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An Assessment of the West Coast of Newfoundland (NAFO Division 4R) Herring Resource in 1988

by

I.H. McQuinn

Ministère des Pêches et des Océans
Division de la Recherche sur les Pêches
Institut Maurice-Lamontagne
C.P. 1000
Mont-Joli (Québec)
G5H 3Z4

ABSTRACT

Herring landings in NAFO Division 4R reached only 18,300 t in 1988, despite a TAC of 30,600 t, mainly due to market and plant-capacity limitations. Spring spawners have dominated the annual catch since 1966. Historically, this spawning group has been dominated by the 1968 and 1974 year-classes. However in 1988, the 1980 and 1982 year-classes comprised 68% of the catch in numbers. The fall spawners had been dominated by the 11+ age group until 1983. In 1988, the 1979 year-class made up 36% of the catch in numbers. Cohort analyses showed that the spring-spawner 5+ biomass stands at 88,000 t in 1988, near 1977 levels. The fall-spawner 5+ biomass has decreased to 31,000 t in 1988 from a high of 42,000 t in 1984. The strong recruitment of the 1979, 1980 and 1982 year-classes has resulted in a significant increase in abundance of these two stocks compared to the lows of the early 1980's. Projections using a fishing mortality 0.3 would result in a catch of 18,400 t of spring spawners in 1989 and 14,200 t in 1989. The $F_{0.1}$ fall-spawner catch would be 6,800 t in 1989 and 5,500 t in 1989.

RESUME

Les débarquements de hareng de la division 4R de l'OPANO n'ont atteint que 18,300 t en 1988, malgré un TPA de 30,600 t, surtout à cause des marchés et de la capacité des usines. Les reproducteurs de printemps dominent la capture annuelle depuis 1966. Les classes d'âge de 1968 et 1974 ont dominé historiquement les captures de ce groupe reproducteur. Cependant, les classes d'âge de 1980 et 1982 ont représenté 68% de la capture en nombres en 1988. Les captures de reproducteurs d'automne entre 1966 et 1983 sont constituées d'une forte proportion de poissons agés de 11 ans et plus. En 1988, la classe d'âge de 1979 a dominé la capture en nombres (36%). L'analyse de cohorte a démontré que la biomasse (5+) de reproducteurs de printemps a atteint 88,000 t en 1988, ce qui est près du niveau de 1977. La biomasse (5+) de reproducteurs d'automne a diminué à 31,000 t en 1988, comparée à 42,000 en 1984. La cause des hausses d'adondance observées depuis le dédut des années 1980 est attribuée au recrutement des classes d'âge de 1979, 1980 et 1982. Un taux de mortalité par la pêche de 0.3 exercé sur les reproducteurs de printemps résulterait en une capture de 18,400 t en 1988 et de 14,200 t en 1989. Les captures des reproducteurs d'automne à un taux de mortalité par la pêche de 0.3 seraient de 6,800 t en 1988 et de 5,500 t en 1989.

INTRODUCTION

Herring in NAFO Division 4R (Figure 1) have been assessed by CAFSAC as a single management unit since 1977 (Moores and Winters, 1977). In summarizing the available information on the 4R herring stock structure, Moores (1983) stated that "the definition of the management unit to encompass this stock was based primarily on external tagging studies, conducted since 1975, which indicate that the west coast of Newfoundland was discrete from adjacent stock areas". Although there were indications from sampling and tagging data that herring concentrations exploited in St. George's Bay in the spring fishery between 1967 and 1972 were possibly a mixture of west coast and southern Gulf stocks, Moores (1983) concluded that herring caught in this area since 1973 were primarily of west coast origin.

As in previous assessments, the spring- and fall-spawning components of the west coast of Newfoundland herring resource have been evaluated separately. It is generally accepted that spring and fall spawners in the northwest Atlantic have different life histories and therefore should be treated as separate stocks within each management unit.

Management Plan:

Total allowable catches (TAC) have been in effect since 1977, when the west coast of Newfoundland was defined as a herring management unit. Since 1981, 45% of the TAC has been allocated to the fixed gear sector (mainly anchored gillnets) and 55% to the mobile gear sector (mainly purse seines). In addition, the purse seine quota has been proportioned among the five active vessels and the gillnet allocation has been divided evenly between the regions north (4Ra and 4Rb) and south (4Rc and 4Rd) of Cape St. Gregory. Compliance with these management measures has been variable, as the TAC was exceeded in 1978, 1979, 1982, 1985 and 1986 by between 21 and 48% (Table 1; Figure 2).

Historical Fishing Patterns:

Total herring landings from the west coast of Newfoundland were relatively constant from 1966 to 1970, ranging between 3,000 and 6,000 t (Table 1, Figure 2). A marked increase in catches began in 1971 which peaked at 27,000 t in 1973, as plant processors shifted from fish meal production to barrelled products for human consumption subsequent to the decline of the North Sea herring stocks. Landings in 4R decreased sharply in 1974 and 1975 as the purse seine fleet shifted its activities to the overwintering herring concentrations in NAFO subdivision 4Vn. Again, landings steadily increased between 1976 and 1980; a trend which was reversed in 1981, mainly due to depressed markets. Augmented sales to eastern block countries in 1985 stimulated another increasing trend in landings which peaked at 21,400 t in 1986, but which leveled off at 16,500 t in 1987 and 18,267 t in 1988.

The fishing pattern of the purse seine fleet has fluctuated considerably over time in response to shifting concentrations of herring schools and their accessibility to buyers. In the latter half of the 1960's, almost 100% of the purse seine catches came from the Bonne Bay area (4Rb). During the 1970's, the fleet shifted its fishing activity northward to St. John Bay (4Ra) and southward to St. Georges Bay (4Rd), where most of the

catch was reported. In the early 1980's, the proportion of market size fish decreased in St. Georges Bay due to the presence of large schools of juvenile herring (the abundant 1980 and 1982 year-classes). Consequently, in 1983 and 1984, the purse seiners concentrated most of their efforts during the spring fishery in the Bay of Islands area (4Rc) (Table 2) on mixed schools of spring and fall spawners (Table 3). However, as a proportion of the total catch, the spring fishery was declining in importance. From 1982 to 1987, the majority of the purse seine catches were taken from overwintering concentrations of mixed spring and fall spawners (Table 3) in areas 4Rb and 4Rc from October to December (Table 2) reaching over 80% of the purse seine landings in 1986 and 1987.

In recent years, the traditional barrelled-product market for Newfoundland herring has been replaced by an expansion in over-the-side sales to the Soviet Union, and by the development of a spring frozen-round fishery for roe products to the Japanese. This, along with some fishing by the fleet of purse seiners based in the southern Gulf of St. Lawrence, accounted for a considerable increase in the proportion of spring spawners taken in the spring fishery in 1988 (Table 3), which accounted for 51% of the total purse seine catch (Table 2).

The nearshore fishery (mostly gillnets) has also gone through pronounced changes since 1966. In the late sixties, the proportion of the total gillnet catch taken in the southern areas rapidly declined, falling from 80% to 25% from 1968 to 1969 (Figure 3). From 1971 to 1978, most of the catch was reported from area 4Ra. After 1975, a major spring gillnet fishery developed south of Cape St. Gregory (Moores and Winters, 1980), resulting in a steady increase in landings reported from areas 4Rc and 4Rd until 1982. In recent years, almost equal proportions of the total gillnet catch have been taken from spawning concentrations in St. Georges Bay and Port-au-Port Bay in April and May (Table 4), and north of Pointe Riche from July to September (Table 2; Figure 3), although a relatively active late fall fishery on mixed spring- and fall-spawner concentrations (Table 4) has occurred sporadically in areas 4Ra to 4Rc throughout this period.

Total gillnet landings have declined since 1980 (Table 1), resulting in a decline in the proportion of the total catch taken by gillnets since 1980 (Figure 4). Due to a limited market demand for gillnetted herring, which traditionally supplied bait for the active lobster fishery, less than 10% of the total 4R landings were reported from the gillnet fishery in 1985, 1986 and 1988, although this proportion increased briefly to 17% in 1987.

SEQUENTIAL POPULATION ANALYSES

Input Data:

Age Composition of the Commercial Catch:

Random samples from the commercial fishery were collected by port samplers, and by gillnet fishermen hired to keep detailed catch and effort data on herring caught on the spawning grounds. Because of the number of people involved, most of the major commercial landings were well sampled (Annex 1). These samples were frozen and sent to the Quebec Region

laboratory in Mont Joli for analyses (length, weight, gonad weight, maturity stage, and otolith collection for age determination).

Individual herring were assigned as either spring or fall spawners by relating the maturity stage, estimated from a gonadosomatic index (GSI) (McQuinn, 1989), to the date of capture, using the 4R maturity cycle chart (McQuinn, 1987a). In the case of immature fish, otolith characteristics were used as described by Cleary et al. (1982). Ages were determined from the otoliths as the number of winter rings for spring spawners and the number of winter rings plus one for fall spawners (Cleary et al., 1982). All herring age 11 or more were aggregated into an 11+ age-group. The 1988 catch at age (Table 5) was generated (CATΔAGE v1.0, Anon, 1986) for spring and fall spawners as described by McQuinn (1987b).

a) The spring-spawner catch at age:

Spring spawners have dominated the catch in every year since 1973 (Table 5), averaging 73.0% of the catch in numbers. The 1968 year-class was the largest ever observed in the spring-spawner catch and completely dominated from 1973 to 1982 (Table 6). Between 1973 and 1982, the only significant recruitment to the spring-spawning stock came from the 1974 year-class. In 1983 about 30% of the catch consisted of the 1979 and 1980 year-classes. The strength of the 1980 year-class became apparent in 1984, when at age 4 it dominated the fishery, representing 40% of the catch in numbers. In 1985, the 1980 year-class was the single most important since the 1968 year-class, contributing to 63% of the catch in numbers, and again 51% in 1986. Since 1987, the 1982 year-class has also contributed strongly to the spring-spawner catch in numbers, maintaining the mean age of the spring spawners at 7.0 years old in 1988.

b) The fall-spawner catch at age:

Herring of the 11+ age group have historically dominated the fall-spawner catch (Table 6). In 1984, the 1979 year-class strongly recruited into the fishery and contributed to more than 49% of the catch in numbers. In 1985, this same cohort increased its dominance to an historical high of 63%, declining steadily to 36% in 1988. The mean age of fall spawners in the catch has therefore risen in recent years, from 6.0 years old in 1985 to 7.6 years old in 1988. However, this stock also appears to have several above average year-classes (1980, 1981 and 1982) helping to maintain the fishery.

Population Abundance Indices:

Abundance indices were estimated, for both spring and fall spawners, from commercial gillnet catch and effort data, and from detailed logbooks of daily catch and effort compiled by indexed gillnetters fishing on spawning concentrations.

Gillnet catch rates:

a) Commercial data

Annual gillnet catch rates were estimated from all available purchase slips from 1977 to 1988, and standardized using a multiplicative model

(Gavaris, 1980). The category types for the model were month, unit area and year. Prior to these analyses, catches in each category type were proportioned to spring and fall spawners using the percent spawning-stock composition determined from the commercial samples (Table 4). In addition, analyses were conducted on the 1985 to 1988 data-sets to identify and exclude those slips which represented a weekly sum of landings rather than a daily trip. This exclusion of slips tended to reduce the annual catch rate estimates and therefore this years catch-rate series differ somewhat from those calculated for last years assessment (McQuinn, 1988). The years most affected were 1986 for spring spawners and 1985 and 1986 for fall spawners.

The total effort for each category type (number of boat-days) was adjusted on the basis of gang size estimates (number of nets fished/day) for each area, standardized to 1 in 1978, to account for interannual variability in effort (Table 7). Analyses of inter-monthly variability showed that it was not necessary to adjust effort for seasonal trends in gang size.

The estimated number of nets per gang for 1977 to 1981 were based on telephone surveys conducted on the Newfoundland east coast (Wheeler and Winters, 1983). For 1982 to 1988, the gang sizes were obtained from written surveys sent between 1984 to 1988 to all licensed fishermen along the west coast. The number of nets fished from 1981 to 1983, recorded on the licence applications, was used to standardize the two data series. The gang size estimates for 1982 to 1988 were calculated using the average number of nets fished by those fishermen within each area who sold the majority of their catches, so as not to include bait fishermen who were not issued purchase slips.

The catch rate indices were thus calculated as:

$$U_{mut} = \frac{C_{mut}}{E_{mut} \times GS_{ut}} \qquad (1)$$

where U_{mut} is the catch rate in month m, unit area u and year t,
C_{mut} is the catch biomass in month m, unit area u and year t,
E_{mut} is the effort (number of boat-days) in month m, unit area u and year t,
GS_{ut} is the standardized gang size in unit area u and year t.

A multiplicative model (STANDAR v1.0, Anon, 1986) was then fitted to these catch and effort data (Tables 8 and 9) to yield standardized annual catch rates for each spawning stock. Initial analyses showed that an unweighted regression resulted in significant trends in the residuals of the model. Because of the inherent high variability of these data (e.g. varying number of nets used by each fisherman), a regression weighted on catch and effort was used to lessen the effect of those cells with very few slips (e.g. <10) using the following equation:

$$\text{Weight} = (\text{Catch} \times \text{Effort})^{0.25} \qquad (2)$$

An examination of the residuals of this weighted model indicated a good model fit. All the category types were significant ($P<0.05$), with a model r^2 of 0.64 and 0.66 for the spring and fall spawners, respectively. The

resulting catch rates and estimates of gillnet effort (Table 10, Figures 5) were used in the calibration of the cohort analyses for the two spawning stocks.

b) Indexed Fishermen

Indexed gillnet fishermen have been hired since 1984 to complete daily logbooks, recording their catch and effort (number of nets/day) as well as their location, mesh-size, size of nets and water depth. Annual gillnet catch rates were also estimated from these data and standardized using the multiplicative model. The category types for the model were month, unit area and year. Catches in each category type were proportioned to spring and fall spawners as with the commercial purchase slip data (Table 4).

A multiplicative model was then fitted to these catch and effort data to yield standardized annual catch rates for each spawning stock. Initial analyses showed the area category type to be highly correlated with month and was therefore removed. An unweighted regression resulted in significant trends in the residuals of the model. The EGLS procedure was used to define step-wise weighting factors for the regression based on the variable catch. An examination of the residuals of this final weighted regression indicated a good model fit. All the category types were significant ($P<0.05$), with an r^2 of 0.41 and 0.51 for spring and fall spawners, respectively (Tables 11 and 12). These catch rates (Table 13, Figures 5) were also used in the calibration of the cohort analyses for the two spawning stocks.

The commercial spring-spawner gillnet catch rates followed a sharp decrease from 1978 to 1981 after an initial increase from 1977, and remained stable until 1985 (Figure 5a). The fall-spawner commercial catch rate declined gradually from 1977 to 1983, and increased slowly to 1985 (Figure 5b). All catch rate series showed a significant increase between 1985 and 1987, and a subsequent decrease in 1988. However, the fall logbook series clearly showed the major increase to have occurred in 1986 with a slight decrease in 1987, rather than the sharp jump in 1987 as seen in the fall commercial series (Figure 5b). The two spring-spawner series exhibited identical trends, within the confidence limits of the data (Figure 5a).

It should be noted that the commercial and logbook series were for the most part derived from independent data sources as the indexed fishermen fished predominately for bait. Both commercial and logbook indices were used in the adaptive framework for the cohort analysis calibrations as the commercial series represented a longer time period while the shorter logbook series afforded a more unbiased view of the most recent years.

Estimation of Parameters:

Natural Mortality Rate:

A value of 0.2 was assumed for the instantaneous natural mortality rate (M) in the present analyses. This value was used in the previous assessment (McQuinn, 1988) and is consistent with estimates made for other herring stocks (Lea, 1930; Runnström, 1936; Beverton, 1963).

Fishing Mortality for the Oldest Ages:

The vector of fishing mortalities for the oldest ages (F_o) was estimated as described by McQuinn (1986) (FISHΔHER v1.0, Anon, 1986). This method assumes that the F for age 10 is equal to the F for ages 11+ and requires only a F value for age group 11+ in the last year as input. The resulting F vector was used to start the cohort analysis at age 10. The 11+ population numbers are then concatenated to the population matrix.

Mean Weight at Age:

The annual weight at age for each spawning stock was estimated as the mean of the weight at age of each sample stratum and gear, weighted by their corresponding landings (McQuinn, 1987b)(WEIGHTΔAGE v1.0). These weight-at-age matrices (Table 14) were used to estimate the catch and population biomasses.

Age by Age Calibration of Cohort Analyses:

Cohort analyses were calibrated age by age using the adaptive framework (Gavaris, 1987). The formulation involved estimating mean population numbers (N) at ages 4 through 11+ in 1988 and the age-specific coefficients (q) by predicting the gillnet catch rates at age (in numbers), using the minimization of the residual sums of squares in the ln scale as the objective criteria. Two gillnet catch-rate-at-age matrices were calculated for each stock by dividing the gillnet catch at age by the annual gillnet effort from the multiplicative model for (a) the commercial purchase slip data and (b) the gillnet logbooks from the indexed fishermen. The calibrations were made using both the commercial and logbook indices simultaneously in the model, where common age-specific coefficients were estimated. As the two catch-rate indices were not directly comparable, a scaling factor relating the two series was also estimated by the model. An initial calibration showed the intercepts to be non-significant. A summary of the formulation used in the calibration is as follows:

Parameters:
- year-class estimates: $N_{i,1988}$ i=4-11+
- calibration constants: q_i i=4-11+
- calibration constant (scaling factor): q_2
- number of parameters: 17

Structure:
- F for oldest age-group (11+) = F at age 10 (CALCΔFOLD)
- model did not include an intercept term (non-significant)

Input:
- Catch at age: $C_{i,t}$ i=2-11+; t=1973-88
- commercial catch rates: $CPUE_{i,t}$ i=4-11+; t=1977-88
- logbook catch rates: $CPUE_{i,t}$ i=4-11+; t=1984-88
- number of observations: 136

Objective function:
- log transformation

ASSESSMENT RESULTS AND DISCUSSION

The estimated population numbers in 1988 for ages 4 through 11+ and the age-specific regression coefficients were all statistically significant for both the spring and fall spawners except for the age 4 spring-spawner numbers (Tables 15). The mean square residuals were 0.703 and 0.525 for spring and fall spawners, respectively. The coefficients of variation for the spring-spawner 1988 numbers were 65% for age 4, 48% for age 5, 39% for age 6, and ranged from 31 and 35% for ages 7 through 11+. The coefficients of variation for the fall-spawner 1988 numbers were 47% for age 4, 42% for age 5, and ranged from 30 and 35% for ages 7 through 11+. The correlations between parameters were non-significant (Table 16).

These analyses indicated that the spring-spawner 4+ mid-year biomass dropped more or less steadily between 1973 and 1983 (Table 17), primarily due to poor recruitment since the appearance of the 1968 year-class (Table 18), and more than doubled in 1984 with the recruitment of the 1980 year-class. The spring-spawner weighted 5+ terminal F in 1988 was estimated at 0.166 (Table 19). This years analyses also indicated that in 1987, the spring-spawner 5+ biomass and terminal fishing mortality were 97,848 t and 0.12, respectively, comparable to the values of 127,869 t and 0.10 estimated for 1987 in last years assessment (McQuinn, 1988).

Cohort analyses indicated that the fall-spawner 4+ mid-year biomass declined continuously between 1973 and 1982 (Table 20), as recruitment had been poor not only during these years (Table 21), but also during the decade following the strong 1958 and 1963 year-classes (McQuinn, 1986). The 4+ biomass more than doubled in 1983 to reach 1976 levels as the 1979 year-class entered the fishery. The 1987 fall-spawner weighted 6+ terminal F was estimated at 0.131 (Table 22). This represents a 2.6 fold increase in the estimate of the 1987 terminal F for the fall-spawning stock over last years estimate (McQuinn, 1988), and therefore a drastic change in the perception of the size of this stock. This significant change was largely due to the reduction of the 1985 and 1986 catch rates, as noted previously, and the decline in CPUE from 1987 to 1988. It is of note that the age-aggregated calibration conducted last year would have been strongly influenced by the high 1987 catch rate and that last years unusually high population-number estimates were considered tentative. The use of the adaptive framework (i.e. log transformation of index data) and the two catch rate series this year appeared to dampen the affect of the high 1987 catch rate.

These analyses indicated the 1988 partial recruitments for spring and fall spawners as shown below. There was no clear and consistant fully-recruited ages-group:

Age	4	5	6	7	8	9	10	11
Spring	.053	.072	.273	.560	.481	.558	1.000	.972
Fall	.987	.097	.497	.863	1.000	.501	.716	.773

PROGNOSIS

Projections for 1989 and 1990 were calculated using a fully-recruited

terminal F of 0.3. The input data used for the projections were (a) population numbers obtained from the ADAPT calibration of the cohort analyses, (b) recruitment at age 2, 3 and 4 set to the geometric mean from 1973 to 1984, (c) the weights at age for 1988, and (d) the average partial recruitment from 1986 to 1988 standardized to the mean of ages 7 through 9.

The results of these projections indicated the spring-spawner catch at this exploitation rate to be 18,400 t in 1989 and 14,200 t in 1990 (Table 23), with a coincidental decrease in the population biomass from 102,000 t in 1989 to 87,000 t in 1990. The fall-spawner catch of 6,800 t in 1989 and 5,500 t in 1990 (Table 24) would correspond to a drop in the population biomass from 36,700 t in 1989 to 30,700 t in 1990.

At present, there are two strong year-classes of spring spawners (1982 and 1980) and one of fall spawners (1979) supporting the fishery. These year-classes are presently 6, 8 and 9 years old, respectively and therefore the fishable biomass will continue to decline unless above average recruitment occurs in the next few years. This is nonetheless the usual pattern for these herring stocks, as interannual recruitment has been highly irregular over the past several decades.

REFERENCES

Anon. 1986. CAFSAC Assessment Software Catalog. Assessment Computation Working Group of the CAFSAC Statistics, Sampling and Surveys Subcommittee. CAFSAC Res. Doc. 86/96, 24p.

Beverton, R.J.H. 1963. Maturation, growth and mortality of clupeid and engraulid stocks in relation to fishing. Rapp. P.-v. Réun. Cons. int. Explor. Mer. 154: 44-67.

Cleary, L., J.J. Hunt, J. Moores and D. Tremblay. 1982. Herring aging workshop, St. John's, Newfoundland, March - 1982. CAFSAC Res. Doc. 82/41, 10p.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can J. Fish. Aquat. Sci. 37: 2272-2275.

Gavaris, S. 1987. Assessment of haddock in NAFO division 5Z. CAFSAC Res. Doc. 87/101.

Lea, E. 1930. Report on age and growth of the herring in Canadian waters. Rapp. Cons. Explor. Mer. 65: 100.

McQuinn, I.H. 1986. Assessment of the west coast of Newfoundland herring stocks in 1985. CAFSAC Res. Doc. 86/68, 41p.

McQuinn. I.H. 1987a. New maturity cycle charts for the herring stocks along the west coast of Newfoundland (NAFO division 4R) and the north shore of Quebec (NAFO Division 4S). CAFSAC Res. Doc. 87/66, 11p.

McQuinn. I.H. 1987b. Revisions to the 4R herring catch-at-age matrices. CAFSAC Res. Doc. 87/68, 23p.

McQuinn, I.H. 1988. An assessment of the west coast of Newfoundland (NAFO division 4R) herring resource in 1987. CAFSAC Res. Doc. 88/52, 40p.

McQuinn, I.H. 1989. Identification of spring- and autumn-spawning herring (Clupea harengus harengus) using maturity stages assigned from a gonadosomatic index model. Can. J. Fish. Aquat. Sci. 46(6):969-980.

Moores, J.A. 1983. A re-examination of the catch matrix utilized for the assessment of the Newfoundland west coast herring stock. CAFSAC Res. Doc. 83/6, 25p.

Moores, J.A. and G.H. Winters. 1977. Production and yield of western Newfoundland herring stocks. CAFSAC Res. Doc. 77/3, 17p.

Moores, J.A. and G.H. Winters. 1980. An assessment of the status of the Newfoundland west coast herring stock. CAFSAC Res. Doc. 80/51, 25p.

Runnström, S. 1936. A study of the life history and migrations of the Norwegian spring herring based on an analysis of the winter rings and summer zones on the scale. Fiskeridir. Skr. Havunders. 5(2): 1-103.

Wheeler, J.P. and G.H. Winters. 1983. 1982 east coast Newfoundland herring assessment. CAFSAC Res. Doc. 83/18, 31p.

Table 1. Herring catches (t) by gear type and fishing area and total allowable catches from NAFO Division 4R from 1966 to 1988.

YEAR	4Rd				4Rc				4Rb				4Ra				COMBINED				TAC
	Purse seine	Gill-net	Other gears*	Total	Purse seine	Gill-net	Other gears	Total	Purse seine	Gill-net	Other gears	Total	Purse seine	Gill-net	Other gears	Total	Purse seine	Gill-net	Other gears	Total	
1966	0	216	0	216	0	103	0	103	5491	39	0	5530	0	18	0	18	5491	376	0	5867	
1967	0	215	0	215	0	66	0	66	5464	76	0	5540	0	13	0	13	5464	370	0	5834	
1968	0	156	789	945	0	59	0	59	3776	67	136	3979	0	11	0	11	3776	293	925	4994	
1969	241	33	6	280	0	46	0	46	2344	201	4	2549	0	68	1	69	2585	348	11	2944	
1970	28	410	3	441	12	81	17	110	2939	526	4	3469	0	763	92	855	2979	1780	116	4875	
1971	3287	424	427	4138	2239	333	24	2596	725	405	21	1151	356	2252	11	2619	6607	3414	483	10504	
1972	4743	351	866	5960	727	134	64	925	1330	214	0	1544	0	4619	146	4765	6800	5318	1076	13194	
1973	12112	428	0	12540	2740	122	0	2862	1763	302	2	2067	3453	6047	15	9515	20068	6899	17	26984	
1974	2465	159	0	2624	756	96	4	856	439	456	47	942	1071	1959	5	3035	4731	2670	56	7457	
1975	3221	117	3	3341	0	97	16	113	0	216	26	242	0	1076	22	1098	3221	1506	67	4794	
1976	6067	496	3	6566	1956	111	2	2069	0	207	20	227	184	1477	140	1801	8207	2291	165	10663	
1977	5289	273	7	5569	2009	193	3	2205	0	125	31	156	2155	2428	183	4766	9453	3019	224	12696	12000
1978	6252	523	33	6808	1037	931	16	1984	0	284	81	365	1834	4103	22	5959	9123	5841	152	15116	12500
1979	4387	1641	3	6031	2774	2267	2	5043	2829	1048	121	3998	0	3247	7	3254	9990	8203	133	18326	12500
1980	3499	1557	41	5097	3703	3224	17	6944	2002	878	88	2968	428	3681	5	4114	9632	9340	151	19123	18000
1981	2269	1367	2	3638	3277	1623	0	4900	2037	912	140	3089	342	1600	27	1969	7925	5502	169	13596	16000
1982	0	1462	3	1465	5575	1572	11	7158	3973	517	58	4548	0	1675	1	1676	9548	5226	73	14847	10000
1983	0	1410	2	1412	3269	873	46	4188	3223	226	108	3557	787	1438	34	2259	7279	3947	190	11416	10000
1984	0	1006	1	1007	3023	902	0	3925	4166	554	2	4722	15	809	4	828	7206	3271	7	10482	10000
1985	1720	398	0	2118	1733	164	0	1897	9718	348	4	10070	0	295	6	301	13171	1205	10	14386	10000
1986	1854	273	0	2127	1586	1069	0	2655	15830	468	0	16298	0	337	0	337	19270	2147	0	21417	17000
1987	222	550	0	772	3183	1137	0	4320	10164	327	5	10496	164	829	0	993	13733	2843	5	16581	30600
1988	-	435	-	-	-	592	-	-	-	256	-	-	-	509	-	-	16475	1792	-	18267[1]	30600

* Includes shrimp trawl, bar seine, trap midwater trawl and otter trawl.

[1] Preliminary

Table 2. Herring landings (t) in NAFO division 4R by gear type, unit area and month from 1983 to 1988.

GEAR	YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
PS	1983	4Ra											604	183	787
		4Rb										480	2263	480	3223
		4Rc				2289	980								3269
		4Rd													0
	1984	4Ra											15		15
		4Rb				24						1090	1763	1289	4166
		4Rc	309			2714									3023
		4Rd													0
	1985	4Ra													0
		4Rb								482		526	5577	3133	9718
		4Rc					1464	99				170			1733
		4Rd					1720								1720
	1986	4Ra													0
		4Rb										3091	10608	2131	15830
		4Rc					1400		186						1586
		4Rd				185	1669								1854
	1987	4Ra											164		164
		4Rb					25			14		748	4426	4951	10164
		4Rc					1319	596			153	565	379	171	3183
		4Rd					222								222
	1988	4R				923	6239	1234	22	22	65	417	3030	4523	16475
GN	1983	4Ra				9	5	43	235	535	233	82	159	137	1438
		4Rb				29	48	9	23	18	6	25	29	39	226
		4Rc	2	1	5	394	358	44	36	26		2	2	3	873
		4Rd	1	2	15	887	429	29	25	12	3	5		2	1410
	1984	4Ra	19				1	47	99	154	131	225	122	11	809
		4Rb				64	117	82	3	2	59	76	138	13	554
		4Rc				248	208	47	24	15	7	199	106	48	902
		4Rd				253	673	30	21	9	8	8	3	1	1006
	1985	4Ra					1	4		20	152	2	112	4	295
		4Rb				1	22	38	2	11	6	26	234	8	348
		4Rc				2	93	28	11	9	4	11	1	5	164
		4Rd					324	28	19	5	11	10		1	398
	1986	4Ra					65	84	19	48	28	68	14	11	337
		4Rb				6	48	46	14	9	8	136	171	30	468
		4Rc				132	319	105	21	10	8	141	319	14	1069
		4Rd				100	83	49	21	10	10				273
	1987	4Ra					19	21	14	142	65	192	353	23	829
		4Rb	1		1	15	22	23	11	7	5	87	135	20	327
		4Rc				146	580	96	77	52	13	55	117	1	1137
		4Rd				146	319	30	22	8	8	13	4		550
	1988	4Ra					14			18	5	208	225	38	508
		4Rb				11	15	23	7	4	2	60	114	21	257
		4Rc				34	61	227	186	10	4	7	18	45	592
		4Rd				108	113	43	142	8	8	11	1		434

Table 3. Proportion (%) of spring- and fall-spawning herring in the purse seine catch by month and fishing area, NAFO Division 4R from 1973 to 1988.

SPAWNING GROUP	FISHING AREA 4Rd		4Rc								4Rb							4Ra				
SPRING	APR	MAY	JAN	APR	MAY	JUN	JUL	SEP	OCT	DEC	JAN	APR	AUG	SEP	OCT	NOV	DEC	JUL	AUG	OCT	NOV	DEC
1973	51.3			36.7	64.7						91.3				91.0	90.8						76.7
1974	68.3	39.1															92.6					
1975	98.0	84.7																				
1976	90.4	97.8			52.3																	87.7
1977	95.4	99.0			32.4															47.3	89.3	
1978	82.4			81.9																	85.8	84.4
1979	86.2			43.2	26.0											93.3					91.6	86.7
1980	95.2			98.0						73.4						88.2						
1981	96.4	92.0		97.3											87.3	63.5	55.7					
1982				99.8	98.0			65.0							78.8	77.7						
1983				61.0	54.5				73.8							79.8	68.9				74.7	62.7
1984			76.4	43.9								40.9			76.9	64.5	60.5				62.0	
1985		92.0			66.0	49.7			82.6				23.8		71.0	70.0	67.7					
1986	77.0	100.0			93.6		78.0								77.3	74.8	71.0					
1987		97.0		100.0	93.0	100.0		65.3	84.7				0.0		74.5	76.9	72.1				28.0	
1988	83.6	99.5			34.0	100.0						37.5		62.0	41.3	65.8	72.1	28.0	2.0			
FALL																						
1973	48.7			63.3	35.3						8.7				9.0	9.2						23.3
1974	31.7	60.9															7.4					
1975	2.0	15.3																				
1976	9.6	2.2			47.7																	12.3
1977	4.6	1.0			67.6															52.7	10.7	
1978	17.6			18.1																	14.2	15.6
1979	13.8			56.8	74.0											6.7					8.4	13.3
1980	4.8			2.0						26.6						11.7						
1981	3.6	8.0		2.7											12.7	36.5	44.3					
1982				0.2	2.0			35.0							21.2	22.3						
1983				39.0	45.5				26.2							20.2	31.1				25.3	37.3
1984			23.6	56.1								59.1			23.1	35.5	39.5				38.0	
1985		8.0			34.0	50.3			17.4				76.2		29.0	30.0	32.3					
1986	23.0	0.0			6.4		22.0								22.7	25.2	29.0					
1987		3.0		0.0	7.0	0.0		34.7	15.3				100.0		25.5	23.1	27.9				72.0	
1988	16.4	0.5			66.0	0.0						62.5		38.0	58.7	34.2	27.9	72.0	98.0			

Table 4. Proportion (%) of spring- and fall-spawning herring in the gillnet catch by month and fishing area, NAFO division 4R from 1973 to 1988.

SPAWNING GROUP	FISHING AREA 4Rd			4Rc						4Rb							4Ra							
SPRING	APR	MAY	JUN	APR	MAY	JUN	JUL	SEP	OCT	MAY	JUN	JUL	SEP	OCT	NOV	DEC	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1973												32.3		29.0	81.2				14.4				62.4	
1974											99.0					86.5				14.3			50.0	
1975		90.0									55.3	12.0												
1976		100.0									98.0								5.3				76.7	
1977											83.3	18.0				86.0		66.0	32.2	8.0	25.7	56.6	78.0	
1978		99.0								85.7	98.0							52.0	33.6				78.9	
1979	84.0			92.8						95.0					84.0				38.7	11.7	44.0	56.0		
1980	96.4			91.1						100.0					81.8		63.3	55.6	34.1	3.0	42.9	72.0	66.0	
1981				95.8						82.4	91.0							37.0	24.9	0.7			43.8	
1982					97.2										64.9				2.7					
1983		95.7											80.0	46.1	41.8				39.6	1.4	46.3	56.9	56.3	68.2
1984		94.1			78.5				84.0					60.2		44.9				8.6	27.9	63.0	36.0	52.7
1985		97.7			86.5	90.0													80.0	9.5	15.7		28.0	
1986	84.4	98.4		50.0	83.7			66.0	80.0						54.4				16.8	10.1	32.0	44.1	27.1	
1987	92.0	99.4		52.0	84.7	88.6								52.2						14.2	26.0	49.5	37.5	
1988	98.0	99.6	96.0	73.5	78.3	81.4	76.0								68.1				28.0	11.8	27.0	41.3	52.8	42.0
FALL																								
1973												67.7		71.0	18.8				85.6				37.6	
1974											1.0					13.5				85.7			50.0	
1975		10.0									44.7	88.0												
1976		0.0									2.0								94.7				23.3	
1977											16.7	82.0				14.0		34.0	67.2	92.0	74.3	43.4	22.0	
1978		1.0								14.3	2.0							48.0	66.4				21.1	
1979	16.0			7.2						5.0					16.0				61.3	88.2	56.0	44.0		
1980	3.6			8.9						0.0					18.2		36.7	44.4	65.9	97.0	57.1	28.0	34.0	
1981				4.2						17.6	9.0							63.0	75.1	99.3			56.3	
1982					2.8										35.1				97.3					
1983		4.3											20.0	53.9	58.2				60.4	98.6	53.7	43.1	43.7	31.8
1984		5.9			21.5				16.0					39.8		55.1				91.4	72.1	37.0	64.0	47.3
1985		2.3			13.5	10.0													20.0	90.5	84.3		72.0	
1986	15.6	1.6		50.0	16.3			34.0	20.0						45.6				83.2	89.9	68.0	55.9	72.9	
1987	8.0	0.6		48.0	15.3	11.4								47.8						85.8	74.0	50.5	62.5	
1988	2.0	0.4	4.0	26.5	21.7	18.6	24.0								31.9				72.0	88.2	73.0	58.7	47.2	58.0

Table 5. Spring- and fall-spawner catch at age ($x10^{-3}$) and proportion of spring spawners in NAFO division 4R herring landings from 1973 to 1988.

SPRING SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	0	0	0	0	45	0	0	3	13	0	4	39	48	265	323	183
2	1833	141	57	484	10	0	167	300	40	594	34	198	362	323	455	734
3	435	261	996	680	534	47	25	854	417	2374	2965	433	4587	2348	329	519
4	1063	130	420	846	541	1987	214	106	2114	693	3562	7773	787	13762	2781	417
5	27872	371	100	201	409	207	10828	355	129	2452	1131	3809	21642	3349	15257	2400
6	2570	9445	1063	350	304	679	617	13872	354	421	1091	595	3993	28781	3507	14830
7	3222	318	8431	2802	348	241	1075	407	8872	2153	293	814	445	5241	12952	4004
8	3232	851	317	15567	4362	2162	547	1344	188	6488	713	209	381	465	1736	14606
9	2598	774	336	759	15959	8208	2772	247	515	704	2990	672	255	167	182	2734
10	4789	490	244	3136	1694	15260	7404	1427	283	950	798	755	380	260	37	480
11+	5696	2175	665	3588	6003	5062	14032	20574	13181	12863	7975	4226	1764	1661	806	2123
1+	53310	14955	12629	28413	30210	33851	37681	39488	26106	29692	21556	19523	34645	56621	38365	43030

FALL SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
2	0	0	0	0	0	0	0	15	0	101	15	0	15	35	0	483
3	1798	20	19	48	3	10	7	181	33	567	83	55	235	426	156	186
4	1180	393	40	272	169	27	116	136	524	1824	2330	668	1340	1431	487	520
5	1114	530	865	290	134	545	345	86	245	956	1356	6259	1907	2671	1354	490
6	2626	325	925	422	404	393	2689	176	90	509	1309	1147	9678	2292	2009	1026
7	1527	592	107	561	721	1108	520	1729	295	140	506	908	902	8421	1728	1267
8	2631	258	157	325	405	1689	1287	250	1234	377	159	220	622	794	5927	1503
9	3830	308	147	253	342	503	1847	675	153	972	467	146	115	384	474	3798
10	8265	313	218	88	293	341	468	308	124	315	618	268	36	66	163	501
11+	17653	5610	3371	4818	6646	6051	6286	5243	3369	2609	2824	3091	468	227	196	671
1+	40626	8348	5848	7076	9116	10668	13564	8799	6067	8371	9667	12762	15333	16745	12494	10445

TOTAL (SPRING AND FALL)

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
93937	23303	18477	35489	39326	44520	51245	48288	32173	38062	31223	32286	49978	73366	50859	53475

PERCENT SPRING SPAWNERS

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
%	56.8	64.2	68.4	80.1	76.8	76.0	73.5	81.8	81.1	78.0	69.0	60.5	69.3	77.2	75.4	80.5

Table 6. Age composition (%) and mean age* of (A) spring and (B) fall spawners in NAFO division 4R herring landings from 1973 to 1988. Dominant year-classes have been underlined.

A) SPRING SPAWNER AGE COMPOSITION (%)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	.0	.0	.0	.0	.1	.0	.0	.0	.1	.0	.0	.2	.1	.5	.8	.4
2	3.4	.9	.5	1.7	.0	.0	.4	.8	.2	2.0	.2	1.0	1.0	.6	1.2	1.7
3	.8	1.7	7.9	2.4	1.8	.1	.1	2.2	1.6	8.0	13.8	2.2	13.2	4.1	.9	1.2
4	2.0	.9	3.3	3.0	1.8	5.9	.6	.3	8.1	2.3	16.5	39.8	2.3	24.3	7.2	1.0
5	52.3	2.5	.8	.7	1.4	.6	28.7	.9	.5	8.3	5.2	19.5	62.5	5.9	39.8	5.6
6	4.8	63.2	8.4	1.2	1.0	2.0	1.6	35.1	1.4	1.4	5.1	3.0	11.5	50.8	9.1	34.5
7	6.0	2.1	66.8	9.9	1.2	.7	2.9	1.0	34.0	7.3	1.4	4.2	1.3	9.3	33.8	9.3
8	6.1	5.7	2.5	54.8	14.4	6.4	1.5	3.4	.7	21.9	3.3	1.1	1.1	.8	4.5	33.9
9	4.9	5.2	2.7	2.7	52.8	24.2	7.4	.6	2.0	2.4	13.9	3.4	.7	.3	.5	6.4
10	9.0	3.3	1.9	11.0	5.6	45.1	19.6	3.6	1.1	3.2	3.7	3.9	1.1	.5	.1	1.1
11+	10.7	14.5	5.3	12.6	19.9	15.0	37.2	52.1	50.5	43.3	37.0	21.6	5.1	2.9	2.1	4.9

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
MEAN AGE	6.50	7.02	6.81	8.14	9.00	9.29	8.61	8.74	8.76	8.43	7.69	6.31	5.25	5.59	5.90	7.05

B) FALL SPAWNER AGE COMPOSITION (%)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.2	.0	1.2	.2	.0	.1	.2	.0	4.6
3	4.4	.2	.3	.7	.0	.1	.1	2.1	.5	6.8	.9	.4	1.5	2.5	1.3	1.8
4	2.9	4.7	.7	3.8	1.9	.2	.9	1.5	8.6	21.8	24.1	5.2	8.7	8.5	3.9	5.0
5	2.7	6.4	14.8	4.1	1.5	5.1	2.5	1.0	4.0	11.4	14.0	49.0	12.4	15.9	10.8	4.7
6	6.5	3.9	15.8	6.0	4.4	3.7	19.8	2.0	1.5	6.1	13.5	9.0	63.1	13.7	16.1	9.8
7	3.8	7.1	1.8	7.9	7.9	10.4	3.8	19.7	4.9	1.7	5.2	7.1	5.9	50.3	13.8	12.1
8	6.5	3.1	2.7	4.6	4.4	15.8	9.5	2.8	20.3	4.5	1.6	1.7	4.1	4.7	47.4	14.4
9	9.4	3.7	2.5	3.6	3.8	4.7	13.6	7.7	2.5	11.6	4.8	1.1	.7	2.3	3.8	36.4
10	20.3	3.8	3.7	1.3	3.2	3.2	3.5	3.5	2.0	3.8	6.4	2.1	.2	.4	1.3	4.8
11+	43.5	67.2	57.6	68.1	72.9	56.7	46.3	59.6	55.5	31.2	29.2	24.2	3.1	1.4	1.6	6.4

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
MEAN AGE	9.22	9.59	9.01	9.59	10.00	9.47	9.05	9.49	9.16	7.36	7.29	6.83	5.98	6.33	7.11	7.63

* assuming ages 11+ to be 11.

Table 7. Gang size estimates by unit area, standardized to 1978, used to adjust the gillnet catch rates from 1977 to 1988 for the multiplicative model.

	4Ra		4Rb		4Rc		4Rd	
YEAR	GANG	n	GANG	n	GANG	n	GANG	n
1977	1.02	30	1.02	30	1.02	30	1.02	30
1978	1.00	90	1.00	90	1.00	90	1.00	90
1979	1.19	139	1.19	139	1.19	139	1.19	139
1980	1.31	149	1.31	149	1.31	149	1.31	149
1981	1.72	99	1.72	99	1.72	99	1.72	99
1982	1.84	129	2.04	132	2.16	97	1.66	87
1983	1.95	112	2.28	117	2.29	87	1.78	92
1984	2.02	101	2.41	113	2.37	73	2.04	78
1985	0.94	23		2.22	39[1]		1.87	25
1986	1.84	17		2.36	42[1]		1.25	8
1987	1.68	18		1.40	8[1]		0.98	13
1988	1.79	9		1.62	5[1]		0.53	9

[1] Estimates for 4Rb and 4Rc from 1985 to 1988 are combined.

Table 8. Analysis of variance and regression coefficients for the 1977 to 1988 commercial spring-spawner catch rate data.

REGRESSION OF MULTIPLICATIVE MODEL

Multiple R..... 0.808
Multiple R squared..... 0.653

ANALYSIS OF VARIANCE

Source of variation	DF	Sums of squares	Mean squares	F
Intercept	1	3.267E0001	3.267E0001	
Regression	23	1.635E0001	7.110E-001	20.547
(Month) Type 1	9	1.172E0001	1.303E0000	37.646
(Area) Type 2	3	3.787E-001	1.262E-001	3.648
(Year) Type 3	11	2.817E0000	2.561E-001	7.402
Residuals	251	8.685E0000	3.460E-002	
TOTAL	275	5.771E0001		

REGRESSION COEFFICIENTS

Category		Code	Variable	Coefficient	Std. Error	No. Obs.
	1	5	Intercept	-0.027	0.254	275
	2	414				
	3	77				
Month	1	3	1	-0.726	0.507	4
		4	2	-0.244	0.141	28
		6	3	-1.247	0.207	35
		7	4	-1.993	0.213	26
		8	5	-3.488	0.227	26
		9	6	-1.943	0.216	27
		10	7	-0.828	0.168	35
		11	8	-0.413	0.174	33
		12	9	-0.001	0.276	19
Area	2	411	10	-0.193	0.177	79
		412	11	-0.413	0.166	80
		413	12	0.048	0.135	72
Year	3	78	13	0.376	0.266	25
		79	14	-0.016	0.253	33
		80	15	0.077	0.254	25
		81	16	-0.608	0.260	28
		82	17	-0.738	0.265	23
		83	18	-0.648	0.263	23
		84	19	-0.629	0.261	26
		85	20	-0.772	0.351	20
		86	21	-0.351	0.315	24
		87	22	0.334	0.305	20
		88	23	-0.309	0.314	16

Table 9. Analysis of variance and regression coefficients for the 1977 to 1988 commercial fall-spawner catch rate data.

REGRESSION OF MULTIPLICATIVE MODEL

Multiple R..... 0.811
Multiple R squared..... 0.658

ANALYSIS OF VARIANCE

Source of variation	DF	Sums of squares	Mean squares	F
Intercept	1	6.179E0001	6.179E0001	
Regression	23	1.856E0001	8.067E-001	20.589
(Month) Type 1	9	4.860E0000	5.400E-001	13.782
(Area) Type 2	3	1.131E0000	3.769E-001	9.619
(Year) Type 3	11	1.533E0000	1.394E-001	3.557
Residuals	246	9.639E0000	3.918E-002	
TOTAL	270	8.998E0001		

REGRESSION COEFFICIENTS

Category		Code	Variable	Coefficient	Std. Error	No. Obs.
	1	8	Intercept	-0.537	0.242	270
	2	411				
	3	77				
Month	1	3	1	-2.520	0.710	4
		4	2	-1.874	0.225	26
		5	3	-1.800	0.204	39
		6	4	-1.567	0.228	33
		7	5	-0.399	0.170	27
		9	6	-0.555	0.176	28
		10	7	-0.758	0.166	35
		11	8	-0.455	0.171	33
		12	9	-0.264	0.283	19
Area	2	412	10	-0.427	0.129	77
		413	11	-0.237	0.149	70
		414	12	-0.985	0.206	42
Year	3	78	13	0.020	0.275	25
		79	14	-0.105	0.261	33
		80	15	-0.046	0.257	22
		81	16	-0.239	0.259	29
		82	17	-0.620	0.262	24
		83	18	-0.676	0.267	23
		84	19	-0.317	0.267	26
		85	20	-0.238	0.372	20
		86	21	-0.288	0.325	24
		87	22	0.502	0.307	20
		88	23	-0.355	0.322	16

Table 10. Predicted mean commercial catch rate and effort estimates for (a) spring- and (b) fall-spawning herring in NAFO Division 4R from 1977 to 1988.

a) Predicted spring spawner catch rates:

Standards used. Variable codes: 5 414

	Catch		Catch rate		
Year	Weight	Prop.	Mean	S.E.	Effort
1977	1717	0.230	0.959	0.240	1791
1978	3402	0.505	1.418	0.254	2399
1979	5772	0.653	0.962	0.152	6001
1980	5933	0.636	1.055	0.174	5624
1981	3534	0.759	0.532	0.088	6646
1982	3575	0.734	0.466	0.078	7664
1983	2710	0.601	0.510	0.089	5316
1984	2217	0.800	0.521	0.087	4259
1985	682	0.475	0.441	0.119	1548
1986	1368	0.300	0.677	0.162	2021
1987	1671	0.320	1.346	0.305	1241
1988	1250	0.300	0.705	0.172	1773

Average C.V. for the Mean: .201

b) Predicted fall spawner commercial catch rates:

Standards used. Variable codes: 8 411

	Catch		Catch rate		
Year	Weight	Prop.	Mean	S.E.	Effort
1977	1589	0.390	0.579	0.138	2744
1978	2609	0.427	0.597	0.113	4369
1979	2629	0.583	0.529	0.087	4966
1980	3578	0.861	0.563	0.086	6354
1981	1971	0.846	0.463	0.075	4253
1982	1693	0.858	0.316	0.054	5356
1983	1238	0.823	0.299	0.052	4144
1984	1242	0.670	0.428	0.076	2905
1985	523	0.181	0.447	0.138	1170
1986	779	0.202	0.432	0.110	1802
1987	1172	0.402	0.959	0.219	1222
1988	541	0.580	0.405	0.102	1337

Average C.V. for the Mean: .206

Table 11. Analysis of variance and regression coefficients for the 1984 to 1988 spring-spawner logbook catch rate data.

REGRESSION OF MULTIPLICATIVE MODEL

Multiple R..... 0.638
Multiple R squared..... 0.408

ANALYSIS OF VARIANCE

Source of variation	DF	Sums of squares	Mean squares	F
Intercept	1	6.312E0002	6.312E0002	
Regression	9	9.726E0002	1.081E0002	87.450
(Month) Type 1	5	5.613E0002	1.123E0002	90.837
(Year) Type 3	4	1.097E0002	2.744E0001	22.201
Residuals	1144	1.414E0003	1.236E0000	
TOTAL	1154	3.018E0003		

REGRESSION COEFFICIENTS

Category	Code	Variable	Coefficient	Std. Error	No. Obs.
1	8	Intercept	-0.184	0.087	1154
3	85				
Month 1	4	1	1.307	0.149	61
	5	2	1.632	0.078	376
	6	3	0.845	0.128	81
	7	4	0.757	0.144	63
	9	5	0.585	0.109	132
Year 3	84	6	-0.641	0.143	96
	86	7	0.425	0.107	223
	87	8	0.516	0.101	278
	88	9	0.125	0.099	355

Table 12. Analysis of variance and regression coefficients for the 1984 to 1988 fall-spawner logbook catch rate data.

REGRESSION OF MULTIPLICATIVE MODEL

Multiple R..... 0.716
Multiple R squared..... 0.513

ANALYSIS OF VARIANCE

Source of variation	DF	Sums of squares	Mean squares	F
Intercept	1	7.943E0002	7.943E0002	
Regression	9	3.354E0003	3.727E0002	134.008
(Month) Type 1	5	2.210E0003	4.420E0002	158.914
(Year) Type 3	4	1.669E0002	4.171E0001	14.998
Residuals	1144	3.182E0003	2.781E0000	
TOTAL	1154	7.331E0003		

REGRESSION COEFFICIENTS

Category	Code	Variable	Coefficient	Std. Error	No. Obs.
1	8	Intercept	1.782	0.103	1154
3	85				
Month 1	4	1	-1.465	0.195	61
	5	2	-2.590	0.105	376
	6	3	-2.787	0.195	81
	7	4	0.043	0.162	63
	9	5	-0.160	0.120	132
Year 3	84	6	-0.718	0.154	96
	86	7	0.374	0.132	223
	87	8	0.178	0.124	278
	88	9	-0.185	0.123	355

Table 13. Predicted mean logbook catch rate and effort estimates for (a) spring- and (b) fall-spawning herring in NAFO Division 4R from 1984 to 1988.

b) Predicted spring-spawner logbook catch rates:

Standards used. Variable codes: 8

	Catch		Catch rate		
Year	Weight	Prop.	Mean	S.E.	Effort
1984	2217	0.425	1.537	0.134	1442
1985	682	5.514	0.807	0.100	845
1986	1368	1.970	2.352	0.195	582
1987	1671	3.350	2.578	0.201	648
1988	1250	2.226	1.743	0.133	717

Average C.V. for the Mean: .090

b) Predicted fall-spawner logbook catch rates:

Standards used. Variable codes: 8

	Catch		Catch rate		
Year	Weight	Prop.	Mean	S.E.	Effort
1984	1242	0.397	2.378	0.244	522
1985	523	0.562	1.157	0.144	452
1986	779	0.463	3.457	0.342	225
1987	1172	0.526	2.844	0.255	412
1988	541	0.670	1.979	0.176	273

Average C.V. for the Mean: .101

Table 14. Annual weight at age (weighted by landings) for (A) spring- and (B) fall-spawning herring in NAFO Division 4R from 1973 to 1987.

A) ANNUAL SPRING SPAWNER WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	101	129	77	69	64	103	115	117	85	95	142	134	109	142	165	154
3	158	172	156	122	156	184	121	201	196	216	190	206	168	171	235	196
4	224	223	197	193	208	228	234	247	262	263	263	239	247	230	250	224
5	222	236	242	241	247	275	268	298	327	290	305	297	283	268	289	258
6	268	262	243	252	278	305	319	321	344	357	337	348	329	315	349	303
7	303	300	279	269	262	313	343	354	385	386	385	379	373	338	370	342
8	322	324	301	299	290	318	357	380	415	395	424	406	404	413	390	375
9	333	351	335	315	313	340	366	398	430	423	434	431	434	415	428	390
10	350	335	350	334	332	362	373	389	429	434	492	437	425	449	422	457
11+	367	384	382	382	353	393	409	430	472	454	475	485	477	459	515	486

B) ANNUAL FALL SPAWNER WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	131	131	131	131	131	131	131	122	131	166	105	131	50	105	105	115
3	105	171	120	107	250	161	218	222	204	150	205	164	155	157	187	140
4	156	218	188	155	229	238	216	242	280	252	218	209	202	214	235	218
5	231	259	266	282	250	282	281	360	328	306	268	249	258	240	272	258
6	274	265	297	271	255	316	308	341	358	328	309	293	292	280	319	282
7	297	284	352	287	301	345	355	404	406	449	338	343	326	317	334	307
8	329	307	323	277	321	367	381	419	436	441	374	359	347	340	363	354
9	334	355	370	308	308	366	405	461	485	444	430	429	374	356	364	376
10	346	378	391	426	330	390	408	468	498	485	462	450	444	363	390	400
11+	382	422	465	454	421	471	458	534	515	507	503	494	432	465	513	429

Table 15. Parameter estimates, standard errors, T-statistics and mean square residuals from the (a) spring-spawner and (b) fall-spawner cohort analyses as estimated from the adaptive framework.

a) Spring Spawners

PARAMETER NO.	PARAMETER EST.	STD. ERROR.	T-STATISTIC
1. age 4 no.	1.53193E0004	9.69278E0003	1.58048E0000
2. age 5 no.	6.85187E0004	3.16943E0004	2.16186E0000
3. age 6 no.	1.22025E0005	4.67908E0004	2.60787E0000
4. age 7 no.	1.80788E0004	6.19518E0003	2.91820E0000
5. age 8 no.	7.63413E0004	2.61234E0004	2.92234E0000
6. age 9 no.	1.27956E0004	4.26218E0003	3.00213E0000
7. age 10 no.	1.36845E0003	4.12945E0002	3.31388E0000
8. age 11+ no.	5.91217E0003	1.85827E0003	3.18154E0000
9. age 4 coef.	1.29048E-003	3.20374E-004	4.02806E0000
10. age 5 coef.	5.40177E-003	1.28273E-003	4.21115E0000
11. age 6 coef.	1.10571E-002	2.60722E-003	4.24097E0000
12. age 7 coef.	1.70534E-002	4.05866E-003	4.20173E0000
13. age 8 coef.	1.53265E-002	3.71960E-003	4.12047E0000
14. age 9 coef.	1.89999E-002	4.78730E-003	3.96882E0000
15. age 10 coef.	2.54840E-002	6.79635E-003	3.74965E0000
16. age 11+ coef.	2.37852E-002	6.80997E-003	3.49270E0000
17. scaling factor	2.89942E-001	5.13853E-002	5.64251E0000
ORTHOGONALITY OFFSET.....		0.000000	
MEAN SQUARE RESIDUALS		0.703466	

b) Fall Spawners

PARAMETER NO.	PARAMETER EST.	STD. ERROR.	T-STATISTIC
1. age 4 no.	2.61864E0003	1.16311E0003	2.25142E0000
2. age 5 no.	2.36376E0004	9.74531E0003	2.42554E0000
3. age 6 no.	1.08250E0004	3.76371E0003	2.87615E0000
4. age 7 no.	8.21479E0003	2.70500E0003	3.03690E0000
5. age 8 no.	8.54821E0003	2.67988E0003	3.18977E0000
6. age 9 no.	4.27146E0004	1.33850E0004	3.19122E0000
7. age 10 no.	4.05496E0003	1.24534E0003	3.25610E0000
8. age 11+ no.	5.03691E0003	1.43957E0003	3.49890E0000
9. age 4 coef.	7.91636E-004	1.78283E-004	4.44034E0000
10. age 5 coef.	6.14300E-003	1.33690E-003	4.59497E0000
11. age 6 coef.	1.36886E-002	2.98096E-003	4.59203E0000
12. age 7 coef.	2.35698E-002	5.21991E-003	4.51536E0000
13. age 8 coef.	2.44480E-002	5.55091E-003	4.40432E0000
14. age 9 coef.	2.93861E-002	6.87446E-003	4.27468E0000
15. age 10 coef.	2.66397E-002	6.47956E-003	4.11134E0000
16. age 11+ coef.	2.53145E-002	6.41572E-003	3.94570E0000
17. scaling factor	3.94405E-001	6.15498E-002	6.40790E0000
ORTHOGONALITY OFFSET.....		0.000013	
MEAN SQUARE RESIDUALS		0.524742	

Table 16. Correlation matrix of estimated parameters for cohort analyses for (a) spring spawners and (b) fall spawners as estimated from the adaptive framework.

a) Spring spawners

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.000	.151	.140	.132	.129	.109	.103	.132	-.384	-.095	-.081	-.073	-.068	-.065	-.068	-.070	-.146
2	.151	1.000	.194	.183	.179	.162	.144	.186	-.325	-.322	-.114	-.104	-.098	-.094	-.096	-.100	-.198
3	.140	.194	1.000	.223	.220	.202	.185	.231	-.285	-.296	-.312	-.131	-.124	-.120	-.123	-.126	-.236
4	.132	.183	.223	1.000	.254	.239	.221	.275	-.254	-.267	-.286	-.324	-.150	-.147	-.150	-.154	-.262
5	.129	.179	.220	.254	1.000	.273	.258	.328	-.237	-.251	-.277	-.298	-.329	-.177	-.183	-.188	-.285
6	.109	.162	.202	.239	.273	1.000	.284	.378	-.188	-.238	-.259	-.292	-.314	-.353	-.218	-.226	-.278
7	.103	.144	.185	.221	.258	.284	1.000	.435	-.175	-.191	-.244	-.272	-.309	-.335	-.407	-.270	-.269
8	.132	.186	.231	.275	.328	.378	.435	1.000	-.241	-.265	-.297	-.353	-.432	-.515	-.592	-.678	-.299
9	-.384	-.325	-.285	-.254	-.237	-.188	-.175	-.241	1.000	.243	.207	.186	.172	.164	.167	.172	.026
10	-.095	-.322	-.296	-.267	-.251	-.238	-.191	-.265	.243	1.000	.226	.207	.195	.188	.186	.191	.016
11	-.081	-.114	-.312	-.286	-.277	-.259	-.244	-.297	.207	.226	1.000	.231	.221	.214	.215	.215	.016
12	-.073	-.104	-.131	-.324	-.298	-.292	-.272	-.353	.186	.207	.231	1.000	.251	.249	.252	.255	.018
13	-.068	-.098	-.124	-.150	-.329	-.314	-.309	-.432	.172	.195	.221	.251	1.000	.294	.304	.313	.018
14	-.065	-.094	-.120	-.147	-.177	-.353	-.335	-.515	.164	.188	.214	.249	.294	1.000	.356	.374	.019
15	-.068	-.096	-.123	-.150	-.183	-.218	-.407	-.592	.167	.186	.215	.252	.304	.356	1.000	.429	.029
16	-.070	-.100	-.126	-.154	-.188	-.226	-.270	-.678	.172	.191	.215	.255	.313	.374	.429	1.000	.037
17	-.146	-.198	-.236	-.262	-.285	-.278	-.269	-.299	.026	.016	.016	.018	.018	.019	.029	.037	1.000

b) Fall Spawners

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	1.000	.178	.174	.167	.172	.158	.155	.192	-.408	-.139	-.128	-.123	-.120	-.115	-.115	-.114	-.174
2	.178	1.000	.238	.232	.236	.228	.215	.267	-.369	-.366	-.179	-.173	-.169	-.163	-.161	-.160	-.236
3	.174	.238	1.000	.282	.286	.280	.269	.326	-.343	-.358	-.370	-.213	-.208	-.201	-.199	-.197	-.279
4	.167	.232	.282	1.000	.326	.322	.314	.380	-.317	-.341	-.367	-.391	-.244	-.238	-.235	-.233	-.308
5	.172	.236	.286	.326	1.000	.360	.354	.437	-.319	-.337	-.359	-.383	-.408	-.274	-.273	-.272	-.333
6	.158	.228	.280	.322	.360	1.000	.381	.483	-.286	-.342	-.363	-.386	-.405	-.415	-.307	-.307	-.328
7	.155	.215	.269	.314	.354	.381	1.000	.530	-.282	-.303	-.360	-.387	-.412	-.428	-.445	-.345	-.320
8	.192	.267	.326	.380	.437	.483	.530	1.000	-.367	-.399	-.431	-.488	-.549	-.607	-.655	-.697	-.343
9	-.408	-.369	-.343	-.317	-.319	-.286	-.282	-.367	1.000	.321	.292	.278	.271	.262	.262	.262	.093
10	-.139	-.366	-.358	-.341	-.337	-.342	-.303	-.399	.321	1.000	.318	.306	.299	.291	.286	.286	.091
11	-.128	-.179	-.370	-.367	-.359	-.363	-.360	-.431	.292	.318	1.000	.333	.326	.320	.315	.310	.093
12	-.123	-.173	-.213	-.391	-.383	-.386	-.387	-.488	.278	.306	.333	1.000	.360	.357	.356	.354	.095
13	-.120	-.169	-.208	-.244	-.408	-.405	-.412	-.549	.271	.299	.326	.360	1.000	.395	.399	.400	.093
14	-.115	-.163	-.201	-.238	-.274	-.415	-.428	-.607	.262	.291	.320	.357	.395	1.000	.439	.445	.085
15	-.115	-.161	-.199	-.235	-.273	-.307	-.445	-.655	.262	.286	.315	.356	.399	.439	1.000	.482	.082
16	-.114	-.160	-.197	-.233	-.272	-.307	-.345	-.697	.262	.286	.310	.354	.400	.445	.482	1.000	.079
17	-.174	-.236	-.279	-.308	-.333	-.328	-.320	-.343	.093	.091	.093	.095	.093	.085	.082	.079	1.000

Table 17. Mid-year population biomass-at-age (t), estimated from cohort analysis, for spring-spawning herring in NAFO Division 4R from 1973 to 1988.

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	1389	3770	1561	8688	1551	1117	1948	1737	7714	36387	8496	40028	13074	3034	9906	9212
3	6735	1686	3712	2025	16055	3641	1075	2760	2326	16009	59574	10070	41011	16752	4044	9551
4	42734	7699	1539	3611	2699	19086	3793	1787	2771	2469	15460	60623	9828	45168	19604	3100
5	82168	36616	6819	1458	3601	2803	17912	3904	1912	2010	2168	13425	56930	8542	43291	15940
6	7234	73329	30825	5798	1332	3541	2607	14749	3589	1669	1233	1700	11181	46367	8145	33270
7	14222	6003	61885	27607	4858	1153	3069	2193	10080	3185	1342	797	1311	8298	35817	5552
8	5635	11620	4858	52177	23778	4736	1005	2450	1967	5607	2115	1062	427	1039	6155	25740
9	3280	4097	9598	4081	40753	21564	3811	740	1798	1574	2743	1508	854	230	719	4492
10	6770	1990	3126	7753	3317	33823	16870	2434	565	1302	1216	1189	985	630	134	560
11+	8458	10103	9304	10135	12494	12186	35061	38775	29004	18453	11734	7384	5117	4117	3587	2572
2+	178625	156912	133228	123334	110437	103650	87151	71529	61727	88664	106081	137788	140718	134177	131402	109990
3+	177236	153142	131666	114646	108886	102533	85203	69793	54013	52277	97584	97759	127644	131143	121496	100778
4+	170501	151456	127954	112621	92832	98892	84129	67032	51687	36269	38010	87689	86632	114391	117452	91227
5+	127767	143757	126415	109009	90133	79806	80335	65245	48916	33800	22550	27066	76804	69223	97848	88127

Table 18. Population numbers-at-age ($x10^3$), estimated from cohort analysis, for spring-spawning herring in NAFO Division 4R from 1973 to 1988.

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	15274	32275	22407	139213	26778	11975	18768	16346	100297	422801	66122	330294	132715	23605	66347	66344
3	47072	10847	26297	18293	113540	21915	9804	15215	13111	82080	345623	54105	270242	108329	19034	53909
4	210464	38146	8645	20629	14362	92475	17900	8004	11684	10358	65053	280289	43906	217105	86569	15286
5	408842	171352	31114	6697	16124	11269	73915	14462	6457	7653	7854	50038	222447	35235	165298	68360
6	29872	309512	139955	25384	5302	12831	9038	50718	11519	5170	4047	5407	37521	162542	25818	121529
7	51957	22131	244861	113623	20466	4066	9891	6842	28973	9111	3852	2327	3889	27106	107036	17965
8	19326	39623	17832	192846	90492	16441	3111	7126	5233	15693	5511	2888	1168	2781	17451	75914
9	10883	12898	31671	14313	143804	70142	11505	2052	4618	4114	6978	3867	2176	612	1856	12717
10	21397	6559	9860	25626	11032	103296	50001	6911	1457	3316	2731	3007	2558	1551	350	1355
11+	25449	29111	26883	29325	39089	34266	94759	99672	67876	44904	27294	16843	11860	9919	7700	5853
2+	840536	672454	559525	585949	480987	378674	298692	227348	251225	605199	535065	749066	728482	588786	497458	439232
3+	825262	640179	537118	446737	454210	366700	279923	211002	150928	182398	468943	418772	595767	565181	431112	372888
4+	778189	629333	510821	428444	340670	344785	270119	195787	137817	100318	123320	364667	325525	456851	412078	318979
5+	567725	591187	502176	407815	326308	252310	252219	187783	126133	89960	58267	84378	281619	239746	325509	303693

Table 19. Instantaneous fishing mortality matrix, estimated from cohort analysis, for spring spawning herring in NAFO Division 4R from 1973 to 1988.

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	.142	.005	.003	.004	.000	.000	.010	.020	.000	.002	.001	.001	.003	.015	.008	.012
3	.010	.027	.043	.042	.005	.002	.003	.064	.036	.032	.010	.009	.019	.024	.019	.011
4	.006	.004	.055	.046	.043	.024	.013	.015	.223	.077	.062	.031	.020	.073	.036	.031
5	.078	.002	.004	.034	.028	.021	.177	.028	.022	.437	.173	.088	.114	.111	.108	.039
6	.100	.034	.008	.015	.065	.060	.078	.360	.035	.094	.354	.130	.125	.218	.163	.144
7	.071	.016	.039	.028	.019	.068	.128	.068	.413	.303	.088	.489	.135	.240	.144	.281
8	.204	.024	.020	.093	.055	.157	.216	.234	.041	.610	.154	.083	.446	.204	.116	.238
9	.306	.069	.012	.060	.131	.138	.310	.143	.131	.210	.642	.213	.139	.358	.115	.269
10	.282	.086	.028	.145	.185	.177	.178	.257	.240	.377	.386	.322	.179	.204	.122	.491
11+	.282	.086	.028	.145	.185	.177	.178	.257	.240	.377	.386	.322	.179	.204	.122	.505
5+	.104	.028	.025	.075	.105	.150	.178	.258	.238	.391	.344	.162	.120	.204	.125	.166

Table 20. Mid-year population biomass-at-age (t), estimated from cohort analysis, for fall-spawning herring in NAFO Division 4R from 1973 to 1988.

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	1982	1671	4111	1090	478	1184	3273	4015	30924	6643	3320	3489	2012	393	2546	2777
3	2437	2111	1252	2747	1701	481	1612	4534	5500	29026	6706	4221	3376	5154	568	2789
4	2474	3834	1906	1321	4815	1327	526	1461	4637	5539	34345	5586	4260	3770	6242	512
5	2445	3111	3751	2326	1691	4805	1275	684	1588	4025	4439	31663	5494	3873	3609	5516
6	2834	2057	2782	2934	1664	1715	4153	1172	532	1234	3081	3644	28926	4443	3521	2756
7	1423	1799	2148	1984	2568	1729	1462	3576	1084	513	900	2433	3009	23155	3717	2274
8	4067	823	1517	1356	1674	2340	1217	1236	2542	857	307	635	1758	2322	19224	2722
9	3947	2825	732	1142	1156	1441	1555	718	1071	1670	551	232	473	1296	1796	14490
10	18575	2478	2451	639	935	1086	1146	764	361	817	1056	300	144	342	1045	1462
11+	43884	49561	45046	37084	27042	23288	17255	14840	10138	7055	5262	3794	1793	1518	1651	1946
2+	84069	70269	65697	52623	43723	39397	33475	33001	58378	57380	59966	55998	51245	46265	43919	37245
3+	82087	68598	61586	51533	43244	38213	30202	28986	27454	50737	56646	52509	49233	45873	41373	34468
4+	79650	66487	60334	48786	41543	37732	28590	24452	21954	21711	49940	48288	45857	40719	40806	31679
5+	77176	62653	58427	47465	36729	36405	28063	22991	17316	16172	15595	42702	41597	36949	34564	31167

Table 21. Population numbers-at-age ($x10^3$), estimated from cohort analysis, for fall-spawning herring in NAFO Division 4R from 1973 to 1988.

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	16710	14089	34655	9185	4032	9980	27593	36369	260693	44227	34843	29409	44376	4134	26797	26792
3	25743	13681	11535	28373	7520	3301	8171	22591	29763	213437	36119	28514	24078	36318	3353	21940
4	17490	19450	11183	9427	23186	6154	2693	6683	18332	24339	174235	29496	23295	19501	29350	2604
5	11717	13252	15568	9120	7472	18831	5015	2100	5349	14534	18276	140543	23545	17860	14672	23589
6	11437	8585	10370	11964	7204	5997	14924	3794	1642	4158	11035	13737	109404	17551	12206	10787
7	5301	6988	6735	7653	9413	5533	4554	9786	2947	1262	2943	7850	10209	80815	12296	8176
8	13651	2958	5186	5417	5759	7055	3527	3258	6447	2146	907	1952	5606	7542	58546	8503
9	13077	8795	2188	4103	4141	4348	4248	1723	2441	4162	1416	598	1399	4026	5457	42570
10	59410	7241	6923	1658	3131	3081	3105	1806	801	1861	2528	736	358	1041	2949	4038
11+	126887	129752	107080	90301	71052	54669	41679	30727	21750	15391	11550	8491	4592	3610	3555	5015
2+	301424	224791	211423	177203	142912	118949	115509	118839	350164	325516	293851	261326	246861	192400	169180	154015
3+	284714	210702	176768	168018	138880	108969	87916	82469	89472	281289	259008	231917	202485	188266	142383	127222
4+	258970	197021	165233	139644	131360	105668	79745	59878	59709	67852	222889	203404	178406	151948	139030	105283
5+	241480	177571	154049	130218	108173	99514	77052	53195	41377	43513	48655	173907	155111	132446	109681	102679

Table 22. Instantaneous fishing mortality matrix, estimated from cohort analysis, for fall-spawning herring in NAFO Division 4R from 1973 to 1988.

AGE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003	.000	.000	.000	.009	.000	.020
3	.080	.002	.002	.002	.000	.004	.001	.009	.001	.003	.003	.002	.011	.013	.053	.009
4	.078	.023	.004	.032	.008	.005	.049	.023	.032	.086	.015	.025	.066	.085	.018	.248
5	.111	.045	.063	.036	.020	.033	.079	.046	.052	.075	.086	.050	.094	.181	.108	.023
6	.293	.043	.104	.040	.064	.075	.222	.053	.063	.146	.141	.097	.103	.156	.201	.111
7	.383	.098	.018	.084	.088	.250	.135	.217	.117	.131	.211	.137	.103	.122	.169	.187
8	.240	.101	.034	.069	.081	.307	.516	.089	.238	.216	.215	.133	.131	.124	.119	.216
9	.391	.039	.077	.070	.096	.137	.655	.567	.072	.299	.454	.315	.095	.111	.101	.103
10	.166	.049	.035	.061	.109	.130	.181	.208	.187	.206	.312	.508	.119	.072	.063	.147
11+	.166	.049	.035	.061	.109	.130	.181	.208	.187	.206	.312	.508	.119	.072	.063	.159
6+	.195	.051	.040	.061	.101	.150	.231	.203	.177	.208	.244	.226	.105	.125	.131	.131

Table 23. Population and catch estimates for spring-spawning herring in NAFO division 4R from 1988 to 1990 assuming a fully recruited fishing mortality rate of 0.3 in 1989 and 1990.

	POPULATION NUMBERS ('000)				FISHING MORTALITY				MID-YEAR POPULATION BIOMASS (t)		
AGE	1988	1989	1990	AGE	1988	1989	1990	AGE	1988	1989	1990
2	66344	66344	66344	2	.012	.018	.018	2	9212	9212	9212
3	53909	53655	53368	3	.011	.030	.030	3	9551	9506	9455
4	37993	43668	42642	4	.031	.072	.072	4	7704	8855	8647
5	68360	30729	33263	5	.039	.147	.147	5	15940	7165	7756
6	121529	53801	21725	6	.144	.262	.262	6	33270	14729	5947
7	17965	86136	33894	7	.281	.300	.300	7	5552	26622	10476
8	75914	11108	52244	8	.238	.278	.278	8	25740	3766	17714
9	12717	49011	6885	9	.269	.297	.297	9	4492	17312	2432
10	1355	7953	29814	10	.491	.287	.287	10	560	3288	12327
11+	5853	3570	7079	11+	.505	.287	.287	11+	2572	1569	3110
2+	461939	405975	347259	5+	.166	.270	.259	2+	114594	102025	87078
5+	303693	242308	184905					5+	88127	74452	77866

	CATCH NUMBERS ('000)				CATCH BIOMASS (t)		
AGE	1988	1989	1990	AGE	1988	1989	1990
2	734	1052	1052	2	113	161	161
3	519	1426	1418	3	102	279	278
4	417	2759	2694	4	94	618	604
5	2400	1505	4125	5	619	388	1063
6	14830	11290	1801	6	4487	3416	545
7	4004	20335	8002	7	1368	6946	2733
8	14606	2457	11556	8	5473	921	4330
9	2734	11473	1612	9	1067	4479	629
10	480	1808	6778	10	219	826	3097
11+	2123	811	1610	11+	1031	394	781
2+	42847	54916	40646	2+	14572	18428	14222
5+	41177	49679	35482	5+	14264	17369	13179

Table 24. Population and catch estimates for fall-spawning herring in NAFO division 4R from 1988 to 1990 assuming a fully recruited fishing mortality rate of 0.3 in 1989 and 1990.

	POPULATION NUMBERS ('000)				FISHING MORTALITY				MID-YEAR POPULATION BIOMASS (t)		
AGE	1988	1989	1990	AGE	1988	1989	1990	AGE	1988	1989	1990
2	26792	26792	26792	2	.020	.024	.024	2	2777	2777	2777
3	21940	21499	21425	3	.009	.061	.061	3	2789	2733	2723
4	16981	17795	16552	4	.248	.188	.188	4	3341	3501	3257
5	23589	13434	12066	5	.023	.208	.208	5	5516	3141	2822
6	10787	18871	8931	6	.111	.291	.291	6	2756	4821	2282
7	8176	7907	11547	7	.187	.300	.300	7	2274	2199	3212
8	8503	5553	4796	8	.216	.300	.300	8	2722	1777	1535
9	42570	5609	3368	9	.103	.257	.257	9	14490	1909	1146
10	4038	31429	3553	10	.147	.214	.214	10	1462	11381	1287
11+	5015	6356	24981	11+	.159	.214	.214	11	1946	2467	9695
2+	168392	155245	134010	6+	.131	.252	.253	2+	40074	36708	30735
6+	79090	75724	57175					6+	25651	24555	19156

	CATCH NUMBERS ('000)				CATCH BIOMASS (t)		
AGE	1988	1989	1990	AGE	1988	1989	1990
2	483	566	566	2	55	65	65
3	186	1163	1159	3	26	163	163
4	520	2779	2585	4	113	604	562
5	490	2297	2063	5	127	594	533
6	1026	4342	2055	6	290	1226	580
7	1267	1867	2726	7	390	574	838
8	1503	1311	1132	8	532	464	401
9	3798	1156	694	9	1429	435	261
10	501	5503	622	10	200	2202	249
11+	671	1113	4374	11+	288	477	1876
2+	10445	22097	17977	2+	3449	6804	5528
6+	8766	15291	11603	6+	3128	5378	4205

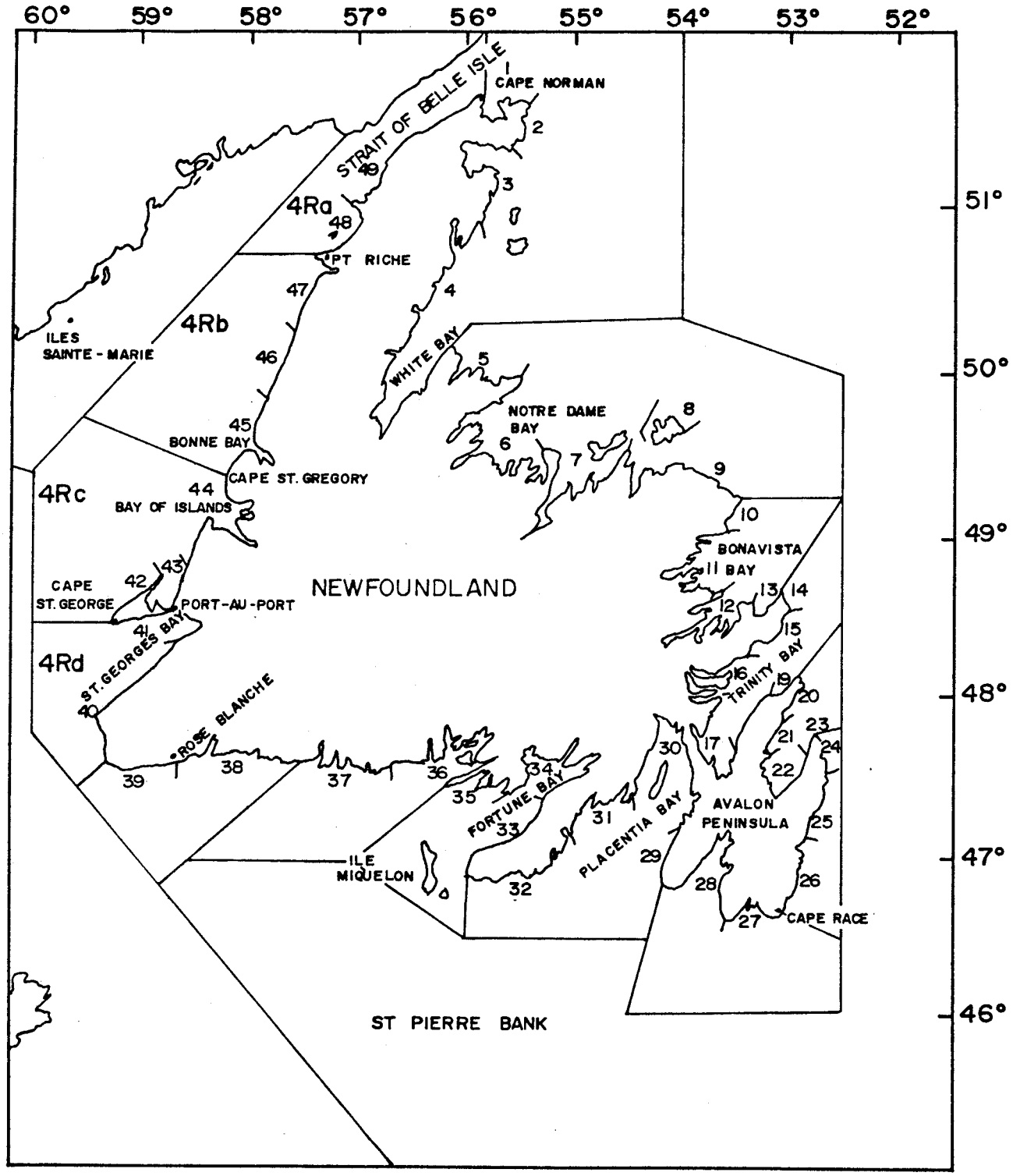

Figure 1. West coast of Newfoundland unit areas and statistical districts.

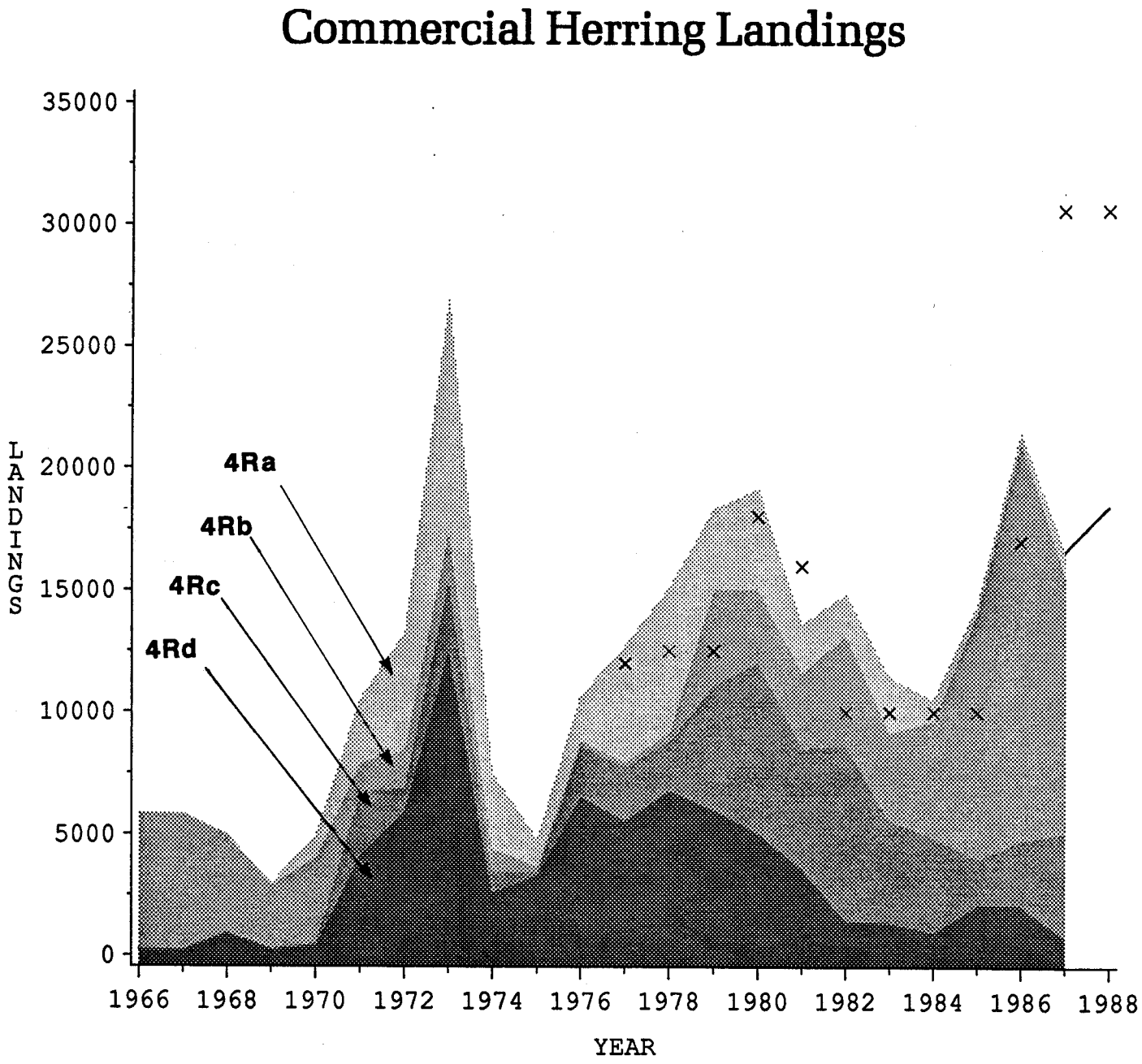

Figure 2. Commercial herring landings ('000 t) by fishing area in NAFO Division 4R from 1966 to 1989. "X" indicates annual TAC's.

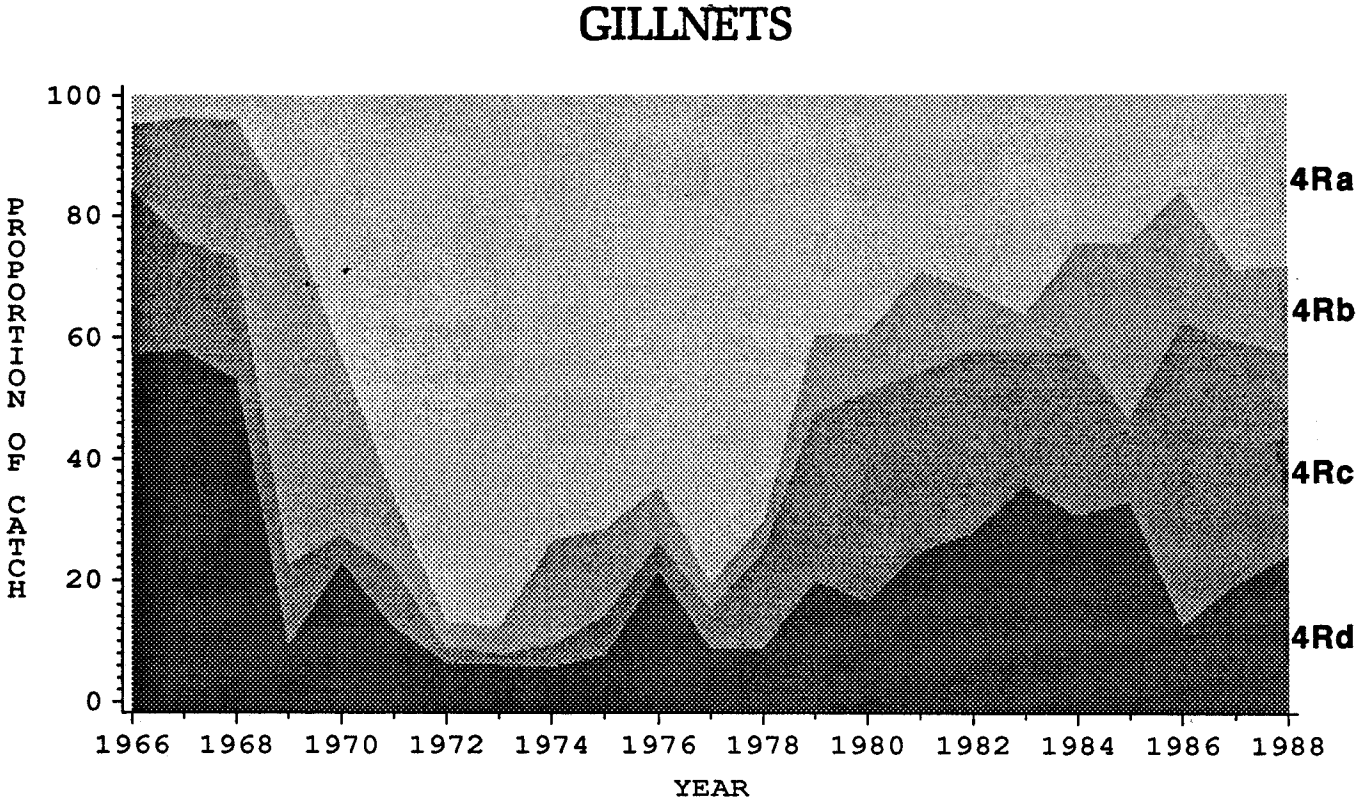

Figure 3. Proportion of gillnet herring landings by fishing area in NAFO Division 4R from 1966 to 1989.

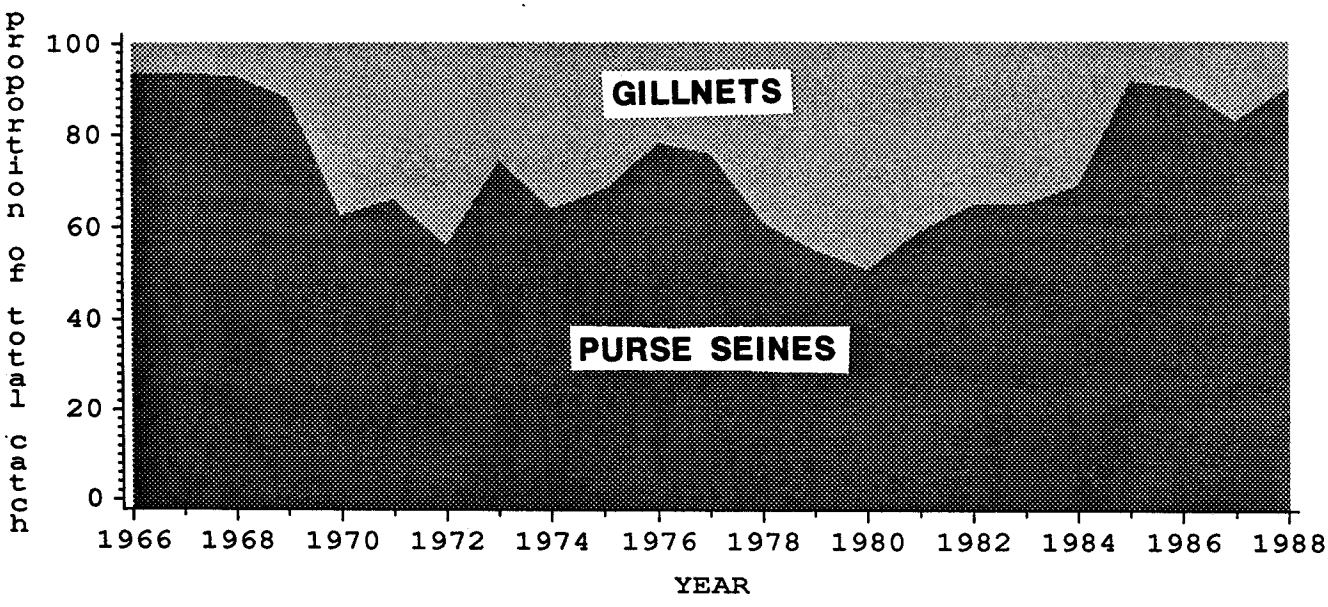

Figure 4. Proportion of total herring landings taken by gillnets and purse seines in NAFO Division 4R from 1966 to 1989.

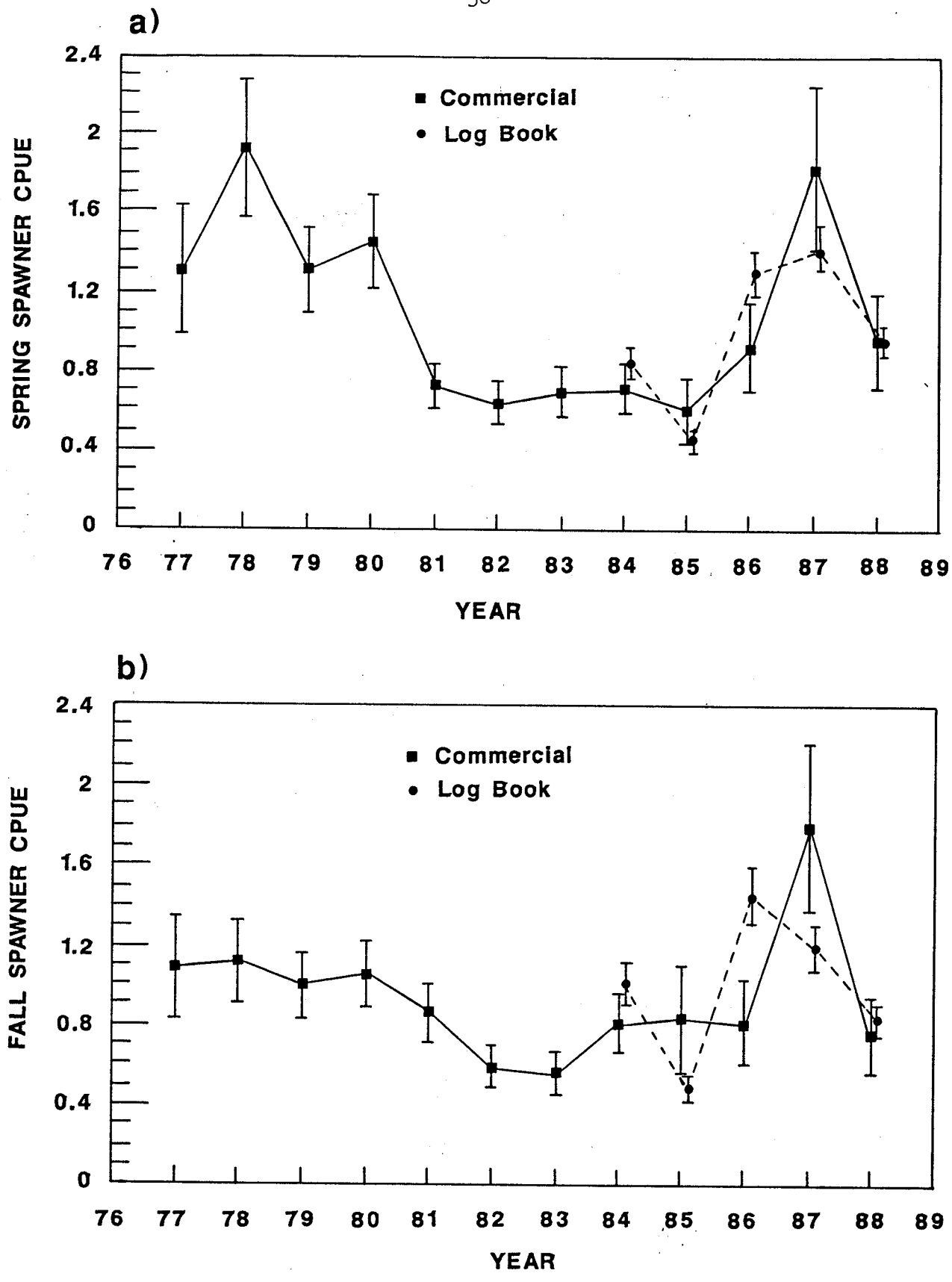

Figure 5. Gillnet catch per unit effort (standardized to the mean of each series) and approximate 90% C.I. for (a) spring- and (b) fall-spawning herring in NAFO Division 4R as calculated from commercial purchase slip and research logbook data.

Annex 1. Number of herring sampled (bold print) and commercial landings (t) in NAFO division 4R by gear, area and month in 1988.

GEAR	AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GN	4Ra					1		343	2 534	3 237	4 143	5 72	50
						14			18	5	208	225	38
	4Rb										6		
				1	11	15	23	7	4	2	60	216 114	21
	4Rc				7 181	8 451	9 377	10 50					
					34	61	227	186	10	4	7	18	46
	4Rd				11 200	12 449	13 50						
					109	113	44	142	8	8	11	1	
PS	4Ra							4 50	5 50				
	4Rb				1 48					6 50	7 196	8 400	9 448
	4Rc					2 50	3 50						
	4Rd				250	933							
	4R				923	6239	1234	22	22	65	417	3030	4523