A Re-evaluation of the West Coast of Newfoundland Herring Resource (NAFO Div. 4R)

by

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ABSTRACT

Several major changes have been made to the NAFO Division 4R herring database for this years assessment, including revised catch-at-age matrices, revisions to the catch rate indices, and the inclusion of previously unreported catches. Herring landings in 1986 reached 21,400 t, from a TAC of 17,000 t. Spring spawners have generally dominated the annual catch since 1966. Historically, this spawning group has been dominated by the 1968 and 1974 year-classes. However in 1986, the 1980 year-class represented 51% of the catch in numbers. The fall spawners had been dominated by the 11+ age group until 1983. In 1986, the 1979 year-class made up 50% of the catch in numbers. Cohort analyses showed that the spring spawner 4+ biomass doubled to 88,000 t in 1986 from 40,000 t in 1983. The fall spawner 4+ biomass has increased to 73,000 t in 1986 from 22,000 t in 1981. The strong recruitment of the 1979, 1980 and 1982 year-classes has resulted in a significant increase in abundance of these two stocks. Projections using a terminal F of 0.3 in 1987 would result in a catch of 16,500 t of spring spawners and a decrease in population biomass from 81,300 t in 1987 to 66,900 t in 1988. The 1988 $F_{0.1}$ catch would be 13,200 t. An $F_{0.1}$ fall spawner catch of 14,100 t would result in a drop in the population biomass from 69,800 t in 1987 to 56,000 t in 1988. The 1988 $F_{0.1}$ catch would then be 10,900 t.

RESUME

Plusieurs changements majeurs ont été apportés aux bases de données des stocks de hareng de la division 4R de l'OPANO pour l'évaluation de cette année. Ces changements portent sur les matrices de capture à l'âge, les prises par unité d'effort et l'inclusion des débarquements non rapportés antérieurement. Les débarquements de hareng en 1986 étaient d'environ 21,400 t, pour un TPA de 17,000 t. Les reproducteurs de printemps sont généralement dominants dans la capture depuis 1966. Les classes d'âge de 1968 et 1974 ont dominé historiquement les captures de ce groupe reproducteur. Cependant, la classe d'âge de 1980 a représenté 51% de la capture en nombre en 1986. Les captures de reproducteurs d'automne entre 1966 et 1983 sont constituées d'une forte proportion de poissons agés de plus de 11 ans. En 1986, la classe d'âge de 1979 a dominé la capture en nombres (50%). Les analyses de cohorte ont démontré que la biomasse (4+) de reproducteurs de printemps a doublé de 40,000 t en 1983 à 88,000 t en 1986. La biomasse (4+) de reproducteurs d'automne en 1986 était d'environ 73,000 t, comparée à 22,000 en 1981. La cause des hausses observées 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 en 1987 résulterait en une capture de 16,500 t et la biomasse totale passerait alors de 81,300 t en 1987 à 66,900 t en 1988. Une mortalité par la pêche de $F_{0.1}$ en 1988 permettrait de capturer 13,200 t. Un taux de mortalité par la pêche de 0.3 exercé sur les reproducteurs d'automne en 1987 occasionnerait une capture de 14,100 t et une baisse de la biomasse de 69,800 t en 1987 à 56,000 t en 1988. En pêchant à un taux $F_{0.1}$ en 1988, on récolterait 10,900 t.

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 years, the west coast of Newfoundland herring resource has been assessed separately for spring and fall spawners as determined from their gonadal development. It is generally accepted that these two spawning components have, at least for the adult phase, different life histories and therefore should be treated as two stocks.

Several major changes have been implemented into this year's assessment. These changes include revised catch-at-age matrices and revisions to the catch rate indices used for the calibration of the cohort analyses. In addition, one of the most important differences between this year's and last year's assessments was the inclusion of previously unreported catches between 1982 and 1986 supplied by the Newfoundland west coast herring industry, in the catch-at-age matrices. Although verifications were made to check the validity of the updated landing information, it should be noted that they were obtained from unofficial sources.

Historical Fishing Patterns and Management Schemes:

Total herring landings from the west coast of Newfoundland ranged between 3,000 and 6,000 t from 1966 to 1970 (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 4Vn. A steady increase in landings again occurred between 1976 and 1980, a trend which was reversed in 1981, mainly due to depressed markets. Improved markets conditions in 1985 allowed for a large increase in landings which reached 21,400 t in 1986.

Total allowable catches (TAC) have been in effect since 1977, when the west coast of Newfoundland was defined as a herring management unit. The TAC has been exceeded every year except in 1981 (Table 1; Figure 2). In order to prevent over-exploitation of local stocks, the Atlantic Herring Management Committee originally allocated the TAC into quotas for three areas: (1) St. Georges Bay (area 4Rd), (2) Cape St. George to Cape St. Gregory (area 4Rc) and (3) Cape St. Gregory to Cape Norman (areas 4Rb and 4Ra) (Moores and Winters, 1978). In recent years, 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 remaining vessels and the gillnet allocation has

been divided evenly between the regions north and south of Cape St. Gregory.

The fishing pattern of the herring fleet has varied greatly over time. Before 1971, most of the catch was reported in area 4Rb (Bonne Bay), while from 1971 to 1978, area 4Rd (St. Georges Bay) was the single most important fishing zone (Figure 3a). More recently, the proportion of the total catch reported in area 4Rd has slowly diminished while increasing in area 4Rc (Bay of Islands and Port-au-Port Bay) and again in area 4Rb.

The purse seine fleet, being very mobile, can direct its fishing effort wherever success and markets are optimal. The fishing pattern of the fleet has therefore fluctuated considerably over time in response to shifting concentrations of herring schools and the accessibility to buyers (Figure 3b). In the latter half of the 1960's, almost 100% of the purse seine catches came from 4Rb. During the 1970's, the fishing activity of this fleet shifted northward to 4Ra (St. John Bay) and southward to 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, the purse seiners concentrated more and more of their efforts during the spring fishery in area 4Rc throughout the mid-1980's. This fishery was declining in importance however, and since 1982, purse seine catches have been taken almost exclusively from overwintering concentrations in areas 4Rb and 4Rc from October to December (Table 2). In 1985 and 1986, over 75% of the purse seine landings were reported in area 4Rb.

The nearshore fishery, made up of all gears other than purse seines (mostly gillnets), has also gone through pronounced changes since 1966. In the late sixties, the dominance of this fishery in the southern areas rapidly declined (Figure 3c). From 1971 to 1978, most of the catch was reported from area 4Ra. After 1975, the development of a major spring gillnet fishery south of Cape St. Gregory (Moores and Winters, 1980) resulted 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, and north of Pointe Riche from July to September (Table 2; Figure 3c), although a relatively active late fall fishery has occurred sporadically in areas 4Ra to 4Rc throughout this period.

Total gillnet landings have declined since 1980 (Table 1). The proportion of the total catch taken by gillnets has also declined since 1980 (Figure 4). In 1985 and 1986, less than 10% of the total landings were reported from the gillnet fishery as there has been little market demand for gillnetted herring.

SEQUENTIAL POPULATION ANALYSES

A) INPUT DATA:

Age Composition of the Commercial Catch:

Random samples from the commercial fishery were collected by port samplers, by gillnet fishermen hired to keep detailed catch and effort data on herring caught on the spawning grounds, and by observers aboard the purse

seine vessels. Because of the number of people involved, all the major commercial landings were well sampled (Annex 1). These samples were frozen and sent to the Quebec laboratory for analyses (length, weight, gonad weight, maturity stage, and otolith collection and reading).

Individual herring were assigned as either spring or fall spawners by relating the maturity stage, determined from the gonadosomatic index (GSI) by discriminant analyses (McQuinn, in preparation), to the date of capture, using the 4R maturity cycle chart (McQuinn, 1987a). Ages were determined from the otoliths as the number of rings read for spring spawners and the number of rings read plus one for fall spawners (Cleary et al., 1982). All herring with 11 or more rings were lumped into an 11+ age group. The catch-at-age matrices for spring and fall spawners were then regenerated for 1973 to 1986, incorporating the GSI method of separating the spawning groups and including the previously unreported purse seine catches from 1982 to 1986 (McQuinn, 1987b)(CATΔAGE v1.0, Anon, 1986).

The Spring Spawner Catch at age:

Spring spawners have dominated the catch in every year since 1973 (Table 3), averaging 72% 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 1978 (Table 4). 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, which again dominated the 1984 fishery, representing 59% of the catch in numbers. In 1985, the 1980 year-class was the dominant cohort and the most important since the 1974 year-class, contributing to 63% of the catch in numbers, and again 51% in 1986. Consequently, the mean age of the spring spawners dropped to 5.6 years old in 1986 from 9.2 in 1978.

The Fall Spawner Catch at age:

Herring of the 11+ age group have historically dominated the fall spawner catch (Table 4). 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 to 50% in 1986. The mean age of fall spawners in the catch has therefore decreased in recent years, from 10 years old in 1977 to 6.3 years old in 1985; an historical low.

Population Abundance Indices:

Catch rate indices have been calculated for the gillnet fishery for both the spring and fall seasons and for the purse seine fall fishery.

Gillnet Catch Rates:

Gillnet catch rates (t/boat/day) were calculated using all available purchase slips from 1977 to 1986. All pertinent information, including the name of the fisherman and/or the commercial fishing vessel (CFV) number, was computerized in order to conduct a series of detailed analyses to find and correct for a number of the known biases associated with these data (HERRING CPUE v1.0, Anon, 1986). It was known that certain fishermen would often split their daily catch among the crew members who would then sell their

shares separately. This resulted in several slips being issued for the same catch. Purchase slips were therefore sorted by day and amount landed to identify those groups of fishermen who repeatedly sold the same amount of fish on the same day. These split landings were then combined. In addition, some fisherman were issued several slips on the same day, either because the catch was separated during weighing and a slip was issued for each batch or because the fisherman made several trips during the day to empty his nets. In either case, the sum of the day's landings represented one day of fishing and therefore the amounts on the slips were combined.

The percent of spring and fall spawners in the commercial gillnet samples were tabulated by month and unit area to determine during which periods the fishery has historically been directed upon only one of each of the spawning components (Table 5). From this table, the major spawning sites were determined to be areas 4Rc and 4Rd in April and May for the spring spawners, and area 4Ra in August for the fall spawners. A weekly catch rate index was then calculated for the weeks within these areas for which more than 80% of the catch was from the relevant spawning stock (Table 6). The abundance indices were calculated as the unweighted mean of these weekly catch rates (where slips were available).

The resulting indices were then adjusted on the basis of gang size estimates to account for annual changes in the number of nets fished per day (Table 7). 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 1986, the gang size was obtained from written surveys sent to all licensed fishermen along the west coast from 1984 to 1986. The number of nets fished from 1981 to 1983, recorded on the licence applications, was used to standardize the two series of data. The gang size estimates for 1982 to 1986 were calculated using the average number of nets fished by those fishermen within the zones and months used for the catch rate estimates who sold the majority of their catches, so as not to include bait fishermen who did not receive purchase slips. The catch rate indices were then multiplied by the resulting gang size estimates, which had been standardized to 1 in 1978. These adjusted catch rates (Table 8; Figure 5) were used to calibrate the cohort analyses for the two spawning stocks.

In 1985, only 2 purchase slips were issued in area 4Ra in August, while in 1986, only one questionnaire was returned from 4Ra by a fisherman who sold the majority of his catch. This precluded the calculation of the 1985 and 1986 abundance indices for the fall spawners from these data. These fall spawner catch rates were therefore calculated using data from logbooks filled out by surveyed gillnet fishermen during this period. Although only five or six fishermen were surveyed, it was felt that these data were consistent with the historic series, as estimates made for the only two years where the data sets overlapped, i.e. 1984 in 4Ra and 1986 in 4Rc and 4Rd, yielded very similar results. In addition, catch rates calculated for these same selected fishermen from their commercial purchase slips and their responses from the written questionnaires in 1984 confirmed the comparability of the two data sets:

	Catch Rates (t/boat/day)		
Area	4Rc + 4Rd		4Ra
Year	1984	1986	1984
All purchase slips	.512	.743	.388
Logbooks		.729	.414
Selected purchase slips	.476		.409

Purse Seine Catch Rates:

Catch and effort data from purse seine observer logbooks have also been analyzed for trends in abundance. Data were available for the fall fishery (October to December in 4Rb and 4Rc) in 1982 and from 1984 to 1986. Catch rates, weighted by the corresponding purse seine catches, were calculated for these selected months and areas. Trends in catch/set and catch/night were very similar (Figure 6), both of which increased slowly between 1982 to 1984 and more sharply from 1984 to 1986. The majority of the catch (60 to 80%) in this fishery over the time period has been comprised of spring spawners (Table 9).

It should be noted that the validity of purse seine catch rates as representative of pelagic fish population abundance has often been discussed and is generally considered to be difficult to interpret (Pope, 1978; Ulltang, 1978; Powles, 1981; Cleary, 1982). Consequently, these data are presented only as additional information on trends in abundance.

B) 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, 1986) and is consistent with estimates made for other herring stocks (Lea, 1930; Runnström, 1936; Beverton, 1963).

Partial Recruitment:

A number of relationships were examined to estimate partial recruitment for ages 4+, including historical trends and recent trends. However it was felt that the historical trends were inappropriate as the fishery and the age composition of the catch had changed considerably since this period and would not reflect present conditions, and the estimates from the recent trends resulted in unrealistic year-class estimates. Last years vectors were therefore used as these values were derived from selectivity coefficients from the 1985 purse seine fishery and were the best available estimates. These values were estimated for ages 4, 5 and 6 from the ratio of the proportion at age from the commercial landings and the purse seine discarded sets (McQuinn, 1986). However, using the selectivity coefficient for age 4 spring spawners, calculated in this manner, resulted in an unrealistically low year-class estimate, given the dominance of this cohort in the catch. This estimate was therefore adjusted downward to the value of the fall spawner 5 year olds, which had approximately the same mean length. Spring

spawners 5 years and older and fall spawners 6 years and older were assumed to be fully recruited. The partial recruitment values for ages 2 and 3 were set to yield the historical mean population numbers from 1973 to 1984 to simulate average recruitment. The partial recruitment values obtained were as follows:

AGE	2	3	4	5	6	7+
SPRING	.035	.33	.63	1.00	1.00	1.00
FALL	.014	.22	.26	.63	1.00	1.00

Fishing Mortality for the Oldest Ages:

A method was developed for determining the vector of fishing mortalities for the oldest ages (F_o) when several cohorts have been lumped into a +group. This method assumes that the F_o on the +group (in this case 11+) is the same as on the first unlumped age (10). The procedure starts with an input value for F_o on the 11+ group in the last fishing year and calculates the F_o for age 10 of the previous year. This was accomplished by (a) determining the population numbers and F for the 10+ group from the 10+ catch and the 11+ population numbers of the following year, and (b) partitioning the 10+ numbers between age 10 and the 11+ group, assuming the same F applies to both. The resulting vector was used as input for the cohort analysis starting at age 10. The 11+ population numbers are then concatenated to the population matrix (FISHΔHER v1.0, Anon, 1986).

Mean Weight at Age:

The annual weight at age for each spawning component 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 10) were used to estimate the catch and population biomasses. Weight-at-age matrices were also calculated from the weighted mean gillnet weight at age of each sample stratum in the second quarter for spring spawners and the third quarter for fall spawners (Table 11). These matrices were used to estimate the gillnet fishable biomass for each spawning component for the calibration of the cohort analyses.

C) CALIBRATION OF COHORT ANALYSES:

Cohort analysis was run separately for spring and fall spawners. Gillnet fishable biomasses were calculated for the second quarter for spring spawners and mid-year for fall spawners as these were the biomasses available during the periods for which the gillnet catch rates were estimated (Table 12). These matrices were calculated by multiplying respectively the second and third quarter numbers at age by the gillnet partial F matrix (Table 13), and then by the appropriate weight at age matrix (FISHΔHER v1.0, Anon, 1986).

A series of cohort analyses was run at various values of terminal fishing mortality (F_t) (Table 14). Least squares regression of gillnet fishable biomass on gillnet CPUE was used to calibrate the cohort analyses for the two stocks. A preliminary regression showed that the intercept was

not significantly different from zero, therefore the zero intercept was fixed for the subsequent regressions. The F_t for each spawning stock was determined by choosing the regression line with the best combination of (a) correlation coefficient, (b) the closeness of the 1986 point to the regression line and (c) the sums of squares of the standardized residuals for the 1984 to 1986 points.

ASSESSMENT RESULTS AND DISCUSSION

The foregoing analyses indicated an F_t in 1986 of 0.25 and 0.085 for spring and fall spawners, respectively (Table 14; Figure 7). The spring spawner 4+ beginning-of-the-year biomass dropped steadily between 1973 and 1983, from 186,000 t to 40,000 t (Table 15; Figure 8), even though the 4+ fishing mortality was below the $F_{0.1}$ value of 0.3 in all years except 1982 during this period (Table 16a). The decline in this spawning component was therefore primarily due to poor recruitment to this stock during the decade following the appearance of the 1968 year-class (Table 16b). This stock seems to be rebounding however, as the 4+ biomass more than doubled in 1984 to 88,000 t with the recruitment of the 1982 year-class (Table 15).

Similarly, the fall spawner 4+ mid-year biomass declined continuously between 1973 and 1982, from 78,000 t to 23,000 t (Table 17; Figure 8). Again, poor recruitment subsequent to the strong 1958 and 1963 year-classes was the major cause for this decline in biomass (Table 18a) as the 4+ fishing mortality has been below 0.3 since 1973 (Table 18b). With the entry of the 1979 year-class into the fishery, the fall spawner biomass almost tripled to 63,000 t in 1983, its highest level since 1974 (Table 17).

PROGNOSIS

Projections for 1987 and 1988 were run using population numbers obtained from the cohort analyses, recruitment at age 2 for 1986 to 1988 set to the geometric mean from 1973 to 1983, the 1986 second and third quarter weights at age, and the 1986 partial recruitment vectors (FISHΔHER v1.0, Anon, 1986). Due to the major revisions to the input parameters in this year's assessment, TAC projections for 1987 as well as 1988 were calculated using the assumed $F_{0.1}$ of 0.30 rather than the projected 1987 catch from last year's assessment.

The results for both spawning groups gave a much improved outlook for the status of the 4R herring resource as compared to last year's assessment. The projected catch for 1987 would be 16,500 t of spring spawners (Table 19) and 14,100 t of fall spawners (Table 20), for a combined TAC of 30,600 t, at the recommended $F_{0.1}$ of 0.3.

MANAGEMENT CONSIDERATIONS

It appears from the foregoing analyses that the spring spawning stock is presently being exploited just below the assumed $F_{0.1}$ level while the fall spawning stock is being fished well below this target. This discrepancy is mainly due to the disproportionate fishing effort exerted on the two components, spring spawners being predominant in the catches in both the spring and fall purse seine fisheries. This imbalance is primarily a market related situation, as spring spawners are preferred by industry in the spring for their roe and in the late fall for their higher fat content.

These analyses suggest major differences with our previous view of the resource. Several factors have contributed to this change in perception. The use of the GSI method for determining spawning groups decreased the estimate of the proportion of fall spawners taken in the fall purse seine fishery, where the majority of catches are taken, from 53% to 26%. In addition, the inclusion of the unreported purse seine landings from 1982 to 1986 has changed considerably our view of the exploitation pattern in recent years. Finally, a sharp increase in the catch rates in 1985 and 1986 in conjunction with the major increases in estimates of the strong 1979, 1980 and 1982 year-classes has improved the outlook of this fishery for the present and near future.

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Table 1. Herring catches (t) by gear type and fishing area and total allowable catches from NAFO division 4R from 1966 to 1986.

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

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

Table 2. Herring landings (t) in NAFO division 4R by gear type, unit area and month from 1982 to 1986.

GEAR	YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
PS	1982	4Ra													0
		4Rb										3062	911		3973
		4Rc				1785	1839				1951				5575
		4Rd													0
	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
GN	1982	4Ra					2	28	532	350	51	621	83	8	1675
		4Rb					44	29	55	12	49	249	80		518
		4Rc				38	1135	133	3	5	29	227	2		1572
		4Rd				12	1319	44	33	15	20	16	3		1462
	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

Table 3. Spring and fall spawner catch at age ($x10^{-3}$) and proportion of spring spawners in NAFO division 4R herring landings from 1973 to 1986.

SPRING

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

FALL

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

TOTAL (SPRING AND FALL)

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

PERCENT SPRING SPAWNERS

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
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

Table 4. Age composition (%) and mean age* of spring and fall spawners in NAFO division 4R herring landings from 1973 to 1986.

SPRING AGE COMPOSITION (pct)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	.0	.0	.0	.0	.1	.0	.0	.0	.1	.0	.0	.2	.1	.5
2	3.4	.9	.5	1.7	.0	.0	.4	.8	.2	2.0	.2	1.0	1.0	.6
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
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
5	52.3	2.5	.8	.7	1.4	.6	28.7	.9	.5	8.3	5.2	19.5	62.5	5.9
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
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
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
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
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
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

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
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

FALL AGE COMPOSITION (pct)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0
2	.0	.0	.0	.0	.0	.0	.0	.2	.0	1.2	.2	.0	.1	.2
3	4.4	.2	.3	.7	.0	.1	.1	2.1	.5	6.8	.9	.4	1.5	2.5
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
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
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
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
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
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
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
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

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
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

* assuming ages 11+ to be 11.

Table 5. Proportion (%) of spring and fall spawning herring in the gillnet catch by month and fishing area, NAFO division 4R from 1965 to 1986.

	FISHING AREA																							
	4Rd			4Rc					4Rb							4Ra								
SPRING	APR	MAY	OCT	APR	MAY	JUN	SEPT	OCT	MAY	JUNE	JULY	SEPT	OCT	NOV	DEC	MAY	JUNE	JULY	AUG	SEPT	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		
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		

Table 6. Distribution of samples by week with greater than (*) and less than (-) 80% of spring spawners for areas 4Rc and 4Rd and fall spawners in area 4Ra. The weeks chosen for the catch rate calculations (where slips were available) are between the hash marks (|).

SPRING SPAWNERS (4Rc-L + 4Rd-K)

WEEK	14	15	16	17	18	19	20	21	22
YEAR									
1978	|					*	*	|	
1979	| *	*	*	*	*			|	
1980	|	*	*	*				|	
1981	| *	*	*	*	*		|		
1982				|		*	*	|	
1983	|						|	-	
1984	|				*			|	
1985					| *	*	*	* |	-
1986				-	| *	*	*	*	* |

FALL SPAWNERS (4Ra-N)

WEEK	27	28	29	30	31	32	33	34	35	36	37	38	39	40
YEAR														
1977	-		-	-	- |				*	*	* |	-	-
1978	-	-	-	- |						|			
1979		-	-	- |	*	*	-	*	*	|			
1980	-	-	-	-	- |			*	*	* |	-	-	-	-
1981			-	- |		*	*	*	*	|			
1982		| *		*					|				
1983			-	|			*	*	|			-	
1984				|	*	*	*	*	-	* |	-	-	-	
1985		-			|	*	*	*	*	* |	-			
1986				|	*	*	*	*	-	* |				-

Table 7. Sources of estimates of the average number of gillnets fished per day, standardized to 1978 (gang size), which were used to adjust purchase slip catch rates from 1977 to 1986.

	DATA SOURCE											
	WHEELER-WINTERS			LICENCE			QUESTIONNAIRES					
							4Rc + 4Rd			4Ra		
YEAR	MEAN	ST	n	MEAN	ST	n	MEAN	ST	n	MEAN	ST	n
1977	9.1	1.02	30									
1978	8.9	1.00	90									
1979	10.6	1.19	139									
1980	11.7	1.31	149									
1981	15.3	1.72	99	10.7	1.72	323						
1982	14.6	1.64	69	12.3	1.98	352	12.0	1.98	168	14.2	1.98	64
1983				13.1	2.10	361	12.9	2.12	164	15.2	2.11	59
1984							14.4	2.38	135	15.3	2.13	47
1985							16.0	2.63	28	* 3.3	.46	4
1986							7.8	1.28	12	* 3.3	.46	5

* Gillnet logbooks

Table 8. Mean weekly gillnet catch rates (t/boat/day) and variances, and catch rates adjusted for gang size for spring (4Rc + 4Rd) and fall (4Ra) spawners (n = number of weeks).

	4Rc + 4Rd					4Ra				
YEAR	t/f/day	(n)	var.	gang size	adj. CPUE	t/f/day	(n)	var.	gang size	adj. CPUE
1977						.9833	(7)	.3924	1.02	.9640
1978	1.3348	(7)	.3823	1.00	1.3348	.6731	(6)	.3046	1.00	.6731
1979	.9608	(8)	.3537	1.19	.8074	.8417	(5)	.5822	1.19	.7073
1980	1.6735	(8)	.1606	1.31	1.2778	.6806	(5)	.2294	1.31	.5195
1981	.9644	(7)	.2772	1.72	.5607	.5443	(6)	.1501	1.72	.3165
1982	1.1054	(4)	.2818	1.98	.5583	.6380	(7)	.2245	1.98	.3222
1983	1.0165	(6)	.2134	2.12	.4795	.7423	(6)	.2728	2.11	.3518
1984	1.2187	(7)	.5265	2.38	.5121	.8280	(4)	.4690	2.13	.3887
1985	1.2257	(4)	.4987	2.63	.4660	* .3342	(5)	.1340	.46	.7252
1986	.9504	(5)	.9389	1.28	.7425	* .3495	(5)	.0928	.46	.7686

* Gillnet logbooks

Table 9. Proportion (%) of spring and fall spawning herring in the purse seine catch by month and fishing area, NAFO division 4R from 1965 to 1986.

	FISHING AREA																						
	4Rd					4Rc									4Rb						4Ra		
SPRING	FEB	MAR	APR	MAY	NOV	JAN	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	APR	AUG	OCT	NOV	DEC	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			
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				6.4		22.0									22.7	25.2	29.0			

Table 10. Annual spring and fall spawner weight at age (weighted by landings) in NAFO division 4R herring landings from 1973 to 1986.

ANNUAL SPRING SPAWNER WEIGHT AT AGE (g)

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

ANNUAL FALL SPAWNER WEIGHT AT AGE (g)

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

Table 11. Spring and fall spawner weight at age (weighted by landings) for the second and third quarter, respectively, in NAFO division 4R gillnet herring landings from 1973 to 1986.

SECOND QUARTER SPRING SPAWNER WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	89	105	77	67	64	84	101	94	85	85	84	84	71	71
3	103	166	156	112	134	172	121	190	189	177	198	203	163	146
4	229	223	262	193	200	216	225	221	257	249	248	237	226	211
5	208	229	239	240	296	248	255	281	312	270	284	292	252	255
6	265	251	244	251	287	288	298	301	333	307	289	349	303	278
7	293	307	287	285	264	311	320	337	368	376	379	377	349	305
8	308	321	349	297	274	290	337	357	395	378	411	363	349	359
9	328	326	369	285	291	308	345	389	413	371	446	437	400	381
10	349	315	470	331	321	335	358	366	413	403	487	423	397	399
11+	369	372	411	377	381	348	388	408	458	446	458	473	433	440

THIRD QUARTER FALL SPAWNER WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	131	131	131	131	131	131	131	122	131	166	105	131	50	105
3	105	171	120	107	250	161	218	222	204	147	242	164	149	157
4	156	242	222	155	269	238	241	242	297	294	266	283	281	214
5	267	281	281	299	276	294	300	376	365	330	301	311	302	274
6	316	273	311	285	299	348	355	363	379	366	333	364	330	321
7	352	299	385	300	338	377	396	425	454	432	411	382	390	373
8	401	299	343	298	376	399	434	429	493	472	413	422	380	476
9	389	379	396	316	350	395	471	487	540	513	460	465	392	437
10	428	392	416	426	388	428	476	482	516	538	482	485	422	500
11+	461	467	494	499	456	540	535	569	590	590	533	518	512	559

Table 12. Spring and fall spawner gillnet fishable biomass for the second and third quarter, respectively, in NAFO division 4R from 1973 to 1986.

SPRING SPAWNER SECOND QUARTER FISHABLE BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	0	0	0	0	0	0	0	2	0	0	10	1	0	0
3	8	51	0	90	76	10	0	101	76	383	951	17	5	9
4	349	0	2108	0	35	1434	100	82	1539	251	2573	2118	209	1417
5	4872	535	349	0	523	368	8808	255	112	1925	833	2818	9034	863
6	667	13944	7516	227	713	701	1453	14328	369	229	983	564	3476	19194
7	3907	1054	35917	10023	1689	364	2193	574	9953	1000	128	950	701	4779
8	2748	3811	4407	33220	13223	4200	969	1818	223	5477	49	158	475	663
9	3131	1347	3440	2155	23492	9787	3698	444	569	633	2798	721	527	300
10	1951	892	3204	7955	3308	27492	14081	2337	352	828	838	845	753	425
11+	8840	10160	10029	10369	13926	11101	30179	27955	12031	14829	9971	6575	3815	2727
2+	26473	31794	66968	64039	56985	55457	61481	47896	25224	25554	19134	14767	18994	30377
3+	26473	31794	66968	64039	56985	55457	61481	47894	25224	25554	19124	14766	18994	30377
4+	26465	31743	66968	63949	56908	55446	61481	47793	25149	25171	18173	14749	18989	30369
5+	26116	31743	64860	63949	56873	54012	61381	47711	23609	24920	15599	12631	18781	28951

FALL SPAWNER THIRD QUARTER FISHABLE BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	0	0	0	0	0	0	0	0	0	19	0	0	0	0
3	0	0	0	0	13	0	0	0	0	17	45	0	0	0
4	66	1047	23	0	176	25	16	52	703	878	2544	251	47	20
5	636	2207	1073	70	142	1012	457	138	514	1272	1274	7760	674	825
6	3226	548	2869	1040	468	799	2880	280	65	464	1712	1312	18471	1824
7	1667	1857	328	1204	2768	1866	521	3117	809	269	509	1692	2412	17963
8	3634	479	867	1411	1496	2515	1367	264	2774	750	278	357	1664	1938
9	4059	2959	770	1057	1282	757	1779	741	174	1847	559	227	429	1107
10	10857	1302	1575	626	960	764	923	710	276	862	866	297	47	401
11+	43614	52433	24906	29138	21287	23815	9933	14014	10568	7134	2796	3134	1845	1553
2+	67759	62832	32410	34546	28591	31553	17877	19316	15883	13512	10583	15029	25587	25632
3+	67759	62832	32410	34546	28591	31553	17877	19316	15883	13493	10583	15029	25587	25632
4+	67759	62832	32410	34546	28579	31553	17877	19316	15883	13475	10538	15029	25587	25632
5+	67693	61784	32388	34546	28403	31528	17861	19264	15180	12597	7994	14778	25541	25612

Table 13. Spring and fall spawner gillnet partial F matrices, normalized to the mean of the three highest F's, used to estimate the gillnet fishable biomasses.

SPRING SPAWNER GILLNET PARTIAL F MATRIX

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.004	.000	.000	.000
3	.002	.030	.000	.048	.005	.003	.000	.035	.036	.029	.016	.003	.000	.002
4	.008	.000	1.000	.000	.013	.076	.028	.054	.513	.114	.173	.037	.046	.068
5	.061	.015	.050	.000	.118	.145	.497	.071	.065	.921	.440	.209	.190	.214
6	.090	.192	.236	.038	.504	.205	.595	1.000	.109	.171	.806	.361	.333	.507
7	.273	.166	.547	.332	.335	.311	.751	.276	1.000	.331	.105	1.000	.637	.634
8	.491	.320	.757	.621	.572	.945	1.000	.778	.120	1.000	.025	.183	1.000	.840
9	.933	.341	.314	.564	.602	.487	1.000	.605	.327	.462	1.000	.506	.746	1.000
10	.278	.460	.738	1.000	1.000	.854	.848	1.000	.640	.685	.713	.777	.907	.869
11+	1.000	1.000	.969	1.000	1.000	1.000	.884	.744	.423	.818	.902	.968	.908	.789

FALL SPAWNER GILLNET PARTIAL F MATRIX

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.000	.000
3	.000	.000	.000	.000	.008	.000	.000	.000	.000	.000	.003	.000	.000	.000
4	.027	.248	.010	.000	.032	.019	.028	.038	.122	.105	.045	.020	.003	.001
5	.229	.667	.274	.029	.079	.206	.348	.206	.316	.249	.194	.145	.062	.059
6	1.000	.264	1.000	.341	.242	.438	.615	.233	.124	.368	.431	.215	.413	.203
7	1.000	1.000	.142	.592	.972	1.000	.331	.852	.693	.585	.514	.511	.484	.467
8	.746	.609	.550	.987	.781	1.000	1.000	.217	1.000	.854	.891	.543	.688	.419
9	.893	1.000	1.000	.919	1.000	.499	1.000	1.000	.153	1.000	1.000	1.000	1.000	.539
10	.480	.517	.616	1.000	.892	.656	.710	.931	.769	1.000	.836	1.000	.396	1.000
11+	.838	.975	.531	.730	.742	.914	.506	.916	.949	.913	.534	.857	1.000	1.000

Table 14. Correlation coefficients, sums of squares of the standardized residuals, sums of squares of the standardized residuals of the last three years and the residual of the last point for different relationships between spring and fall spawner fishable (gillnet) biomass at various F values from cohort analysis and gillnet catch rates.

SPRING SPAWNERS			
F	0.20	0.25	0.30
r	.801	.810	.809
S.S. ST. RES.	.0532	.0349	.2138
S.S. LAST 3 ST. RES.	.4034	.4878	.7636
RES. OF LAST POINT	.2306	.1869	-.4623

FALL SPAWNERS				
F	0.05	0.075	0.085	0.10
r	.729	.831	.833	.813
S.S. ST. RES.	1.0472	.0430	.0212	.3100
S.S. LAST 3 ST. RES.	2.3999	.3968	.1545	.4164
RES. OF LAST POINT	1.0233	.2073	-.1455	-.5568

Table 15. Beginning-of-the-year population biomass for spring spawning herring in NAFO division 4R from 1973 to 1986.

BEGINNING-OF-YEAR POPULATION BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	1507	4064	1652	9496	1599	1102	2253	1736	8277	36070	4577	21624	4420	5774
3	7310	1824	4000	2143	17547	3755	1060	3194	2319	17177	59044	5421	22140	5624
4	46294	8356	1665	3887	2850	20859	3912	1761	3216	2452	16572	60017	5242	23896
5	89494	39661	7400	1575	3871	2954	19571	4022	1881	2360	2134	14361	56154	4457
6	7879	79771	33386	6291	1437	3804	2745	16079	3690	1638	1495	1635	11924	45071
7	15502	6528	67284	29896	5270	1242	3291	2300	10924	3266	1300	1003	1234	8807
8	6157	12653	5282	56693	25735	5136	1081	2617	2055	6014	2109	1016	578	954
9	3588	4465	10448	4436	44206	23311	4120	790	1903	1640	2867	1477	806	344
10	7405	2169	3404	8438	3601	36592	18176	2610	601	1369	1249	1179	935	579
11+	9251	11013	10130	11030	13565	13183	37775	41573	30822	19401	12054	7321	4858	3786
2+	194388	170504	144651	133885	119683	111938	93983	76680	65686	91387	103401	115055	108290	99290
3+	192881	166440	142999	124389	118083	110836	91730	74945	57409	55317	98824	93431	103870	93517
4+	185570	164616	138999	122246	100536	107081	90671	71751	55090	38141	39780	88009	81730	87893
5+	139277	156260	137334	118359	97686	86222	86759	69989	51875	35689	23208	27992	76488	63997

Table 16. (a) Fishing mortalities and (b) population numbers ('000) as estimated from cohort analysis for spring spawning herring in NAFO division 4R from 1973 to 1986.

A) FISHING MORTALITY

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	.145	.005	.003	.004	.000	.000	.009	.023	.000	.002	.001	.001	.010	.009
3	.010	.028	.044	.044	.005	.003	.003	.061	.040	.033	.011	.018	.039	.082
4	.006	.004	.056	.048	.045	.024	.014	.017	.211	.086	.064	.035	.042	.158
5	.080	.002	.004	.034	.029	.022	.179	.030	.025	.405	.197	.091	.128	.250
6	.101	.035	.009	.016	.067	.062	.083	.366	.037	.107	.317	.151	.130	.250
7	.072	.016	.039	.028	.019	.069	.132	.072	.423	.331	.101	.415	.161	.250
8	.207	.024	.020	.095	.056	.160	.223	.243	.043	.636	.172	.097	.348	.250
9	.310	.070	.012	.061	.133	.142	.318	.148	.138	.224	.695	.244	.164	.250
10	.285	.087	.028	.147	.189	.182	.183	.266	.251	.401	.422	.366	.211	.250
11+	.285	.087	.028	.147	.189	.182	.183	.266	.251	.401	.422	.366	.211	.250
4+	.079	.027	.026	.075	.105	.119	.172	.258	.246	.380	.208	.068	.127	.218

B) SPRING SPAWNER POPULATION NUMBERS ('000)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	14997	31475	21454	137681	24991	10684	19643	14781	97375	379228	32229	161453	40596	40644
3	46234	10619	25642	17513	112286	20452	8747	15930	11830	79687	309948	26356	132007	32909
4	206297	37460	8459	20093	13723	91448	16703	7139	12270	9309	63094	251081	21187	103928
5	402920	167940	30553	6545	15685	10746	73074	13482	5749	8133	6995	48434	198534	16634
6	29440	304663	137162	24924	5177	12472	8610	50030	10716	4590	4440	4704	36208	142963
7	51244	21778	240891	111336	20089	3964	9597	6491	28409	8453	3377	2648	3313	26031
8	19108	39040	17542	189596	88619	16133	3027	6885	4946	15232	4973	2500	1432	2310
9	10773	12720	31193	14076	141142	68608	11252	1983	4421	3879	6600	3427	1857	828
10	21175	6470	9714	25235	10838	101117	48745	6705	1401	3154	2539	2698	2197	1290
11+	25185	28713	26484	28878	38402	33543	92380	96693	65265	42718	25371	15111	10188	8252
2+	827374	660878	549093	575877	470953	369167	291779	220119	242382	554383	459566	518411	447518	375789
3+	812377	629403	527639	438196	445962	358483	272136	205338	145007	175155	427338	356959	406922	335145
4+	766143	618784	501997	420683	333676	338031	263389	189408	133177	95468	117389	330603	274915	302236
5+	559846	581323	493538	400590	319953	246583	246686	182269	120907	86159	54295	79522	253729	198308

Table 17. Mid-year population biomass for fall spawning herring in NAFO division 4R from 1973 to 1986.

MID-YEAR POPULATION BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	1963	1618	4023	1055	450	1093	3832	5185	41579	11135	10022	12812	1439	3015
3	2414	2091	1213	2688	1647	453	1487	5308	7104	39027	11251	12745	12399	3684
4	2434	3795	1888	1279	4711	1285	496	1348	5437	7155	46213	9383	12881	13954
5	2403	3056	3712	2303	1636	4701	1234	642	1463	4742	5852	42768	9323	12243
6	2797	2017	2731	2901	1647	1658	4060	1131	498	1132	3672	4908	39597	7845
7	1407	1767	2105	1944	2538	1710	1409	3476	1044	478	813	2971	4158	32622
8	4006	809	1488	1328	1637	2311	1201	1185	2453	821	283	559	2203	3305
9	3896	2771	718	1119	1130	1406	1529	702	1022	1597	522	210	409	1671
10	18276	2431	2402	626	914	1060	1114	739	346	777	993	276	125	291
11+	43179	48623	44152	36321	26451	22723	16778	14351	9728	6713	4949	3487	1555	1291
2+	82774	68977	64430	51564	42761	38398	33141	34067	70675	73576	84570	90119	84087	79921
3+	80811	67359	60407	50510	42311	37306	29308	28883	29096	62441	74548	77307	82649	76906
4+	78397	65268	59195	47821	40664	36853	27821	23574	21992	23415	63297	64562	70250	73221
5+	75963	61473	57306	46542	35953	35568	27325	22226	16555	16259	17084	55179	57370	59267

Table 18. (a) Fishing mortalities and (b) population numbers ('000) as estimated from cohort analysis for fall spawning herring in NAFO division 4R from 1973 to 1986.

A) FISHING MORTALITY

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000	.000	.001	.001
3	.081	.002	.002	.002	.000	.004	.001	.008	.001	.002	.002	.001	.003	.018
4	.079	.023	.004	.033	.008	.005	.052	.025	.027	.066	.011	.015	.021	.022
5	.113	.046	.064	.036	.021	.033	.082	.049	.057	.064	.064	.037	.054	.054
6	.297	.044	.106	.040	.065	.078	.228	.055	.067	.160	.117	.071	.074	.085
7	.389	.100	.018	.086	.089	.253	.140	.224	.122	.141	.236	.111	.073	.085
8	.244	.103	.035	.070	.083	.312	.526	.093	.247	.226	.236	.153	.103	.085
9	.397	.040	.079	.072	.098	.140	.671	.585	.075	.315	.485	.355	.111	.085
10	.169	.050	.036	.062	.111	.133	.187	.216	.195	.218	.336	.567	.139	.085
11+	.169	.050	.036	.062	.111	.133	.187	.216	.195	.218	.336	.567	.139	.085
4+	.186	.049	.041	.058	.082	.124	.222	.185	.119	.122	.040	.055	.060	.063

B) FALL SPAWNERS POPULATION NUMBERS ('000)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
2	16550	13641	33911	8891	3796	9210	32307	46967	350509	74130	105176	108006	31729	31738
3	25502	13550	11168	27764	7279	3108	7541	26451	38440	286973	60601	86097	88428	25964
4	17206	19252	11076	9127	22687	5957	2535	6167	21492	31442	234440	49541	70441	72186
5	11514	13019	15406	9032	7226	18422	4853	1971	4927	17122	24092	189836	39956	56459
6	11285	8418	10179	11831	7132	5795	14589	3661	1536	3812	13153	18499	149761	30988
7	5239	6863	6599	7497	9305	5474	4389	9512	2838	1176	2660	9584	14108	113856
8	13445	2907	5084	5306	5631	6966	3479	3123	6223	2057	836	1720	7026	10734
9	12910	8627	2146	4020	4050	4244	4175	1684	2331	3978	1343	540	1209	5189
10	58454	7104	6785	1624	3063	3006	3019	1747	768	1770	2377	677	310	886
11+	124847	127296	104953	88444	69501	53341	40529	29714	20870	14643	10863	7805	3982	3072
2+	296951	220678	207307	173536	139671	115524	117417	130998	449934	437103	455543	472304	406948	351071
3+	280401	207036	173396	164645	135875	106314	85110	84030	99425	362973	350367	364298	375219	319333
4+	254899	193486	162228	136881	128596	103206	77569	57580	60985	76000	289765	278201	286792	293370
5+	237694	174235	151152	127755	105909	97249	75034	51412	39494	44558	55325	228660	216351	221184

Table 19. Population and catch estimates for spring spawning herring in NAFO division 4R from 1986 to 1988 assuming a fishing mortality rate of 0.3 in 1987 and 1988.

	POPULATION NUMBERS ('000)				FISHING MORTALITY				BEGINNING-OF-YEAR POPULATION BIOMASS (t)		
	1986	1987	1988		1986	1987	1988		1986	1987	1988
2	40644	40644	40644	2	.009	.011	.011	2	5774	5774	5774
3	32909	32984	32926	3	.082	.098	.098	3	5624	5637	5627
4	103928	24826	24479	4	.157	.189	.189	4	23896	5708	5628
5	16634	72689	16825	5	.250	.300	.300	5	4457	19476	4508
6	142963	10606	44088	6	.250	.300	.300	6	45071	3344	13899
7	26031	91157	6433	7	.250	.300	.300	7	8807	30840	2176
8	2310	16598	55290	8	.250	.300	.300	8	954	6854	22832
9	828	1473	10067	9	.250	.300	.300	9	344	612	4181
10	1290	528	893	10	.250	.300	.300	10	579	237	401
11+	8252	823	320	11+	.250	.300	.300	11+	3786	377	147
12+	0	5262	499	12+	.000	.300	.300	12+	0	2414	229
13+	0	0	3191	13+	.000	.000	.300	13+	0	0	1464
2+	375789	297590	235656	2+	.184	.229	.210	2+	99290	81272	66867
3+	335145	256946	195012					3+	93517	75498	61093
4+	302236	223962	162086					4+	87893	69861	55466
5+	198308	199136	137608					5+	63997	64153	49838

	CATCH NUMBERS ('000)			CATCH BIOMASS (t)			
	1986	1987	1988		1986	1987	1988
2	323	388	388	2	46	55	55
3	2348	2802	2797	3	401	479	478
4	13762	3887	3833	4	3164	894	881
5	3349	17161	3972	5	897	4598	1064
6	28781	2504	10408	6	9074	789	3281
7	5241	21521	1519	7	1773	7281	514
8	465	3919	13053	8	192	1618	5390
9	167	348	2377	9	69	144	987
10	260	125	211	10	117	56	95
11+	1661	194	76	11+	762	89	35
12+	0	1242	118	12+	0	570	54
13+	0	0	753	13+	0	0	346
2+	56356	54089	39504	2+	16495	16573	13180
3+	56033	53701	39116	3+	16449	16518	13125
4+	53685	50900	36319	4+	16048	16039	12647
5+	39923	47012	32487	5+	12884	15145	11766

Table 20. Population and catch estimates for fall spawning herring in NAFO division 4R from 1986 to 1988 assuming a fishing mortality rate of 0.3 in 1987 and 1988.

POPULATION NUMBERS ('000)				FISHING MORTALITY				MID-YEAR POPULATION BIOMASS (t)			
	1986	1987	1988		1986	1987	1988		1986	1987	1988
2	31738	31738	31738	2	.001	.004	.004	2	3015	3015	3015
3	25964	25953	25873	3	.018	.064	.064	3	3684	3683	3671
4	72186	20872	19922	4	.022	.078	.078	4	13954	4035	3851
5	56459	57809	15807	5	.054	.189	.189	5	12243	12536	3508
6	30988	43815	39179	6	.085	.300	.300	6	7845	11092	9919
7	113856	23303	26575	7	.085	.300	.300	7	32622	6677	7615
8	10734	85622	14134	8	.085	.300	.300	8	3305	23630	4351
9	5189	8072	51932	9	.085	.300	.300	9	1671	2599	16720
10	886	3902	4896	10	.085	.300	.300	10	291	1281	1608
11+	3072	666	2367	11+	.085	.300	.300	11+	1291	280	994
12+	0	2310	404	12+	.000	.300	.300	12+	0	971	169
13+	0	0	1401	13+	.000	.000	.300	13+	0	0	588
2+	351072	304062	234228	2+	.054	.213	.208	2+	79921	69799	56009
3+	319333	272325	202490					3+	76906	66784	52994
4+	293370	246372	176617					4+	73221	63101	49323
5+	221184	225499	156695					5+	59267	59066	45472

CATCH NUMBERS ('000)				CATCH BIOMASS (t)			
	1986	1987	1988		1986	1987	1988
2	35	123	123	2	4	12	12
3	426	1470	1466	3	67	209	208
4	1431	1421	1357	4	306	275	262
5	2671	9052	2475	5	640	1963	537
6	2292	10344	9250	6	641	2619	2342
7	8421	5501	6274	7	2667	1576	1798
8	794	20214	3337	8	270	6223	1027
9	384	1906	12260	9	137	614	3947
10	66	921	1156	10	24	302	380
11+	227	157	559	11+	106	66	235
12+	0	545	95	12+	0	229	40
13+	0	0	331	13+	0	0	139
2+	16745	51655	38681	2+	4860	14088	10927
3+	16710	51531	38558	3+	4856	14076	10915
4+	16284	50061	37093	4+	4789	13867	10707
5+	14854	48640	35736	5+	4484	13592	10445

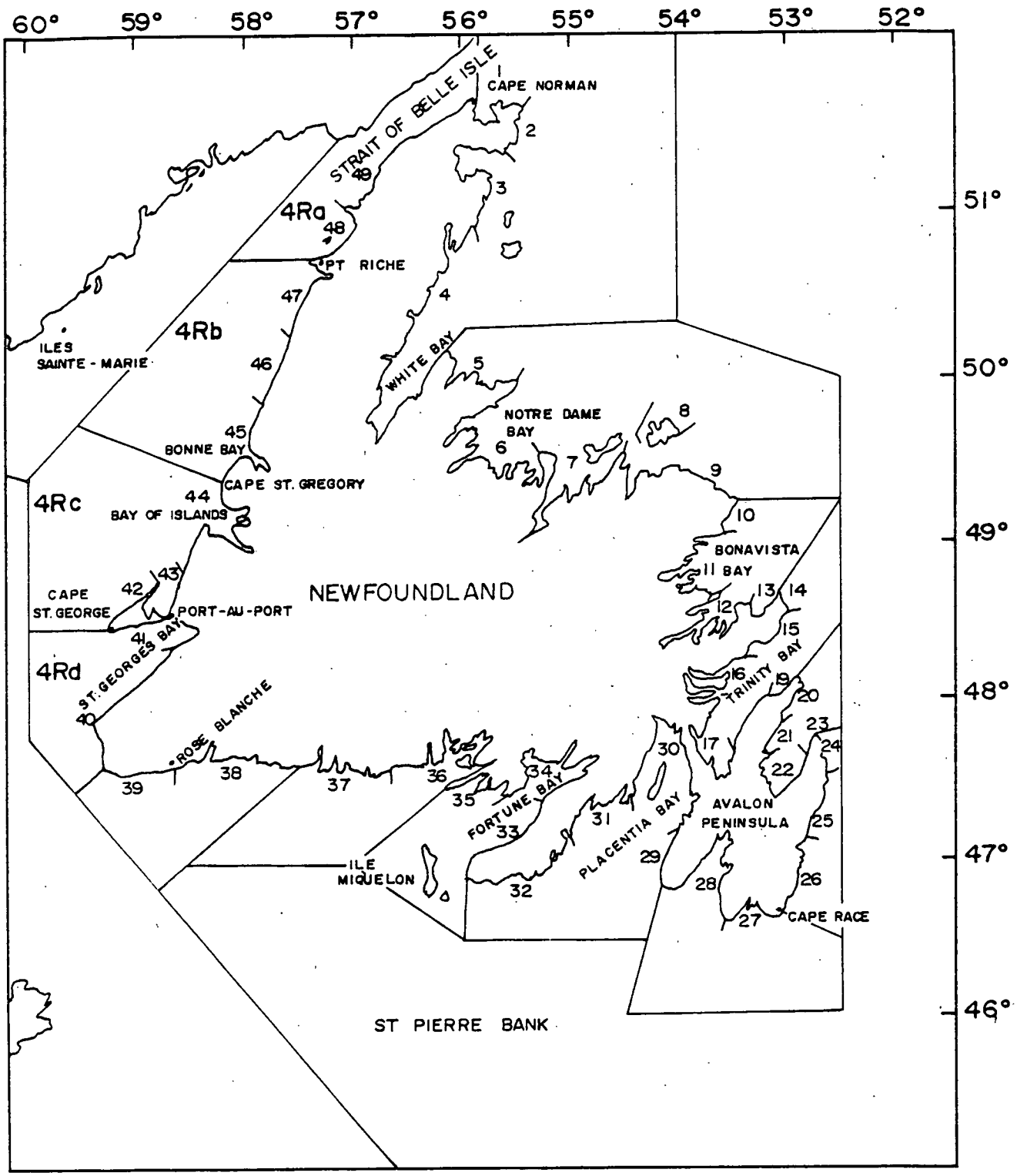


Figure 1. West coast of Newfoundland unit areas and statistical districts.

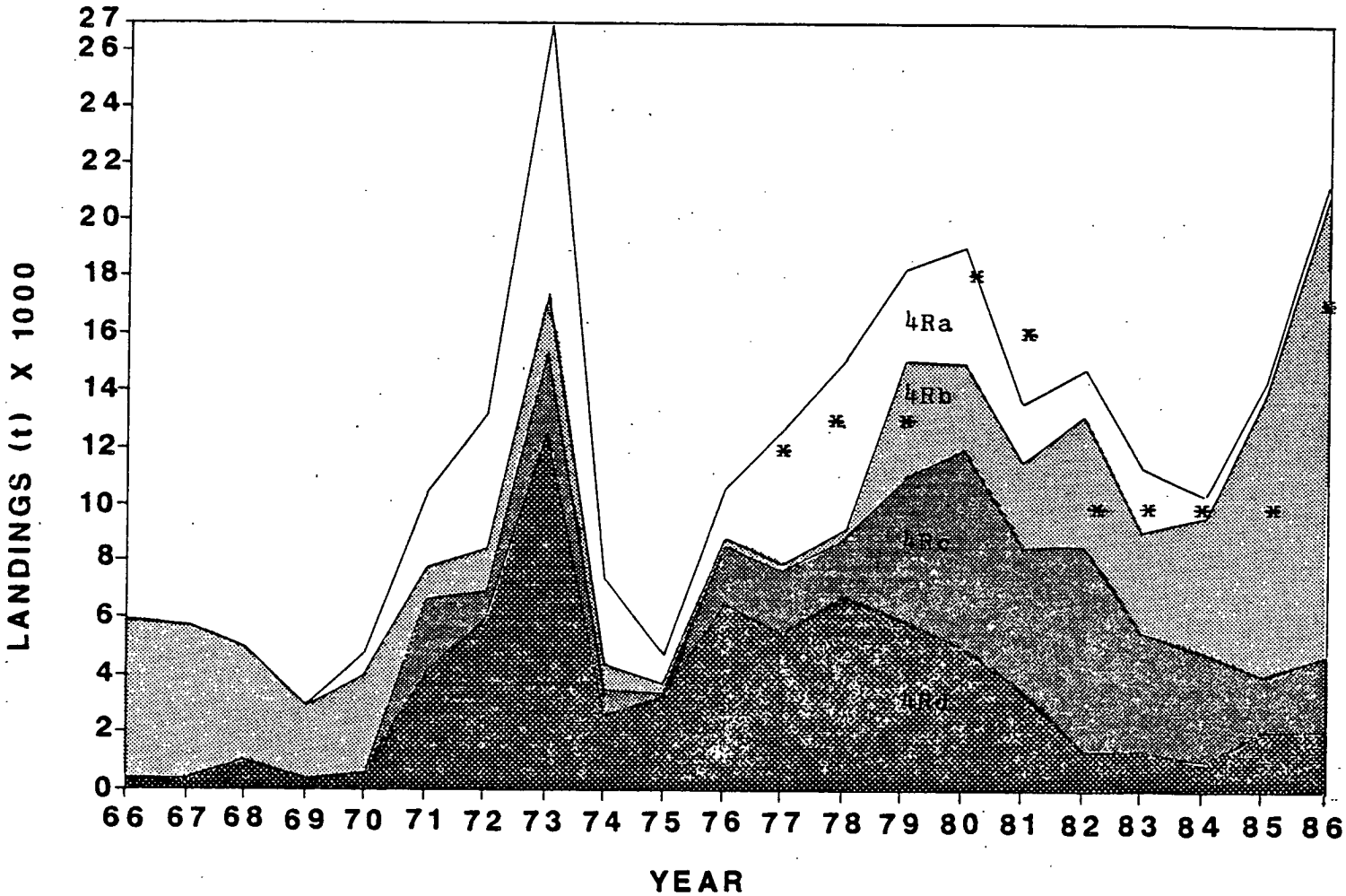


Figure 2. Commercial herring landings (t) by fishing area from NAFO division 4R from 1966 to 1986 (stars indicate annual TAC's).

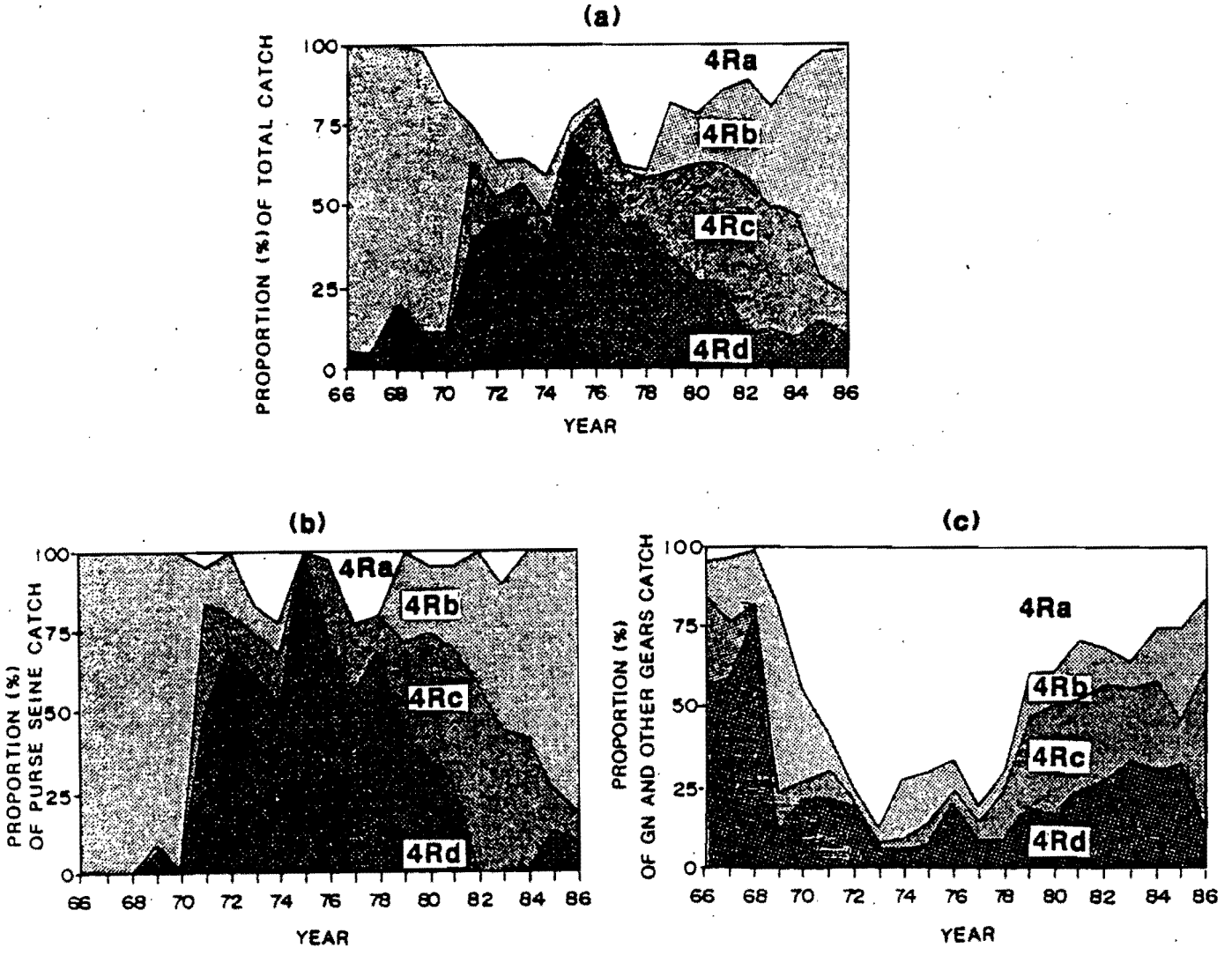


Figure 3. Proportions of herring catches from each fishing area from 1966 to 1986 for (a) all gears combined, (b) purse seines, and (c) all other gears (mainly gillnets).

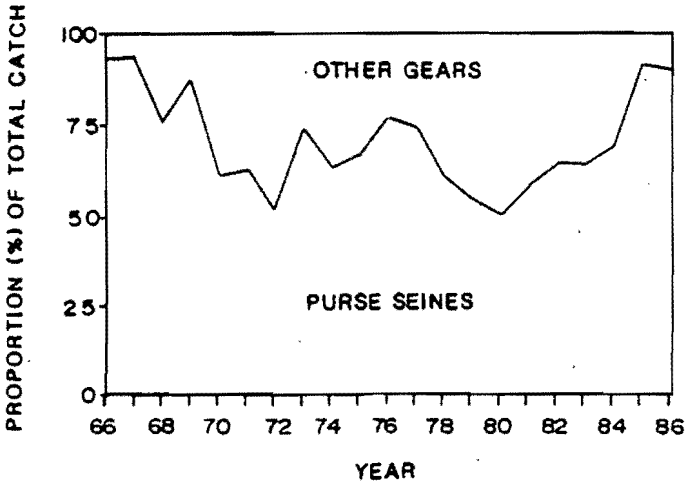


Figure 4. Proportion of total herring catches taken by purse seines and all other gears in NAFO division 4R from 1966 to 1986.

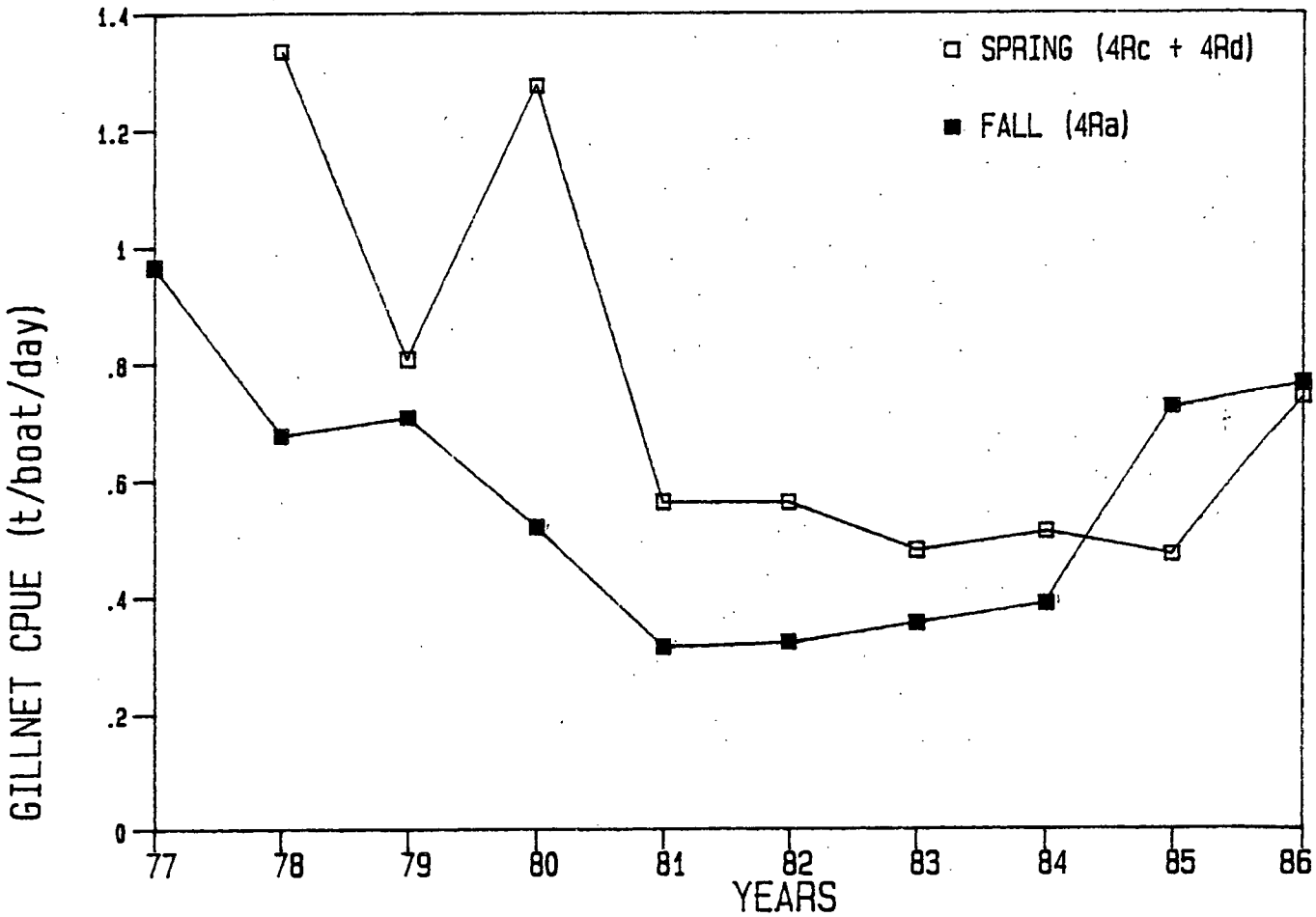


Figure 5. Gillnet catch rates, adjusted for gang size, for spring and fall spawning herring in NAFO division 4R from 1977 to 1986.

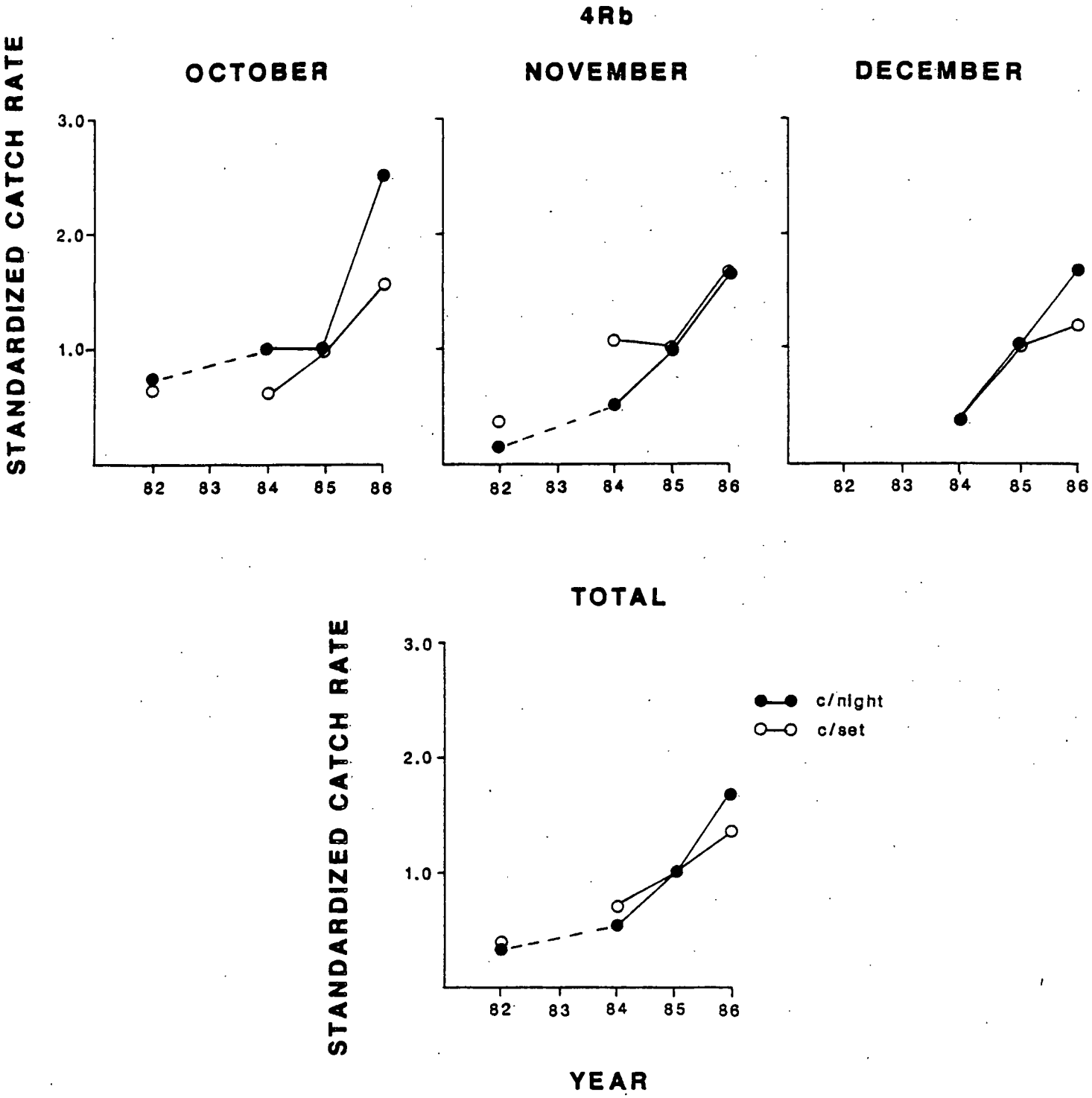
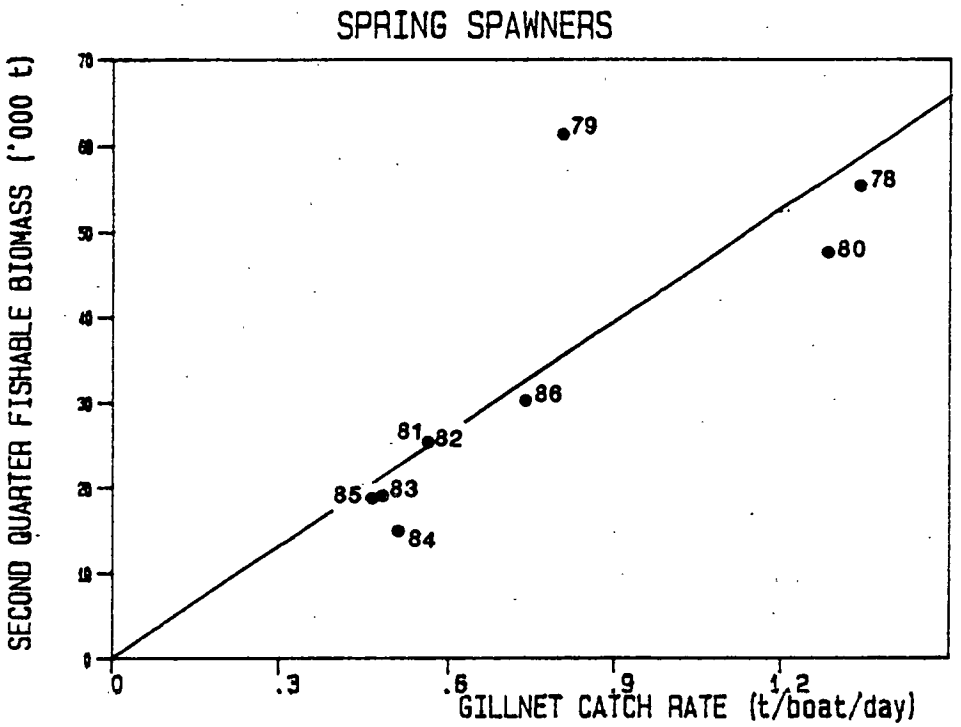


Figure 6. Purse seine catch rates from observer logbooks, standardized to 1985, from the NAFO division 4R fall mixed fishery from 1982 to 1986.

(a)



(b)

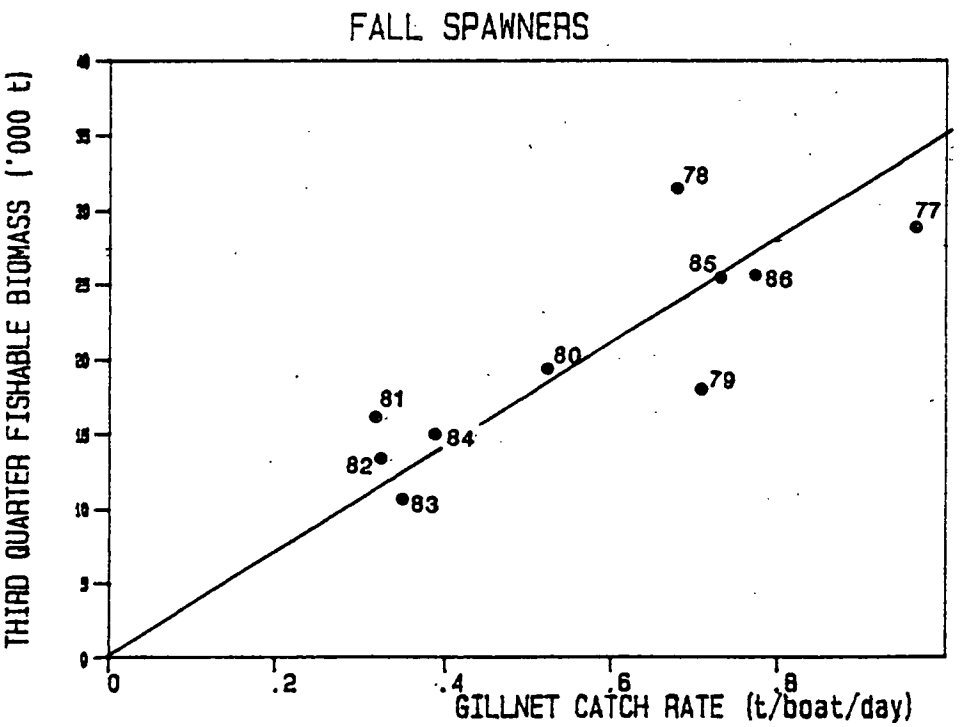


Figure 7. Least square regression of (a) spring spawner second quarter fishable biomass and gillnet catch rate for unit areas 4Rc and 4Rd in April and May from 1978 to 1986 and (b) fall spawner third quarter fishable biomass and gillnet catch rate for unit area 4Ra in August from 1977 to 1986.

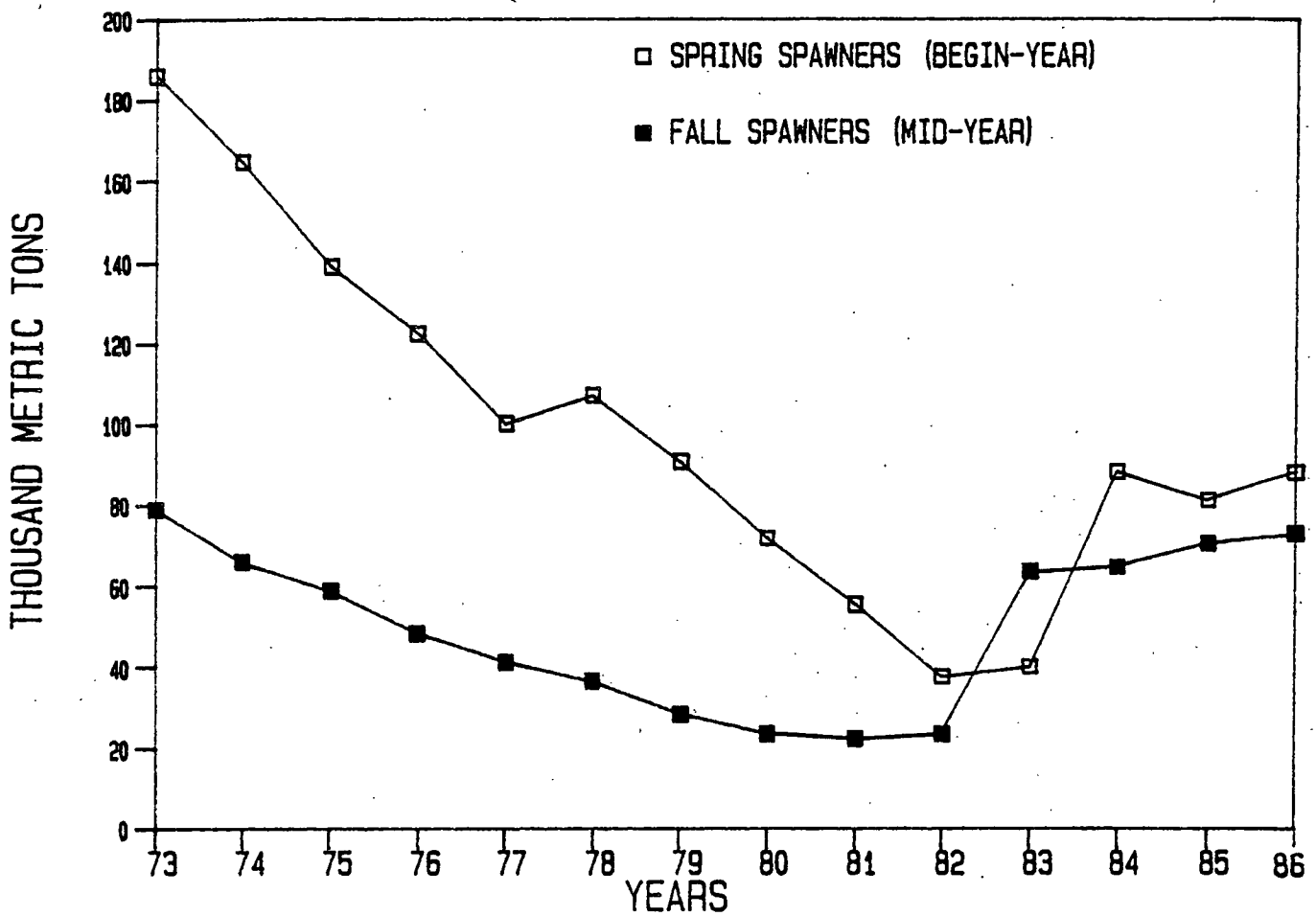


Figure 8. Beginning-of-the-year and mid-year 4+ biomass estimates ($x10^{-6}$) for spring and fall spawning herring, respectively, in NAFO division 4R from 1973 to 1986.

Annex 1. Number of herring sampled (bold print) and commercial landings (t) in NAFO division 4R by gear, area and month in 1986.

GEAR	AREA	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GN	4Ra				**149**	**792**	**50**	**347**	**48**	
		*	65	84	19	48	28	68	14	11
	4Rb								**90**	
		6	48	46	14	9	8	136	171	30
	4Rc	**100**	**750**				**50**	**100**		
		132	319	105	21	10	8	141	319	14
	4Rd	**250**	**699**							
		100	83	49	21	10	10			
PS	4Ra									
	4Rb							**550**	**1000**	**100**
								3091	10608	2131
	4Rc		**250**		**50**			**50**		
			1400		186					
	4Rd	**100**	**250**							
		185	1669							

* : < 1t