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A Review of the West Coast of Newfoundland (NAFO Division 4R) Herring Fishery Data up to 1990

by

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ABSTRACT

Herring stocks are exploited in NAFO Division 4R from April to December, by both fixed and mobile gears. Landings reached only 17,000 t in 1990, despite a TAC of 35,000 t, mainly due to poor market and late-fall weather conditions. A limited market demand for gillnetted herring has reduced the fixed gear landings to < 20% of the total since 1985. The traditional U.S. barrelled-product market has been slowly replaced by over-the-side sales to the Soviet Union, and frozen-round products for the Japanese. Spring spawners have been prevalent in the annual catch since 1973. Historically, this spawning group has been dominated by the 1968 and 1974 year-classes. Since 1985, the 1980 and 1982 year-classes have comprised > 68% of the catch in numbers. The fall spawners had been dominated by the 11+ age group until 1983, when the 1979 year-class became the single most important cohort in the catch. The spring index-fishermen gillnet catch-rate series showed a significant increase from 1984 to 1986, and a subsequent decreasing trend to 1988 and stability to 1990. The fall-spawner series showed a major increase to 1986, and has followed a declining trend to 1990. Cohort analysis were not attempted as the population numbers were unconverged in last years assessment. However, the 1987 spring-spawner year-class, and 1986 fall-spawner cohort, have appeared in the fall purse seine catches in numbers not seen since the 1980 cohort recruited to the fishery. This is a promising sign for the continued good health of these stocks.

RÉSUMÉ

Les stocks de hareng de la division 4R de l'OPANO sont exploitées d'avril à décembre, à l'aide d'engins fixes et mobiles. Malgré un TPA de 35,000 t, les débarquements de hareng n'ont atteint que 17,000 t en 1990, particulièrement à cause des marchés restreints et des mauvaises conditions météorologiques à l'automne. Un marché restreint pour les harengs capturés au filet maillant a réduit les débarquements associés aux engins fixes à moins de 20% du total depuis 1985. Le marché traditionnel américain du hareng en baril a été remplacé graduellement par les ventes directes à l'URSS et par les ventes aux Japonais de poissons gelés entiers. Les reproducteurs de printemps dominent les captures depuis 1973. 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 plus de 68% de la capture en nombre depuis 1985. Les captures de reproducteurs d'automne entre 1966 et 1983 étaient constituées d'une forte proportion de poissons âgés de 11 ans et plus. Depuis 1983, la classe d'âge de 1979 a dominé les captures. L'indice d'abondance des reproducteurs de printemps calculé à partir des données des pêcheurs-repères a démontré une augmentation d'abondance significative entre 1984 et 1986, une diminution subséquente jusqu'à 1988, et ensuite la stabilité jusqu'à 1990. L'indice du groupe d'automne a démontré une augmentation majeure jusqu'à 1986, suivie par un déclin jusqu'à 1990. L'analyse de cohorte n'a pas été considérée cette année étant donné les estimations des effectifs non-convergentes produites par l'analyse de l'an dernier. Cependant, les classes d'âge de 1987 et 1986 des reproducteurs de printemps et d'automne, respectivement, ont paru dans les prises de la senne bourse dans des quantités non observées depuis le recrutement de la classe d'âge de 1980. Ceci est un signe révélateur de bonne santé de ces stocks.

INTRODUCTION

Atlantic herring (*Clupea harengus* L.) in NAFO Division 4R (Figure 1) have been assessed by CAFSAC as a single management unit since 1977 (Moores and Winters, 1977). The 4R herring management unit was defined essentially on the basis of tagging studies conducted between 1975 and 1980 (Moores and Winters, 1984). These studies indicated that herring tagged during the pre-spawning, spawning and overwintering seasons along the west coast of Newfoundland were primarily (99.2%) recaptured within Division 4R. This division was therefore considered to be "an appropriate reference for [herring] stock assessment purposes" (Moores and Winters, 1984). Although there were indications from sampling and tagging data that herring concentrations exploited in Bay St. Georges 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 reviewed separately. It is generally accepted that sympatric spring and fall spawners in the northwest Atlantic have different adult life histories and therefore should be treated as separate stocks within each management unit (McQuinn, 1989).

DESCRIPTION OF THE FISHERY AND HISTORICAL FISHING PATTERNS

The herring stocks in NAFO Division 4R are exploited by both fixed (mostly gillnets) and mobile (mostly purse seines) gears from April to December on both spawning and overwintering concentrations. Since 1985, the proportion of the total catch taken by the purse seines has been in excess of 80%, and reached 95% in 1990.

Total herring landings from the west coast of Newfoundland were relatively small 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, this trend being 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 has levelled off at between 16,500 t and 18,200 t in the last four years.

From 1982 to 1987, the majority of the purse seine catches were taken in areas 4Rb and 4Rc from October to December (Table 2a) from overwintering concentrations of mixed spring and fall spawners (Table 3). This fishery contributedto over 80% of the purse seine landings in 1986 and 1987. In recent years, the traditional barrelled-product market for Newfoundland herring has been slowly replaced by an expansion in over-the-side sales (OSS) to the Soviet Union, and by the development of a spring frozen-round market for the Japanese. This, along with some quota sharing with the purse seine fleet based in the southern Gulf of St. Lawrence, explains the

considerable increase in landings from the spring fishery in 4Rc and 4Rd (from approximately 2,000 t in 1987 to 12,000 t in 1990). This spring fishery accounted for over 75% of the total purse seine catch in 1990 (Figure 3a), as landings also decreased in the late fall of 1990 due to poor weather conditions and an early end to the season as too many small fish were being encountered in the Bonne Bay area.

From 1979 to 1989, almost equal proportions of the total gillnet catch was taken from spawning concentrations (Table 4) in Bay St. Georges and Port-au-Port Bay (4Rc,4Rd) in April and May, and north of Pointe Riche (4Ra,4Rb) from July to September (Table 2b; Figure 3b). A late fall fishery on mixed spring- and fall-spawner concentrations (Table 4) has also occurred, although sporadically, in areas 4Ra to 4Rc throughout this period. In 1990, gillnet landings in Bay St. Georges and Port-au-Port Bay were marginal (Table 2b), representing only 26% of the gillnet catch and 1% of the total catch.

Total gillnet landings (Table 1), and therefore the proportion of the total catch taken by gillnets (Figure 4), have dwindled since 1980. Due to a limited market demand for gillnetted herring, less than 10% of the total 4R landings have been reported from the fixed gear sector since 1985, except for 1987 when this proportion topped 17%. The inshore fishery is now almost exclusively oriented toward filling the traditional role of supplying bait for the active lobster fishery. In 1989 and 1990, the late fall (October-December) fishery was extremely limited, although this was at least in part due to exceptionally poor weather conditions.

MANAGEMENT PLAN

Total allowable catches (TAC) have been in effect since 1977. Since 1981, 45% of the TAC has been allocated to the fixed gear sector and 55% to the mobile gear sector, although transfers between gear sectors have been allowed since the early 1980's. 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 and south of Cape St. Gregory. Since 1989, an additional inshore allocation has been made for an experimental, small-purse-seine fishery. This allocation has increased from 2,000 to 3,500 to 7,000 t in 1989, 1990 and 1991, respectively. Purse seine allocations to the OSS programme have also increased, from 8,000 t in 1990 to 10,000 t in 1991. The TAC has not been exceeded since 1986 (Table 1; Figure 2).

COMMERCIAL FISHERY DATA

a) 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 throughout the fishing season, covering most of the major commercial landings (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 (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 1990 catch at age (Table 5) was generated (CATΔAGE v1.0, Anon, 1986) for spring and fall spawners as described by McQuinn (1987b).

b) Spring-Spawner Catch at Age:

Spring spawners have dominated the catch in every year since 1973 (Table 5), averaging 73% of the catch in numbers. This proportion has been over 80% of the catch in numbers since 1988 due to the active spring fishery in Bay St. Georges. The 1968 year-class was the largest ever observed in the spring-spawner catch and completely dominated from 1973 to 1982 (Table 6). During these years, 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 represented 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 (assuming ages 11+ to be 11) at 7 years old in 1990. In 1990 the dominant year-class in the spring catch at age shifted to 1983.

c) 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 31% in 1989. The mean age of fall spawners in the catch has therefore risen in recent years, from 6 years old in 1985 to 8 years old in 1989. The fall spawner catch at age showed a shift in 1990, the bulk (47%) of the fall-spawner catch at age consisting of the 1982 and 1983 year-classes.

The appearance of these strong year-classes at ages 7 and 8 in the 1990 catch at age was unexpected and inconsistent with the previous years catches at age, suggesting an ageing error. Although changes in fishing patterns may cause such a shift in dominant year classes in the catch, industry representatives confirmed that the purse seine fleet has operated in a similar fashion in recent years. A preliminary examination of lengths and weights at age suggested a bias toward younger ages for these year-classes, indicating that older fish (> 6 years old) were under-aged. Although the 1990 otoliths were aged by the same reader as for 10 of the past 13 years, a bias in ageing appears to be the most plausible explanation for the discrepancy. However, without validation of the 1990 ageing, it was difficult to draw conclusions about the age composition on the 1990 catch at age. A workshop is planned during the coming year where a re-examination of the 1990 ages will be undertaken.

d) Recruitment:

The late fall purse seine fishery is normally prosecuted on a mixture of spring and fall spawners (Table 3) concentrated in schools in and around the major bays along the coast (e.g. Bonne Bay, St. John Bay). These schools also contain newly recruited "maturing" fish, who have for the first time joined the adult schools. When a strong recruiting year-class enters the fishery, it is often in these late fall schools that they are first noticed by the purse seine fleet. This occurred in 1982, as the strong 1980 spring-spawner year-class was first seen at age 2 yr 6 mo in the fall commercial purse-seine catches and then again in the following spring of 1983. This showed up as a large influx of fish below 30 cm (Figure 5). The 1982 year-class was also evident as a mass of fish below 30 cm as it recruited to the fishery in the fall of 1985 at 3 yr 6 mo. Throughout the remainder of the 1980's, very little additional recruitment was seen entering the fishery. However, in 1990, the 1987 spring-spawner year-class, and 1986 fall-spawner cohort, have appeared in the fall purse seine catches in numbers not seen since the 1980 cohort recruited to the fishery (Figure 5). Although these fish are normally too small for market requirements, they were nonetheless hard to avoid by the purse seine fleet. This fishery was eventually curtailed in December due to excessive numbers of these young fish in the sets. It is worthy of note that the 1987 cohort has also recruited strongly in the southern Gulf herring (4T), as well as in the Atlantic mackerel (Grégoire, 1991).

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 index gillnet fishermen, covering most of the fishing season.

a) Commercial Data

Annual gillnet catch rates were estimated using all available purchase slips from 1981 to 1990 using a multiplicative model (Table 7). Prior to these analyses, catches were proportioned to spring and fall spawners using the percent spawning-stock composition determined from the commercial samples (Table 4). In addition, slips which represented a weekly sum of landings rather than a daily trip were excluded.

The estimated number of nets fished/day between 1982 to 1990 were obtained from written surveys sent between 1984 to 1990 to all licensed fishermen along the west coast. In addition, estimates of the numbers of nets fished by each fishermen were also available between 1981 and 1983 from the licence application forms. In order to weigh the mean number of nets used in the multiplicative model by the number of landings of each fisherman, the purchase slip and questionnaire files were merged. This involved matching the Commercial Fishing Vessel number from the questionnaires with the individual purchase slips to produce a combined data set where effort was the number of nets/fisherman/day rather than a daily trip.

A multiplicative model was then fitted to these catch and effort data to yield standardized annual catch rates for each spawning stock (Gavaris, 1980). The category types for the model were month, unit area and year (Tables 8 and 9).

b) Logbook Data

Index 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 (Table 11 and 12). The category types for the model were year and fisherman (Tables 13, 14 and 15). As each fisherman fished in the same area and during the same time period each year, the category types month (or week) and area were highly correlated with the fisherman category type and could not be used in the model. Catches in each category type were proportioned to spring and fall spawners in the same manner as with the commercial purchase slip data (Table 4).

TRENDS IN CATCH RATES

Both spring catch-rate series showed a significant increase between 1984 and 1986. The commercial series decreased significantly to 1990 while the index-fisherman series declined to 1988 and remained stable to 1990 (Tables 10 and 15; Figure 6).

The fall-spawner series both showed a major increase to 1986. The commercial series decreased to 1988 and increased to 1990 while the index-fisherman series decreased significantly to 1990. Trends in the logbook series were more regular than the commercial series, and have followed the recruitment and subsequent decline of the 1980 and 1982 spring-spawning, and 1979 fall-spawning year-classes. The logbook catch rates were considered more reliable than the commercial series due to the greater control of data quality from the logbooks and the inherent errors associated with commercial catch and questionnaire data.

PROGNOSIS

Cohort analyses performed on these data in 1990 revealed that fishing mortalities at age have been generally below 0.2 since 1985. At these light exploitation levels, the analyses did not produce converged population-number estimates. Since very little has changed in the intervening year, i.e. landings have remained stable, and the spring index-fisherman catch rates have not changed since 1988 (spring spawners making up 80% of the catch in numbers since 1988), cohort analyses were not attempted this year. In addition, the possibility of an ageing bias in the 1990 catch at age precludes an analytical assessment of the commercial data. Without estimates of population size, catch projections for 1992 could not be estimated. However, as was noted by McQuinn and Lambert (1990), "recent catch levels of between 14,000-22,000 t have not been detrimental to these populations". With the stable landings and spring index-fisherman catch rates of 1990, this assertion should still apply. It was also encouraging to note that the dominant year-classes in the late fall (Nov-Dec) purse seine fishery were 3 and 4 years old (Figure 5). The early dominance of these year-classes is a promising sign for the future of this fishery; their importance should be more evident within two years, when they will be 5 and 6 years old and hence of marketable size.

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Table 1. Herring catches (t) by gear type and fishing area and total allowable catches (t) from NAFO Division 4R from 1966 to 1990.

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	45	0	45	5491	403	0	5894	
1967	0	215	0	215	0	66	0	66	5464	76	0	5540	0	40	0	40	5464	397	0	5861	
1968	0	156	789	945	0	59	0	59	3776	67	136	3979	0	11	0	11	3776	293	925	4994	
1969	241	36	6	283	0	46	0	46	2344	201	4	2549	0	68	1	69	2585	351	11	2947	
1970	28	51	3	82	12	15	17	44	2939	534	4	3477	0	407	92	499	2979	1007	116	4102	
1971	3287	543	427	4257	2239	185	24	2448	725	338	21	1084	356	1598	11	1965	6607	2664	483	9754	
1972	4743	178	866	5787	727	135	64	926	1330	214	0	1544	0	3628	146	3774	6800	4155	1076	12031	
1973	12112	429	0	12541	2740	122	0	2862	1763	305	2	2070	3453	5760	15	9228	20068	6616	17	26701	
1974	2465	159	0	2624	756	101	4	861	439	479	47	965	1071	1972	5	3048	4731	2711	56	7498	
1975	3221	116	3	3340	0	112	16	128	0	240	26	266	0	1764	22	1786	3221	2232	67	5520	
1976	6067	499	3	6569	1956	111	2	2069	0	226	20	246	184	2143	140	2467	8207	2979	165	11351	
1977	5289	272	7	5568	2009	193	3	2205	0	158	31	189	2155	2028	183	4366	9453	2651	224	12328	12000
1978	6252	522	33	6807	1037	931	16	1984	0	288	81	369	1834	3795	22	5651	9123	5536	152	14811	12500
1979	4387	1642	3	6032	2774	2267	2	5043	2829	1048	121	3998	0	3258	7	3265	9990	8215	133	18338	12500
1980	3499	1558	41	5098	3703	3224	17	6944	2002	879	88	2969	428	3810	5	4243	9632	9471	151	19254	18000
1981	2269	1368	2	3639	3277	1622	0	4899	2037	913	140	3090	342	1600	27	1969	7925	5503	169	13597	16000
1982	0	1463	3	1466	5575	1572	11	7158	3973	519	58	4550	0	1695	1	1696	9548	5249	73	14870[2]	10000
1983	0	1410	2	1412	3269	873	46	4188	3223	226	108	3557	787	1438	34	2259	7279	3947	190	11416[2]	10000
1984	0	1006	1	1007	3023	902	0	3925	4166	554	2	4722	15	790	4	809	7206	3252	7	10465[2]	10000
1985	1720	398	0	2118	1733	164	0	1897	9718	348	4	10070	0	295	6	301	13171	1205	10	14386[2]	10000
1986	1854	273	0	2127	1586	1069	0	2655	15830	468	0	16298	0	337	0	337	19270	2147	0	21417[2]	17000
1987	222	550	0	772	3183	1137	0	4320	10164	327	5	10496	164	829	0	993	13733	2843	5	16581	30600
1988	2019	435	0	2454	13197	592	0	13789	1093	256	0	1349	44	509	0	553	16353	1792	0	18145[1]	30600
1989	9111	177	0	9288	6589	444	0	7033	947	69	0	1016	13	337	0	350	16660	1027	0	17687[1]	37000
1990	5156	97	0	5253	7495	79	0	7574	3404	181	6	3591	28	323	133	484	16084	677	140	16903[1]	35000

* Includes shrimp trawl, bar seine, cod trap, midwater trawl and otter trawl.
1 Preliminary
2 Purse seine landings adjusted according to industry records

Table 2.a. Herring landings (t) by purse seines in NAFO division 4R by unit area and month from 1983 to 1990.

YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
1983	4Ra											604	183	787
	4Rb										480	2263	480	3223
	4Rc				2289	980								3269
	4Rd													
	Total				2289	980					480	2867	663	7279
1984	4Ra											15		15
	4Rb				24						1090	1763	1289	4166
	4Rc	309			2714									3023
	4Rd													
	Total	309			2738						1090	1778	1289	7204
1985	4Ra													
	4Rb								482		526	5577	3133	9718
	4Rc					1464	99				170			1733
	4Rd					1720								1720
	Total					3184	99		482		696	5577	3133	13171
1986	4Ra													
	4Rb										3091	10608	2131	15830
	4Rc					1400		186						1586
	4Rd				185	1669								1854
	Total				185	3069		186			3091	10608	2131	19270
1987	4Ra											164		164
	4Rb					25			14		748	4426	4951	10164
	4Rc					1319	596			153	565	379	171	3183
	4Rd					222								222
	Total					1566	596		14	153	1313	4969	5122	13733
1988	4Ra							22	22					44
	4Rb									71	312	437	273	1093
	4Rc				639	5342	70		6		990	1985	4165	13197
	4Rd				1308	711								2019
	Total				1947	6053	70	22	28	71	1302	2422	4438	16353
1989	4Ra								13					13
	4Rb				33						81	347	486	947
	4Rc				35		51		6	514	776	3080	2127	6589
	4Rd				379	8587	145							9111
	Total				447	8587	196		19	514	857	3427	2613	16660
1990	4Ra						14	14						28
	4Rb							138			379			3404
	4Rc					6536	450	205	27	17	261	2888		7495
	4Rd					4799	335				23			5156
	Total					11335	798	357	27	17	662	2888		16084

Table 2.b. Herring landings (t) by gillnets in NAFO division 4R by unit area and month from 1983 to 1990.

YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
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
	Total	3	3	20	1319	840	125	319	591	242	114	190	181	3947
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
	Total	19			565	999	206	147	180	205	508	369	73	3271
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
	Total				3	440	98	32	45	173	49	347	18	1205
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
	Total				238	515	284	75	77	54	345	504	55	2147
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
	Total	1		1	307	940	170	124	209	91	347	609	44	2843
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
	Total				153	203	293	335	40	19	286	358	104	1791
1989	4Ra					4	34	13			4	182	100	337
	4Rb		1	2	8	16	24	8	2	1	7			69
	4Rc				10	213	101	108		11		1		444
	4Rd				2	107	36	19	7	5		1		177
	Total		1	2	20	340	195	148	9	17	11	184	100	1027
1990	4Ra					4	9	3	13	49	28	216		323
	4Rb				10	13	23	14	3	1	1	117		181
	4Rc					4	19	46	3	2	5			79
	4Rd					34	11	40	9	2	1			97
	Total				10	55	62	102	28	54	35	333		679

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 1990.

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			
1989		91.3			34.0			79.5	66.9						68.5	70.1	70.1					
1990		91.4					70.0	24.0							65.0	59.9						
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			
1989		8.7			66.0			20.5	33.1						31.5	29.9	29.9					
1990		8.6					30.0	76.0							35.0	40.1						

Table 4. Proportion (%) of spring- and fall-spawning herring in the gillnet catch by month and fishing area, NAFO division 4R from 1973 to 1990.

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
1989		99.0	91.1	86.0	85.3	79.6								71.0	56.7				22.3	11.6	23.3	44.0	40.0	
1990		96.9	98.6		94.3	96.5	40.2								42.9				15.4	17.4	0.7	18.0	32.5	
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
1989		1.0	8.9	14.0	14.7	20.4								29.0	43.3				77.7	88.4	76.7	56.0	60.0	
1990		3.1	1.4		5.7	3.5	59.8								57.1				84.6	82.6	99.3	82.0	67.5	

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 1990.

SPRING SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0	0	0	0	45	0	0	3	13	0	4	39	48	265	323	183	0	0
2	1833	141	57	484	10	0	167	300	40	594	34	198	362	323	455	734	305	115
3	435	261	996	680	534	47	25	854	417	2374	2965	433	4587	2348	329	519	574	1234
4	1063	130	420	846	541	1987	214	106	2114	693	3562	7773	787	13762	2781	417	763	1144
5	27872	371	100	201	409	207	10828	355	129	2452	1131	3809	21642	3349	15257	2400	461	935
6	2570	9445	1063	350	304	679	617	13872	354	421	1091	595	3993	28781	3507	14830	3036	4869
7	3222	318	8431	2802	348	241	1075	407	8872	2153	293	814	445	5241	12952	4004	18705	16863
8	3232	851	317	15567	4362	2162	547	1344	188	6488	713	209	381	465	1736	14606	3072	7695
9	2598	774	336	759	15959	8208	2772	247	515	704	2990	672	255	167	182	2734	10910	3380
10	4789	490	244	3136	1694	15260	7404	1427	283	950	798	755	380	260	37	480	779	656
11+	5696	2175	665	3588	6003	5062	14032	20574	13181	12863	7975	4226	1764	1661	806	2123	1380	750
1+	53310	14955	12629	28413	30210	33851	37681	39488	26106	29692	21556	19523	34645	56621	38365	43030	39985	37642

FALL SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0
2	0	0	0	0	0	0	0	15	0	101	15	0	15	35	0	483	43	12
3	1798	20	19	48	3	10	7	181	33	567	83	55	235	426	156	186	599	301
4	1180	393	40	272	169	27	116	136	524	1824	2330	668	1340	1431	487	520	540	978
5	1114	530	865	290	134	545	345	86	245	956	1356	6259	1907	2671	1354	490	923	716
6	2626	325	925	422	404	393	2689	176	90	509	1309	1147	9678	2292	2009	1026	808	484
7	1527	592	107	561	721	1108	520	1729	295	140	506	908	902	8421	1728	1267	749	1482
8	2631	258	157	325	405	1689	1287	250	1234	377	159	220	622	794	5927	1503	828	2470
9	3830	308	147	253	342	503	1847	675	153	972	467	146	115	384	474	3798	961	753
10	8265	313	218	88	293	341	468	308	124	315	618	268	36	66	163	501	2873	1108
11+	17653	5610	3371	4818	6646	6051	6286	5243	3369	2609	2824	3091	468	227	196	671	983	442
1+	40626	8348	5848	7076	9116	10668	13564	8799	6067	8371	9667	12762	15333	16745	12494	10445	9307	8745

TOTAL (SPRING AND FALL)

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
TOTAL REMOVALS	93937	23303	18477	35489	39326	44520	51245	48288	32173	38062	31223	32286	49978	73366	50859	53475	49292	46387
% SPRING SPAWNERS	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	81.1	81.1

Table 6. Age composition (%) and mean age* of (A) spring and (B) fall spawners in NAFO division 4R herring landings from 1973 to 1990. 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	1989	1990
1	.0	.0	.0	.0	.1	.0	.0	.0	.1	.0	.0	.2	.1	.5	.8	.4	.0	.0
2	3.4	.9	.5	1.7	.0	.0	.4	.8	.2	2.0	.2	1.0	1.0	.6	1.2	1.7	.8	.3
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	1.4	3.3
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	1.9	3.0
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	1.2	2.5
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	12.9
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	46.8	44.8
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	7.7	20.4
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	27.3	9.0
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	1.9	1.7
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	3.5	2.0

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
MEAN AGE	6.5	7.0	6.8	8.1	9.0	9.3	8.6	8.7	8.8	8.4	7.7	6.3	5.3	5.6	5.9	7.0	7.6	7.1

B) FALL SPAWNER AGE COMPOSITION (%)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.2	.0	1.2	.2	.0	.1	.2	.0	4.6	.5	.1
3	4.4	.2	.3	.7	.0	.1	.1	2.1	.5	6.8	.9	.4	1.5	2.5	1.3	1.8	6.4	3.4
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	5.8	11.2
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	9.9	8.2
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	8.7	5.5
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	8.0	16.9
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	8.9	28.2
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	10.3	8.6
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	30.9	12.7
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	10.6	5.1

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
MEAN AGE	9.2	9.6	9.0	9.6	10.0	9.5	9.0	9.5	9.2	7.4	7.3	6.8	6.0	6.3	7.1	7.6	7.9	7.5

* assuming ages 11+ to be 11.

Table 7. Frequency of observations of commercial catch and effort data by month, unit area and year for herring in NAFO Division 4R.

MONTH	Frequency	Percent	Cumulative Frequency	Cumulative Percent
3	21	0.2	21	0.2
4	1408	13.9	1429	14.1
5	2288	22.7	3717	36.8
6	305	3.0	4022	39.8
7	1519	15.0	5541	54.9
8	1524	15.1	7065	69.9
9	881	8.7	7946	78.7
10	1459	14.4	9405	93.1
11	636	6.3	10041	99.4
12	60	0.6	10101	100.0

SUBAREA	Frequency	Percent	Cumulative Frequency	Cumulative Percent
4RA	5357	53.0	5357	53.0
4RB	1067	10.6	6424	63.6
4RC	1879	18.6	8303	82.2
4RD	1798	17.8	10101	100.0

YEAR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
81	1949	19.3	1949	19.3
82	3094	30.6	5043	49.9
83	2814	27.9	7857	77.8
84	1134	11.2	8991	89.0
85	142	1.4	9133	90.4
86	102	1.0	9235	91.4
87	321	3.2	9556	94.6
88	279	2.8	9835	97.4
89	110	1.1	9945	98.5
90	156	1.5	10101	100.0

Table 8. Analysis of variance and regression coefficients for the 1981 to 1990 commercial spring-spawning 4R herring catch rate data (catch per net).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	35229.31319	1677.58634	833.91	0.0001
Error	10079	20276.15452	2.01172		
Corrected Total	10100	55505.46770			

R-Square	C.V.	Root MSE	Mean Catch Rate
0.634700	64.64010	1.418352	2.194230

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	9	11474.57872	1274.95319	633.76	0.0001
SUBAREA	3	135.13872	45.04624	22.39	0.0001
YEAR	9	1401.33954	155.70439	77.40	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		3.856240280 B	16.62	0.0001	0.23203324
MONTH	3	0.402765133 B	1.09	0.2761	0.36977508
	4	0.052811684 B	0.26	0.7940	0.20225817
	5	0.504838062 B	2.52	0.0117	0.20011659
	6	-1.449212170 B	-7.14	0.0001	0.20291607
	7	-2.742939744 B	-14.43	0.0001	0.19011057
	8	-4.156861067 B	-21.89	0.0001	0.18990413
	9	-2.829451391 B	-14.70	0.0001	0.19254131
	10	-0.497699076 B	-2.62	0.0087	0.18964875
	11	-0.556640821 B	-2.89	0.0039	0.19271793
	12	0.000000000 B	.	.	.
SUBAREA	4RA	-0.522711432 B	-6.26	0.0001	0.08354146
	4RB	-0.536899119 B	-6.93	0.0001	0.07744018
	4RC	-0.321085034 B	-6.59	0.0001	0.04872438
	4RD	0.000000000 B	.	.	.
YEAR	81	-0.294344599 B	-2.45	0.0143	0.12018888
	82	-0.320967829 B	-2.71	0.0068	0.11863723
	83	0.347645761 B	2.93	0.0034	0.11869325
	84	0.299455071 B	2.43	0.0150	0.12305777
	85	0.222353118 B	1.32	0.1866	0.16834659
	86	1.129012803 B	6.18	0.0001	0.18273145
	87	1.034989462 B	7.43	0.0001	0.13923940
	88	0.500710863 B	3.49	0.0005	0.14331844
	89	0.883962349 B	4.95	0.0001	0.17873338
	90	0.000000000 B	.	.	.

Table 9. Analysis of variance and regression coefficients for the 1981 to 1990 commercial fall-spawning 4R herring catch rate data (catch per net).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	11867.12446	565.10116	392.75	0.0001
Error	10079	14501.90462	1.43882		
Corrected Total	10100	26369.02908			

R-Square	C.V.	Root MSE	Mean Catch Rate
0.450040	56.63122	1.199510	2.118107

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	9	1600.915216	177.879468	123.63	0.0001
SUBAREA	3	142.657318	47.552439	33.05	0.0001
YEAR	9	571.639296	63.515477	44.14	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		3.462604477 B	17.65	0.0001	0.19623204
MONTH	3	-2.360629820 B	-7.55	0.0001	0.31272123
	4	-1.917561615 B	-11.21	0.0001	0.17105107
	5	-2.108504199 B	-12.46	0.0001	0.16923992
	6	-1.798576566 B	-10.48	0.0001	0.17160746
	7	-0.415534868 B	-2.58	0.0098	0.16077777
	8	-0.051139123 B	-0.32	0.7502	0.16060318
	9	-0.711884591 B	-4.37	0.0001	0.16283346
	10	-0.836965360 B	-5.22	0.0001	0.16038720
	11	-0.403863017 B	-2.48	0.0132	0.16298282
	12	0.000000000 B	.	.	.
SUBAREA	4RA	0.632572903 B	8.95	0.0001	0.07065156
	4RB	0.455490960 B	6.95	0.0001	0.06549167
	4RC	-0.025353975 B	-0.62	0.5384	0.04120653
	4RD	0.000000000 B	.	.	.
YEAR	81	-0.554769006 B	-5.46	0.0001	0.10164453
	82	-0.745807972 B	-7.43	0.0001	0.10033229
	83	-0.880595249 B	-8.77	0.0001	0.10037966
	84	-0.323266150 B	-3.11	0.0019	0.10407077
	85	-0.474644381 B	-3.33	0.0009	0.14237182
	86	0.389174640 B	2.52	0.0118	0.15453720
	87	-0.195944955 B	-1.66	0.0961	0.11775568
	88	-0.516219833 B	-4.26	0.0001	0.12120535
	89	-0.029412184 B	-0.19	0.8457	0.15115600
	90	0.000000000 B	.	.	.

Table 10. Predicted mean commercial catch rate and standard error estimates for (a) spring- and (b) fall-spawning herring in NAFO Division 4R.

	SPRING SPAWNERS		FALL SPAWNERS	
YEAR	CATCH RATE	STANDARD ERROR	CATCH RATE	STANDARD ERROR
81	0.38631	0.01948	0.64981	0.02771
82	0.37630	0.01605	0.53695	0.01937
83	0.73419	0.03498	0.46916	0.01891
84	0.69935	0.03900	0.81891	0.03863
85	0.64385	0.07669	0.70107	0.07069
86	1.58872	0.22990	1.65899	0.20333
87	1.45615	0.12490	0.92869	0.06740
88	0.85274	0.08080	0.67379	0.05403
89	1.24382	0.17739	1.09182	0.13188
90	0.51536	0.06243	1.12673	0.11555

Table 11. Frequency of observations of logbook catch and effort data by fisherman and year for spring-spawning herring in NAFO Division 4R.

FISHERMAN	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	226	15.1	226	15.1
2	131	8.7	357	23.8
3	42	2.8	399	26.6
4	58	3.9	457	30.5
5	105	7.0	562	37.5
6	173	11.5	735	49.0
7	147	9.8	882	58.8
8	140	9.3	1022	68.2
9	121	8.1	1143	76.3
10	4	0.3	1147	76.5
11	124	8.3	1271	84.8
12	141	9.4	1412	94.2
13	64	4.3	1476	98.5
15	23	1.5	1499	100.0

YEAR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
84	92	6.1	92	6.1
85	192	12.8	284	18.9
86	214	14.3	498	33.2
87	263	17.5	761	50.8
88	307	20.5	1068	71.2
89	235	15.7	1303	86.9
90	196	13.1	1499	100.0

Table 12. Frequency of observations of logbook catch and effort data by fisherman and year for fall-spawning herring in NAFO Division 4R.

FISHERMAN	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	264	21.1	264	21.1
2	178	14.2	442	35.3
3	45	3.6	487	38.9
4	64	5.1	551	44.0
5	113	9.0	664	53.0
6	63	5.0	727	58.0
7	116	9.3	843	67.3
8	43	3.4	886	70.7
9	90	7.2	976	77.9
10	3	0.2	979	78.1
11	128	10.2	1107	88.3
12	110	8.8	1217	97.1
13	9	0.7	1226	97.8
15	27	2.2	1253	100.0

YEAR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
84	96	7.7	96	7.7
85	171	13.6	267	21.3
86	166	13.2	433	34.6
87	216	17.2	649	51.8
88	249	19.9	898	71.7
89	188	15.0	1086	86.7
90	167	13.3	1253	100.0

Table 13. Analysis of variance and regression coefficients for the 1984 to 1990 logbook spring-spawning 4R herring catch rate data (catch per net).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	1392.745424	73.302391	62.03	0.0001
Error	1479	1747.773084	1.181726		
Corrected Total	1498	3140.518508			

R-Square	C.V.	Root MSE	Mean Catch Rate
0.443476	-29.65165	1.087072	-3.666144

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FISHERMAN	13	1125.661274	86.589329	73.27	0.0001
YEAR	6	46.343055	7.723843	6.54	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-4.699856489 B	-20.73	0.0001	0.22667025
FISHERMAN	1	-0.112758941 B	-0.45	0.6536	0.25120284
	2	0.394795823 B	1.52	0.1298	0.26043901
	3	0.041430606 B	0.14	0.8898	0.29896073
	4	-0.705212498 B	-2.44	0.0148	0.28909144
	5	0.236435943 B	0.90	0.3665	0.26175012
	6	2.311270133 B	9.12	0.0001	0.25355422
	7	1.396879605 B	5.46	0.0001	0.25588465
	8	1.897347671 B	7.35	0.0001	0.25816194
	9	1.163032387 B	4.49	0.0001	0.25898415
	10	3.165708569 B	5.27	0.0001	0.60094471
	11	0.272262061 B	1.03	0.3017	0.26352619
	12	1.768044071 B	6.93	0.0001	0.25512099
	13	1.640192954 B	6.02	0.0001	0.27265997
	15	0.000000000 B	.	.	.
YEAR	84	-0.380115334 B	-2.47	0.0136	0.15381074
	85	-0.123794588 B	-1.03	0.3011	0.11968117
	86	0.261451030 B	2.33	0.0200	0.11224927
	87	0.321588759 B	2.93	0.0034	0.10971341
	88	0.083603653 B	0.79	0.4268	0.10518278
	89	0.076359312 B	0.70	0.4869	0.10980165
	90	0.000000000 B	.	.	.

Table 14. Analysis of variance and regression coefficients for the 1984 to 1990 logbook fall-spawning 4R herring catch rate data (catch per net).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	19	952.4734642	50.1301823	44.75	0.0001
Error	1233	1381.1625834	1.1201643		
Corrected Total	1252	2333.6360475			

R-Square	C.V.	Root MSE	Mean Catch Rate
0.408150	-29.31413	1.058378	-3.610471

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FISHERMAN	13	829.0626703	63.7740516	56.93	0.0001
YEAR	6	119.3481840	19.8913640	17.76	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-3.022992041 B	-14.84	0.0001	0.20368497
FISHERMAN	1	-0.857829344 B	-3.75	0.0002	0.22895834
	2	-0.888772261 B	-3.82	0.0001	0.23243978
	3	-0.705524891 B	-2.54	0.0113	0.27792197
	4	-1.493810146 B	-5.62	0.0001	0.26575557
	5	-0.343041738 B	-1.43	0.1525	0.23959721
	6	-2.544218628 B	-9.88	0.0001	0.25744406
	7	-2.378688476 B	-9.75	0.0001	0.24392680
	8	-2.992190445 B	-10.75	0.0001	0.27826670
	9	-2.370285077 B	-9.47	0.0001	0.25018745
	10	-3.261993731 B	-4.97	0.0001	0.65649695
	11	-0.389567137 B	-1.58	0.1133	0.24581125
	12	-2.027916578 B	-8.19	0.0001	0.24757578
	13	-2.840395998 B	-6.75	0.0001	0.42088705
	15	0.000000000 B	.	.	.
YEAR	84	0.469543893 B	3.18	0.0015	0.14742537
	85	0.718994291 B	5.66	0.0001	0.12693531
	86	1.155582007 B	9.21	0.0001	0.12542525
	87	1.011919374 B	8.54	0.0001	0.11843610
	88	0.757568039 B	6.57	0.0001	0.11535010
	89	0.713311073 B	5.80	0.0001	0.12296311
	90	0.000000000 B	.	.	.

Table 15. Predicted mean logbook catch rate estimates for (a) spring- and (b) fall-spawning herring in NAFO Division 4R.

	SPRING SPAWNERS		FALL SPAWNERS	
YEAR	CATCH RATE	STANDARD ERROR	CATCH RATE	STANDARD ERROR
84	0.64396	0.09144	0.75718	0.09871
85	0.83423	0.10269	0.97371	0.11072
86	1.22692	0.14596	1.50667	0.17193
87	1.30393	0.14697	1.30644	0.13655
88	1.02788	0.11497	1.01332	0.10320
89	1.01946	0.12249	0.96813	0.11064
90	0.94361	0.12053	0.47455	0.05298

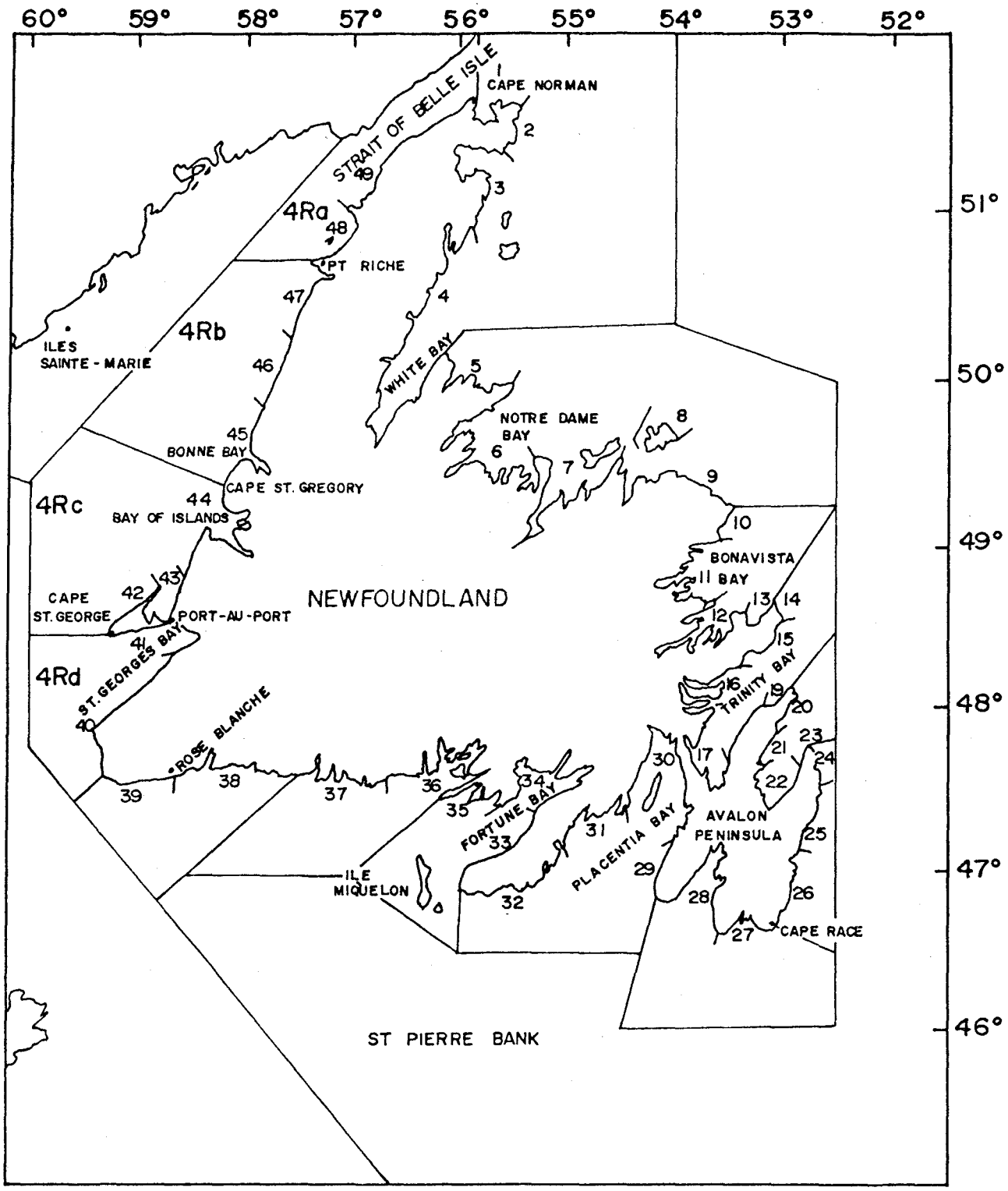


Figure 1. West coast of Newfoundland unit areas and statistical districts.

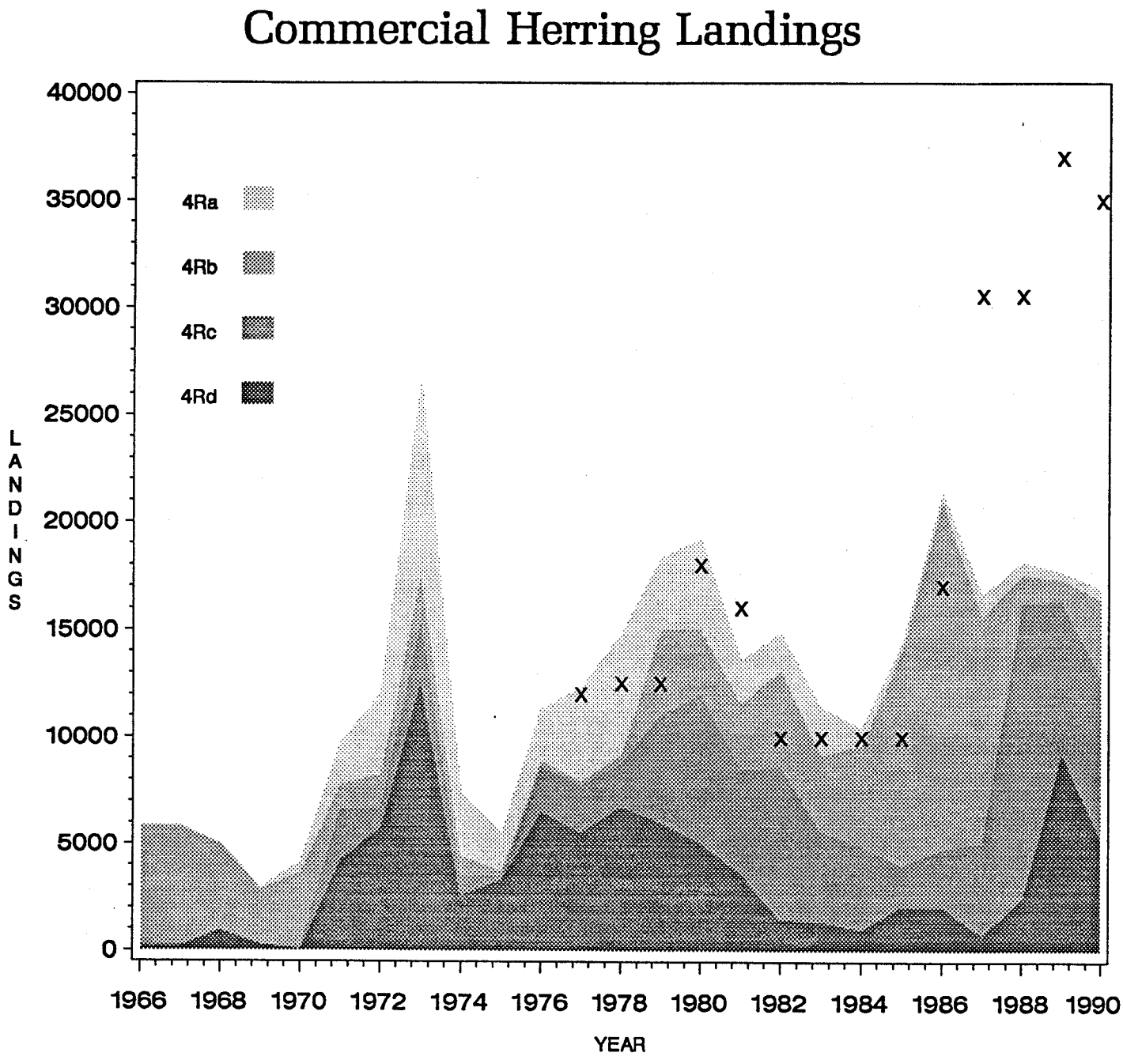


Figure 2. Cumulative commercial herring landings (t) by unit area in NAFO Division 4R from 1966 to 1990. "X" indicates annual total allowable catch.

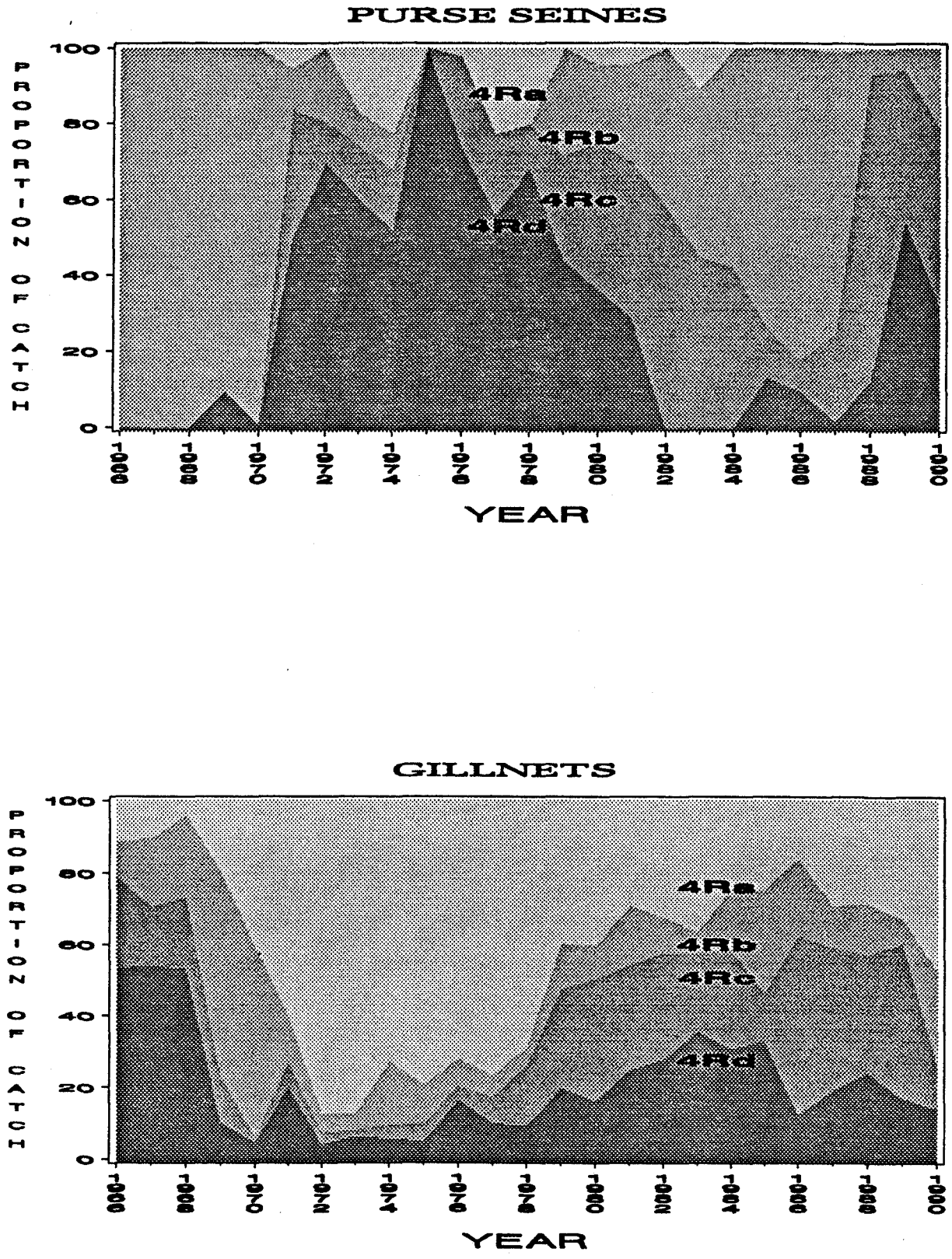


Figure 3. Proportion of (a) purse seine and (b) gillnet herring landings by unit area in NAFO Division 4R from 1966 to 1990.

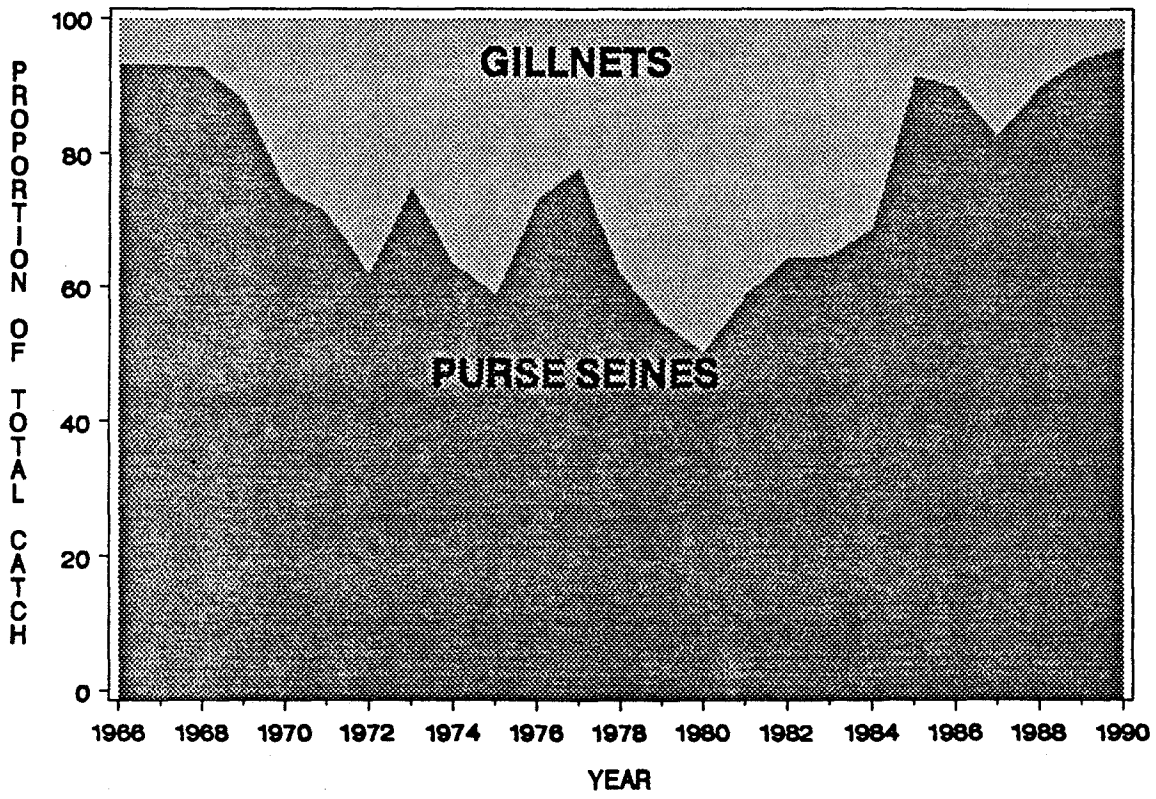


Figure 4. Proportion of total herring landings taken by gillnets and purse seines in NAFO Division 4R from 1966 to 1990.

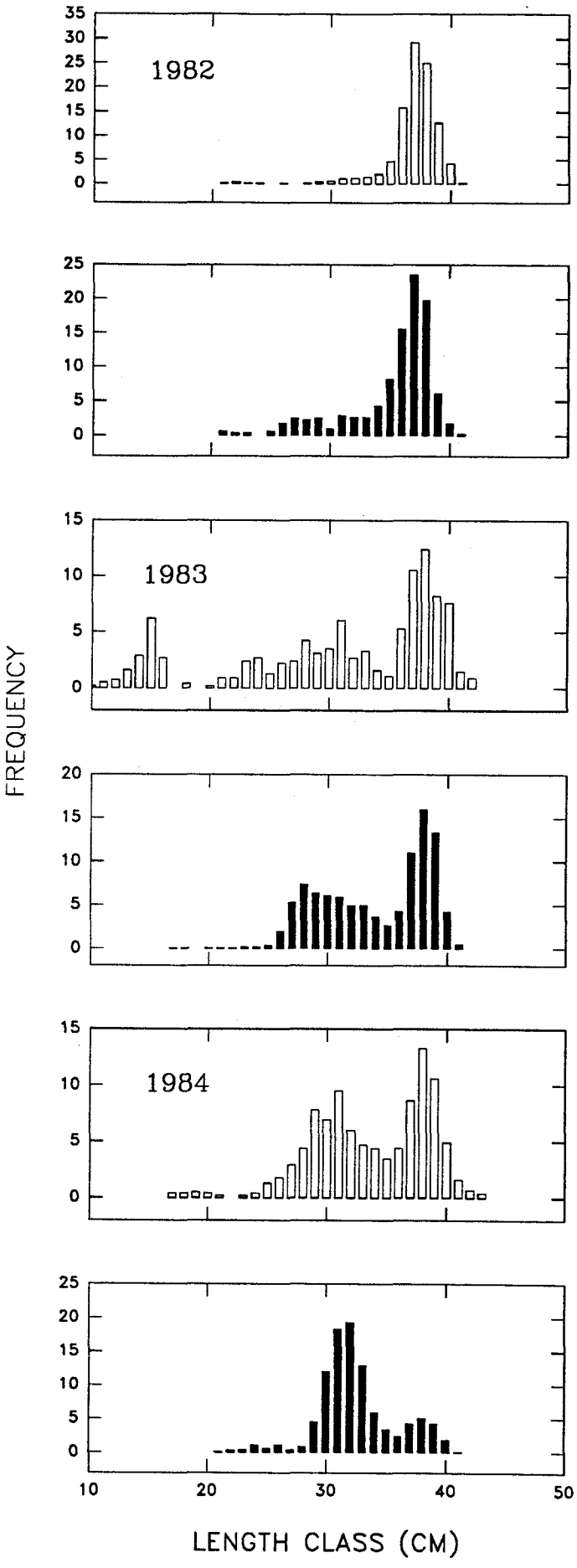


Figure 5. Length frequency distribution of 4R spring-spawning herring from the spring (open bars) and fall (solid bars) purse seine fisheries between 1982 and 1990.

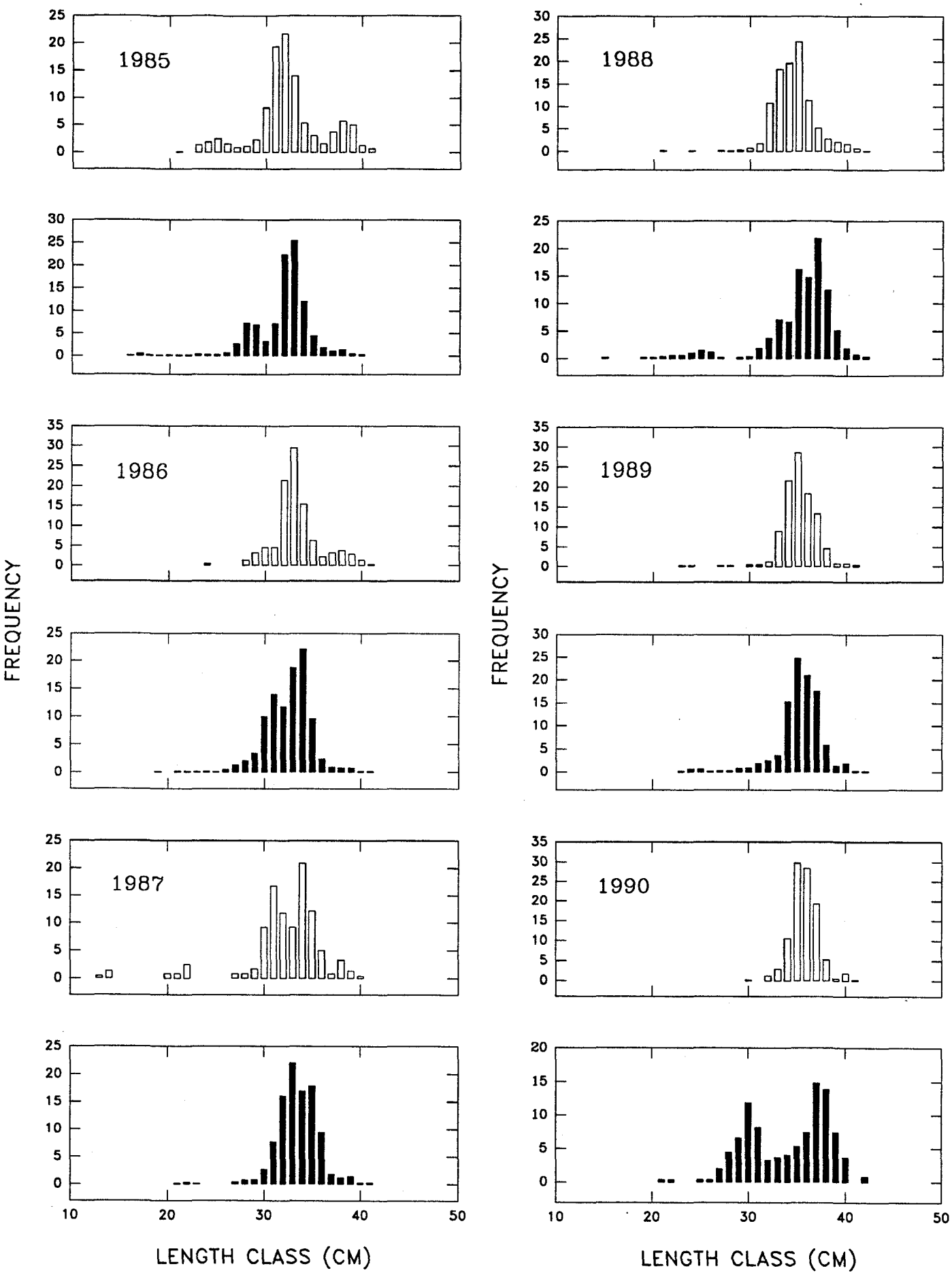
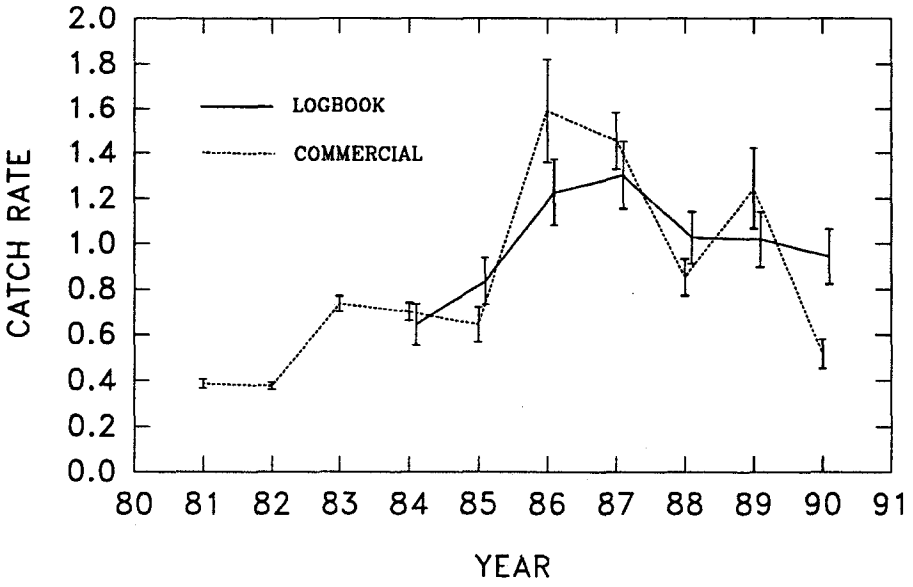


Figure 5. (con't).

A) Spring Spawners



B) Fall Spawners

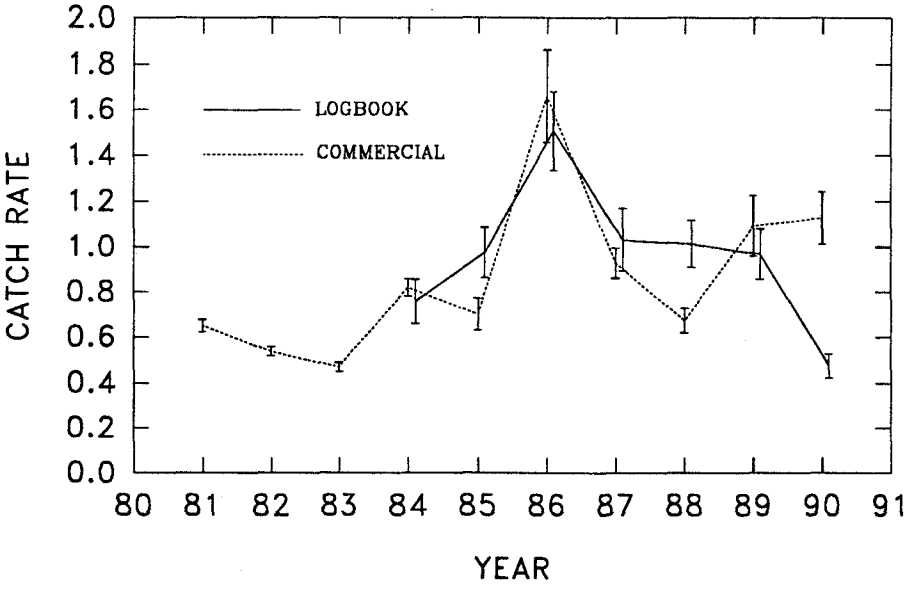


Figure 6. Standardized gillnet catch per unit effort and standard deviations for (a) spring–spawning and (b) fall–spawning herring in NAFO Division 4R as calculated from research logbook data, and commercial purchase slip and questionnaire data.

Annex 1. Number of herring sampled (**bold print**) and commercial landings (t) in NAFO division 4R by gear, area and month in 1990. (Boxed areas indicate sample-landing combinations for the weighting of the catch at age)

GEAR	AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GN	4Ra					4	9	1 **149** 135	2 **438** 14	3 **148** 50	4 **50** 29	5 **200** 216	
	4Rb				7 10	16	25	17	3	1	1	6 **50** 117	
	4Rc					**226** 4	**200** 19	**87** 47	3	2	5		
	4Rd					10 **194** 34	11 **147** 12	40	9	2	1		
PS	4Ra						14	14	1				
	4Rb							138			1 **100** 379	2 **300** 2888	**250**
	4Rc					6536	450	3 **100** 205	26	4 **57** 17	261		
	4Rd					5 **500** 4799	335				23		