landings.

Cumulative catches and daily fishing effort in each port were estimated by fisheries officers and reported to Resource Allocation Branch at regional headquarters, where the information was used to set timely season closures for each area. In fall 1987, daily boat quotas were also imposed on the gillnet fleet. These quotas were 20,000 lbs. (9.07 t) in Chaleur Bay and Pictou areas, and 15,000 lbs. (6.80 t) in the Western P.E.I. and Fisherman's Bank areas. The fall gillnet 1987 fishery did not open at predetermined dates as in previous years, but instead opened when percentage of roe in samples caught by test fishermen exceeded threshold levels set for each area.

2. INPUT DATA

2.1 Catch at Age Matrices

As with previous assessments, we divided the 4T fishery by area, fishing season, spawning group, and gear type. Areas chosen were Statistical Districts 431-435, 436, and 437-439. Landings and spawning group affinity of the herring catch in these areas are given in Table 2. Fishing seasons were spring (prior to 1 July) and fall (after 1 July). Spawning groups were spring (spring plus early summer) and fall (late summer plus fall). Gear types were gillnet (including a small number of traps) and purse seine.

For 1987 samples, herring were designated as spring spawners if they were caught before July and their gonads showed maturity stages 5, 6 or 7. Fish caught after 1 July with maturity stages 5, 6 or 7 were classified as fall spawners. Spawning group affinity of fish not meeting the above criteria was assigned by eye by an experienced ager on the basis of otolith morphology.

The 1987 catch and weight at age were added to equivalent data used in previous years. Landings in the spring gillnet fishery are usually of mature spring spawners while gillnetters in the fall usually capture mature fall spawners. The fall purse seine fishery captures a mixture of spring and fall spawners, estimated to be 53% spring spawners in 1987.

Since 1981, catches of both spawning groups have been dominated by the gillnet fishery.

Year	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Spring Spawners														
GN Catch, Kt.	8	8	7	5	9	9	9	6	8	8	5	8	11	11
PS Catch, Kt.	7	17	15	18	15	10	11	3	1	2	2	2	7	7
Fall Spawners														
GN Catch, Kt.	5	4	3	3	4	5	4	11	10	14	18	19	38	52
PS Catch, Kt.	16	16	15	19	25	25	17	2	2	2	1	2	4	6

Catch-at-age matrices for gillnets, purse seines and all years are summarized for spring spawners (Table 3) and fall spawners (Table 4), 1974-87. The 1980 year-class was particularly strong in both spawning groups. The mean weights at age are summarized in Table 5. Figure 2 compares the catch biomass at age calculated from commercial samples for 1987 with that projected by last year's assessment. Observed age composition is older than projected composition among both spring and fall spawners. The 1987 assessment underestimated the strength of the spring spawners 1980, 1981 and 1982 year-classes and the fall spawners 1980 and 1982 year-classes.

Revised catch-at-age and weight-at-age matrices for the years 1984 to 1987 were presented, but it was decided not to examine these revisions until the entire matrices (1974 to present) were available with adequate documentation. They will be reviewed in 1989.

The revised catch-at-age matrix, however, was used to make a preliminary comparison of age distributions among catches in southern (areas 431-435) and northern (areas 436-439) districts (Table 6). Catch-at-age matrices followed roughly similar patterns between the two regions. The 1980 year-class showed strongly in both regions in all years. The 1982 year-class, which was strong in the south, was weak in the north. This analysis will be repeated in greater detail in 1989.

2.2 Commercial Catch Rates

Two catch rates were calculated. The first was the same mean catch rate in the gillnet fishery which has been used in previous years. Catch per trip data were aggregated across areas and months, 1974-87, for five areas for the spring and fall fisheries. The spring fishery occurs up to June 30 and the fall fishery during the last half of the year. These areas were selected because they are areas of major gillnet landings where most of the catch is from discrete spawning aggregations.

The number of nets used per trip was estimated from a series of six questionnaire surveys of fishermen in recent years. The 1987 survey indicated that the number of nets used in the fishery had not changed significantly since 1984.

An error in the number of nets estimated for the 1980-82 fisheries was corrected. In the 1986 and 1987 assessments we used the number of nets owned by fishermen who sold more than 50% of their catch to plants; we should have used the number of nets fished by these fishermen. This error came to light in a recent report by (Cleary and Hamel 1986), and results in a substantial change to the catch rates calculated for these years. The revised catch rates are summarized in Table 7.

	Year		
Spring Fishery	1980	1981	1982
Catch per trip	1.09	0.92	1.73
No. nets old	39.2	41.4	39.7
No. nets revised	20.2	18.6	20.4
CPUE old	0.028	0.022	0.044
CPUE revised	0.054	0.050	0.085
Fall Fishery			
Catch per trip	1.45	2.15	2.33
No. nets old	18.4	19.3	18.6
No. nets revised	10.4	9.6	9.0
CPUE old	0.08	0.11	0.13
CPUE revised	0.14	0.22	0.26

The impact of these changes on the assessment would be minimal in the calibrations of fall spawners, because the adjustments were made at a time when both fisheries were exhibiting very low catch rates. The calibration procedure in last year's assessment fixed the origin at zero. Consequently, the slope of the line would not have been dramatically influenced by these changes.

A second catch rate was calculated using a multiplicative model (Gavaris 1980). The model was used to compare the relative variation of catch rates among, season, area or Statistical Districts, and year. Daily catch rate data were available from 1978 to present on purchase slips. Each slip was assumed to represent one fishing trip or one unit of effort. Slips without a date were not included in the analysis. Only days with a record of 5 or more slips were included in the analysis. This measure was taken to avoid the problem of truncation where the slips from several boats could be combined together.

Previous attempts to use a multiplicative model to analyze catch rates in the gillnet fishery have failed because of large within season variability. In the 1987 assessment, it was noted that there was pronounced within season variation in the catch rates of 15 index fishermen.

In this assessment an attempt was made to account for seasonal variation by separating catch rates into two categories. The first category included catch rates during the time period when the first and last 25% of the catch was taken; these would be the first and last quartiles on a cumulative frequency distribution of catch. The second category included catch rates during the middle time intervals, that is one quartile on each side of median.

The cumulative catch and the daily catch rate of herring taken during 1983 in Statistical District 65 are shown in Fig 3. It is clear that the catch rates around the time when the median catch was taken were higher than catch rates during the first and last quartiles. The reason for this difference could be, because the gillnet fishery is directed at spawning fish, catch rates are high when herring move into an area for spawning but they are low both prior to and after spawning.

In Fig 4 there is evidence that several spawnings occurred in the 1984 fall fishery for Statistical District 65. In this situation the separation of catch rates into quartiles is not effective; a more detailed breakdown would be better. To avoid compromising objectivity, however, further partitioning of catch rates was not done.

There are 34 Statistical Districts where herring are landed (Figs 5 and 6). In the fall fishery, 10 Statistical Districts (SD) account for 99% of the landings; (Fig. 6) only these were used in the multiplicative model. The analysis was significant (Table 8). In addition, examination of residuals indicated a reasonable fit of the model (Fig. 7). Annual variations inresiduals of four important statistical districts are compared to those resulting from the aggregated mean catch rate which has been used in previous years (Fig 8). It is clear that use of the multiplicative model gives considerable improvement in fit over the aggregated mean catch rate method.

It has been previously suggested that the dynamics of stocks in northern and southern 4T would be different. Separate multiplicative models were used to calculate catch rates for northwestern (S.D. 65, 66, 67, 73, 82 and 92) and southeastern (S.D. 11, 13, 78 and 87) Gulf of St. Lawrence. While both analyses were significant (with north $R^2 = 0.39$, $F = 39.5$; and south $R^2 = 0.53$, $F = 57$), the annual variation in catch rates had similar trends suggesting that the catch rates from both areas could be combined into one model. Nevertheless, it was clear that catch rates increased sharply in 1984 in the south, but they did not increase until a year later in the north (Fig 9).

Gillnet catch rates standardized (to 1978-87 mean)

	78	79	80	81	82	83	84	85	86	87
North	1.02	0.47	0.24	0.68	0.62	0.65	0.74	1.98	1.72	1.89
South	0.54	0.44	0.32	0.66	0.63	0.62	1.41	1.65	2.10	1.61

In the spring fishery, 95% of the catch is taken in 11 S.D.'s. An analysis which includes these areas is significant, (Table 9) and an examination of the residuals indicated reasonable model fit (Fig 10). Residuals of the model are shown in Fig. 11. Although there is considerable annual variation in the fit of the model, it is clearly an improvement over the aggregated mean catch rate.

The final abundance indices for both fisheries were obtained by dividing the multiplicative model catch rates by the number of nets used in the fishery (Table 10). These final values (standardized to the 1978-87 mean) are presented in Fig. 12 and compared to the old (revised) catch rates which have been used in previous years. In the spring fishery, the 1987 catch rate from the multiplicative model indicates a more rapid increase in abundance than the old (revised) catch rate. In the fall fishery, the multiplicative model indicates that the catch rates reached a peak in 1985 and were stable thereafter; by contrast, the old catch rates indicate a gradual increase, with a slight decline from 1986 to 1987.

Differences between the two catch rates can be explained as follows. It was shown in several important S.D.'s that there were large patterns in the residuals of the old catch rate around its mean: (Fig 8 and 11). Results of the multiplicative model, however, indicated that there were no area effects. Therefore the residuals in the old catch rate were due to the weighting of effort which is implicit when calculating an aggregated mean. This weighting would have given more emphasis to areas with high effort but low catches.

The high catch rates in the 1987 fall fishery were corroborated by the results of the survey of 18 index fishermen. This survey indicated that catch rates had not changed significantly between 1986 and 1987. The index fishermen noted that catch rates in 1987 were probably under estimates of the true catch rate. This observation was because of the widespread imposition of trip limits and because of the increased number of novice fishermen which interfered with the normal fishing patterns of experienced fishermen.

Area	No. Fishermen	tonnes/net/trip 1986 $\bar{X}$	1986 SD	1987 $\bar{X}$	1987 SD
Chaleur Bay	10	1.88	1.50	1.66	1.04
Pictou	4	1.26	1.00	0.92	0.59
Fishermen's Bank	4	0.91	0.42	0.94	0.53

The time of median catches could be a useful indicator of peak spawning activity and they are summarized for several important Statistical Districts from 1978-1987 in Fig. 13. In the spring fishery most catches occur between days 130 and 140. Fish tend to arrive in S.D. 92 and 73 before the other areas. There is also some evidence that the same stock spawns in both districts because landings in S.D. 73 are reduced when the season in S.D. starts earlier.

In the fall fishery the spread in timing of median catches tends to be less than the spring fishery. In the years 1981, 1982, 1983, and 1986, the spread in dates of median catches was less than 10 days. This spread was greatest in 1979 and 1980 which were also the egg depositions which produced two of the largest year-classes in the past 20 years.

2.3 Research Survey Data

The November acoustic survey for 4T herring has been conducted using a single beam system since 1984. Results from the 1987 survey are summarized by Cairns et al. (1988). Summed backscatter coefficients (m^2 sr^{-1}) for the past four surveys are:

	1984	1985	1986	1987
Chaleur Bay	28,908	19,053	61,320	197,100
Sydney Bight	33,069	38,106	33,288	124,830

Because of uncertainty regarding interpretation of echo strengths, the value of this series lies principally in its indication of relative, rather than absolute, abundance.

Acoustic estimates in both Chaleur and Sydney Bight rose three to four-fold between 1986 and 1987. About 75% of the herring encountered in Chaleur Bay in 1987 were concentrated in a large aggregation in the West Miscou stratum, which has shown low herring abundance in previous surveys. Because of light sampling intensity in the West Miscou stratum, and because the large aggregation was found near the stratum boundary, it is possible that large quantities of herring could have been missed on the south side of Chaleur Bay in 1987 and in previous years.

The increase in Sydney Bight estimates in fall 1987 coincided with a major decrease in acoustic estimates for Chedabucto Bay in January 1988, leading to the suggestion that some herring which normally winter in Chedabucto Bay migrated to Sydney Bight instead.

3. ESTIMATION OF STOCK SIZE

3.1 Fall Spawners

i) Age-by-age calibration

The last year F was calculated two ways. First, using last year's technique, the gillnet catch rate was broken down across ages by using the gillnet sampling data. Fully recruited F's were chosen on the basis of regressions between spawning group gillnet catch numbers-at-age per unit effort and estimated beginning of year SPA spawning group population numbers at age. As with last year, the tuning regressions were forced through the origin. The selection criteria were based upon maximizing the correlation coefficient and minimizing the sum of squared standardized residuals of the last four years (1984, 1985, 1986, and 1987). This was repeated individually for each age group starting at the oldest age group (Age 9). The oldest age F was also fixed to this value. Subsequently the calibration proceeded age by age towards the youngest ages. A range of oldest age Fs were used to initiate the analysis. The F which gave the best relationships for all ages was selected. Fishing mortality rates at age 10 for all years were calculated iteratively as in previous years. The age 11+ and fishing mortality was set equal to that at age 10. Natural mortality was assumed to be 0.2.

ii) Adaptive Framework Method (AFM):

The second method used was the AFM which uses a non-linear least squares technique called ADAPT written in apl by S. Gavaris, Biological Station, St. Andrews, NB. Fourteen parameters were estimated including population numbers for ages 4 to 10 in 1987 and the slopes of regressions between gillnet catch rate and SPA numbers for these seven ages. Natural logorithms were used to stabilize the variance. A previous formulation indicated that the intercepts were not significant. Oldest age (age 10) F's were calculated iteratively as the mean F for ages 6 to 8. The AFM was run using the new and old (revised) catch rates. It was initiated using the final F's from the age structured analysis.

iii) Partial recruitment:

The results of the above caliabrations indicate that partial recruitments were probably incorrectly estimated in previous assessments. First, there was no change over the past three years in the distribution of mesh sizes used in the fall fishery (Fig. 14), and therefore, it could be assumed that the partial recruitment vector had also not changed. Partial recruitment in the 1987 gillnet fishery was calculated by comparing age structure of fall spawners taken in the gillnet fishery of areas 437-439

(Table 11). The resulting PR indicates that fish were not fully recruited until age 8 (Fig. 15). It should be noted that it was not possible to weight the acoustic samples by abundance, because only one good sample was taken from the large Miscou school. This sample alone indicates that the PR would be 1.0 at age 6.

A second estimate of partial recruitment was from an age-by-age calibration of SPA numbers against the abundance index. This method also indicated that herring were not fully recruited until age 8 and gave results similar to the acoustic survey. A third estimate was from the AFM which indicated that herring were fully recruited at age 9, but not at the two older ages. A comparison of the three methods is summarized in Table 12. Finally, a two-way analysis of variance of the historical gillnet partial F's indicated that full recruitment did not occur until age 8 (Table 13).

3.2 Spring Spawners

i) Age-by-age calibration:

The same method described for fall spawners was used.

ii) Adaptive Framework Method

For spring spawners, several different formulations of AFM were tried. First, models of gillnet catch rate against total exploitable numbers, with and without intercepts, and with dome-shaped and flat-topped PR's, were attempted but rejected because of high correlation between the parameters. Second, a ten parameter model (population numbers for ages 3 to 7 and slopes of regressions between catch rate and SPA numbers at age) was tried. Age 8 and older were dropped from the model because of small catches in this part of the matrix. Natural logorithms were used to stabilize the variance.

iii) Partial recruitment:

The 1987 mesh size distribution was similar to that in the 1985 fishery, but slightly different from the 1986 fishery (Fig. 14). Because only few samples were collected during the 1986 acoustic survey, it was not possible to use this information to estimate partial recruitment. If it is assumed that the age structure of spring spawners sampled in the fall acoustic survey was from the same population exploited in the spring fishery then partial recruitments can also be calculated. This method indicates that recruitment is flat-topped for ages 6 and older. Secondly, the AFM indicated that the PR increased to age 7, but it was not possible to calculate the F's at older ages (Table 12).

A two-way analysis of variance on the historical gillnet partial Fs indicated that the PR was dome-shaped and similar to the recruitment vector used in 1987 (Table 14). In the fall fishery in areas 437-439, the experimental 2¼" gillnets (the predominate mesh size used in the spring fishery), captured a larger fraction of age 3 and 4 and proportionally fewer fish at older ages than the regular 2 5/8" mesh (Fig. 16). This experiment would also suggest a dome-shaped PR for the spring fishery.

4. ASSESSMENT RESULTS

4.1 Fall Spawners

i) Age-by-age calibration:

The results of the age-by-age calibration indicated a fully recruited fishing mortality in 1987 of 0.27 (see text table below). The calibration plots of predicted and observed values over time indicate a good fit to the model (Fig. 17).

AGE	F	R^2	SS RESIDUALS
5	0.15	0.791	0.291
	0.17	0.796	0.284
	0.19	0.794	0.299
6	0.22	0.921	0.110
	0.24	0.935	0.080
	0.26	0.946	0.090
7	0.22	0.997	0.022
	0.24	0.998	0.012
	0.26	0.995	0.016
8	0.25	0.926	0.070
	0.27	0.931	0.070

ii) Adaptive Framework Method

Results of the analysis indicated that autocorrelation among the parameters was low (Table 15). The coefficients of variation of the estimates ranged from 30% to 40% except for population numbers at age 4 where it was 54%; this latter estimate was not significantly different from zero. The fit of the model was good (Fig. 18) and there were no patterns in the residuals.

A comparison of AFM and the standard age-by-age analysis is given below. In general, the two methods give very similar results. The big advantage of the AFM is that confidence limits can be calculated for each value, for this reason the AFM results were used as the basis of yield projections.

	1987 POPULATION NUMBERS		FISHING MORTALITY	
AGE	Age-by-age	AFM	Age-by-age	AFM
4	354,421	261,826	0.120	0.166
5	232,640	257,998	0.170	0.152
6	141,078	183,854	0.240	0.179
7	219,899	213,595	0.240	0.248
8	90,589	85,121	0.270	0.290
9	50,524	44,945	0.270	0.309
10	20,782	24,137	0.270	0.228

The population numbers and fishing mortality matrices estimated from the AFM are summarized in Table 16. The table indicates that the 1980 year-class is particularly large but the 1979, 1981 and 1982 year-classes are also well above average. The average F for ages 6 to 8 was 0.24.

The current assessment is predicting much larger 1979, 1980, 1981, 1982 and 1983 year-classes than the previous assessment. The previous assessment estimated that the average F for ages 6 to 8 was 0.36; the current assessment estimates that the average F in 1986 was 0.17, less than half the previous value. This new assessment results in a doubling of the mature biomass for the past four years (Fig. 19) and a radically different view of the year-classes currently in the fishery, as seen below:

	Year								
Recruitment ($\times 10^6$) at age 2	78	79	80	81	82	83	84	85	86
Last year	76	265	244	314	383	204	318	159	159
This year	97	350	341	458	767	493	534	397	379*

* Geometric mean 1978-85

Two factors could account for this dramatic change in perception of the resource the new catch rate, and the use of the AFM method for calibration. Summarized below are comparisons of the average unweighted F's on ages 6 to 8 for both methods and catch rates for the 1986 and 1987 assessments.

Method	1986 Assessment catch rate		1987 Assessment catch rate	
	Old	New	Old	New
Old (age-by-age)	0.36	---	---	0.25
New (AFM)	0.25(0.24)*	0.21(0.17)*	0.38	0.24

* 1986 results based on 1987 analysis.

Although the comparisons are not complete, they indicate that the new catch rate accounts for most of the change in the view of the resource. There also appears to be an interaction in effect between the catch rate and method. When the new catch rate is used, the two methods provide the same result. When the old catch rate is used, the results are quite different. Also with the new method the old catch rate provides more consistent results between the 1986 and 1987 analyses.

There are two differences between the old and new catch rates: year span and pattern in the recent period. Without doing a run with 1978-87 old catch rate series, it is impossible to tell how much effect the recent trends have had on the analysis. It is evident however that addition of the 1987 point to the old catch rate series generates a more pessimistic view of the resource than addition of the 1987 point to the new catch rate series.

It is clear that the new catch rate series indicated catch rates in 1985 had been underestimated and also a greater increase between the low period in the early 1980's and the high period (1985-87) than the old catch rate series (Fig. 12). Year span appears to be influential on how the models interpret recent stock size. The longer catch rate series generally creates a more pessimistic view of the resource. In addition, the new method provides substantially lower F's with this series. Without conducting a rigorous analysis, it appears that the 1974-77 data are influential on the calibration algorithm of both methods. The new method uses log transforms to stabilize the variance; transformations were not used in the old method. The use of transformations could explain why the longer, and presumably more variable catch rate series is being interpreted differently by the two methods.

It also appears that the partial recruitment vectors used in the past four assessments were inappropriate. They had suggested that herring were fully recruited at age 5, when in fact it appears that herring were not fully recruited until ages 7 or 8. The previous partial recruitment vector was calculated from a gillnet selectivity study done in the 1984 fall fishery. This study assumed that selectivity curves were normally distributed around modes. Results of this year's assessment and of gillnet experiments in 1987 indicate that selectivity curves are not normally distributed but heavily skewed.

4.2 Spring spawners

i) Age-by-age calibration:

The results of the age-by-age calibration were not conclusive. Maximization of correlation coefficients indicated F's below 0.002.

ii) Adaptive Framework Method

Attempts to calibrate with AFM were also not definitive. The best calibration was found with the ten parameter model. It indicated that a fully recruited F in 1987 of 0.27 and an F in 1986 of 0.34 which compared to last year's F of 0.40. The results are summarized below:

	Year								
	78	79	80	81	82	83	84	85	86
Last year Age 2 nos. ($x10^6$)	52	116	109	240	176	149	97	118	118
Biomass age 4-10	44	25	14	10	12	34	42	56	55
This year Age 2 nos. ($x10^6$)	55	118	97	258	281	332	647	245	186
Biomass age 4-10	42	25	13	10	11	32	53	90	155

The analysis indicates a large increase in the size of the 1981, 1982 and 1983 year-classes. These age groups, however, are not well estimated by the method, and thus, the analysis should be viewed with caution. For example, the population estimates were not significantly different from zero and had coefficients of variation which ranged from 75% at age 7 to 130% at age 3.

The poor calibration of spring spawners resulted from the relatively greater contrast in the catch rate series (which has varied by five fold since 1978) compared to gillnet catches which have varied by less than two fold for the same period.

5. PROGNOSIS

A projection was done for fall spawners only. The 1987 numbers at ages 2 and 3 were set by the age 2 geometric mean population numbers for the period 1978 to 1985. Above average recruitment is suggested from the high incidental captures of age 2 herring in the Gulf groundfish surveys (Table 17). The catch in 1988 was assumed to be 60,000 t of fall spawners. Mean weights in the period 1988 to 1991 were assumed to be as estimated for the

1987 fishery. The average partial recruitments for 1985-87 were used in the projection.

The following input parameters were used to run the projection:

Age	Fall Spawners Nos. ($\times 10^3$)	Catch ($\times 10^3$)	Wt. (kg)	PR
2	379,000	60	0.158	0.007
3	294,983	7,838	0.233	0.117
4	261,826	36,397	0.248	0.619
5	257,998	33,057	0.282	0.642
6	183,854	27,392	0.312	0.765
7	213,595	42,696	0.341	0.891
8	85,121	19,515	0.366	1.00
9	44,945	10,884	0.373	1.00
10	24,137	4,477	0.395	1.00*
11	10,184	1,889	0.404	1.00*

* Assumed to equal to age 9 PR.

The results are summarized below:

SUMMARY OF PROJECTIONS

Year	1987	1988	1989	1990	1991
Population Biomass (t)	389031	362394	338423	322422	311350
Catch (t)	57060	59646	53653	49116	45715
F or Quota	57060	.30	.30	.30	.30

Compared to the 1987 projections, 1988 catches at $F_{0.1}$ have increased by more than two fold.

It was not possible to do a projection for the spring spawners. A projection was made using information from the assessment of fall spawners. In the historical time period, trends in biomass have been similar in both stock components. If it is assumed that current fishing mortalities on the spring spawner are similar to those of fall spawners, then during 1978-86 2+ spring spawner population biomass as estimated by AFM would average about 34% of the total.

The 1987 acoustic survey indicated a similar proportion. Of the combined acoustic backscatter in Chaleur Bay and Sydney Bight (north of the Pt. Aconi line). 30% was spring spawners.
Based on an estimated proportion of 30% and assuming that population structure and exploitation rate are similar for both spawning groups, a projected $F_{0.1}$ catch 1989 to 1991 would be:

	Year		
	1989	1990	1991
Catch (t)	21,000	20,000	19,000

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Table 1. Catches (t) of herring by gear and by season in NAFO Division 4T 1971-1987. Spring fishery occurs from January to June; the fall fishery from July to December.

	GILLNETS (and other inshore)		SEINES (and other offshore)		
YEAR	SPRING	FALL	SPRING	FALL	TOTAL
1971	14074	10327	13316	97129	134846
1972	8137	9585	948	34910	53580
1973	11713	7920	7185	13539	40357
1974	8285	4199	8681	13988	35153
1975	7119	4741	18566	14139	44565
1976	6611	3419	17217	12206	39453
1977	4926	3285	19887	16726	44824
1978	8484	4853	8048	31756	53141
1979	7444	5780	13899	20620	47743
1980	6443	6784	13330	13886	40443
1981	6545	10926	20	3663	21154
1982	6742	14130	0	3109	23981
1983	8545	13858	0	3470	25873
1984	5269	15902	0	2809	23980
1985	7098	23654	0	3685	34437
1986	7828	39956	0	11247	59031
1987	11114	51931	0	13500	76545

Table 2. Landings and spawning affinity of herring in 4T, 1978-1987, by year, stock area, season gear. Landing tonnage (t), percent of spring spawners among sampled fish (%), and the number of fish used in spawning affinity determinations (N) are shown for each year. The spring season is January to June; the fall season is July to December. Fixed gear landings are primarily gillnet, but also include landings from traps and miscellaneous gears. Mobile gear is primarily purse seine, but also includes Danish seines and otter trawls.

Year		Areas 431-435				Area 436				Areas 437-439			
		Spring		Fall		Spring		Fall		Spring		Fall	
		Fixed	Mobile	Fixed	Mobile	Fixed	Mobile	Fixed	Mobile	Fixed	Mobile	Fixed	Mobile
1978	t	2317	5762	560	3619	3796	0	322	1106	2352	2256	4568	19218
	%	96	8	0	10	85	—	2	28	72	—	2	53
	N	3076	1514	*	370	527	—	*	371	134	*	1041	1428
1979	t	836	13777	1234	39	3532	118	572	672	3034	4	3929	19585
	%	90	22	0	0	86	—	2	17	89	—	12	51
	N	4171	1323	727	96	485	*	188	344	*	*	287	2269
1980	t	2353	13332	1618	8254	1730	10	1059	82	3354	0	4574	5232
	%	96	24	0	5	100	—	2	11	100	—	12	72
	N	4275	1196	*	*	941	*	194	96	190	*	390	1709
1981	t	2010	21	2224	167	1974	0	1618	1	2540	0	7087	3020
	%	100	100	0	5	100	—	0	—	85	—	0	16
	N	2827	86	106	*	302	—	489	*	919	—	1968	537
1982	t	1417	0	3526	0	2604	0	1021	0	1418	62	7820	2579
	%	98	—	0	—	100	—	0	—	99	—	2	53
	N	3075	—	299	—	371	—	*	—	6234	*	1134	*
1983	t	1584	0	4726	0	4771	0	1440	0	2088	0	7552	3470
	%	92	—	0	—	93	—	4	—	96	—	1	51
	N	*	—	1102	—	681	—	188	—	113	—	1133	1031
1984	t	536	0	7295	0	3670	0	1222	0	1063	0	7385	2809
	%	72	—	0	—	91	—	1	—	85	—	4	62
	N	127	—	447	—	*	—	404	—	139	—	878	867
1985	t	1893	0	8483	0	3489	0	1297	0	1716	0	13874	3685
	%	100	—	0	—	99	—	0	—	89	—	10	68
	N	115	—	*	—	236	—	*	—	*	—	*	277
1986	t	2855	0	12253	0	3297	0	1267	0	1676	0	26163	11247
	%	84	—	1	—	83	—	0	—	88	—	17	49
	N	163	—	683	—	204	—	*	—	272	—	595	668
1987	t	3321	0	18161	0	3798	0	1953	0	3995	0	31817	13500
	%	88	—	0	—	100	—	0	—	93	—	6	53
	N	260	—	1625	—	222	—	124	—	315	—	1286	518

* Sample size is inadequate to indicate percent of spring spawners. Percent of spring spawners is estimated from samples taken in other years from the same area.

Table 3. Catch at age matrices for spring spawning 4T herring, in 1000's of fish.

CATCH OF SPRING SPAWNERS ALL GEARS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	5260	1521	15931	3351	14434	21741	21382	6141	924	424	207	125	315	150
3	8736	27837	8498	58673	14121	13689	42580	17775	33383	10821	3476	8473	5021	1643
4	3285	18829	27893	6874	65301	5856	5689	8250	6201	31206	11033	11330	17265	6777
5	1647	3260	6746	10264	4692	33954	3096	1304	1476	3934	13838	11707	20651	25483
6	21560	16243	2237	3563	6956	2130	15768	868	337	1104	1509	5368	16048	16091
7	3699	20158	465	604	1277	3072	3269	4444	217	70	116	2036	5797	14764
8	4128	2683	8805	498	1182	707	2033	755	339	50	11	364	1667	6291
9	6245	3395	1034	6513	191	203	740	756	114	17	11	249	538	799
10	947	5457	1488	510	3584	718	320	108	2	2	22	1	117	588
11	2529	6157	19853	13472	1992	3488	2910	1198	110	10	34	1	461	155

CATCH OF SPRING SPAWNERS IN GILLNETS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	108	8	1	86	38	55	541	45	68	1	13	2	8	0
3	4911	14874	2338	13965	6459	7667	22219	13031	32597	5160	1877	6602	3882	542
4	1974	3710	18058	3301	27332	3056	3567	7527	6047	29194	7932	9341	12248	5140
5	1191	1377	2307	3691	1386	20895	1406	1270	1475	3646	11970	9663	14241	19778
6	14032	1793	535	540	1902	556	9528	785	326	1019	1195	4543	9205	10281
7	2600	6672	97	42	315	1404	216	3197	177	36	52	1655	1961	9436
8	2272	1925	2946	59	262	110	1074	79	332	1	0	257	284	3487
9	2532	1628	419	1084	96	63	104	285	113	1	0	197	8	662
10	338	2640	292	1	1361	362	140	38	1	1	0	0	63	468
11	469	1660	2894	1497	1164	1672	2134	1009	109	1	0	0	425	104

CATCH OF SPRING SPAWNERS IN PURSE SEINES

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	5152	1513	15930	3265	14396	21686	20841	6096	856	423	194	123	307	150
3	3825	12963	6160	44708	7662	6022	20361	4744	786	5661	1599	1871	1139	1101
4	1311	15119	9835	3573	37969	2800	2122	723	154	2012	3101	1989	5017	1637
5	456	1883	4439	6573	3306	13059	1690	34	1	288	1868	2044	6410	5705
6	7528	14450	1702	3023	5054	1574	6240	83	11	85	314	825	6843	5810
7	1099	13486	368	562	962	1668	3053	1247	40	34	64	381	3836	5328
8	1856	758	5859	439	920	597	959	676	7	49	11	107	1383	2804
9	3713	1767	615	5429	95	140	636	471	1	16	11	52	530	137
10	609	2817	1196	509	2223	356	180	70	1	1	22	1	54	120
11	2060	4497	16959	11975	828	1816	776	189	1	9	34	1	36	51

Table 4. Catch at age matrices for fall spawning 4T herring, in 1000's of fish.

CATCH OF FALL SPAWNERS IN ALL GEARS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	5403	96	93	205	1514	2906	1369	109	184	35	9	30	331	60
3	5715	2090	277	3037	19348	6217	32429	10075	9273	4782	1135	3736	4372	7838
4	17524	4169	1758	7676	27378	35031	9995	33204	21526	23879	27519	17694	35927	36397
5	6097	25621	5034	3604	14092	27629	23278	5971	26147	10971	16248	24072	26265	33057
6	4235	6860	28944	3622	3973	11109	8343	2606	5663	13643	12972	12625	35034	27392
7	10666	3262	4154	22200	3465	2323	4130	978	2344	2409	6718	5798	20078	42696
8	2827	4854	1849	2219	13853	3128	637	977	1004	1867	1386	2144	10143	19515
9	5444	2159	3510	1412	1606	5242	848	216	641	623	480	431	3308	10884
10	4295	3568	737	2761	890	702	320	108	132	114	154	203	535	4477
11	19110	20635	16451	16704	16259	10386	2966	872	162	309	174	1	667	1889

CATCH OF FALL SPAWNERS IN GILLNETS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	1	1	1	1	5	1	25	1	1	1	0	0	258	6
3	125	1	39	122	351	128	7254	6851	3542	792	931	2755	3605	6890
4	4258	1602	276	1879	4389	7809	3293	28863	18645	21648	26518	16301	34220	34758
5	1765	8163	1455	340	3104	3821	4027	5537	23280	10465	14918	21838	23241	30368
6	515	1227	5839	253	593	1883	929	2471	5308	12544	12214	11787	30308	21905
7	1876	742	465	3215	614	402	836	974	2250	2223	6236	5473	17661	36853
8	180	616	243	133	3440	484	185	830	960	1782	1308	1993	9361	15868
9	2070	403	419	81	83	694	210	104	491	589	446	332	2961	9975
10	730	315	50	468	178	11	139	53	131	81	154	197	518	4337
11	4813	1800	2143	1162	1785	1418	620	866	61	260	171	0	614	1882

CATCH OF FALL SPAWNERS IN PURSE SEINES

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	5402	95	92	204	1509	2905	1344	108	183	34	9	30	73	54
3	5590	2089	238	2915	18997	6089	25175	3224	5731	3990	204	981	767	948
4	13266	2567	1482	5797	22989	27222	6702	4341	2881	2231	1001	1393	1707	1639
5	4332	17458	3579	3264	10988	23808	19251	434	2867	506	1330	2234	3024	2689
6	3720	5633	23105	3369	3380	9226	7414	135	355	1099	758	838	4726	5487
7	8790	2520	3689	18985	2851	1921	3294	4	94	186	482	325	2417	5843
8	2647	4238	1606	2086	10413	2644	452	147	44	85	78	151	782	3647
9	3374	1756	3091	1331	1523	4548	638	112	150	34	34	99	347	909
10	3565	3253	687	2293	712	691	181	55	1	33	0	6	17	140
11	14297	18835	14308	15542	14474	8968	2346	6	101	49	3	1	53	7

Table 5. Weight at age matrices for spring and fall spawning herring in 4T.

MEAN WEIGHTS (KG) OF SPRING SPAWNERS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.095	.090	.104	.133	.133	.133	.133	.124	.117	.146	.144	.103	.101	.181
3	.160	.154	.177	.172	.172	.172	.172	.173	.170	.178	.168	.160	.159	.214
4	.202	.185	.210	.213	.213	.213	.213	.232	.202	.214	.202	.210	.213	.210
5	.238	.229	.247	.247	.247	.247	.247	.277	.247	.242	.220	.244	.251	.235
6	.275	.266	.275	.287	.287	.287	.287	.318	.295	.252	.281	.288	.284	.276
7	.291	.298	.271	.291	.291	.291	.291	.346	.285	.310	.224	.359	.325	.301
8	.319	.304	.304	.310	.310	.310	.310	.366	.299	.254	.320	.409	.309	.314
9	.320	.316	.310	.348	.348	.348	.348	.376	.305	.398	.312	.428	.331	.323
10	.328	.329	.333	.324	.324	.324	.324	.369	.312	.375	.241	.324	.279	.332
11	.348	.357	.353	.359	.359	.359	.359	.413	.420	.385	.216	.359	.299	.402

MEAN WEIGHTS (KG) OF FALL SPAWNERS

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.047	.040	.035	.119	.119	.119	.119	.076	.094	.143	.137	.119	.167	.158
3	.126	.115	.111	.177	.177	.177	.177	.143	.151	.174	.214	.249	.221	.233
4	.190	.169	.184	.245	.245	.245	.245	.242	.155	.249	.244	.279	.242	.249
5	.235	.215	.217	.283	.283	.283	.283	.273	.189	.285	.290	.312	.294	.282
6	.255	.248	.253	.313	.313	.313	.313	.317	.237	.317	.306	.355	.331	.312
7	.283	.272	.276	.338	.338	.338	.338	.326	.324	.343	.344	.384	.374	.341
8	.314	.288	.283	.359	.359	.359	.359	.348	.237	.362	.367	.404	.386	.366
9	.327	.314	.300	.380	.380	.380	.380	.394	.285	.365	.380	.405	.404	.373
10	.331	.325	.323	.364	.364	.364	.364	.328	.380	.348	.416	.423	.436	.395
11	.354	.362	.349	.395	.395	.395	.395	.427	.389	.398	.361	.395	.424	.404

Table 6. Percentage catch-at-age of fall spawning 4T herring caught in gillnets in areas 431-435 (southeastern Gulf) and areas 436-439 (northwestern Gulf).

AGE	Catch at age							
	Areas 431-435				Areas 436-439			
	1984	1985	1986	1987	1984	1985	1986	1987
2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
3	0.7	3.8	3.9	2.2	1.8	1.5	3.2	5.5
4	53.6	25.3	46.8	21.6	32.5	9.9	16.9	21.2
5	20.1	43.6	14.6	23.2	28.9	49.8	22.4	14.9
6	13.5	17.2	23.6	10.5	19.8	30.9	24.6	15.3
7	8.3	6.7	6.4	23.1	13.1	7.2	18.8	22.4
8	2.1	2.1	3.2	9.3	3.1	0.2	10.0	10.0
9	1.1	1.1	0.6	6.1	0.5	0.0	3.3	6.1
10	0.4	0.3	0.2	2.5	0.3	0.6	0.5	2.8
11	0.1	0.0	0.3	1.6	0.2	0.0	0.5	0.9

Table 7. Catch (t) per successful trip, number of nets fished per trip and CPUE index for spring and fall inshore gillnet fisheries of NAFO Division 4T.

YEAR	Spring Fishery			Fall Fishery		
	Catch (t) per successful trip[1]	Number of nets fished per trip[2]	CPUE index tons per net per trip	Catch (t) per successful trip[1]	Number of nets fished per trip[3]	CPUE index tons per net per trip
1974	1.23	20.6	0.060	2.99	7.6	0.39
1975	1.29	30.1	0.043	3.63	7.2	0.50
1976	1.34	29.9	0.045	3.13	8.9	0.35
1977	1.89	27.9	0.068	3.56	9.3	0.38
1978	2.22	29.4	0.076	3.21	11.4	0.28
1979	1.49	34.4	0.043	1.78	11.9	0.15
1980	1.09	20.2	0.054	1.45	10.4	0.14
1981	0.92	18.6	0.050	2.15	9.6	0.22
1982	1.73	20.4	0.085	2.33	9.0	0.26
1983	1.79	22.5	0.080	3.45	7.3	0.47
1984	1.90	26.5	0.072	3.02	5.3	0.57
1985	1.81	27.2	0.067	4.59	5.2	0.88
1986	2.47	27.1	0.091	5.91	5.2	1.14
1987	2.91	21.8	0.133	5.13	4.8	1.05

1 - For combined Statistical Districts 11, 65, 66, 67, 73, 75, 78, 80, 82, and 92.

2 - For combined Statistical Districts 63, 64, 65, 66, 67, 68, 70, 73, 75, 76, 77, 78, 80, 82, 83, and 92.

3 - For combined Statistical Districts 63, 64, 65, 66, 67, 68

Table 8. Results of analysis of catch rates in fall gillnet fishery using the multiplicative model. The three categories are: statistical district (1), quartile on cumulative catch curve (2), and year (3).

Regression of Multiplicative Model

Multiple R.............. .638
Multiple R Squared...... .407

ANALYSIS OF VARIANCE

Source of Variation	DF	Sums of Squares	Mean Squares	F-Value
Intercept	1	1.055E0005	1.055E0005	———
Regression	19	1.326E0003	6.976E0001	57.957
Type 1	9	5.130E0002	5.700E0001	47.352
Type 2	1	1.895E0002	1.895E0002	157.388
Type 3	9	4.969E0002	5.522E0001	45.871
Residuals	1603	1.930E0003	1.204E0000	———
TOTAL	1623	1.088E0005	———	———

REGRESSION COEFFICIENTS

Category	Code	Variable	Coefficient	Std. Error	No. Obs.
1	65	Intercept	7.916	0.111	1623
2	1	———	———	———	———
3	86	———	———	———	———
1	11	1	0.316	0.087	343
	13	2	0.376	0.132	91
	66	3	1.454	0.091	260
	67	4	1.034	0.105	167
	73	5	1.686	0.177	47
	78	6	-0.482	0.516	5
	82	7	0.635	0.284	16
	87	8	1.263	0.095	227
	92	9	0.814	0.121	110
2	2	10	0.728	0.058	566
3	78	11	-0.831	0.176	62
	79	12	-1.421	0.143	113
	80	13	-1.903	0.137	138
	81	14	-1.023	0.119	251
	82	15	-1.115	0.122	204
	83	16	-1.095	0.121	213
	84	17	-0.696	0.126	177
	85	18	-0.007	0.131	149
	87	19	-0.066	0.125	179

Table 9. Results of analysis of catch rates in spring gillnet fishery using the multiplicative model. The three categories are: statistical district (1), quartile on cumulative catch curve (2), and year (3).

Regression of Multiplicative Model

Multiple R.............. .588
Multiple R Squared...... .346

ANALYSIS OF VARIANCE

Source of Variation	DF	Sums of Squares	Mean Squares	F-Value
Intercept	1	6.705E0004	6.705E0004	———
Regression	20	4.969E0002	2.485E0001	31.548
Type 1	10	1.708E0002	1.708E0001	21.692
Type 2	1	7.976E0001	7.976E0001	101.274
Type 3	9	2.189E0002	2.432E0001	30.884
Residuals	1195	9.411E0002	7.875E-001	———
TOTAL	1216	6.849E0004	———	———

REGRESSION COEFFICIENTS

Category	Code	Variable	Coefficient	Std. Error	No. Obs.
1	65	Intercept	6.882	0.117	1216
2	1	———	———	———	———
3	78	———	———	———	———
1	11	1	-1.217	0.349	7
	13	2	-0.591	0.193	26
	66	3	-0.030	0.161	41
	67	4	1.178	0.244	15
	73	5	0.726	0.095	235
	75	6	0.262	0.133	68
	78	7	0.230	0.101	175
	80	8	0.302	0.095	222
	82	9	-0.385	0.102	173
	92	10	0.180	0.115	100
	2	11	0.543	0.054	459
	79	12	-0.211	0.128	96
	80	13	-0.519	0.126	104
	81	14	-0.512	0.121	122
	82	15	0.042	0.120	129
	83	16	0.096	0.113	202
	84	17	0.158	0.139	80
	85	18	0.456	0.120	131
	87	20	0.912	0.122	135

Table 10. Final catch rates based on the multiplicative model.

YEAR	Spring Fishery			Fall Fishery		
	kg/trip	Nets	t/net/trip	kg/trip	Nets	t/net/trip
1978	1435	29.4	.05	2151	11.4	.19
1979	1162	34.4	.03	1199	11.9	.10
1980	854	20.2	.04	741	10.4	.07
1981	861	18.6	.05	1792	9.6	.19
1982	1499	20.4	.07	1633	9.0	.18
1983	1584	22.5	.07	1666	7.3	.23
1984	1677	26.5	.06	2483	5.3	.47
1985	2269	27.2	.08	4939	5.2	.95
1986	3013	27.1	.11	4972	5.2	.96
1987	3580	21.8	.16	4658	4.8	.97

Table 11. Comparison of age composition of fall spawning herring taken by 2 5/8" gillnets, mid-water tows during acoustic surveys, and by purse seiners in areas 437-439 during fall 1987.

AGE	gillnet percent at age	cruise percent at age	gillnet percent: cruise percent	partial recruitment based on cruise	seine percent at age	gillnet percent: seine percent	partial recruitment based on seine
1	0	0.3	0	0.00	0	——	0.00
2	0	10.5	0	0.00	0.3	0	0.00
3	5.6	40.5	0.14	0.05	4.4	1.25	0.44
4	21.8	19.4	1.12	0.44	7.7	2.84*	1.00
5	15.6	8.3	1.87	0.73	12.6	1.24	0.44
6	15.4	7.4	2.09	0.82	25.7	0.60	0.21
7	22.4	8.9	2.51	0.98	27.4	0.82	0.29
8	9.9	3.9	2.55*	1.00	17.1	0.58	0.20
9	5.7	0.9	6.24	1.00	4.3	1.35	0.38
10	2.8	0.04	65.31	1.00	0.7	4.29	1.00
11	0.9	0	——	1.00	0.03	29.8	1.00

* Age considered to be fully recruited.

Table 12. Partial recruitment estimated for 1988 compared to valued used in 1987.

AGE	SPRING SPAWNER Last yr. Assess.	This year AFM	This year Acoustic	FALL SPAWNER Last yr. Assess.	This year Acoustic survey	This year Age-by-age	This year AFM
1	0	0	0	0	0	0.00	0
2	0.05	0.001	0	0.001	0	0.001	0.001
3	0.53	0.04	0.02	0.17	0.05	0.17	0.17
4	1.00	0.18	0.24	0.58	0.44	0.44	0.54
5	1.00	0.32	0.66	1.00	0.73	0.63	0.49
6	1.00	0.59	1.00	1.00	0.82	0.89	0.58
7	0.50	1.00	1.00	1.00	0.98	0.89	0.80
8	0.50	1.00	1.00	1.00	1.00	1.00	0.94
9	0.50	1.00	1.00	1.00	1.00	1.00	1.00
10	0.50	1.00	1.00	1.00	1.00	1.00	0.74
11	0.50	0.74	1.00	1.00	1.00	1.00	0.74

* Age considered to be fully recruited.

Table 13. A summary of a two-way analysis of variance on the historical gillnet partial F's for fall spawners. Estimation is done on a ln scale using the last year as the reference category.

GILLNET FISHING MORTALITY

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
3	.003	.001	.032	.026	.010	.001	.003	.008	.009	.047
4	.067	.094	.052	.184	.093	.080	.058	.070	.125	.115
5	.102	.142	.095	.124	.229	.070	.074	.062	.138	.156
6	.078	.142	.121	.100	.170	.190	.109	.077	.117	.192
7	.077	.117	.184	.327	.126	.100	.138	.066	.161	.207
8	.225	.143	.114	.476	.638	.140	.079	.060	.154	.220
9	.010	.152	.172	.108	.705	1.201	.047	.026	.120	.247
10	.009	.002	.076	.084	.204	.282	1.484	.026	.052	.262
11	.072	.153	.228	.982	.155	.868	2.075	.000	.108	.269

RESIDUALS (OBS - PRED) AROUND LN F MATRIX

AGE	78	79	80	81	82	83	84	85	86	87
2	.686	.101	-.048	-.957	-.943	-.700	-.627	.876	2.012	-.399
3	-.289	-1.047	1.275	.706	-.204	-1.916	-1.016	1.352	-.040	1.178
4	.467	.580	-.685	.208	-.453	-.366	-.592	1.107	.180	-.376
5	.653	.765	-.314	-.421	.217	-.740	-.586	.748	-.024	-.299
6	.277	.655	-.191	-.742	-.195	.153	-.303	.852	-.302	-.204
7	.170	.371	.140	.345	-.588	-.581	-.160	.598	-.074	-.221
8	.991	.316	-.587	.471	.787	-.500	-.963	.262	-.366	-.412
9	-1.771	.715	.158	-.680	1.220	1.984	-1.152	-.236	-.278	.041
10	-1.290	-3.097	-.106	-.377	.533	1.085	2.847	.325	-.567	.646
11	.106	.640	.357	1.449	-.374	1.581	2.552	-5.885	-.470	.045
Year effects	.252	.314	.620	.896	.876	.694	.628	.140	.670	1.000

Age effects:	2	3	4	5	6	7	8	9	10	11
Coefficients	.00	.014	.167	.211	.235	.258	.331	.238	.137	.257
Normalized	.001	.043	.503	.635	.710	.779	1.000	.717	.413	.776

Table 14. A summary of a two-way analysis of variance on the historical gillnet partial F's for spring spawners. Estimatation is done on a ln scale using the last year as the reference category.

SPRING GILLNET FISHING MORTALITY

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.001	.001	.007	.000	.000	.000	.000	.000	.000	.000
3	.241	.360	.491	.292	.193	.025	.008	.014	.022	.004
4	.257	.226	.383	.421	.228	.268	.051	.049	.032	.036
5	.104	.475	.196	.262	.137	.212	.172	.082	.100	.068
6	.146	.069	.651	.185	.099	.133	.101	.093	.111	.102
7	.067	.218	.056	.792	.058	.014	.009	.207	.056	.174
8	.050	.037	.361	.049	.203	.000	.000	.057	.058	.151
9	.011	.017	.059	.222	.117	.001	.000	.128	.002	.225
10	.111	.054	.051	.034	.001	.001	.000	.000	.057	.216
11	.248	.244	.591	.679	.134	.002	.000	.000	.408	.134

RESIDUALS (OBS - PRED) AROUND LN F MATRIX

AGE	78	79	80	81	82	83	84	85	86	87
2	.408	-.119	1.500	-1.413	-.327	.306	1.778	.041	-.675	-1.499
3	.650	.927	.486	.253	.700	.579	.697	-.342	-.916	-3.034
4	-.083	-.332	-.558	-.177	.072	2.136	1.778	.108	-1.311	-1.632
5	-1.131	.266	-1.373	-.796	-.582	1.754	2.850	.493	-.333	-1.148
6	-.651	-1.513	-.029	-1.003	-.766	1.432	2.465	.755	-.088	-.604
7	-.912	.144	-1.968	.966	-.779	-.272	.567	2.069	-.253	.440
8	-.103	-.533	.987	-.712	1.559	-2.494	-2.851	1.875	.879	1.391
9	-1.166	-.852	-.373	1.234	1.457	-1.465	-2.403	3.132	-1.805	2.240
10	1.784	.942	.128	.025	-2.201	-.379	-1.749	-3.373	1.963	2.854
11	1.204	1.068	1.199	1.623	.865	-1.598	-3.133	-4.757	2.538	.992
Year effects	1.494	1.688	3.582	2.690	1.137	.170	.046	.234	.647	1.00

Age effects:	2	3	4	5	6	7	8	9	10	11
Coefficients	.000	.084	.187	.216	.187	.112	.037	.024	.012	.050
Normalized	.002	.391	.866	1.000	.868	.519	.174	.111	.057	.231

Table 15. A summary of results of the final calibration using the non-linear least squares calibration (AFM). There are 14 parameters: parameters 1 to 7 are populations numbers for ages 4 to 10; parameters 8 to 14 are slopes of regressions between gillnet catch rate and SPA numbers for ages 4 to 10.

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

Orthogonality Offset........... 0.018243
Mean Square Residuals.......... 0.334671

	PAR. EST.	STD. ERR.	T-STATISTIC
1.	2.50356E0005	1.35996E0005	1.84091E0000
2.	2.34959E0005	9.90812E0004	2.37138E0000
3.	1.69250E0005	6.08572E0004	2.78111E0000
4.	1.98754E0005	6.38971E0004	3.11053E0000
5.	8.04626E0004	2.60783E0004	3.08543E0000
6.	4.39832E0004	1.38879E0004	3.16702E0000
7.	2.34443E0004	7.32407E0003	3.20100E0000
8.	5.31189E-003	1.18043E-003	4.49998E0000
9.	4.77348E-003	1.05270E-003	4.53449E0000
10.	5.29932E-003	1.17820E-003	4.49782E0000
11.	6.99848E-003	1.56082E-003	4.48385E0000
12.	5.67196E-003	1.26437E-003	4.48599E0000
13.	4.88584E-003	1.06906E-003	4.57021E0000
14.	6.83450E-003	1.50457E-003	4.54248E0000

CORRELATION MATRIX OF PARAMETERS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	.042	.060	.089	.121	.131	.129	-.086	.082	-.358	-.097	-.086	-.088	-.095
2	.042	1.000	.143	.132	.145	.169	.184	-.128	.301	-.117	-.131	-.132	-.328	-.130
3	.060	.143	1.000	.158	.172	.217	.252	-.315	.376	-.168	-.195	-.334	-.219	-.185
4	.089	.132	.158	1.000	.236	.284	.327	-.412	.260	-.250	-.394	-.443	-.278	-.376
5	.121	.145	.172	.236	1.000	.269	.304	-.393	.246	-.337	-.401	-.257	-.340	-.376
6	.131	.169	.217	.284	.269	1.000	.302	-.255	.328	-.336	-.405	-.330	-.359	-.366
7	.129	.184	.252	.327	.304	.302	1.000	-.348	.389	-.360	-.337	-.378	-.363	-.393
8	-.086	-.128	-.315	-.412	-.393	-.255	-.348	1.000	-.263	.241	.300	.307	.259	.293
9	.082	.301	.376	.260	.246	.328	.389	-.263	1.000	-.228	-.252	-.280	-.281	-.253
10	-.358	-.117	-.168	-.250	-.337	-.366	-.360	.241	-.228	1.000	.270	.240	.246	.267
11	-.097	-.131	-.195	-.394	-.401	-.405	-.337	.300	-.252	.270	1.000	.295	.278	.313
12	-.086	-.132	-.334	-.443	-.257	-.330	-.378	.307	-.280	.240	.295	1.000	.259	.290
13	-.088	-.328	-.219	-.278	-.340	-.359	-.363	.259	-.281	.246	.278	.259	1.000	.273
14	-.095	-.130	-.185	-.376	-.376	-.366	-.393	.293	-.253	.267	.313	.290	.273	1.000

Table 16. Estimated population numbers (000's), fishing mortality and mean population biomass (t) for fall spawners.

POPULATION NUMBERS

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	97001	350366	341498	458709	767287	492809	534389	396533	201117	220698
3	163790	78048	284226	278356	375460	628035	403446	437513	324626	164361
4	88251	116593	58275	203361	218783	299010	509864	329287	354825	261826
5	41448	47481	63761	38667	136454	159647	223202	392541	253587	257998
6	9968	21184	13875	31140	26255	88060	120781	168041	299604	183854
7	9791	4566	7292	3811	23138	16372	59753	87149	126157	213595
8	23166	4881	1636	2233	2235	16823	11224	42843	66106	85121
9	3153	6432	1166	763	945	921	12084	7936	33137	44945
10	2016	1128	523	187	430	193	191	9459	6107	24137
11	36832	16689	4847	1510	527	524	215	47	7614	10184

FISHING MORTALITY

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.017	.009	.004	.000	.000	.000	.000	.000	.002	.000
3	.140	.092	.135	.041	.028	.008	.003	.009	.015	.054
4	.420	.404	.210	.199	.115	.092	.062	.061	.119	.166
5	.471	1.030	.517	.187	.238	.079	.084	.070	.122	.152
6	.581	.866	1.092	.097	.272	.188	.126	.087	.138	.179
7	.496	.826	.983	.334	.119	.177	.133	.076	.193	.248
8	1.081	1.232	.562	.661	.686	.131	.147	.057	.186	.290
9	.828	2.309	1.630	.375	1.386	1.376	.045	.062	.117	.309
10	.657	1.122	1.088	.987	.411	1.021	1.997	.024	.101	.228
11	.657	1.122	1.088	.987	.411	1.021	1.997	.024	.101	.228

MEAN POPULATION BIOMASS

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	14073	37621	36753	31593	65362	63869	66354	42766	25405	9480
3	24620	16486	42753	35375	50704	98640	78134	98287	64554	28096
4	16142	21495	16829	40581	29088	64556	109470	80852	73530	54596
5	8683	7758	12928	13418	20884	39704	56352	107323	63755	61329
6	2396	4209	2463	8582	8281	23139	31534	51865	84133	47745
7	2711	1173	1563	983	6454	8605	17485	29239	39007	58707
8	5570	1239	587	616	363	5217	6920	15264	21171	24629
9	3123	1768	469	385	204	186	4100	5932	11473	13138
10	6891	2083	667	209	246	102	47	3610	5035	7756
11	9769	3658	1076	377	153	120	31	16	2787	3347
2+	93980	97489	116089	132119	181739	304139	370429	435154	390852	308824
3+	79907	59868	79335	100526	116377	240269	304075	392388	365447	299344
4+	55286	43382	36582	65151	65673	141629	225941	294101	300893	271248
5+	39145	21887	19754	24571	36585	77073	116470	213249	227362	216652

Table 17. Comparison of estimates of herring year class strength from Virtual Population Analysis (VPA) with estimates from groundfish surveys. VPA estimates are number of two year old fall spawners (in 1000's) for each year class in 4T. Groundfish estimates are for numbers of 1 year old and 2 year old herring in the Gulf of St. Lawrence south of the Laurentian Channel. These estimates are derived from data on the number of herring caught in groundfish tows, the cross-sectional area traversed by towed nets, and by the area of the southern Gulf. Herring between 170 and 210 mm were assumed to be 1 year old, and those between 230 and 260 mm were assumed to be 2 years old.

Year of hatching	Number of fish in year class at age 2 from VPA	Number of fish in year class at age 1 from groundfish surveys	Number of fish in year class at age 2 from groundfish surveys
1976	97001	9766039	25215083
1977	350366	47108453	521461
1978	341498	34282281	2475882
1979	458709	608097	514134
1980	767287	341930	648330
1981	492809	15407641	2903743
1982	534389	782875	64693681
1983	396533	4956114	30149852
1984	201117	11236471	83698961
1985	220698	8503119	56950997
r*	———	-0.28	-0.40

* Correlation between VPA and groundfish survey population estimates.

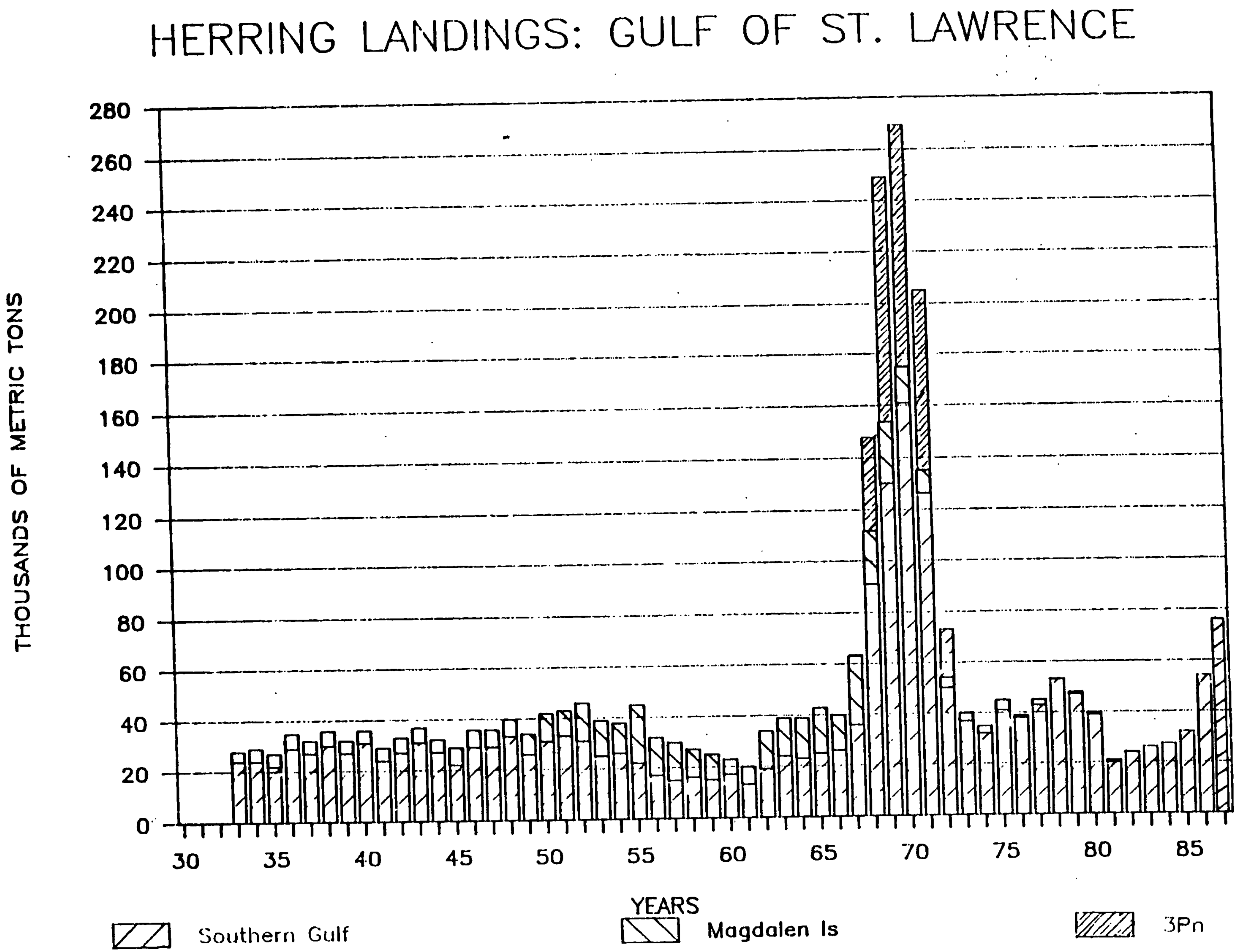
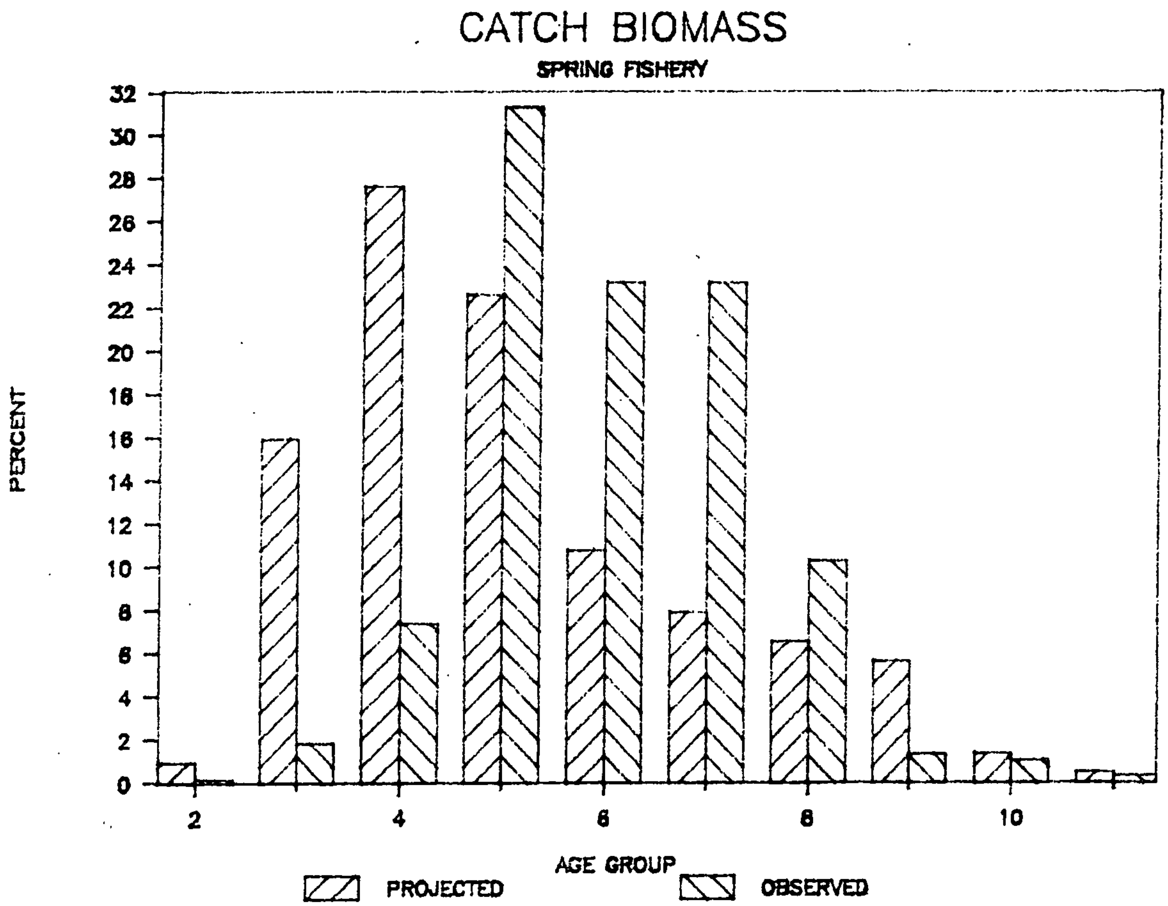


Figure 1. Landings of herring in NAFO Division 4T.

Fig. 2. Comparison of catch at age of 4T herring calculated from commercial samples with catch at age projected by VPA.



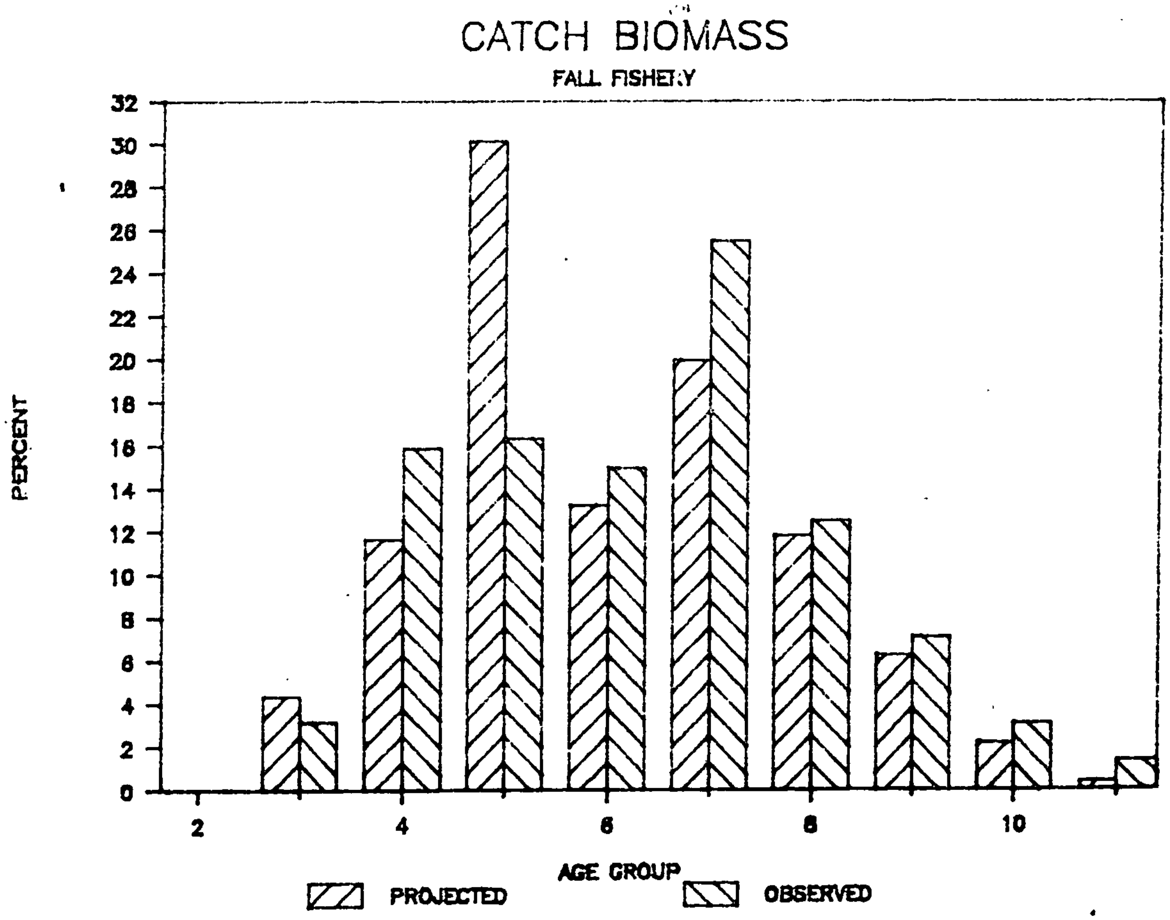
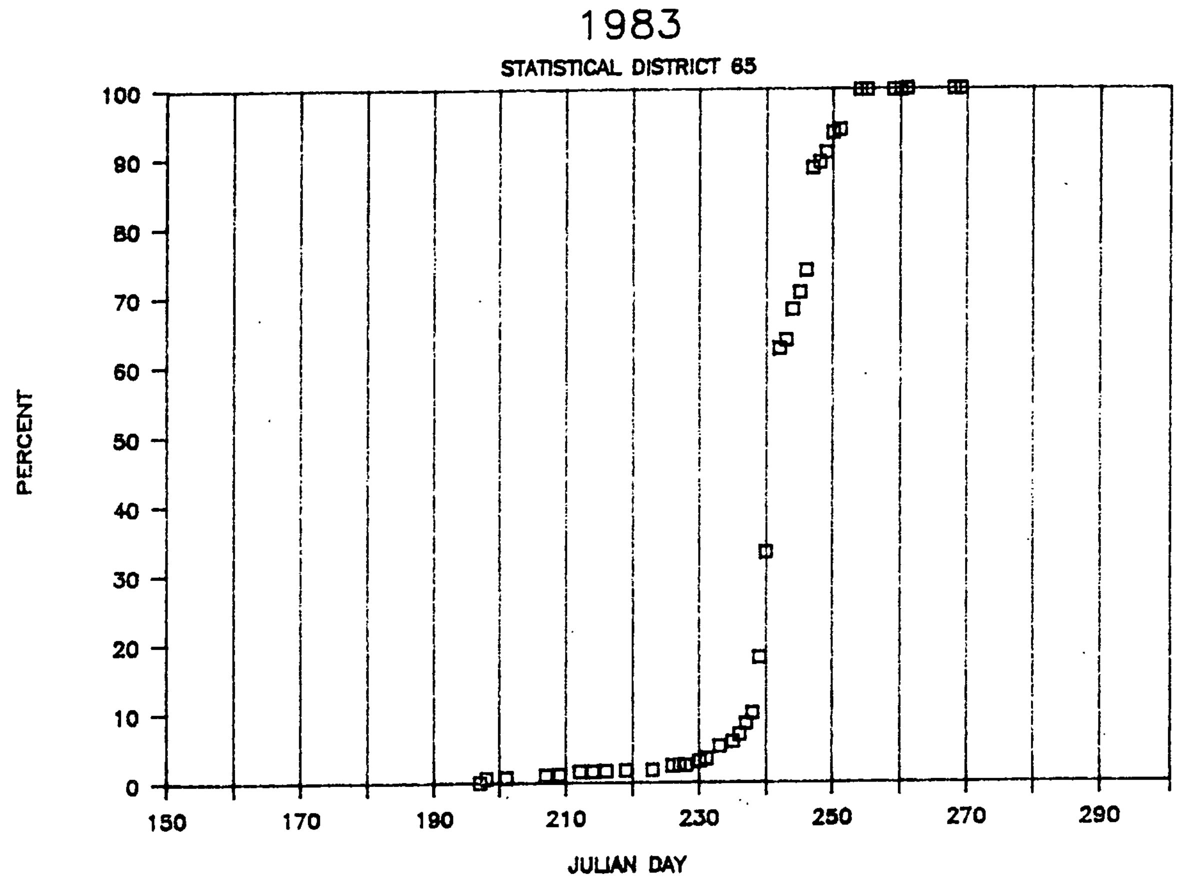


Fig. 3. Cumulative daily catch (top panel) and daily catch rate for (bottom panel) the herring gillnet fishery in statistical district 65, 1983.



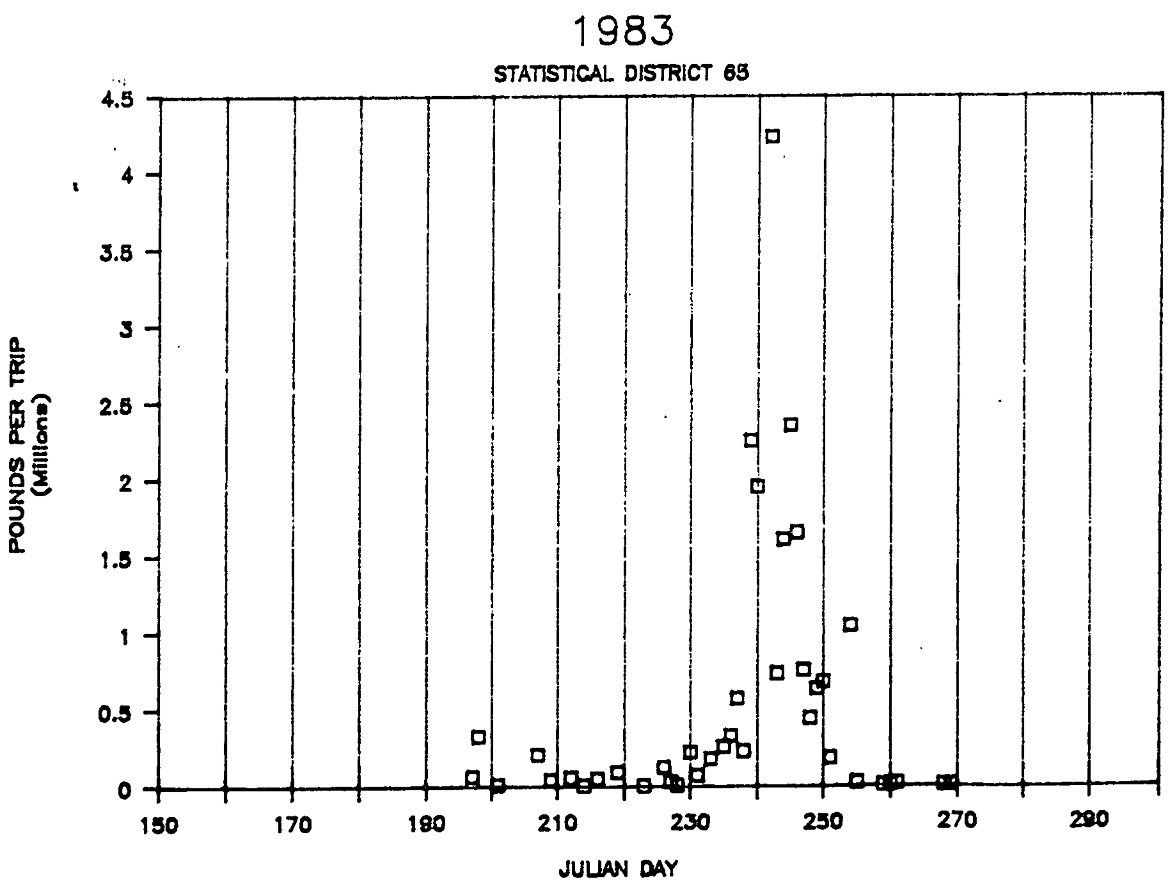
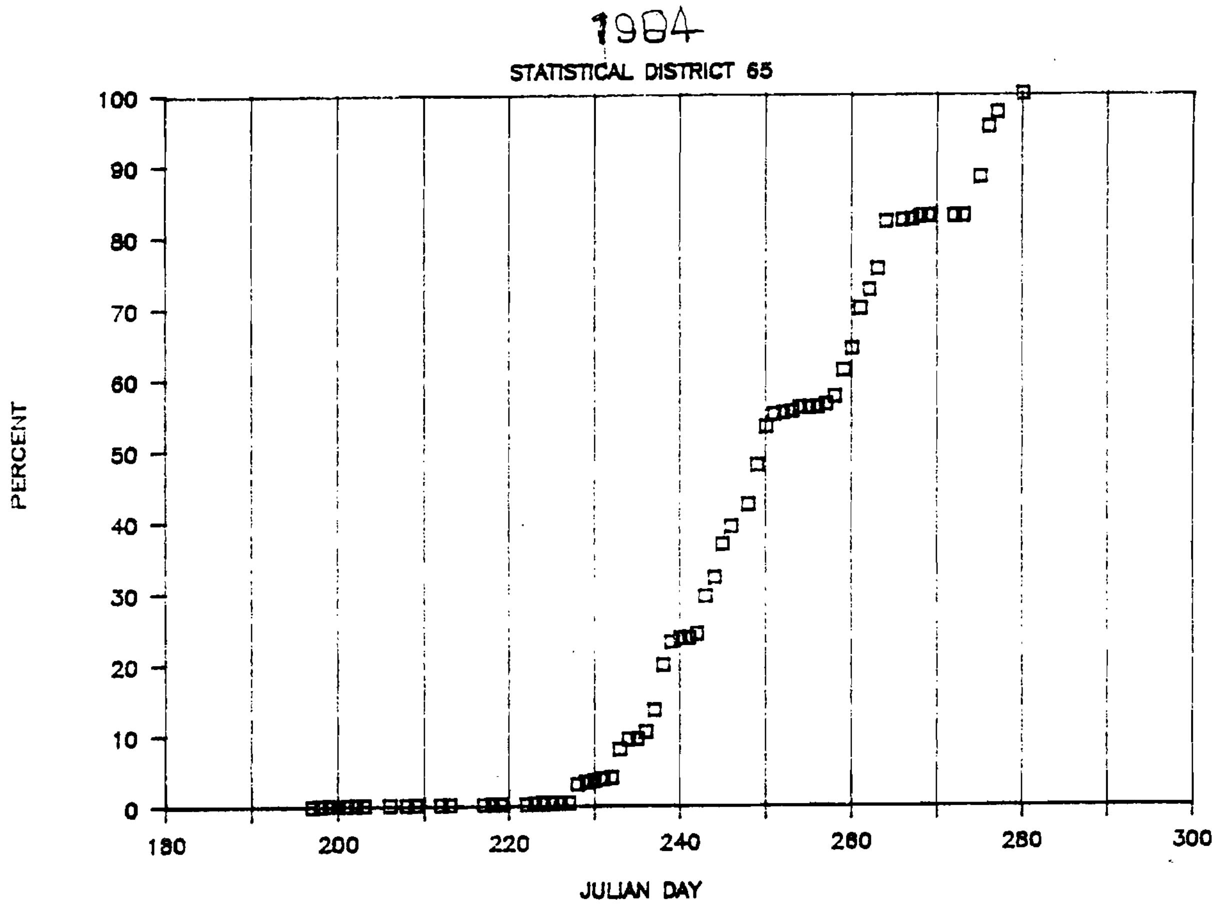


Fig. 4. Cumulative daily catch (top panel) and daily catch rate (bottom panel) for the herring gillnet fishery in statistical district 65, 1984.



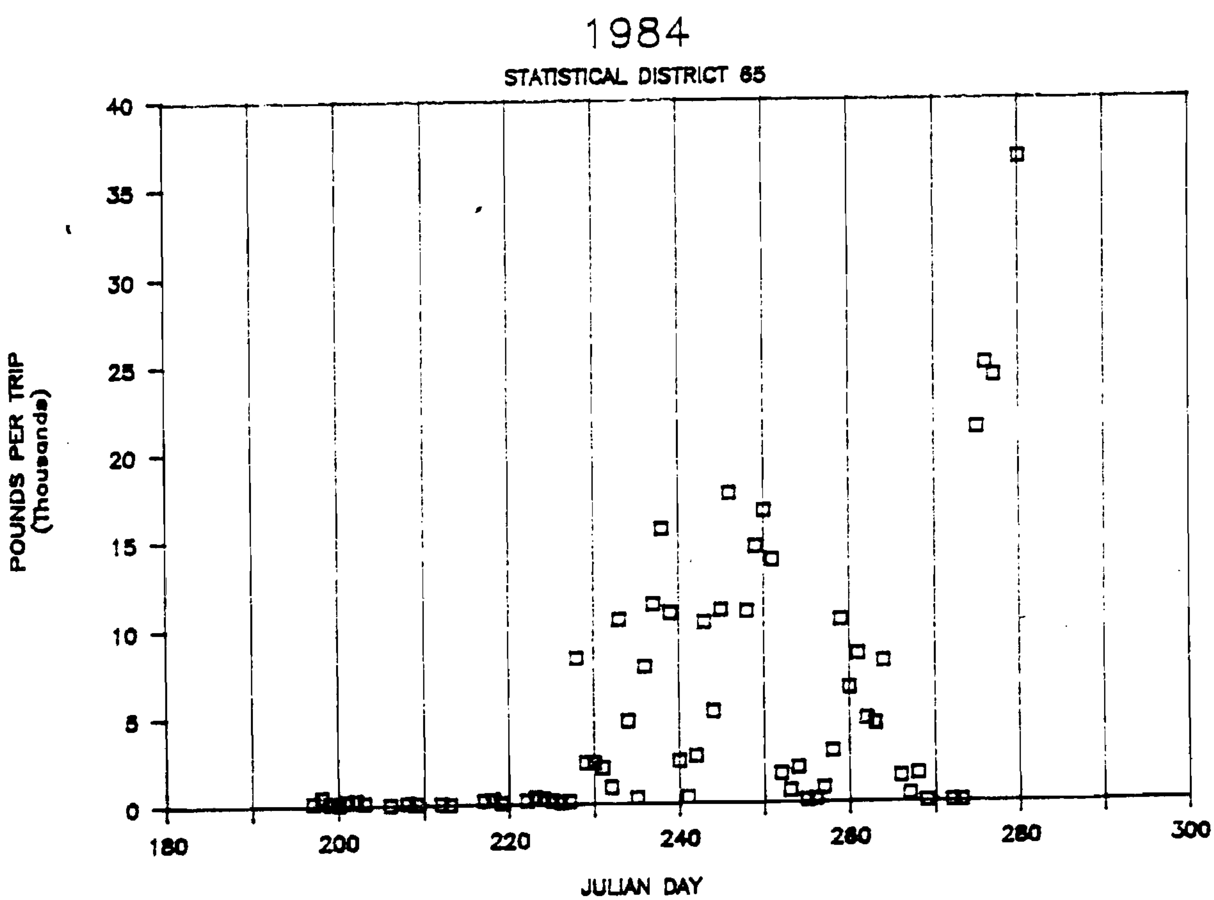


Fig. 5. Distribution of catch by statistical district in the 1987 spring gillnet fishery compared to the previous nine years.

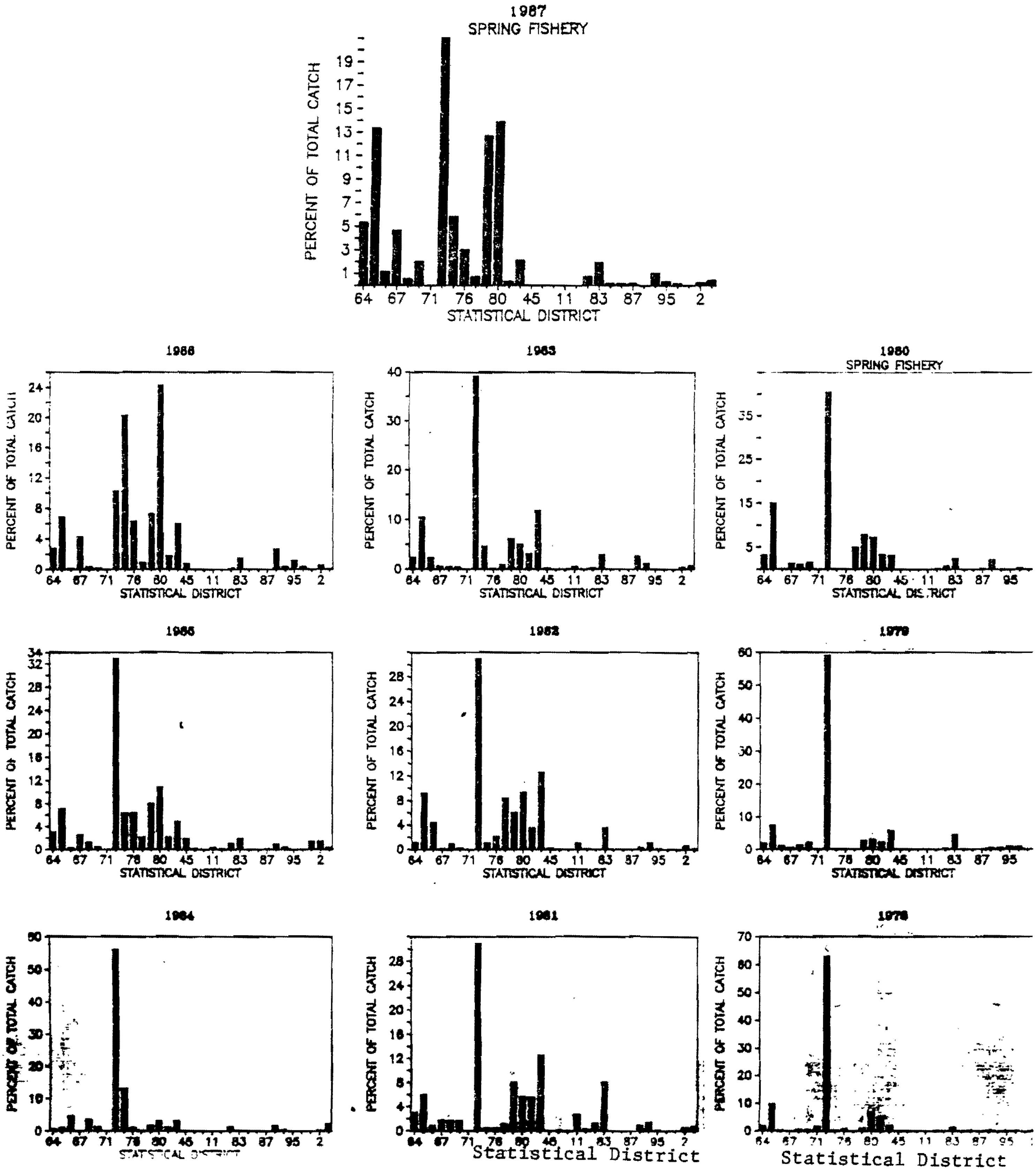


Fig. 6. Distribution of catch by statistical district in the 1987 fall gillnet fishery compared to the previous years.

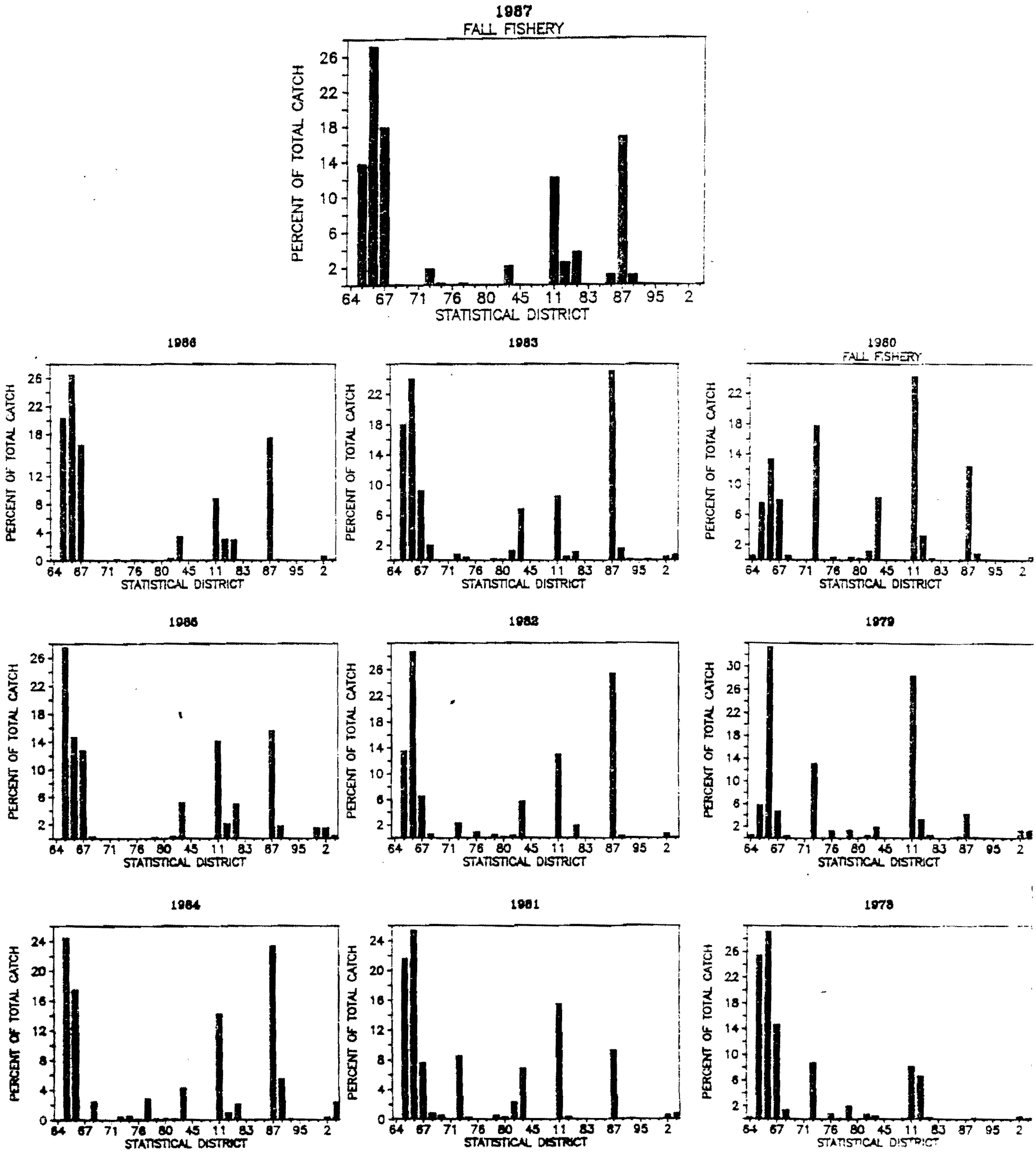
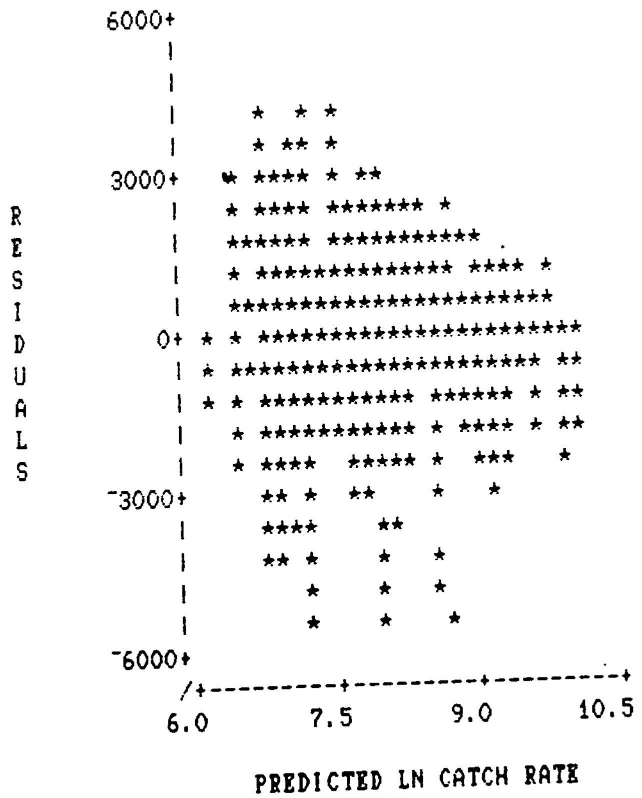
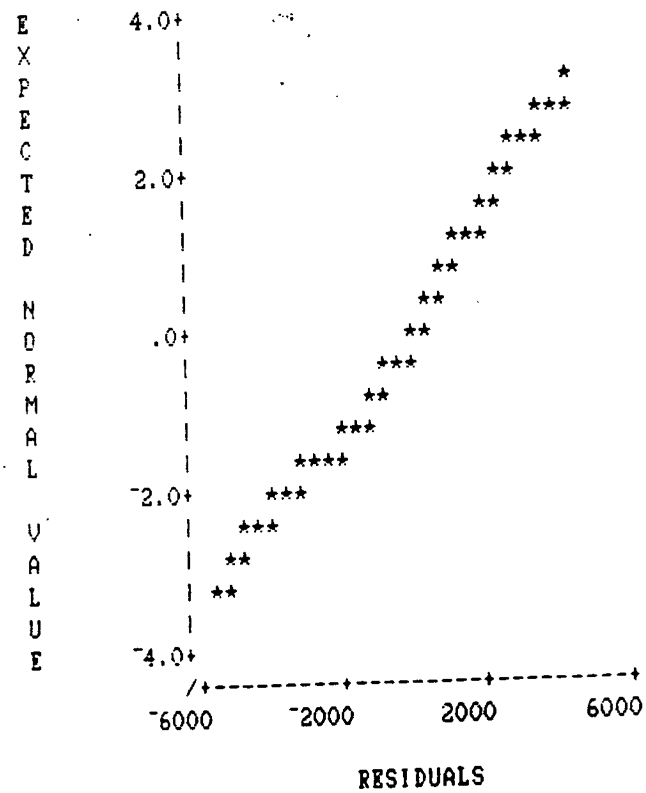


Fig. 7. Plots of residuals of multiplicative model in fall gillnet fishery.





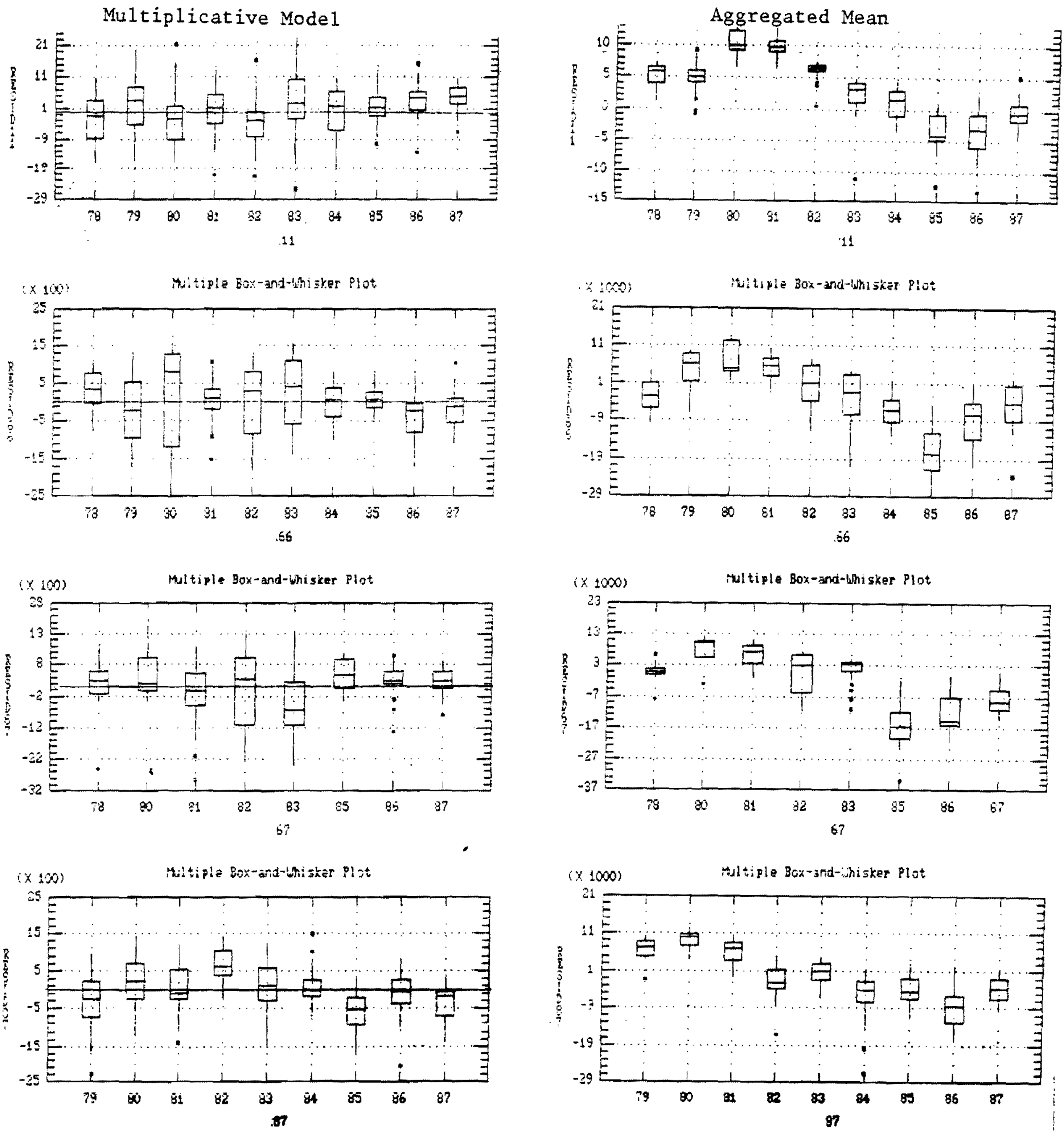


Fig. 8. Annual variation of residuals for four important statistical districts in the fall gillnet fishery using predicted values from the multiplicative model (left panel) and aggregated mean (right panel).

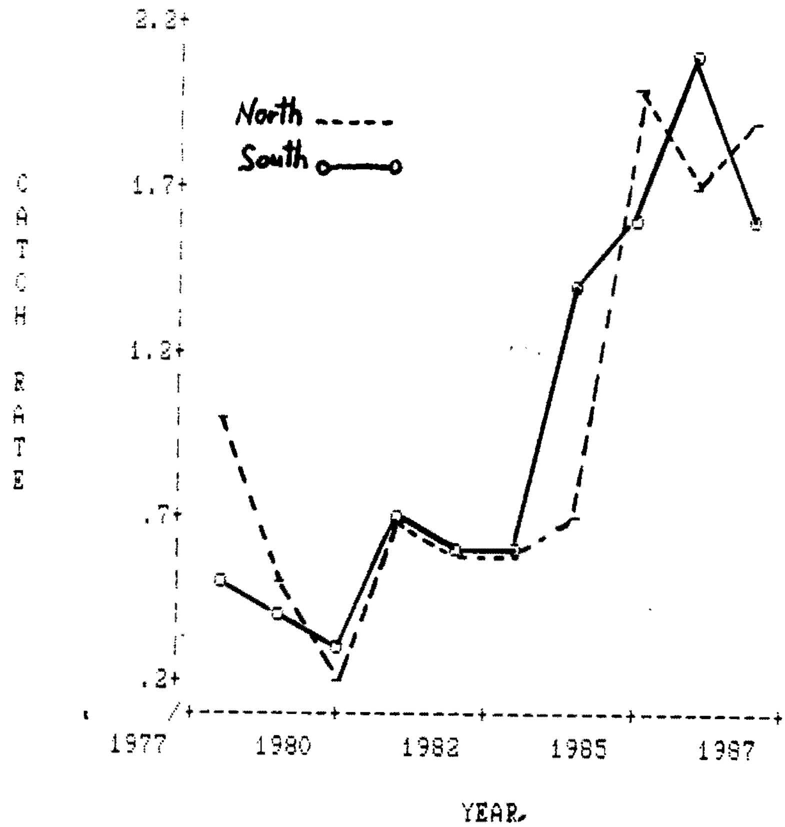
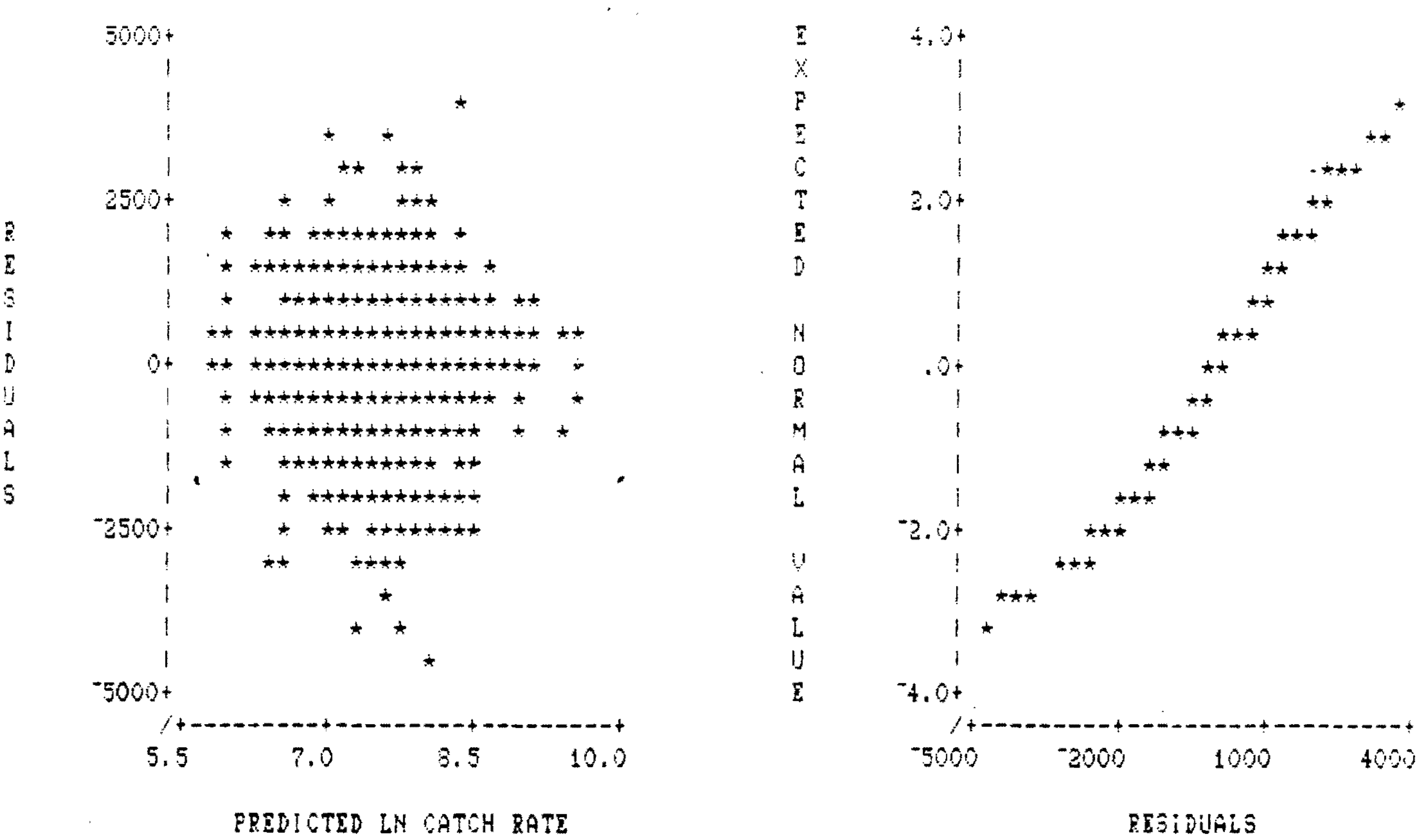


Fig. 9. Comparison of catch rates in the fall gillnet fishery derived from multiplicative models for northern Gulf of St. Lawrence (statistical districts 65, 66, 67, 73, 82 and 92) and southern Gulf (statistical districts 11, 13, 78 and 87).

Fig. 10. Plots of residuals from multiplicative model for catch rates in the spring gillnet fishery.



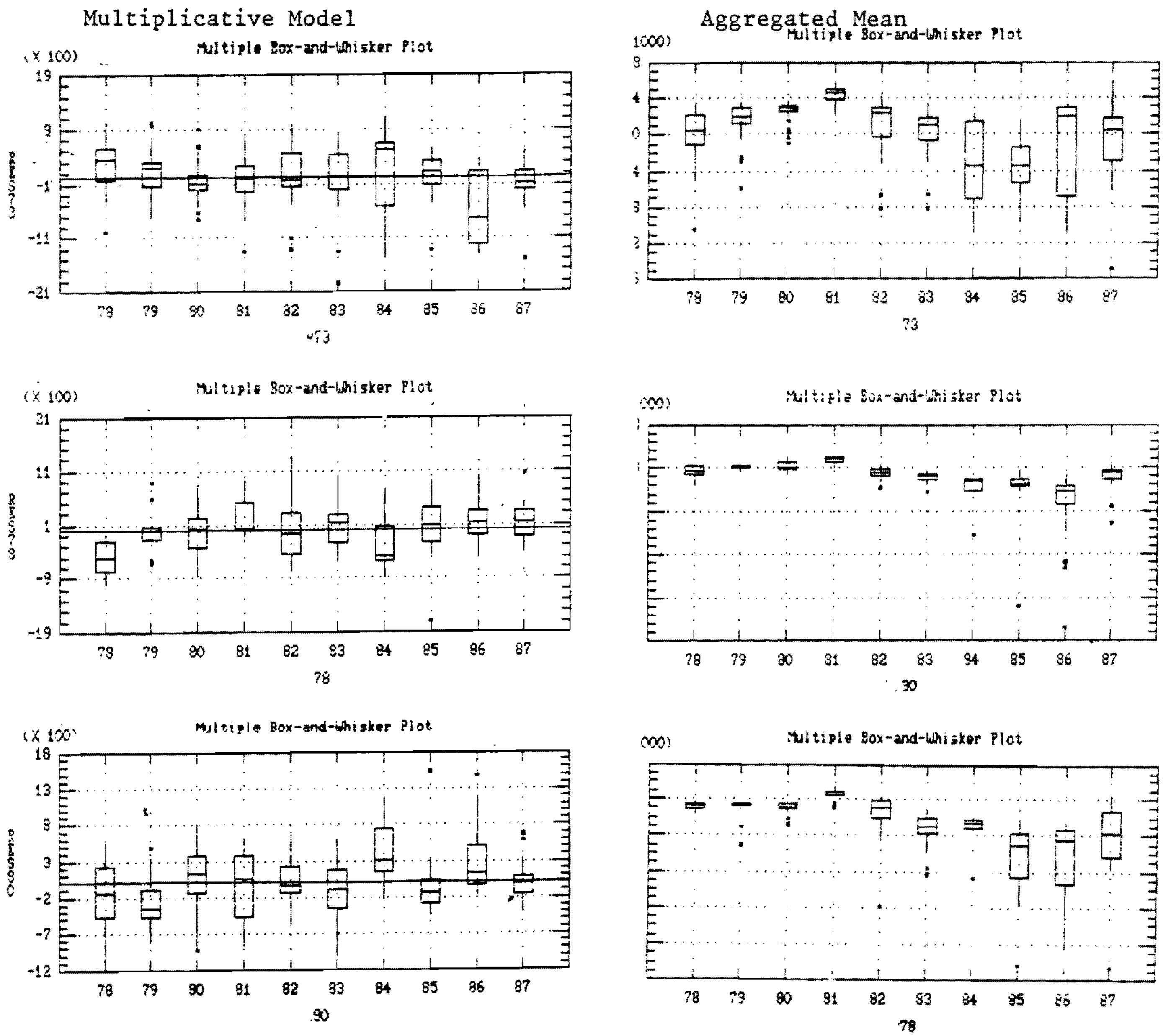
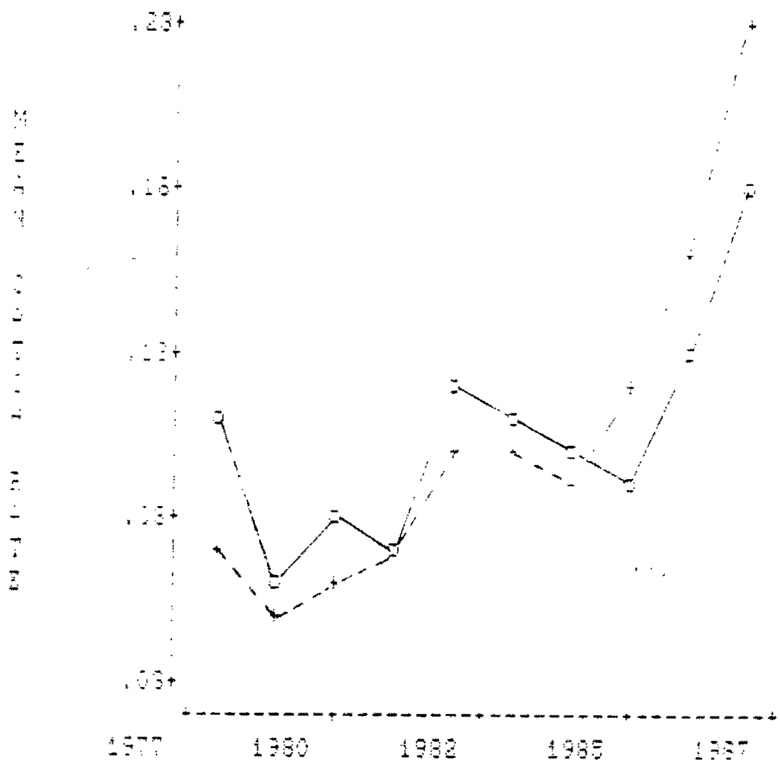


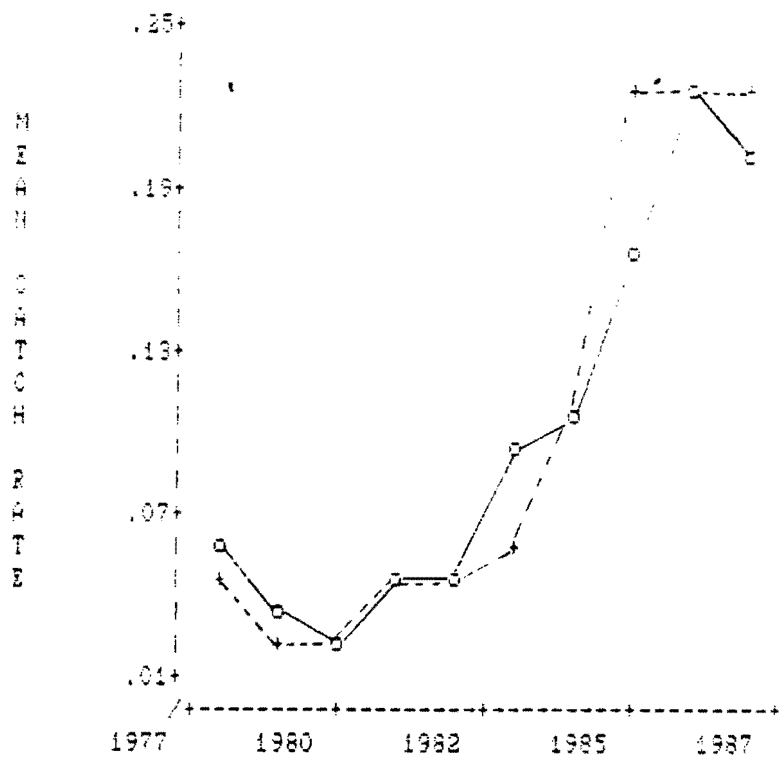
Fig. 11. Annual variation of residuals for three important statistical districts in the spring gillnet fishery using predicted values from the multiplicative model (left panel) and aggregated mean (right panel).

Fig. 12. Catch rates in the herring gillnet fishery comparing results of the multiplicative model (mm) to the aggregated mean (am): spring fishery in top panel; fall fishery in bottom panel. Catch rates have been standardized to the 1978-87 mean.



a) Spring gillnet fishery

mm+.....+
am o———o



b) Fall gillnet fishery

mm+.....+
am o———o

Fig. 13. Timing of catches for selected statistical districts in the spring and fall gillnet fisheries.

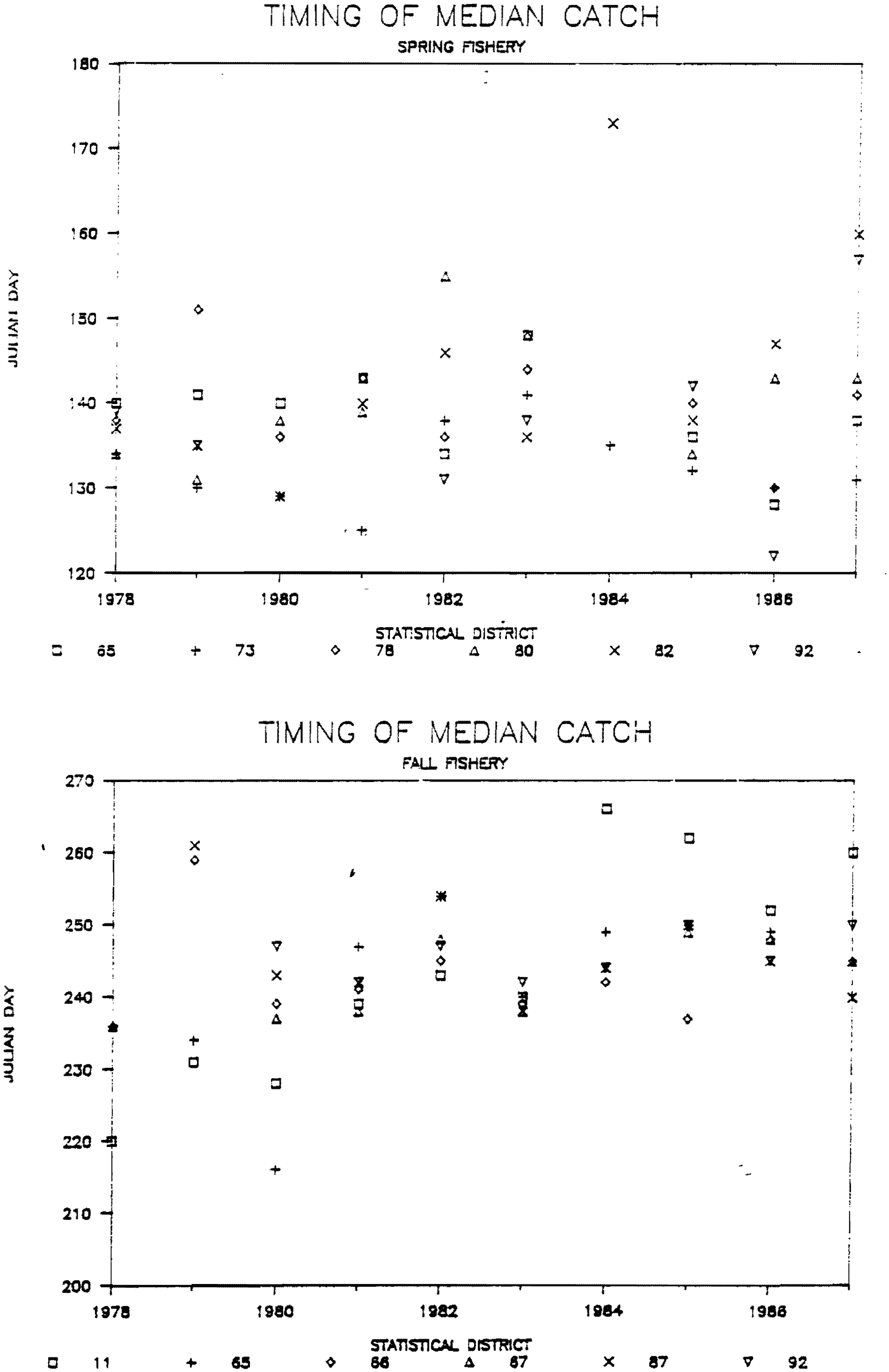
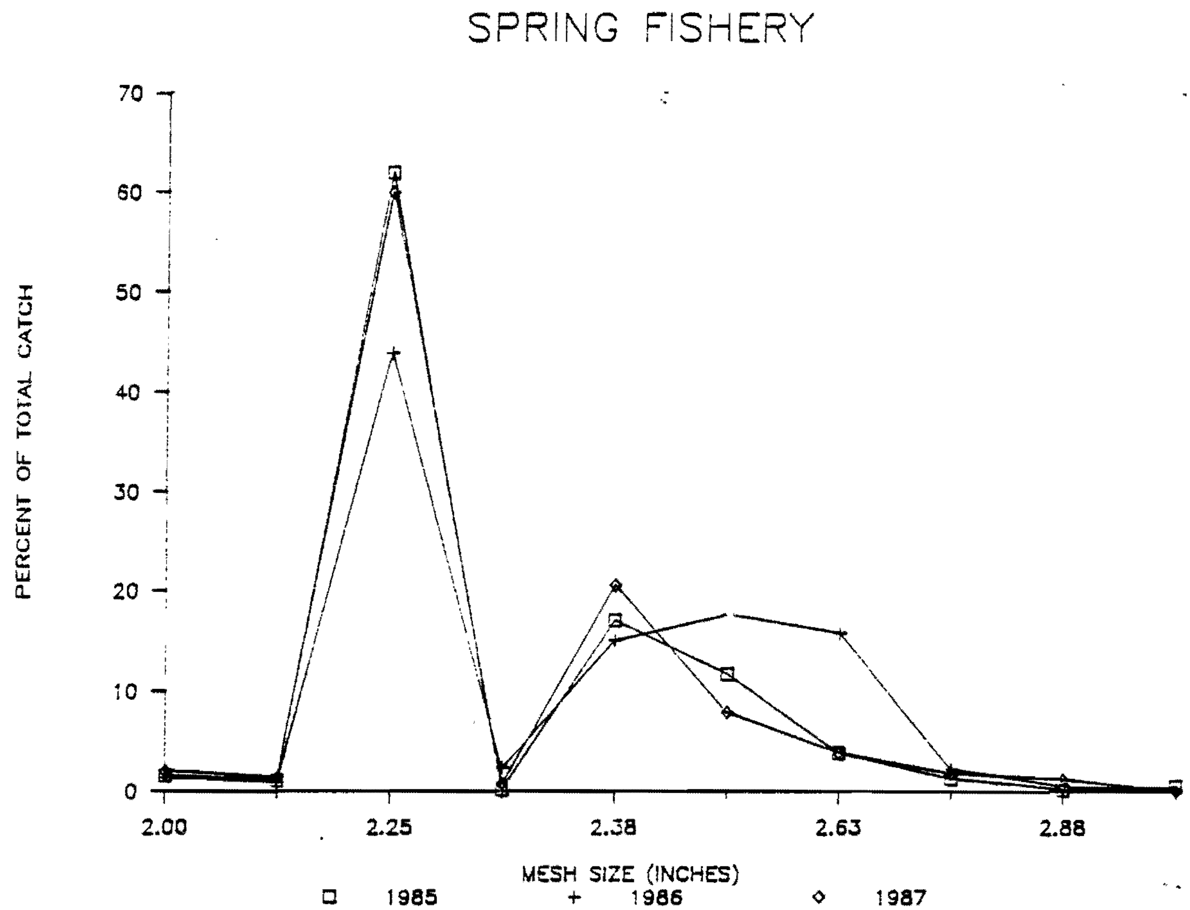
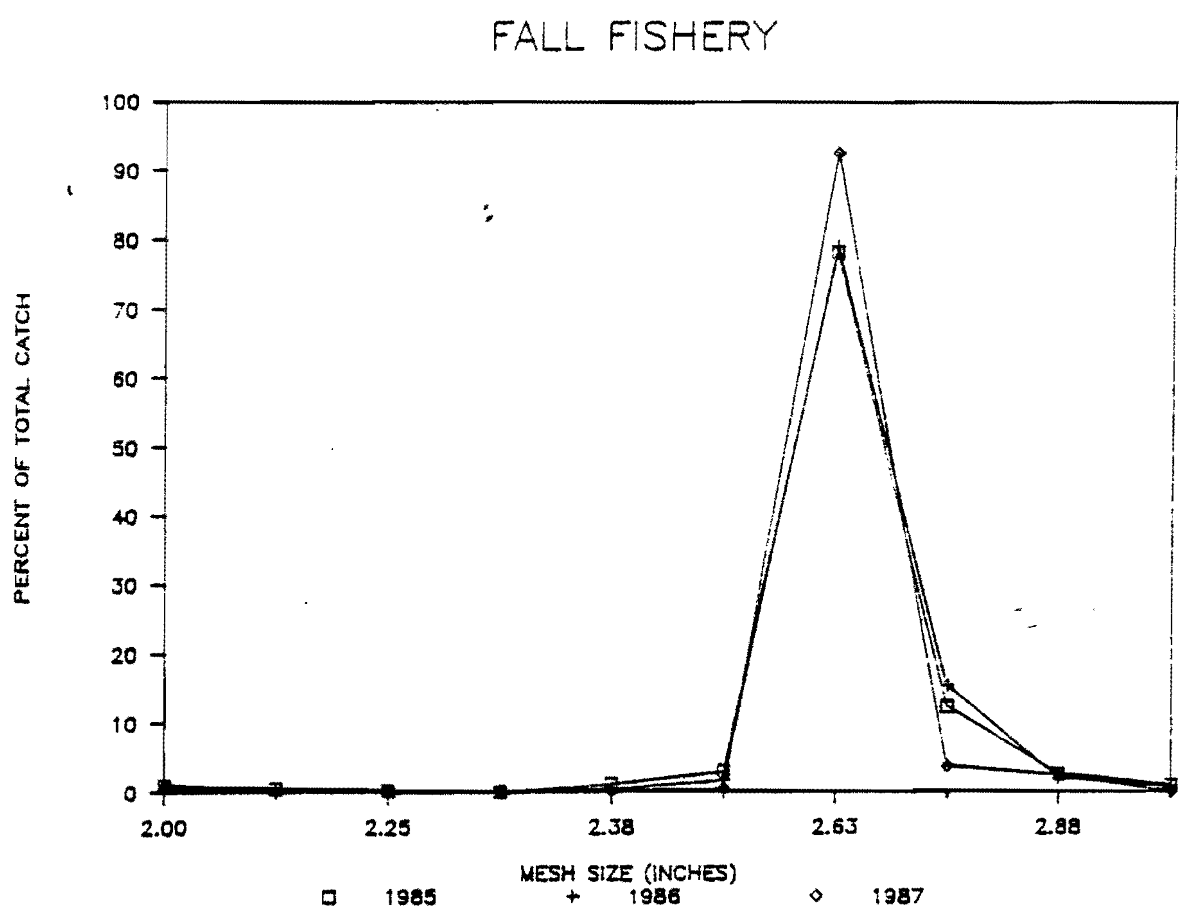


Fig. 14. Distribution of mesh sizes in gillnet fishery, 1985-87.





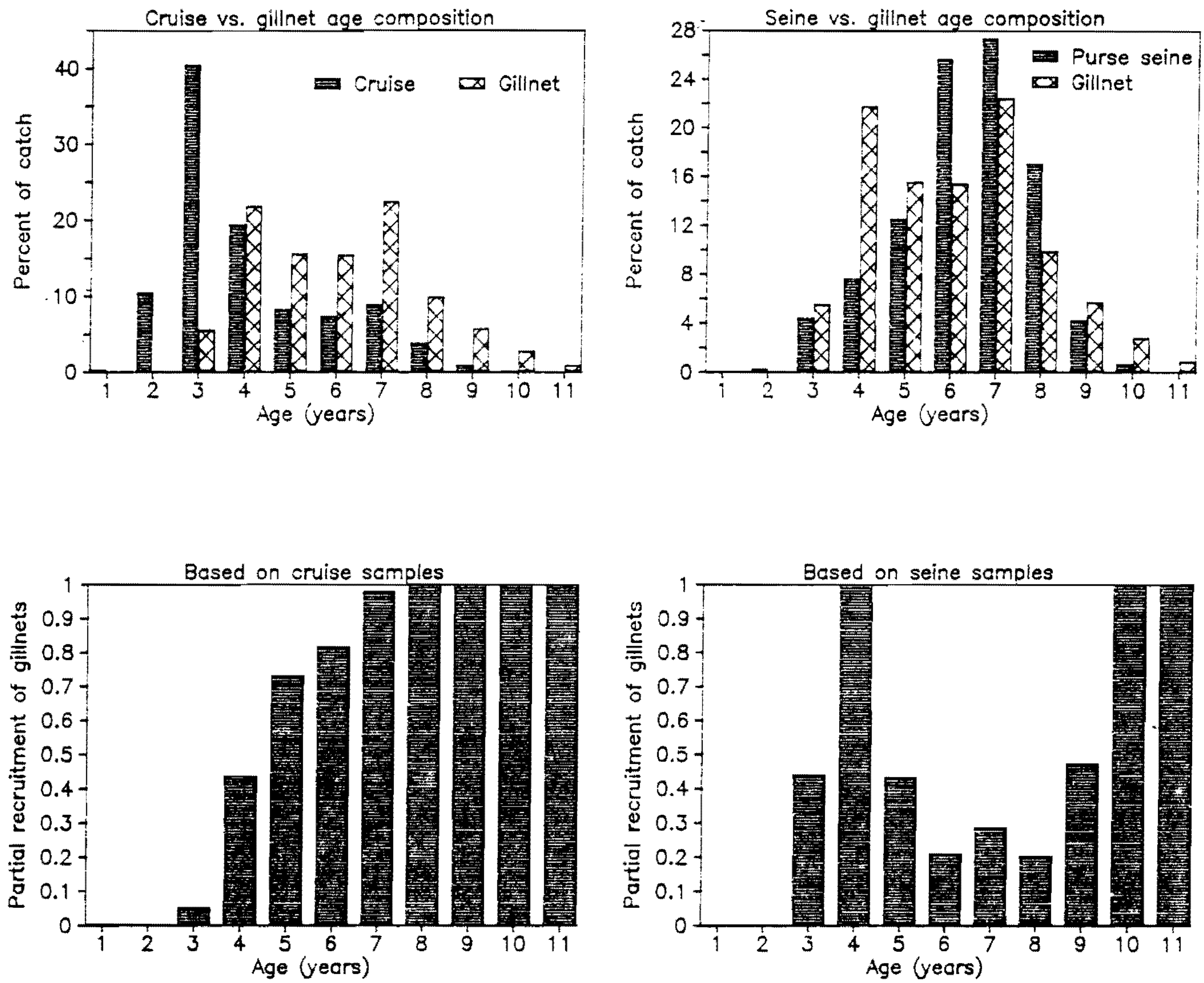


Fig. 15 Partial recuitment of fall spawning herring to gillnets in areas 437–439, as indicated by age composition of samples of fall spawners from acoustic cruises and from the purse seine fishery in the Bay of Chaleur.

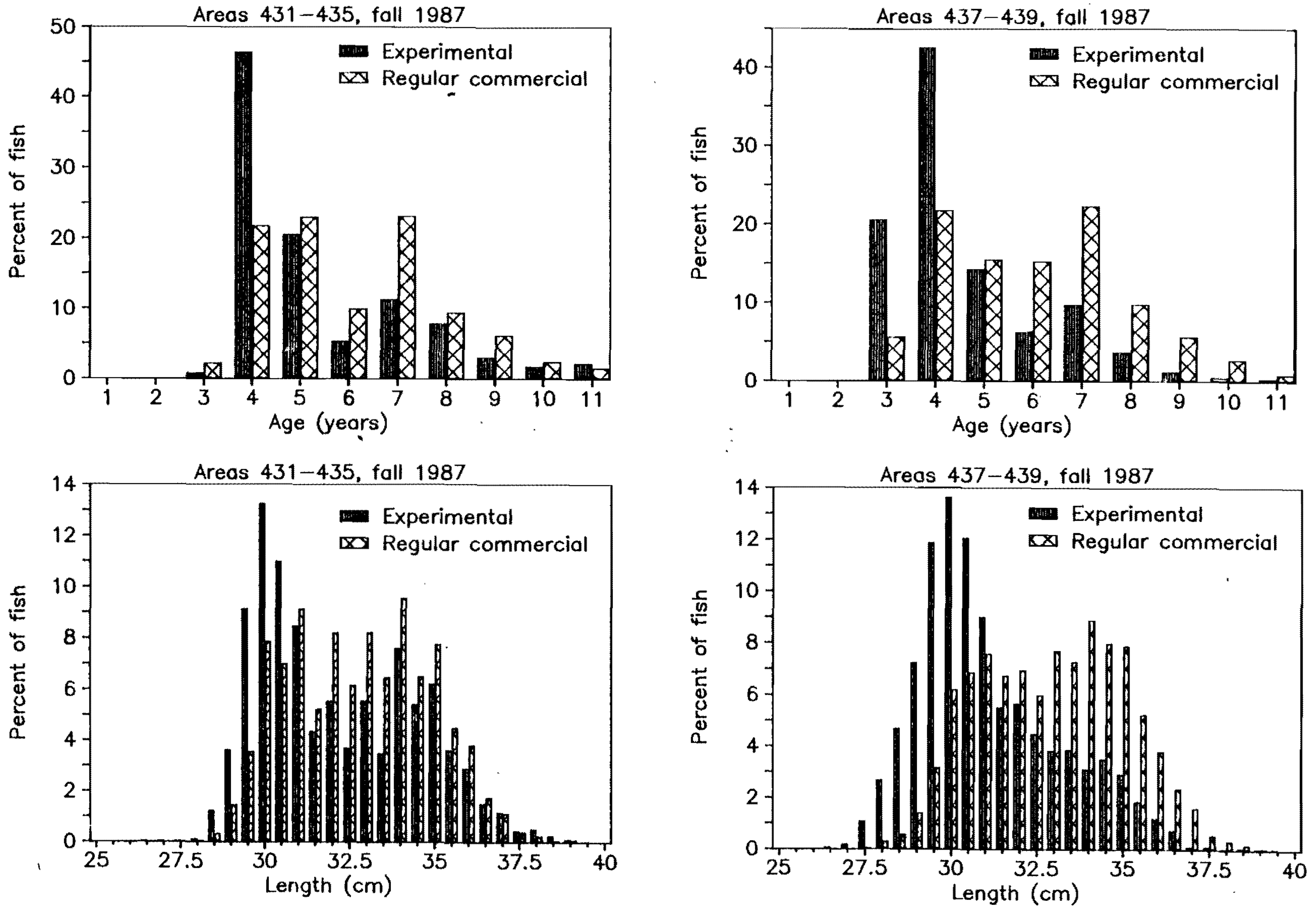


Fig. 16 Percent at age of fall spawning herring taken in gillnets, fall 1987. Experimental gillnets had 2.25 inch mesh. Most regular commercial gillnets had 2.625 inch mesh.

Fig. 17. Observed predicted population numbers at ages 5 to 8 using results of age by age calibration. Coefficients of determination for each calibration plot are also given..

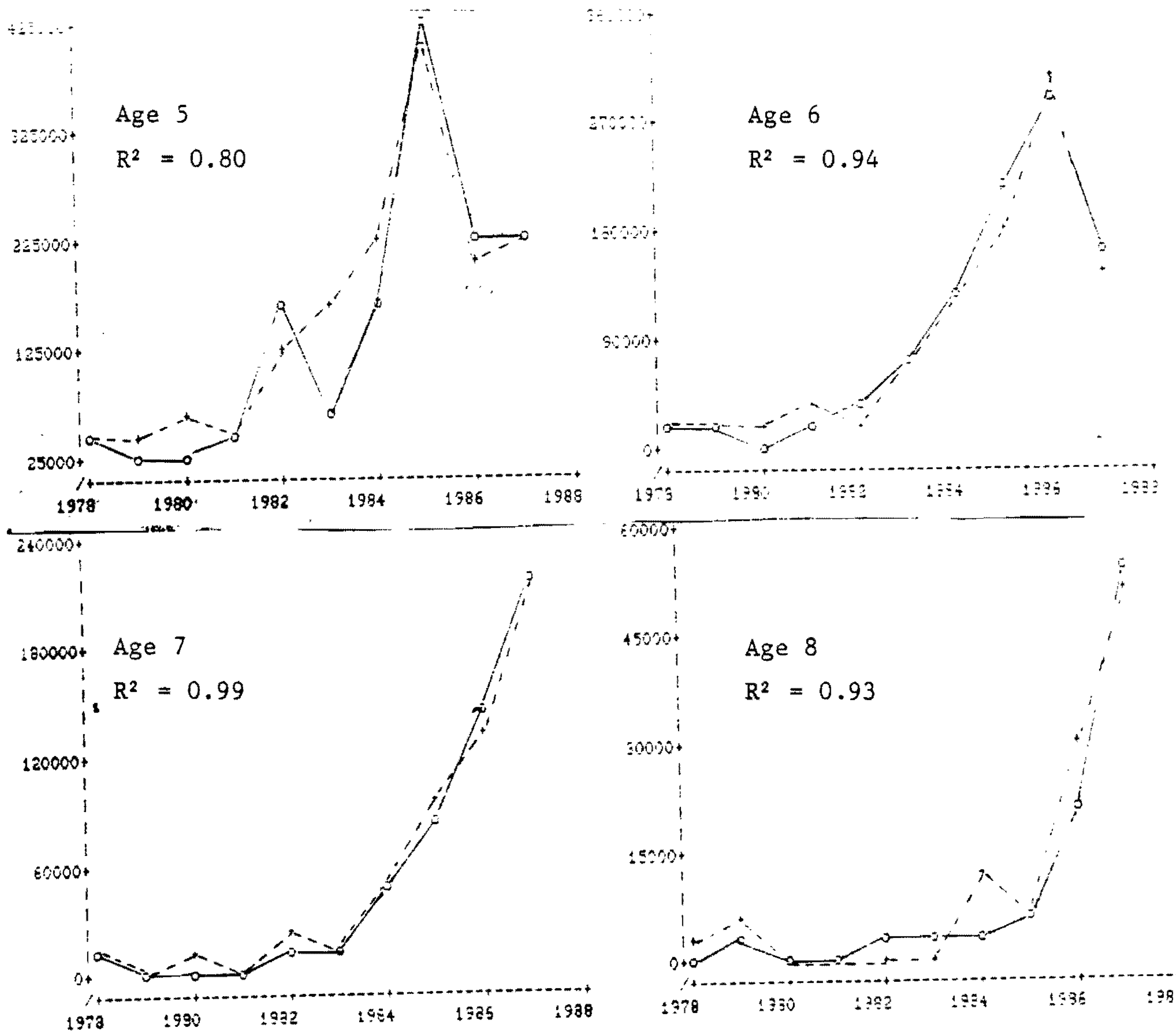
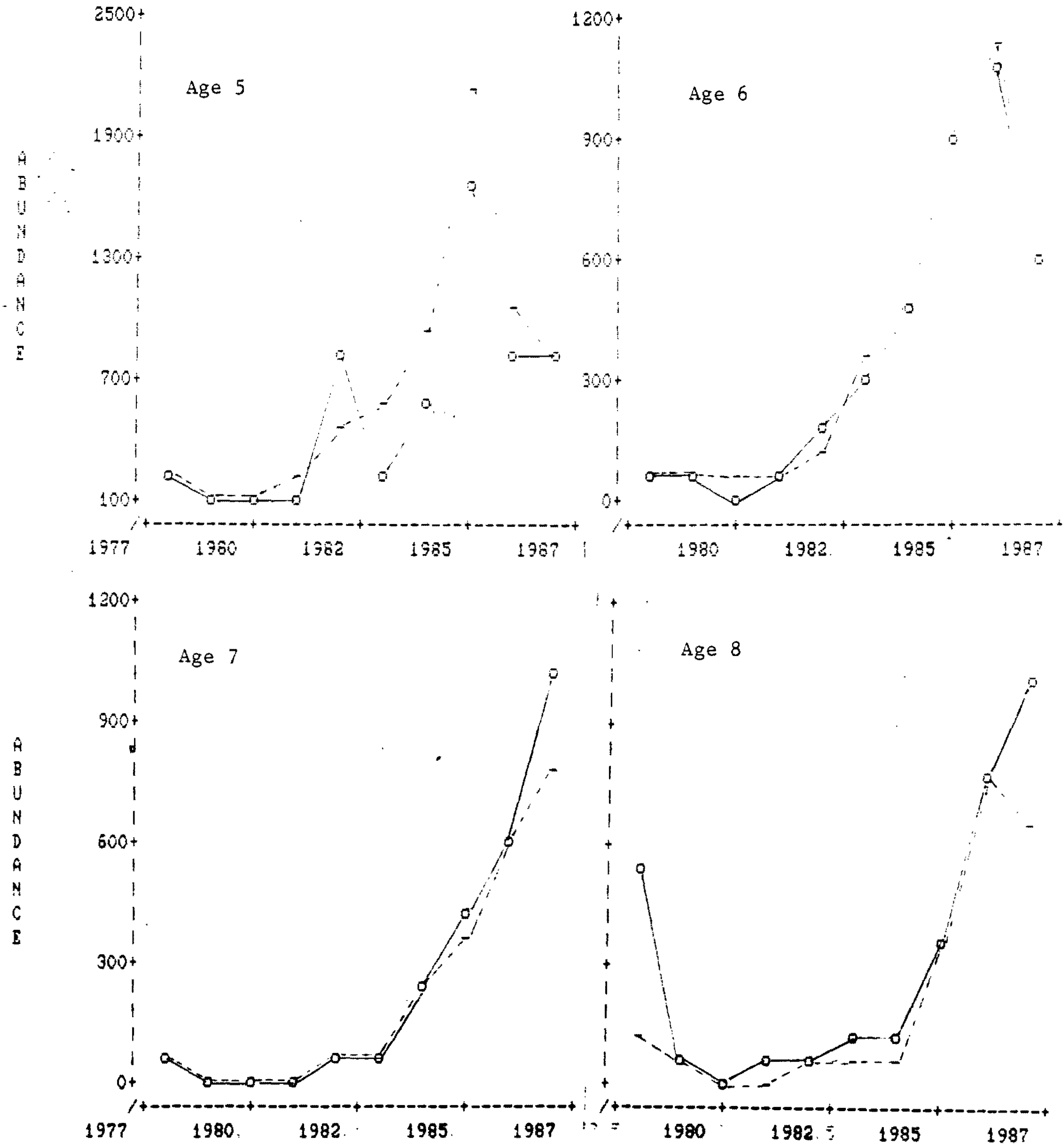


Fig. 18. Predicted and observed population numbers at ages 5 to 8 AFM calibration.



BIOMASS OF HERRING AGE FIVE AND OLDER

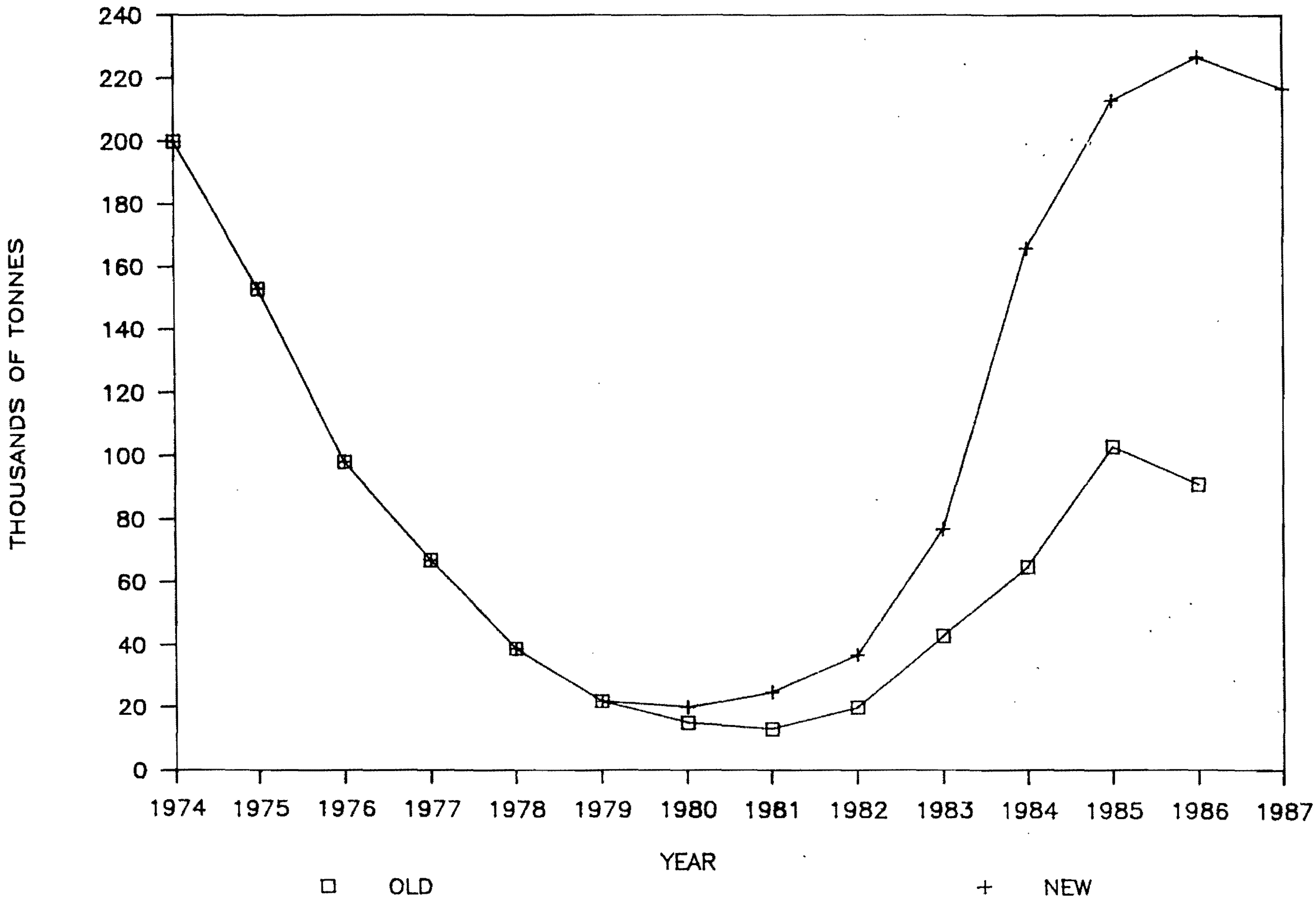


Fig. 19.