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An Assessment of the West Coast of Newfoundland (NAFO Division 4R) Herring Resource up to 1993

by

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ABSTRACT

Since 1986, NAFO division 4R herring landings have been between 15,100 t and 19,400 t. The proportion of the total catch taken by seiners versus the fixed gear sector has risen from 80% in 1985, to 98% in 1993. Cohort analysis indicated a 2+ mid-year spring-spawner biomass of 46,300 t, the lowest estimate since 1973. The 5+ F for the spring-spawning stock in 1993 was estimated at 0.27. However, fishing mortality on older fish has been well above 0.3 since 1990. The abundance of the 1987 year-class is about one half that of either the 1980 or the 1982 cohorts. Our present perception of the state of this stock indicates that the fishing mortality is high and we do not foresee any reconstruction in the mid-term. The cohort analysis results indicated that the autumn-spawning stock has not undergone as high an exploitation rate as the spring-spawning component in recent years. The analysis did not converge, the fully recruited F being well below 0.1 since 1985. The presence of the 1986 year-class was first manifest in the late fall fishery in 1990, and has been dominant since 1991, indicating a strong recruitment pulse into this stock. The autumn-spawning stock seems to be rebuilding. If present exploitation patterns are maintained, i.e. the targeting of the spring-spawning component, the future of this stock is threatened in the short term. Several indices have suggested that spawning activity has already been affected by the reduced stock size. Fishing effort must therefore be reduced to a minimum on this component by eliminating any fisheries directed upon spring spawners. A reorientation of fishing effort towards the autumn-spawning stock could be supported by this component, at least in the short term.

RÉSUMÉ

Depuis 1986, les débarquements du hareng de la division 4R sont demeurés entre 15,100 t et 19,400 t. La proportion des prises totales des senneurs par rapport aux engins fixes est passée de 80% en 1985 à 98% en 1993. L'analyse de cohorte indique une biomasse de stock de printemps en 1993 de mi-année 2+ de 46,300 t, laquelle est la plus faible estimation depuis 1973. Le F en 1993 pour le stock du printemps a été estimé à 0.27. Toutefois, la mortalité par pêche sur les vieux poissons est supérieure à 0.3 depuis 1990. L'abondance de la classe d'âge de 1987 est à peu près à la moitie de la classe d'âge de celle de 1980 ou bien celle de 1982. Notre perception actuelle de l'état du stock du printemps indique que la mortalité par pêche est élevée et nous ne prévoyons pas de reconstruction à moyen terme. Les résultats d'analyses pour le stock d'automne indiquent que cette composante n'a pas subi ces dernières années un taux d'exploitation aussi élevé que les reproducteurs de printemps. L'analyse pour le stock d'automne ne convergeait pas, le F au plein recrutement étant de beaucoup inférieur à 0.1 depuis 1985. La présence de la classe d'âge de 1986 du stock d'automne se manifeste dans la pêche de la fin d'automne depuis 1990, et sa dominance depuis 1991, indique un fort recrutement pour ce stock. Le stock d'automne apparaît en reconstruction. Si le patron d'exploitation actuel est maintenu, qui consiste à cibler la composante de printemps, le futur du stock à court terme est menacé. Plusieurs indices suggèrent que les activités de la fraie ont déjà été affectées par la réduction de la taille du stock. L'effort de pêche doit donc être réduit au minimum sur cette composante en y éliminant toute pêche dirigée. Une réorientation d'effort de pêche vers le stock d'automne peut être supportée au moins à court terme par cette composante.

INTRODUCTION

Atlantic herring (*Clupea harengus* L.) in NAFO Division 4R (Figure 1) have been assessed by CAFSAC (DFO) as a single management unit since the stock limits were defined in 1977 (Moores and Winters, 1977). The 4R herring management unit was defined mainly 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.

Sympatric seasonal-spawning herring stocks have been shown to exhibit different population dynamics, i.e. differential strengths of recruiting year-classes (McQuinn, 1992). The spring- and autumn-spawning herring stocks of the west coast of Newfoundland have therefore been evaluated separately in the past, and again for this assessment.

DESCRIPTION OF THE FISHERY AND HISTORICAL FISHING PATTERNS

Total herring landings from the west coast of Newfoundland were relatively small between 1966 and 1970, ranging from 3,000 to 6,000 mt (Table 1, Figure 2). A marked increase in catches began in 1971, peaking at 27,000 mt 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 mt in 1986, but which has levelled off at between 15,100 mt and 19,400 mt in the last seven years.

The herring stocks in 4R are exploited mainly by large (>85') purse seiners, small (<65') purse seiners and to a much lesser extent by fixed gillnetters 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 98% in 1993 (Figure 3).

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 from the fixed gear sector to the mobile fleet 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 the experimental, small-purse-seine fishery. The allocation for this gear sector has come from the inshore (fixed gear) quota and has increased from 2,000 to 3,800 mt from 1989 to 1993. Allocations to the OSS programme have been from 8,000 mt to 10,000 mt from 1990 to 1993. Neither the TAC nor the advised target fishing level have been exceeded since 1986 (Table 1; Figure 2).

The Purse Seine Fleet

From 1985 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 autumn spawners (Table 3). This fishery contributed to 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 Russians, and by the development of a spring frozen-round market for the Japanese and Koreans. 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 mt in 1987 to 12,400 mt in 1991). This spring fishery accounted for 71% of the total purse seine catch in 1993 (Table 2a, Figure 4a) and has captured mainly spring spawners (Table 3) in the Bay St. George/ Port-au-Port area.

Concurrent with changes to the fishing pattern of the large purse seine fleet has been an increase in the activity of the smaller (<65') purse seiners along the west coast. These vessels, which have traditionally fished capelin, have been issued herring licences under the inshore allocation since 1989. Annual landings from this gear sector had not exceeded 800 mt until 1992, when they landed 2,200 mt. In 1993, this fleet accounted for 3,100 mt.

The Gillnet Fleet

Total gillnet landings (Table 1), and therefore the proportion of the total catch taken by gillnets (Figure 3), 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, with the exception of 1987 (17%). The inshore fishery is now almost exclusively oriented toward supplying bait for the active lobster fishery. Since 1989, the late fall (October-December) fishery has been extremely limited, although this was at least in part due to exceptionally poor weather conditions over the past several years. Since 1991, the market for gillnetted herring has been essentially moribund, with recorded landings below 550 mt, totalling only 139 mt in 1993 (Table 2b).

From 1979 to 1989, almost equal proportions of the total gillnet catch was taken from spawning concentrations of spring spawners (Table 4) in Bay St. Georges and Port-au-Port Bay (4Rd,4Rc), and north of Pointe Riche (4Ra,4Rb)(Figure 4b). A late fall fishery on mixed spring- and autumn-spawner concentrations (Table 4) has also occurred, although sporadically, in areas 4Ra to 4Rc throughout this period. Since 1990, gillnet landings in Bay St. Georges and Port-au-Port Bay have been marginal (Table 2b). In 1993, the late-fall 4Ra fishery was non-existent.

Industry Input

Gillnet fishermen in the Bay St. Georges/Port-au-Port areas have noted a decrease in the abundance of spring-spawning herring over the past two or three years. Comments collected from written questionnaires sent to all licensed inshore herring fishermen, as well as comments from index-fishermen, showed a general consensus on this observation in southern 4R (Figure 5). However, north of Pointe Riche in unit area 4Ra (the major autumn-spawning area), the general opinion is that the abundance of herring is high.

A summary of the comments received from these questionnaires also suggests a decrease in spawning activity in the southern unit areas, both in duration as well as in a later arrival on the grounds (Table 5). Purse seiner fishing effort is the most commonly cited cause attributed to the decline in the southern stock and for the disruption of normal spawning activity (Table 5).

Index gillnet fishermen have been hired since 1984 to complete daily logbooks, recording their catch and effort as well as their location, mesh-size, size of nets and water depth, and to supply biological samples and comments on the extent of spawning in their area. Half of these fishermen set their nets in the vicinity of the major spring-spawning sites in the Bay St. Georges/Port-au-Port area (Figures 6 and 7) while the other half fish autumn-spawners in the area north of Point Riche (4Ra) during the summer and fall.

Although there are both spring and autumn spawners in the Bay St. Georges area, spring spawners are preferred by the purse seine fleet for the oriental frozen-round market. Adequate concentrations of this spawning group were difficult to locate in the spring of 1992 and 1993 (R. Dumphy, purse seine fleet manager, Barry's Fisheries Ltd, pers. comm.). Equally, the traditional fall Bonne Bay fishery was curtailed in 1992 and 1993, resulting in a shortfall of approximately 1,300 and 3,000 mt, respectively (compared to 1991), as the typically large concentrations of herring left the Bay area a month earlier than usual (end of November rather than the end of December). Curiously, this earlier-than-usual winter migration was also observed for the herring stocks in the Sydney Bight (4Vn) and Chedabucto Bay (4W) areas at approximately the same time (R. Dumphy, ibid., pers. comm.).

COMMERCIAL FISHERY DATA

Age Composition of the Commercial Catch

Random samples from the commercial fishery were collected by port samplers, and by index 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 Maurice Lamontagne Institute (MLI) in Mont-Joli, Quebec for analyses (length, weight, gonad weight, maturity stage, and otolith collection for age determination).

Individual herring were assigned as either spring or autumn spawners by relating the maturity stage, estimated from a gonadosomatic index model (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 autumn spawners (Cleary *et al.*, 1982). All herring age 11 or more were aggregated into an 11+ age-group. As in previous years, the 1993 catch at age (Table 6) was generated (CATΔAGE v1.0, Anon, 1986) for spring and autumn spawners as described by McQuinn (1987b), weighting the age compositions by the corresponding landing as grouped in Annex 1.

Spring-Spawner Catch at Age:

Spring spawners have dominated the catch in every year since 1973 (Table 6), averaging 73% of the catch in numbers. The proportion was over 80% of the catch between 1988 and 1990 due to the active spring fishery in Bay St. Georges, which traditionally exploits pre-spawning and spawning concentrations. However in 1991, only 71% of the total removals consisted of spring spawners (Table 6) primarily due to a higher catch of autumn spawners in the Bay St. Georges spring fishery (Table 3). Typically herring schools at the head of Bay St. Georges near the spawning beds are predominately spring spawners (Figures 8 and 9), while the autumn spawners are concentrated towards the mouth of the Bay or north of Cape St. Georges (4Rc). In 1991, the purse seine fleet concentrated their fishing effort in April and May near the mouth and along the south shore of the Bay (Figure 8) and encountered a relatively high percentage of autumn spawners. In 1992, the market was oriented more towards spring spawners, therefore fishing effort was more near the spawning grounds at the head of the Bay (Figure 8). In 1993, most of the purse seine catches were again near the head of the Bay (Figure 9), and as a result, catches were almost exclusively spring spawners as in 1992.

The 1968 year-class was the largest ever observed in the spring-spawner catch and completely dominated from 1973 (the beginning of the time series) to 1982 (Table 7a). In 1985, the 1980 year-class was the single most important cohort 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. Since 1991, the 1987 year-class has represented 18 to 24% of the spring-spawner catch, lowering the mean age of the catch to 7.6 years old.

Autumn-Spawner Catch at Age:

Herring of the 11+ age group have historically dominated the autumn-spawner catch (Table 7b). In 1983, the 1979 year-class strongly recruited into the fishery and contributed to more than 24% of the catch in numbers at age 4. In 1990, the 1986 year-class strongly recruited to the autumn-spawner purse seine catch at age, but only became a significant contributor to the gillnet fishery in 1992 (Table 8). Since 1992, the 1988 year-class has also contributed significantly to the total autumn-spawner catch (Table 7b). In 1993, the 11+ age group, mostly comprised of the 1979 year-class, was still dominant in the commercial catch, making up 37% of the catch in numbers.

Length Frequencies in the Commercial Catch

Purse Seine Samples:

The strength of the 1986 and 1988 autumn-spawning and the 1987 spring-spawning year-classes will be the most important factor affecting the 4R herring fishery for the near future. The length distribution of the purse seine catches showed the presence of these recruiting year-classes as juveniles in the Bonne Bay fishery (4Rb) since 1990 although at the time the relative strength of each was unknown (McQuinn and Lefebvre, 1992). These recruiting year-classes were caught further and further south from 1991 to 1992, and have become dominant in the Bonne Bay fall fishery. This indicates that the autumn-spawner 1986 year-class has been expanding southward over the past three years. However, the spring-spawning 1987 year-class has only been seen in the catches in Bay St. Georges (4Rd) and Port-au-Port (4Rc) in 1992, indicating that this year-class has not influenced the catches in southern regions to the same extent as the 1986 autumn-spawning cohort has in the north.

Comparing the length frequencies of herring caught by the large and small seiners in Bay St. Georges during this spring fishery in 1993 revealed that in April, both fleets were exploiting similar sizes of fish (Figure 10). However in May, the smaller seiners were capturing relatively more larger fish (>35 cm) than they were in April, as well as compared to the larger seiners also in May. Mapping the set positions of samples taken from the two fleets in May showed that the small seiners were concentrated more at the head of the Bay (Figure 11) on or near the spawning grounds (Figure 6) while the larger seiners were split between the south shore and the mouth of the Bay. It appears therefore that proportionally more large herring were spawning on the Sandy Point grounds.

An examination of the length distributions from the late fall fishery (Figure 12a) showed significant temporal and spatial patterns in the size distribution of herring. Generally speaking, larger herring (>35 cm) were found towards the north (4Ra), while a greater mixing of sizes was observed towards the south, and similarly from October to November in 4Rb. Separating the samples by spawning type (Figures 12b and 12c) showed that the length distributions were similar regardless of spawning type in 4Ra and 4Rb, while in 4Rc, the smaller individuals (<31 cm) were mostly autumn spawners.

Gillnet Samples:

Length frequency distributions from the gillnet fishery (Figure 13) showed the dominance of the larger individuals (>35 cm) in the catches, regardless of season. One can however detect an increase in the proportion of smaller herring (<35 cm) during both the spring-spawning (May-June; 4Rc) and autumn-spawning (July-September; 4Ra) seasons.

The length distributions of spring spawners from the individual captures of the index fishermen in Bay St. Georges/Port-au-Port showed the dominance of the 1980 and 1982 year-classes since 1987 (Figures 14 and 15). As is usually the case, incoming year-classes recruit to the gillnet fishery 1 to 2 years later than to the purse seiners, due to the large mesh size (2.5 to

3.0 in) common in this fishery (Konan, 1991). However, the 1987 year-class has only been seen in significant numbers in the catches in Bay St. Georges (4Rd) and Port-au-Port (4Rc) in 1992 and 1993, and even then, not equally for each fisherman.

POPULATION DISTRIBUTION AND ABUNDANCE

Research Survey Data

Distribution:

Distributional data on herring have been collected from three research surveys during the summer (August-September), fall (November) and winter (January). Although capture data from the summer and winter groundfish surveys should only be considered qualitative for herring, catch/tow information has been presented here as an indication of geographic presence or absence.

Catches from the summer northern Gulf groundfish survey (*A. Needler*) from 1990 to 1993 showed herring to be consistently found in northern 4R at the time when autumn spawning occurs (Figure 16 and 17). Biological data from samples collected in this area showed that, at least in 1991 and 1993, the majority of the adult herring captured were autumn spawners (Figure 18) and as seen in the commercial data, the larger (>30 cm) and thus older individuals were more prevalent towards the northern areas.

Results from the fall 1993 4R herring acoustic survey (*F.G. Creed*) mapped the large concentrations of mixed spring- and autumn-spawning herring which had moved into the Bonne Bay/Bay of Islands area by November (Figures 19 and 20). The late fall purse seine fishery is also prosecuted in this area at this time. The dominant length classes sampled during this survey (Figure 21) reflected those seen from the commercial fishery in November (Figure 12a), although the range of length distributions from the survey included more immature individuals (<25 cm). Again, the larger herring (>35 cm) were found towards the northern end of stratum 6, although the range of lengths was quite variable depending on the concentration being sampled (Figure 21).

Finally, catches from the winter northern Gulf groundfish survey (*Gadus Atlantica*) have consistently shown herring in the Esquiman Channel in January (Figures 22 and 23). These schools of mixed spring and autumn spawners have left the inshore waters since the end of November and presumably are heading out of the Gulf for the winter. Once again, samples showed a tendency for larger herring (>35 cm), also dominated by autumn spawners, to be found towards the northern end of the Gulf (Figure 24).

Abundance:

The 1993 fall acoustic survey was designed to cover the entire west coast of Newfoundland down to 100 m. However, exceptionally poor weather conditions prevented the coverage of the two most northerly strata (Figures 19 and 20). Widespread concentrations were

nonetheless found in the Bonne Bay/Bay of Islands area. Preliminary biomass estimates indicated the presence of approximately 71,000 mt of spring and autumn spawners in these southern strata, of which approximately half were spring spawners (McQuinn, unpubl. data). From purse seine samples in 4Ra in November, it is assumed that the majority (78%) of herring in the northern strata were autumn spawners (Table 3).

Index-Fisherman Logbook Data

Catch Rate Standardization:

Annual gillnet catch rates were estimated, for both spring and autumn spawners, from the index-fisherman logbook data which covered most of the fishing season (Table 9 and 10) and which were standardized using a multiplicative model (Gavaris, 1980). The category types for the model were year, month and fishing site to account for spatial and temporal variability (Table 11 and 12). Prior to these analyses, catches were proportioned to spring and autumn spawners using the percent spawning-stock composition determined from the commercial samples (Table 4).

Trends in Catch Rates:

Spring-spawner catch rates calculated from the logbook data reflected the recruitment and subsequent decline of the 1980 and 1982 spring-spawning year-classes to the gillnet fishery (Figure 25a; Table 13). Similarly, the passage of the 1979 year-class was equally obvious in the autumn-spawning series (Figure 25b). Furthermore, the recruitment of the 1986 autumn-spawning and 1987 spring-spawning year-classes was also evident. From these catch rates, there is a strong indication that the 1986 autumn-spawning cohort is well above average, while the spring-spawning 1987 cohort appears much less substantial, as it has already started to decline in importance at age five in the gillnet catch. The rather sharp decline in the 1993 autumn-spawner catch rate was unexpected, but may be related to the observation from inshore fishermen that the autumn spawners were farther offshore than usual in 1993, and thus less available to their gear. This is also substantiated by the higher catches of autumn spawners in the offshore by the summer groundfish survey in 1993 (Figure 17).

Gillnet catch-rate-at-age matrices were calculated for each spawning stock by dividing the gillnet catch at age by the annual gillnet effort from the multiplicative model (Table 14) for the calibration of the cohort analyses.

SEQUENTIAL POPULATION ANALYSES

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 previous assessments (McQuinn, 1989) and is consistent with

estimates made for other herring stocks (Runnström, 1936; Beverton, 1963; Cushing, 1981, Chaput *et al.*, 1993).

Fishing Mortality for the Oldest Ages:

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

Mean Weight at Age:

The annual mean weights at age for each spawning stock were estimated as the average of the weight at age of each sample (McQuinn, 1987b), weighted by the corresponding landings as grouped in Annex 1 (WEIGHTΔAGE v1.0). These weight-at-age matrices (Table 15) were used to calculate the catch- and population-biomass-at-age matrices.

Age by Age Calibration of Cohort Analyses

Cohort analyses were calibrated age by age using the adaptive framework (Gavaris, 1987). The formulation involved estimating mean population numbers (N) at ages 4 through 10 in 1993 and the age-specific catchability coefficients (q) by predicting the logbook gillnet catch rates at age (in numbers), using the minimization of the residual sums of squares in the natural log scale as the objective criteria. An initial calibration showed the intercepts to be non-significant. A summary of the formulation used in the calibration is as follows:

Parameters:

- year-class estimates:	$N_{i,t}$	i=4-10; t=1993
- calibration constants:	q_i	i=4-10
- number of parameters:	14	

Structure:

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

Input Data:

- Catch at age:	$C_{i,t}$	i=2-11+; t=1973-93
- logbook catch rates:	$CPUE_{i,t}$	i=4-10 ; t=1984-93
- number of observations:	70	
- natural mortality (M):	0.2	

Objective function:

- minimize $\Sigma_i\Sigma_t$ [(obs. ln $CPUE_{i,t}$)-(pred. ln $CPUE_{i,t}$)]^2

ASSESSMENT RESULTS AND DISCUSSION

Spring Spawners

The estimated spring-spawner population numbers and the age-specific catchability coefficients in 1993 for ages 4 through 10 from the ADAPT formulation were all statistically significant (Table 16a) with a mean square residual of 0.554. The coefficient of variation (relative error) ranged between 34 and 51% for the estimated numbers at age, and between 26 and 30% for the catchability coefficients. The correlation matrix and standardized residuals indicated that the model fit was adequate (Tables 17 and 18).

The spring-spawner analysis indicated that the 4+ mid-year biomass dropped more or less steadily between 1974 and 1983 (Figure 26, Table 21), primarily due to poor recruitment since the appearance of the 1968 year-class (Table 22), and rose by more than three times by 1987 with the recruitment of the 1980 and 1982 year-classes (Figure 27). Again the stock biomass declined until 1992, when the recruitment of the 1987 year-class caused a slowing of this downward trend, which continued in 1993.

The weighted 5+ fishing mortality in 1993 was estimated at 0.33 (Table 25a) indicating that on average the exploitation rate on these age groups was approximately at the target F of 0.3. However, fishing mortalities on the older ages have increased over that past five years relative to the previous five years and were estimated to be well above 0.3 since 1990. This was not unexpected given the increased importance of the spring Bay St. Georges fishery which concentrates on pre-spawning herring.

It is obvious that this stock is in need of a strong recruitment pulse to reverse the steady decline in the mature biomass (Figures 26 and 27). Although the 1987 year-class has recruited to both the purse seine and the gillnet fisheries since 1991, several indicators concur that this year-class may not be sufficiently strong to support this fishery at present exploitation rates over the next few years and that this spawning stock is not rebuilding:

- the cohort analysis estimated the 1987 year-class to be only about half as strong as either the 1980 or 1982 year-classes;
- the decline in the gillnet catch rate index in 1992 and 1993;
- the generalized observation from the fixed gear sector that spring spawning in Bay St. Georges/Port-au-Port is more restricted in both time and space than over the past decade; and
- the recognition by the mobile fleet that the pre-spawning herring in spring Bay St. Georges fishery are harder to locate.

Autumn Spawners

The estimated autumn-spawner population numbers in 1993 for ages 6 through 10 and the age-specific regression coefficients for ages 4 to 10 from the ADAPT formulation were all statistically significant (Table 16b) with a mean square residual of 0.614. However, the population number estimates for ages 4 and 5 were not significantly different from 0, and thus

were not deemed reliable. Also, although the correlation matrix and standardized residuals indicated that the model fit was adequate (Tables 19 and 20), an examination of the fishing mortality matrix showed that the cohort analysis was not converged, the fully recruited F being ≤ 0.1 since 1985 (Table 25b). The resulting population number and biomass estimates are nonetheless presented here (Tables 23 and 24) for illustrative purposes (the bias correction was not applied to the estimates), although it was felt that the cohort analysis results for the autumn-spawning component were not sufficiently reliable for the projection of $F_{0.1}$ catches in 1995.

The cohort analysis results do nonetheless indicate that the autumn-spawning stock has not undergone as high an exploitation rate in recent years as the spring-spawning component. The logbook catch rates index indicates that the 1986 year-class is of substantial importance, as the stock abundance estimate in 1992 was the highest in the series. The questionnaire responses also indicate that the situation with this spawning component north of Point Riche (the major spawning zone) is relatively good. Finally, the presence of this cohort in the late fall purse seine fishery since 1990, and its dominance since 1991, also points to a strong recruiting pulse.

PROGNOSES

Catch Projections

The following data were used to calculate catch projections for the spring-spawning stock:

AGE	JANUARY 1994 POPULATION NUMBERS ('000)	AVERAGE WEIGHT (g)	PARTIAL RECRUITMENT
2	49727	115	0.041
3	40603	146	0.187
4	7188	195	0.503
5	18651	250	0.304
6	53112	280	0.240
7	5995	320	0.403
8	6389	388	0.801
9	7023	408	0.838
10	6252	425	1.000
11	19695	439	1.000

Partial recruitment was derived from the average fishing mortalities from 1991 to 1993. Weights at age were those calculated from the commercial fishery in 1993. Recruitment at age 3 was set to the geometric average over the past 10 years. Two projection scenarios were

performed (a) assuming catches in 1994 and 1995 to be at a fully-recruited fishing mortality of 0.3 (the assumed long-term $F_{0.1}$) and (b) assuming a catch of spring spawners of 11,000 mt, equal to the spring-spawner catch of the last 2 yrs. These projections indicated that if present catches of spring spawners are maintained, the 5+ fishing mortality will be 0.53 in 1994, and the 4+ (mature) biomass will continue to decline and will be at an historic low of 22,600 mt in January 1995 (Table 26). However, reducing fishing mortality to $F_{0.1}$ would result in a spring-spawner catch of 4,700 mt in 1994 and should considerably slow the decline in stock biomass (Table 27; Figure 26).

The present analyses point to an increase in the fishing effort and mortality on the spring-spawning stock in recent years and, according to the gillnet catch rates, as well as auxiliary information from both the inshore and the offshore gear sectors, a decrease in the amount of spring spawners in the Bay St. Georges/Port-au-Port Bay spawning grounds. Industry should be aware that our present view of the spring-spawning stock status suggests that fishing mortality is high and no mid-term prospect of rebuilding is forecast. Furthermore, if the current pattern of exploitation is maintained, i.e. targeting of the spring-spawning component, we have serious concerns about the short-term health of this stock. Several indices presented here suggest that the extent of spawning activities has already been affected by the reduced stock size. Fishing effort must therefore be reduced to a minimum, and that any directed fishery on this stock should be eliminated. Therefore, if present total catch levels are to be maintained, fishing effort must be directed towards the autumn-spawning stock in areas where the two stock components are spatially segregated, or where autumn-spawners predominate. These areas appear to be outside of Bay St. Georges in the spring of the year (April to June), and north of Point Riche in the fall (after July).

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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 1993.

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	30600
1989	9111	177	0	9288	6589	444	0	7033	947	69	0	1016	13	337	0	350	16660	1027	0	17415	37000
1990	5156	97	0	5253	7495	79	0	7574	3404	181	6	3591	28	323	133	484	16084	677	140	16903[1]	35000
1991	11871	37	0	11918	1557	31	0	1588	5342	59	0	5401	98	323	54	377	18877	450	54	19381[1]	35000
1992	8696	27	1	8724	1523	37	0	1560	4091	47	1	4139	346	440	115	901	14655	552	117	15324[1]	35000
1993	10967	55	0	11022	1015	9	5	1029	2198	20	0	2218	694	55	103	852	14874	139	108	15121[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 2a. Herring landings (t) by purse seines in NAFO division 4R by unit area and month from 1985 to 1993.

YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
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
1991	4Ra							62	36					98
	4Rb					8	42	113	18	45	501	3285	1330	5342
	4Rc					490	87	127		107	130	161	463	1567
	4Rd				6090	5567	214							11871
	Total				6090	6065	345	303	54	152	631	3446	1793	18877
1992	4Ra						86	258	2					346
	4Rb						18				87	3986		4091
	4Rc					23	779	43		51	56	567	4	1523
	4Rd					8297	124				2	273	1	8696
	Total					8320	1007	301	2	51	145	4825	5	14655
1993	4Ra					11	127	78	51	4		423		694
	4Rb		15						57	62	824	1241		2198
	4Rc				2	143	29		9	2	764	67		1015
	4Rd				1337	9122					78	431		10967
	Total		15		1339	9276	156	78	117	68	1666	2162		14874

Table 2b. Herring landings (t) by gillnets in NAFO division 4R by unit area and month from 1985 to 1993.

YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
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
1991	4Ra						21	169	40	23	24	45		323
	4Rb									1	12	46		59
	4Rc								6	19	5			31
	4Rd				2	4	1		9	12	6	4		37
	Total				2	4	22	169	56	56	47	95		450
1992	4Ra					9	16	179	34	12	107	84		440
	4Rb			2	3	15	20	1			3	3		47
	4Rc					22	2	5	3	1	2	2		37
	4Rd					15	3	3	2	1	1	2	1	27
	Total			2	3	62	41	188	39	14	113	91	1	552
1993	4Ra						5	47	1	1				55
	4Rb						10	2	1		4	4		20
	4Rc					2		1	1	3	3			9
	4Rd				6	38	1	1	2	2	5	1		55
	Total				6	40	16	51	5	5	11	5		139

Table 3. Proportion (%) of spring- and autumn-spawning herring in the purse seine catch by month and fishing area, NAFO Division 4R from 1973 to 1993.

SPAWNING	FISHING AREA																									
GROUP	4Rd			4Rc									4Rb									4Ra				
SPRING	APR	MAY	NOV	JAN	APR	MAY	JUN	JUL	SEP	OCT	NOV	DEC	JAN	APR	MAY	JUN	AUG	SEP	OCT	NOV	DEC	JUL	AUG	SEP	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		89.8						78.0		88.0									74.0	55.3	66.0						
1991		71.6						72.0	48.0	66.0		80.0							56.3	65.3	63.4						
1992		94.7	72.7			100.0	100.0		28.6		68.2					47.7			32.0	49.9							
1993	90.0	84.9								67.7					74.0				72.7	56.6				0.0		22.0	
AUTUMN																											
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		10.2						22.0		12.0									26.0	44.7	34.0						
1991		28.4						28.0	52.0	34.0		20.0							43.7	34.7	36.6						
1992		5.3	27.0						71.4		31.8					52.3			68.0	50.1							
1993	10.0	15.1				0.0	0.0			32.1					26.0				27.2	43.4				100.0		78.0	

Table 4. Proportion (%) of spring- and autumn-spawning herring in the gillnet catch by month and fishing area, NAFO division 4R from 1973 to 1993.

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	99.3		92.0	88.5	34.5								44.0				15.5	17.8	10.8	18.0	32.5	
1991		95.9	96.0		88.8	59.2							32.0	44.0	70.0				4.5	27.0	38.1	50.0	43.4	
1992		93.2	76.0		74.8	70.4	52.0											26.0	10.0	8.3	1.0	10.2		
1993		98.0			78.7	89.0												86.0	4.0	4.0	1.7			
AUTUMN																								
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	0.7		8.0	11.5	65.5								56.0				84.5	82.2	89.2	82.0	67.5	
1991		4.1	4.0		11.2	40.8							68.0	56.0	30.0				95.5	72.1	61.9	50.0	56.6	
1992		6.8	24.0		25.2	29.6	48.0											74.0	90.0	91.7	99.0	89.8		
1993		2.0			21.3	11.0												14.0	96.0	96.0	98.3			

Table 5. Number of comments received from questionnaires sent to inshore herring fishermen along the west coast of Newfoundland in 1993.

COMMENTS	3Pn	4Rd	4Rc	4Rb	4Ra	TOTAL
Herring Abundant		1			12	13
Herring Stock in Decline	3	12	16	19	6	56
Stock decrease due to seiners:						
- catch everything		18	11	18	16	63
- on spawning grounds		7	3	4	2	16
- dumping at sea		1	2	1	3	7
Stock decrease due to other causes:						
- draggers	1	1				2
- Russian vessels (OSS)		4				4
- decrease in temperature		1		1		2
Spawning						
- decrease		4	9	1	1	15
- late arrival on grounds			2	3		5
Size of Herring						
- small		1	4	5	3	13
- large	1			2	2	5
Poor Markets[1]	1	6	6	3	40	56
TOTAL	6	56	53	57	85	257

1: Lack of buyers or market, price too low, seiners control the market, cannot sell gillnetted herring.

N.B. Total number of questionnaires sent: 903
Total number of questionnaires received: 384 (42,5%)

Table 6. Spring- and autumn-spawner catch at age ($x10^3$) and proportion of spring spawners in NAFO division 4R herring landings from 1973 to 1993 (all gears).

SPRING SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0	0	0	0	45	0	0	3	13	0	4	39	48	265	323	183	0	0	0	0	0
2	1833	141	57	484	10	0	167	300	40	594	34	198	362	323	455	734	305	100	480	90	79
3	435	261	996	680	534	47	25	854	417	2374	2965	433	4587	2348	329	519	574	2056	1706	1243	1589
4	1063	130	420	846	541	1987	214	106	2114	693	3562	7773	787	13762	2781	417	763	610	7036	1708	3800
5	27872	371	100	201	409	207	10828	355	129	2452	1131	3809	21642	3349	15257	2400	461	412	934	8377	3411
6	2570	9445	1063	350	304	679	617	13872	354	421	1091	595	3993	28781	3507	14830	3036	983	631	997	6776
7	3222	318	8431	2802	348	241	1075	407	8872	2153	293	814	445	5241	12952	4004	18705	5002	2072	998	1504
8	3232	851	317	15567	4362	2162	547	1344	188	6488	713	209	381	465	1736	14606	3072	16049	4939	2783	2110
9	2598	774	336	759	15959	8208	2772	247	515	704	2990	672	255	167	182	2734	10910	3782	15660	2168	2713
10	4789	490	244	3136	1694	15260	7404	1427	283	950	798	755	380	260	37	480	779	6472	1649	11882	2798
11+	5696	2175	665	3588	6003	5062	14032	20574	13181	12863	7975	4226	1764	1661	806	2123	1380	2130	4762	4064	8816
1+	53310	14955	12629	28413	30210	33851	37681	39488	26106	29692	21556	19523	34645	56621	38365	43030	39985	37594	39869	34310	33597

AUTUMN SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	15	0	101	15	0	15	35	0	484	43	38	50	0	21
3	1798	20	19	48	3	10	7	181	33	567	83	55	235	426	156	207	599	463	719	337	210
4	1180	393	40	272	169	27	116	136	524	1824	2330	668	1340	1431	487	511	539	1391	949	1446	676
5	1114	530	865	290	134	545	345	86	245	956	1356	6259	1907	2671	1354	481	923	387	4279	1446	1955
6	2626	325	925	422	404	393	2689	176	90	509	1309	1147	9678	2292	2009	1240	807	312	628	1235	1011
7	1527	592	107	561	721	1108	520	1729	295	140	506	908	902	8421	1728	1740	749	466	1082	776	1651
8	2631	258	157	325	405	1689	1287	250	1234	377	159	220	622	794	5927	1667	828	323	609	542	569
9	3830	308	147	253	342	503	1847	675	153	972	467	146	115	384	474	4165	961	1027	485	777	918
10	8265	313	218	88	293	341	468	308	124	315	618	268	36	66	163	705	2873	442	1658	389	884
11+	17653	5610	3371	4818	6646	6051	6286	5243	3369	2609	2824	3091	468	227	196	777	983	4223	5543	3925	4592
1+	40626	8348	5848	7076	9116	10668	13564	8799	6067	8371	9667	12762	15333	16745	12494	11977	9305	9072	16002	10873	12486

TOTAL (SPRING AND AUTUMN)

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
TOTAL	93937	23303	18477	35489	39326	44520	51245	48288	32173	38062	31223	32286	49978	73366	50859	53475	49292	46666	55871	45183	46084
% SS	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	80.6	71.4	75.9	72.9

Table 7. Age composition (%) and mean age* of (A) spring and (B) autumn spawners in NAFO division 4R herring landings from 1973 to 1993. 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	1991	1992	1993
1	.0	.0	.0	.0	.1	.0	.0	.0	.1	.0	.0	.2	.1	.5	.8	.4	.0	.0	.0	.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	1.2	.3	.2
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	5.5	4.3	3.6	4.7
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	1.6	17.6	5.0	11.3
5	52.3	2.5	.8	.7	1.4	.6	28.7	.9	.5	8.3	5.2	19.5	62.5	5.9	39.8	5.6	1.2	1.1	2.3	24.4	10.2
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	2.6	1.6	2.9	20.2
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	13.3	5.2	2.9	4.5
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	42.7	12.4	8.1	6.3
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	10.1	39.3	6.3	8.1
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	17.2	4.1	34.6	8.3
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	5.7	11.9	11.8	26.2

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	1991	1992	1993
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	8.0	7.7	7.9	7.6

B) AUTUMN SPAWNER AGE COMPOSITION (%)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.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	.4	.3	.0	.2
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	5.1	4.5	3.1	1.7
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	15.3	5.9	13.3	5.4
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	4.3	26.7	13.3	15.7
6	6.5	3.9	15.8	6.0	4.4	3.7	19.8	2.0	1.5	6.1	13.5	9.0	63.1	13.7	16.1	9.8	8.7	3.4	3.9	11.4	8.1
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	5.1	6.8	7.1	13.2
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	3.6	3.8	5.0	4.6
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	11.3	3.0	7.1	7.4
10	20.3	3.8	3.7	1.3	3.2	3.2	3.5	3.5	2.0	3.8	6.4	2.1	.2	.4	1.3	4.8	30.9	4.9	10.4	3.6	7.1
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	46.5	34.6	36.1	36.8

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	1991	1992	1993
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	7.7	7.9	8.5	7.8	7.8	8.2

* assuming ages 11+ to be 11.

Table 8. Spring- and autumn-spawner gillnet catch at age ($x10^3$) in NAFO division 4R herring landings from 1973 to 1993.

SPRING-SPAWNER GILLNET CATCH AT AGE

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	3	0	0	21	1	0	0	0	0	0	0	0	0	0
3	7	10	0	13	13	3	0	71	59	319	842	13	1	3	0	4	8	30	3	0	0
4	145	0	89	0	4	368	42	50	805	145	1770	1416	33	296	125	30	46	26	82	14	1
5	2148	76	10	0	39	82	2980	123	53	879	468	1486	1220	143	1714	600	58	35	7	50	10
6	228	1781	219	15	53	132	441	5485	163	106	513	242	391	2909	602	1436	349	75	4	18	36
7	1225	111	878	581	141	63	606	225	4038	340	57	469	67	662	2388	561	996	78	22	31	8
8	769	383	89	1790	1041	751	337	620	83	2495	19	67	75	78	418	1139	165	433	31	66	29
9	784	130	66	123	1680	1659	1597	146	192	229	1200	236	44	55	26	132	396	53	90	22	32
10	467	89	48	540	325	4228	3403	927	113	256	249	271	62	45	18	27	51	112	14	87	36
11	2830	1210	172	1336	1712	2408	6726	8291	3484	4144	3151	1892	290	261	175	98	53	36	47	26	48
1+	8603	3789	1573	4398	5007	9695	16131	15942	8988	8912	8290	6094	2183	4452	5466	4026	2121	880	300	316	201

AUTUMN-SPAWNER GILLNET CATCH AT AGE

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	3	0	0	0	0	16	24	0	0	0	0	0	0	0	1	0	0
4	32	106	6	0	39	9	11	43	342	405	1229	83	4	3	36	2	8	43	15	30	1
5	179	190	200	11	30	296	260	73	201	523	531	2319	49	102	178	102	32	70	55	32	10
6	766	49	586	178	90	193	1289	153	24	164	627	329	1211	189	354	251	63	119	63	178	18
7	331	207	46	191	467	463	218	1342	245	81	143	397	134	1596	473	202	108	79	82	80	27
8	639	38	134	228	228	708	504	120	876	199	78	74	93	135	1909	169	187	132	88	136	21
9	683	198	108	161	239	156	527	603	46	554	169	64	26	84	194	679	174	228	55	148	42
10	1862	80	201	88	140	147	315	272	71	220	199	95	2	31	74	89	182	51	68	51	44
11+	6941	2719	2683	2826	2647	3624	3018	4552	2396	1529	581	442	115	160	54	68	55	654	495	678	221
1+	11434	3586	3964	3684	3884	5595	6142	7159	4201	3708	3582	3803	1633	2299	3273	1561	809	1376	921	1334	385

Table 9. Frequency of observations of index-fisherman catch and effort data by month, fishing area and year for spring-spawning herring in NAFO Division 4R.

MONTH	Frequency	Percent	Cumulative Frequency	Cumulative Percent
4	93	3.0	93	3.0
5	967	31.5	1060	34.5
6	584	19.0	1644	53.5
7	211	6.9	1855	60.4
8	825	26.8	2680	87.2
9	338	11.0	3018	98.2
10	33	1.1	3051	99.3
11	22	0.7	3073	100.0

FISHING AREA	Frequency	Percent	Cumulative Frequency	Cumulative Percent
FISCHELL	234	7.6	234	7.6
SANDY POINT	420	13.7	654	21.3
ST-GEORGES	149	4.8	803	26.1
BARACHOIS BROOK	150	4.9	953	31.0
LOURDES	215	7.0	1168	38.0
BLACK DUCK BROOK	253	8.2	1421	46.2
BLUE BEACH	243	7.9	1664	54.1
CASTOR RIVER	78	2.5	1742	56.7
WHALE ISLAND	18	0.6	1760	57.3
EDDIES COVE E	1313	42.7	3073	100.0

YEAR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
84	126	4.1	126	4.1
85	218	7.1	344	11.2
86	259	8.4	603	19.6
87	349	11.4	952	31.0
88	411	13.4	1363	44.4
89	364	11.8	1727	56.2
90	368	12.0	2095	68.2
91	310	10.1	2405	78.3
92	307	10.0	2712	88.3
93	361	11.7	3073	100.0

Table 10. Frequency of observations of index-fisherman catch and effort data by month, fishing area and year for autumn-spawning herring in NAFO Division 4R.

MONTH	Frequency	Percent	Cumulative Frequency	Cumulative Percent
4	93	3.0	93	3.0
5	967	31.5	1060	34.5
6	584	19.0	1644	53.5
7	211	6.9	1855	60.4
8	825	26.8	2680	87.2
9	338	11.0	3018	98.2
10	33	1.1	3051	99.3
11	22	0.7	3073	100.0

FISHING AREA	Frequency	Percent	Cumulative Frequency	Cumulative Percent
ROBINSONS	19	0.6	19	0.6
FISCHELL	215	7.0	234	7.6
SANDY POINT	420	13.7	654	21.3
ST-GEORGES	149	4.8	803	26.1
BARACHOIS BROOK	150	4.9	953	31.0
LOURDES	215	7.0	1168	38.0
BLACK DUCK BROOK	253	8.2	1421	46.2
BLUE BEACH	207	6.7	1628	53.0
LONG PT. (BAY)	36	1.2	1664	54.1
CASTOR RIVER	78	2.5	1742	56.7
BARTLETT HBR	88	2.9	1830	59.6
WHALE ISLAND	18	0.6	1848	60.1
FORRESTER POINT	455	14.8	2303	74.9
EDDIES COVE E	770	25.1	3073	100.0

YEAR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
84	126	4.1	126	4.1
85	218	7.1	344	11.2
86	259	8.4	603	19.6
87	349	11.4	952	31.0
88	411	13.4	1363	44.4
89	364	11.8	1727	56.2
90	368	12.0	2095	68.2
91	310	10.1	2405	78.3
92	307	10.0	2712	88.3
93	361	11.7	3073	100.0

Table 11. Analysis of variance and regression coefficients for the 1984 to 1993 spring-spawning 4R herring catch rate data (catch/(surface*hours)).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	5465.148482	218.605939	111.61	0.0001
Error	2503	4902.616788	1.958696		
Corrected Total	2528	10367.765270			

R-Square	C.V.	Root MSE	CATRATE Mean
0.527129	-14.07548	1.399534	-9.943063

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	7	295.2713875	42.1816268	21.54	0.0001
FISH	9	956.7717768	106.3079752	54.27	0.0001
YEAR	9	297.1445433	33.0160604	16.86	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-19.58136436 B	-31.88	0.0001	0.61429879
MONTH	4	4.55303362 B	7.84	0.0001	0.58058810
	5	4.79097265 B	8.65	0.0001	0.55409181
	6	3.98284632 B	7.16	0.0001	0.55624976
	7	3.47357900 B	7.54	0.0001	0.46056649
	8	3.33791390 B	7.41	0.0001	0.45041561
	9	3.40985148 B	7.51	0.0001	0.45432734
	10	3.02064357 B	5.85	0.0001	0.51630269
	11	0.00000000 B	.	.	
FISHING	BARACHOIS BK	5.43705984 B	9.91	0.0001	0.54852906
AREA	BLACK DUCK BK	5.24144551 B	9.78	0.0001	0.53591076
	BLUE BEACH	5.69342406 B	10.64	0.0001	0.53485941
	CASTOR RIVER	3.01332492 B	6.47	0.0001	0.46589548
	EDDIES COVE E	4.56132790 B	11.04	0.0001	0.41301833
	FISCHELL	6.99510430 B	12.97	0.0001	0.53942417
	LOURDES	4.56208489 B	8.56	0.0001	0.53317435
	SANDY POINT	5.98648226 B	11.17	0.0001	0.53570638
	ST-GEORGES	6.49862619 B	11.84	0.0001	0.54869991
	WHALE ISLAND	0.00000000 B	.	.	
YEAR	84	0.09195576 B	0.54	0.5890	0.17017757
	85	1.14090305 B	8.52	0.0001	0.13391518
	86	0.86240588 B	6.78	0.0001	0.12721874
	87	1.04843624 B	8.61	0.0001	0.12174337
	88	0.69118575 B	6.07	0.0001	0.11395085
	89	0.52146352 B	4.50	0.0001	0.11594126
	90	0.08548734 B	0.71	0.4794	0.12085009
	91	0.71269594 B	5.70	0.0001	0.12498744
	92	0.44559888 B	3.67	0.0002	0.12135159
	93	0.00000000 B	.	.	

Table 12. Analysis of variance and regression coefficients for the 1984 to 1993 autumn-spawning 4R herring catch rate data (catch/(surface*hours)).

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Source	DF	Squares	Square	F Value	Pr > F
Model	29	4221.899474	145.582740	72.66	0.0001
Error	2499	5007.151734	2.003662		

R-Square	C.V.	Root MSE	CATRATE Mean
0.457458	-13.73600	1.415508	-10.30509

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MONTH	7	358.704886	51.243555	25.57	0.0001
FISHING AREA	13	1064.526068	81.886621	40.87	0.0001
YEAR	9	659.554171	73.283797	36.57	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-18.43967644 B	-27.92	0.0001	0.66049545
MONTH	4	5.46544056 B	8.66	0.0001	0.63110858
	5	4.40733269 B	7.29	0.0001	0.60441046
	6	4.01810749 B	6.63	0.0001	0.60622522
	7	4.83007675 B	9.33	0.0001	0.51762868
	8	4.88424559 B	9.68	0.0001	0.50452785
	9	4.50367349 B	8.76	0.0001	0.51384828
	10	3.63285955 B	6.38	0.0001	0.56918570
	11	0.00000000 B	.	.	
FISHING AREA	BARACHOIS BK	1.34850994 B	2.43	0.0152	0.55488761
	BARTLETT HBR	4.38945849 B	9.29	0.0001	0.47246804
	BLACK DUCK BK	3.20671061 B	5.92	0.0001	0.54211459
	BLUE BEACH	3.80643946 B	7.02	0.0001	0.54203499
	CASTOR RIVER	2.82195874 B	5.99	0.0001	0.47129151
	EDDIES COVE E	4.45334850 B	10.63	0.0001	0.41912260
	FISCHELL	3.67984611 B	6.72	0.0001	0.54735582
	FORRESTER PT	4.54094692 B	10.76	0.0001	0.42201700
	LONG PT.	3.26577476 B	5.46	0.0001	0.59766653
	LOURDES	2.64188998 B	4.90	0.0001	0.53936527
	ROBINSONS	2.06309376 B	3.26	0.0011	0.63242486
	SANDY POINT	1.99729384 B	3.69	0.0002	0.54194596
	ST-GEORGES	2.45578792 B	4.42	0.0001	0.55504394
	WHALE ISLAND	0.00000000 B	.	.	
YEAR	84	-0.65730108 B	-3.56	0.0004	0.18473608
	85	0.72598762 B	5.19	0.0001	0.13992929
	86	0.53253267 B	3.97	0.0001	0.13413178
	87	0.31996418 B	2.46	0.0139	0.12994206
	88	-0.36081831 B	-2.98	0.0029	0.12119231
	89	0.11710141 B	0.94	0.3486	0.12491598
	90	-0.80426042 B	-6.26	0.0001	0.12851158
	91	-0.12193634 B	-0.92	0.3591	0.13294729
	92	0.98129879 B	7.53	0.0001	0.13031718
	93	0.00000000 B	.	.	

Table 13. Predicted mean catch rate estimates for spring- and autumn-spawning herring in NAFO Division 4R.

	SPRING SPAWNERS		AUTUMN SPAWNERS	
YEAR	CATCH RATE	STANDARD ERROR	CATCH RATE	STANDARD ERROR
84	0.57933	0.08587	0.41188	0.06890
85	1.66175	0.18585	1.65400	0.19860
86	1.25905	0.12941	1.36432	0.15319
87	1.51774	0.14323	1.10377	0.11751
88	1.06229	0.09509	0.55916	0.05563
89	0.89583	0.08689	0.90131	0.09410
90	0.57909	0.05801	0.35852	0.03908
91	1.08350	0.11597	0.70897	0.08043
92	0.82958	0.08828	2.13685	0.24167
93	0.53184	0.05131	0.80122	0.08817

Table 14. Spring- and autumn-spawner catch rate at age from herring gillnet logbook data for NAFO division 4R from 1984 to 1993.

SPRING-SPAWNER GILLNET CATCH RATE AT AGE

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	3.5	2.5	2.5	.0	3.6	9.5	59.2	30.5	.8	.0
4	370.1	80.0	272.2	113.4	25.6	57.6	51.6	887.5	97.9	10.0
5	388.5	2972.8	131.5	1556.6	510.1	72.8	69.2	80.0	338.4	75.5
6	63.1	952.1	2677.1	546.5	1219.9	439.5	147.8	48.1	123.7	273.0
7	122.5	164.1	609.2	2169.1	476.5	1252.4	152.2	239.7	207.4	63.4
8	17.5	182.6	71.6	379.7	967.5	207.6	849.5	330.9	444.8	219.3
9	61.6	107.5	50.5	24.0	111.9	498.2	104.0	967.2	149.6	247.1
10	70.9	152.0	41.4	16.3	22.6	64.0	220.1	151.3	587.9	273.0
11	494.4	705.8	240.5	158.5	83.1	66.9	70.5	504.1	178.3	364.9

AUTUMN-SPAWNER GILLNET CATCH RATE AT AGE

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	1.0	.0	2.8	.0	.0
4	27.6	11.7	5.5	34.2	1.6	23.9	29.5	29.1	116.9	4.7
5	769.1	153.9	177.9	168.0	105.0	92.6	48.0	106.9	125.7	46.8
6	109.1	3829.1	330.4	333.8	259.0	180.2	81.0	122.3	697.8	81.3
7	131.5	423.2	2796.9	445.8	208.8	309.3	53.5	159.3	313.4	123.1
8	24.6	294.9	236.4	1799.1	174.3	533.9	90.1	170.8	533.5	96.3
9	21.3	82.0	147.0	182.7	701.7	497.2	155.0	107.2	581.1	191.8
10	31.5	7.4	53.5	69.3	91.7	520.5	34.5	133.4	198.5	197.9
11	146.6	363.4	280.2	50.5	70.5	157.7	445.0	965.1	2656.7	1001.1

Table 15. Annual weight at age (weighted by landings) for (A) spring- and (B) autumn- spawning herring in NAFO Division 4R from 1973 to 1993.

(A)

ANNUAL SPRING SPAWNER WEIGHT AT AGE (Kg)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	.101	.129	.077	.069	.064	.103	.115	.117	.085	.095	.142	.134	.109	.142	.165	.153	.149	.120	.154	.103	.115
3	.158	.172	.156	.122	.156	.184	.121	.201	.196	.216	.190	.206	.168	.171	.235	.192	.193	.180	.159	.115	.146
4	.224	.223	.197	.193	.208	.228	.234	.247	.262	.263	.263	.239	.247	.230	.250	.223	.233	.257	.203	.214	.195
5	.222	.236	.242	.241	.247	.275	.268	.298	.327	.290	.305	.297	.283	.268	.289	.261	.301	.270	.276	.246	.250
6	.268	.262	.243	.252	.278	.305	.319	.321	.344	.357	.337	.348	.329	.315	.349	.302	.307	.301	.318	.276	.280
7	.303	.300	.279	.269	.262	.313	.343	.354	.385	.386	.385	.379	.373	.338	.370	.338	.350	.343	.332	.366	.320
8	.322	.324	.301	.299	.290	.318	.357	.380	.415	.395	.424	.406	.404	.413	.390	.371	.384	.373	.374	.368	.388
9	.333	.351	.335	.315	.313	.340	.366	.398	.430	.423	.434	.431	.434	.415	.428	.385	.399	.409	.401	.399	.408
10	.350	.335	.350	.334	.332	.362	.373	.389	.429	.434	.492	.437	.425	.449	.422	.457	.408	.417	.408	.411	.425
11	.367	.384	.382	.382	.353	.393	.409	.430	.472	.454	.475	.485	.477	.459	.515	.490	.488	.461	.440	.422	.439

(B)

ANNUAL AUTUMN SPAWNER WEIGHT AT AGE (Kg)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	.100	.122	.122	.122	.122	.122	.122	.122	.144	.166	.105	.078	.050	.105	.110	.115	.115	.088	.068	.068	.072
3	.105	.171	.120	.107	.250	.161	.218	.222	.204	.150	.205	.164	.155	.157	.187	.139	.139	.164	.102	.158	.121
4	.156	.218	.188	.155	.229	.238	.216	.242	.280	.252	.218	.209	.202	.214	.235	.216	.216	.201	.217	.189	.194
5	.231	.259	.266	.282	.250	.282	.281	.360	.328	.306	.268	.249	.258	.240	.272	.259	.259	.238	.203	.227	.197
6	.274	.265	.297	.271	.255	.316	.308	.341	.358	.328	.309	.293	.292	.280	.319	.281	.281	.273	.297	.276	.251
7	.297	.284	.352	.287	.301	.345	.355	.404	.406	.449	.338	.343	.326	.317	.334	.310	.310	.322	.319	.295	.296
8	.329	.307	.323	.277	.321	.367	.381	.419	.436	.441	.374	.359	.347	.340	.363	.354	.354	.355	.361	.346	.323
9	.334	.355	.370	.308	.308	.366	.405	.461	.485	.444	.430	.429	.374	.356	.364	.377	.377	.373	.381	.384	.370
10	.346	.378	.391	.426	.330	.390	.408	.468	.498	.485	.462	.450	.444	.363	.392	.398	.398	.399	.415	.420	.409
11	.382	.422	.465	.454	.421	.471	.458	.534	.515	.507	.503	.494	.432	.465	.513	.428	.428	.432	.426	.442	.422

Table 16. Parameter estimates, standard errors, T-statistics and mean square residuals from the (a) spring-spawning and (b) autumn-spawning cohort analyses as estimated from the adaptive framework.

a) Spring Spawners:

PARAMETER	PARAMETER ESTIMATE	STD. ERROR	RELAT. ERROR	BIAS	RELAT. BIAS
1. age 4 no.	8.885E3	3.694E3	.4157	1.584E3	.1783
2. age 5 no.	2.254E4	1.153E4	.5114	3.785E3	.1680
3. age 6 no.	6.132E4	2.808E4	.4580	7.983E3	.1302
4. age 7 no.	6.744E3	2.656E3	.3939	7.067E2	.1048
5. age 8 no.	7.080E3	2.475E3	.3496	6.318E2	.0892
6. age 9 no.	7.827E3	2.746E3	.3509	7.285E2	.0931
7. age 10 no.	7.037E3	2.571E3	.3654	7.052E2	.1002
8. age 4 coef.	2.629E-3	7.279E-4	.2768	3.143E-5	.0120
9. age 5 coef.	7.527E-3	2.004E-3	.2663	1.057E-4	.0141
10. age 6 coef.	1.408E-2	3.663E-3	.2601	1.925E-4	.0137
11. age 7 coef.	2.720E-2	7.055E-3	.2594	4.121E-4	.0152
12. age 8 coef.	3.263E-2	8.608E-3	.2638	5.517E-4	.0169
13. age 9 coef.	2.990E-2	8.179E-3	.2735	5.897E-4	.0197
14. age 10 coef.	3.540E-2	1.047E-2	.2958	1.003E-3	.0283

MEAN SQUARE RESIDUALS 0.554255

b) Autumn Spawners:

PARAMETER NO.	PARAMETER EST.	STD. ERROR	T-STAT.
1. age 4 no.	1.78630E0004	1.44114E0004	1.24 $
2. age 5 no.	9.13091E0004	5.42583E0004	1.68 $
3. age 6 no.	3.85749E0004	1.90579E0004	2.02
4. age 7 no.	4.48385E0004	1.95244E0004	2.30
5. age 8 no.	2.02783E0004	7.96036E0003	2.55
6. age 9 no.	1.37399E0004	4.99773E0003	2.75
7. age 10 no.	1.87846E0004	6.31132E0003	2.98
8. age 4 coef.	3.34159E-004	1.00162E-004	3.34
9. age 5 coef.	2.38790E-003	6.75521E-004	3.53
10. age 6 coef.	6.23228E-003	1.69697E-003	3.67
11. age 7 coef.	8.08871E-003	2.14325E-003	3.77
12. age 8 coef.	9.84618E-003	2.55094E-003	3.86
13. age 9 coef.	1.25908E-002	3.21074E-003	3.92
14. age 10 coef.	8.16453E-003	2.05304E-003	3.98

MEAN SQUARE RESIDUALS 0.613598

$ estimates are non-significant

Table 17. Parameter correlation matrix for 4R spring-spawning herring as estimated from cohort analyses using the adaptive framework.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	0.095	0.086	0.077	0.074	0.066	0.085	-0.349	-0.072	-0.058	-0.051	-0.049	-0.049	-0.051
2	0.095	1.000	0.121	0.107	0.102	0.091	0.119	-0.274	-0.301	-0.081	-0.071	-0.068	-0.068	-0.072
3	0.086	0.121	1.000	0.131	0.123	0.109	0.148	-0.248	-0.260	-0.271	-0.087	-0.084	-0.084	-0.090
4	0.077	0.107	0.131	1.000	0.140	0.126	0.177	-0.221	-0.228	-0.237	-0.273	-0.098	-0.099	-0.107
5	0.074	0.102	0.123	0.140	1.000	0.147	0.215	-0.213	-0.215	-0.216	-0.227	-0.283	-0.119	-0.130
6	0.066	0.091	0.109	0.126	0.147	1.000	0.262	-0.189	-0.191	-0.193	-0.206	-0.243	-0.317	-0.158
7	0.085	0.119	0.148	0.177	0.215	0.262	1.000	-0.243	-0.256	-0.277	-0.312	-0.379	-0.467	-0.605
8	-0.349	-0.274	-0.248	-0.221	-0.213	-0.189	-0.243	1.000	0.207	0.167	0.147	0.141	0.140	0.147
9	-0.072	-0.301	-0.260	-0.228	-0.215	-0.191	-0.256	0.207	1.000	0.173	0.151	0.145	0.145	0.155
10	-0.058	-0.081	-0.271	-0.237	-0.216	-0.193	-0.277	0.167	0.173	1.000	0.158	0.152	0.155	0.167
11	-0.051	-0.071	-0.087	-0.273	-0.227	-0.206	-0.312	0.147	0.151	0.158	1.000	0.167	0.172	0.189
12	-0.049	-0.068	-0.084	-0.098	-0.283	-0.243	-0.379	0.141	0.145	0.152	0.167	1.000	0.207	0.230
13	-0.049	-0.068	-0.084	-0.099	-0.119	-0.317	-0.467	0.140	0.145	0.155	0.172	0.207	1.000	0.283
14	-0.051	-0.072	-0.090	-0.107	-0.130	-0.158	-0.605	0.147	0.155	0.167	0.189	0.230	0.283	1.000

Table 18. Standardized residuals (obs. - pred.) from the adaptive framework for 4R spring-spawning herring

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
4	-0.33	-0.38	-0.79	-0.13	-1.06	0.33	0.46	1.39	0.51	0.00
5	0.61	1.03	-0.65	0.18	0.58	-0.85	-0.31	0.13	-0.31	-0.42
6	-0.08	1.25	0.76	0.48	-0.39	0.09	-0.52	-1.04	0.27	-0.82
7	1.15	0.52	0.70	0.27	0.07	-0.64	-1.21	-0.35	0.08	-0.57
8	-1.71	1.91	-0.13	0.43	-0.24	-0.52	-0.79	-0.07	0.56	0.56
9	-0.51	0.49	1.16	-0.85	-0.04	-0.23	-0.42	-0.01	-0.33	0.75
10	-0.18	0.55	-0.29	0.14	-0.60	-0.32	-0.61	0.40	0.03	0.88

Table 19. Parameter correlation matrix for 4R autumn-spawning herring as estimated from cohort analyses using the adaptive framework.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	.107	.097	.089	.085	.078	.075	-.356	-.082	-.062	-.047	-.034	-.022	-.011
2	.107	1.000	.131	.121	.114	.105	.100	-.301	-.294	-.084	-.064	-.045	-.029	-.014
3	.097	.131	1.000	.142	.133	.123	.117	-.273	-.269	-.257	-.074	-.053	-.034	-.016
4	.089	.121	.142	1.000	.147	.135	.128	-.250	-.250	-.238	-.226	-.058	-.038	-.018
5	.085	.114	.133	.147	1.000	.146	.137	-.239	-.233	-.221	-.209	-.194	-.041	-.019
6	.078	.105	.123	.135	.146	1.000	.143	-.219	-.215	-.204	-.195	-.181	-.173	-.020
7	.075	.100	.117	.128	.137	.143	1.000	-.210	-.204	-.194	-.181	-.167	-.154	-.141
8	-.356	-.301	-.273	-.250	-.239	-.219	-.210	1.000	.230	.175	.132	.095	.061	.030
9	-.082	-.294	-.269	-.250	-.233	-.215	-.204	.230	1.000	.172	.130	.092	.060	.029
10	-.062	-.084	-.257	-.238	-.221	-.204	-.194	.175	.172	1.000	.124	.087	.057	.027
11	-.047	-.064	-.074	-.226	-.209	-.195	-.181	.132	.130	.124	1.000	.083	.054	.026
12	-.034	-.045	-.053	-.058	-.194	-.181	-.167	.095	.092	.087	.083	1.000	.050	.024
13	-.022	-.029	-.034	-.038	-.041	-.173	-.154	.061	.060	.057	.054	.050	1.000	.022
14	-.011	-.014	-.016	-.018	-.019	-.020	-.141	.030	.029	.027	.026	.024	.022	1.000

Table 20. Standardized residuals (obs. - pred.) from the adaptive framework for 4R autumn-spawning herring

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
4	.51	-1.07	-.78	.59	-1.96	.59	.19	.58	1.35	.00
5	.06	.50	-.09	.91	-.04	.34	-.46	-.22	.31	-1.31
6	-.98	.95	.58	-.19	.63	-.24	-.54	-.26	.92	-.85
7	-.36	.33	.61	.88	-.69	.79	-1.50	.13	.65	-.84
8	-.91	.48	-.22	.21	.03	.27	-.42	-.31	1.37	-.50
9	.08	.27	-.24	-.51	-.75	1.10	-.98	-.26	.90	.38
10	.89	-.32	.49	-.35	-.53	-.39	-.90	-.44	1.03	.51

Table 21. Mid-year population biomass (mt), estimated from cohort analysis, for spring-spawning herring in NAFO division 4R from 1973 to 1993.

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	1448	3990	1717	8913	1794	1401	2035	2002	6068	31920
3	7017	1769	3929	2229	16472	4213	1348	2885	2688	12591
4	44725	8025	1617	3832	2982	19585	4391	2242	2904	2867
5	84969	38331	7109	1536	3831	3109	18392	4527	2406	2130
6	7480	76032	32272	6045	1405	3774	2898	15220	4179	2111
7	14681	6228	64246	28915	5068	1221	3284	2458	10542	3726
8	5785	12022	5043	54247	24936	4945	1069	2645	2221	5995
9	3357	4230	9939	4240	42528	22673	4008	798	1979	1785
10	6935	2054	3236	8031	3454	35501	17866	2605	616	1452
11	8664	10428	9629	10499	13011	12790	37132	41503	31630	20568
2+	185061	163109	138738	128486	115482	109214	92422	76885	65233	85145
3+	183613	159119	137020	119573	113688	107813	90387	74883	59165	53225
4+	176596	157350	133091	117345	97216	103600	89039	71998	56477	40634
5+	131871	149325	131474	113513	94234	84015	84648	69756	53573	37767

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	10500	52636	9301	6391	4342	3219	20156	4242	1804	4622	5180 †
3	52250	12446	53937	11902	8587	4073	3197	19982	4600	1053	5347 †
4	12051	53098	12168	59675	13789	6622	3942	3375	18092	4770	1272
5	2545	10274	49640	10617	58243	11200	7219	3564	2830	16537	4212
6	1348	2053	8315	39714	10355	45999	10145	5792	3334	2100	13452
7	1732	903	1620	5888	29427	7253	39261	8429	4970	2948	1737
8	2601	1399	519	1320	3882	20212	5581	28584	5989	3875	2244
9	3092	1913	1148	308	957	2592	13359	3842	19917	3625	2591
10	1418	1477	1312	879	198	769	1403	7712	1876	11420	2406
11	13680	9172	6816	5747	5322	4011	2973	2808	5839	4007	7822
2+	101216	145371	144776	142442	135103	105950	107236	88332	69251	54956	46262
3+	90716	92735	135476	136050	130761	102731	87080	84090	67447	50334	41082
4+	38467	80288	81539	124148	122174	98658	83883	64108	62847	49282	35736
5+	26416	27191	69371	64473	108385	92036	79940	60732	44755	44512	34464

Table 22. Population numbers at age ($x10^3$), estimated from cohort analysis, for spring-spawning herring in NAFO division 4R from 1973 to 1993.

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	15927	34156	24650	142820	30986	15016	19608	18839	78895	370899
3	49044	11381	27838	20130	116493	25360	12294	15902	15152	64557
4	220270	39760	9082	21890	15865	94893	20721	10042	12247	12029
5	422777	179380	32436	7056	17157	12500	75894	16772	8126	8114
6	30888	320921	146528	26466	5595	13677	10046	52339	13410	6537
7	53633	22963	254202	119005	21351	4306	10584	7667	30300	10659
8	19840	40996	18513	200494	94898	17166	3308	7692	5909	16779
9	11140	13319	32794	14870	150065	73749	12099	2213	5082	4667
10	21918	6770	10205	26546	11488	108422	52954	7398	1588	3695
11	26068	30046	27823	30378	40707	35966	100356	106683	74021	50049
2+	871506	699693	584070	609655	504606	401055	317863	245547	244730	547985
3+	855579	665537	559420	466835	473620	386040	298255	226708	165835	177087
4+	806535	654155	531583	446705	357127	360680	285962	210806	150683	112529
5+	586264	614395	522500	424815	341262	265786	265241	200764	138436	100500

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	81714	434322	94410	49723	29082	23185	149785	39214	12932	49693	49727 †
3	303129	66871	355414	76968	40417	23399	18347	122358	32015	10153	40603 †
4	50707	245498	54358	286838	60892	32793	18669	14502	98318	24668	7188
5	9222	38292	193963	43792	222390	47337	26485	14595	11322	74129	18651
6	4425	6527	27904	139220	32824	168272	36529	21267	11577	8424	53112
7	4971	2636	4806	19233	87942	23701	124140	27161	16523	8907	5995
8	6779	3804	1421	3532	11005	60281	16077	84712	17712	11653	6389
9	7867	4905	2926	819	2471	7440	37034	10384	54834	10032	7023
10	3184	3736	3407	2165	520	1858	3805	20449	5079	30724	6252
11	31820	20922	15800	13846	11423	9045	6738	6729	14664	10509	19695
2+	503816	827512	754407	636135	498965	397311	437608	361369	274975	238893	214636
3+	422103	393190	659998	586412	469883	374126	287824	322155	262043	189201	164908
4+	118974	326319	304584	509444	429466	350728	269477	199798	230028	179047	124305
5+	68267	80822	250227	222607	368574	317935	250807	185296	131710	154379	117117

† geometric mean of last 10 years

Table 23. Mid-year population biomass (mt), estimated from cohort analysis, for autumn-spawning herring in NAFO division 4R from 1973 to 1993.

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	1877	2799	5895	1833	1101	3247	9568	14994	89817	13778
3	3012	2621	2254	4234	3076	1189	4750	14241	20549	76752
4	3486	4816	2367	2379	7424	2400	1305	4309	14655	20711
5	3513	4486	4732	2890	3091	7431	2311	1745	4755	13004
6	3782	3061	4069	3752	2083	3163	6497	2203	1398	3827
7	1843	2605	3242	3003	3313	2193	2793	6096	2088	1401
8	5605	1179	2268	2059	2608	3082	1637	2524	4768	1749
9	5218	4182	1082	1726	1797	2313	2226	1133	2289	3526
10	26089	3658	3675	970	1448	1750	1941	1399	728	1816
11	61637	73165	67555	56269	41890	37518	29234	27153	20455	15681
2+	116063	102570	97141	79115	67830	64285	62260	75796	161502	152245
3+	114186	99771	91246	77281	66729	61038	52693	60802	71685	138467
4+	111174	97151	88992	73048	63653	59849	47943	46561	51136	61715
5+	107688	92335	86624	70668	56229	57449	46638	42252	36481	41004

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
2	17962	4836	4727	6129	7266	14190	9414	13452	1667	4052	4290	†
3	13926	22845	7867	12112	8939	7540	14083	11003	12738	3168	5895	†
4	90983	11617	23095	8838	14779	8437	9549	16488	11876	19356	3128	$
5	17697	84661	11577	22160	8890	13240	8162	8473	13453	10004	16228	$
6	10492	15501	79849	9847	23440	7213	11644	6821	8566	13988	8756	
7	3086	9170	13793	68335	9000	18140	6196	10697	6460	6828	11978	
8	912	2539	7339	11544	61615	7306	16463	5597	9689	5422	5912	
9	1262	801	2093	5987	9869	50543	5852	13947	4818	8260	4585	
10	2637	910	625	1631	5270	8685	42354	4755	12370	4175	6941	
11	13140	11516	7805	7237	8330	10298	15596	49285	42396	44295	37633	
2+	172097	164396	158769	153820	157400	145593	139314	140519	124033	119548	105346	
3+	154135	159559	154042	147691	150134	131403	129900	127067	122366	115496	101056	
4+	140209	136715	146175	135579	141195	123863	115817	116064	109628	112329	95161	
5+	49226	125097	123080	126740	126416	115425	106268	99576	97752	92972	92033	

Table 24. Population numbers at age ($x10^3$), estimated from cohort analysis, for autumn-spawning herring in NAFO division 4R from 1973 to 1993.

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
2	20745	25355	53401	16608	9970	29414	86671	135831	689328	91731
3	31821	16984	20759	43721	13598	8163	24082	70960	111196	564374
4	24647	24426	13888	16978	35752	11130	6674	19710	57933	91010
5	16834	19111	19642	11335	13655	29118	9089	5359	16015	46957
6	15264	12775	15167	15299	9017	11059	23347	7129	4310	12890
7	6864	10120	10165	11581	12144	7017	8699	16682	5677	3447
8	18811	4238	7751	8226	8975	9291	4742	6652	12093	4382
9	17289	13020	3236	6203	6441	6981	6078	2718	5220	8784
10	83443	10690	10382	2516	4850	4964	5260	3305	1615	4135
11	178218	191548	160585	137017	110067	88073	70615	56221	43882	34207
2+	413936	328267	314976	269485	224469	205210	245257	324568	947269	861916
3+	393191	302912	261575	252877	214499	175796	158586	188736	257941	770186
4+	361370	285928	240816	209156	200901	167633	134503	117776	146745	205812
5+	336723	261502	226928	192178	165149	156503	127830	98066	88812	114802

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	
2	188506	68526	104267	64511	73003	136889	90813	169430	27096	65848	65852	†
3	75012	154322	56105	85353	52786	59770	111637	74313	138683	22139	53912	†
4	461557	61339	126299	45722	69496	43076	48748	90859	60424	112894	17821	$
5	72862	375783	49615	102192	36140	56458	34805	39423	73130	48612	91121	$
6	37580	58428	302002	38896	81251	28364	45789	27661	31927	56002	38492	
7	10092	29584	46799	238501	29772	64705	22100	36758	22364	25571	44733	
8	2695	7805	23400	37500	187648	22811	51402	17417	29674	17332	20234	
9	3246	2063	6191	18595	29984	148270	17168	41335	13967	23744	13700	
10	6312	2235	1557	4965	14877	24119	117624	13187	32912	10997	18737	
11	28844	25771	19983	17216	17930	26586	40265	126054	110042	110833	96074	
2+	886708	785857	736217	653451	592886	611048	580352	636437	540220	493970	460674	
3+	698202	717331	631950	588940	519883	474159	489539	467007	513124	428122	394822	
4+	623190	563008	575845	503586	467098	414389	377902	392694	374440	405983	340911	
5+	161633	501669	449547	457864	397602	371314	329153	301835	314017	293089	323090	

† geometric mean of last 10 years
$ estimates are non-significant

Table 25. Instantaneous fishing mortality matrix and average for ages 5+ (weighted and unweighted), estimated from cohort analysis, for (a) spring-spawning and (b) autumn-spawning herring in NAFO division 4R from 1973 to 1993.

A)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	.136	.005	.003	.004	.000	.000	.009	.018	.001	.002	.000	.001	.004	.007	.017	.034	.002	.003	.042	.002	.002
3	.010	.026	.040	.038	.005	.002	.002	.061	.031	.041	.011	.007	.014	.034	.009	.026	.035	.019	.061	.145	.044
4	.005	.004	.052	.044	.038	.023	.011	.012	.212	.066	.081	.036	.016	.054	.052	.014	.046	.048	.082	.080	.856
5	.076	.002	.003	.032	.027	.018	.172	.024	.018	.406	.146	.116	.132	.088	.079	.059	.019	.032	.096	.133	.224
6	.096	.033	.008	.015	.062	.056	.070	.347	.030	.074	.318	.106	.172	.259	.126	.104	.096	.052	.062	.140	.151
7	.069	.015	.037	.026	.018	.064	.119	.061	.391	.253	.067	.418	.108	.358	.178	.188	.182	.228	.149	.132	.322
8	.199	.023	.019	.090	.052	.150	.202	.214	.036	.557	.124	.063	.351	.157	.192	.287	.237	.235	.368	.306	.449
9	.298	.066	.011	.058	.125	.131	.292	.132	.119	.182	.545	.164	.101	.255	.085	.471	.394	.515	.379	.273	.549
10	.274	.083	.027	.139	.177	.168	.167	.238	.218	.331	.322	.251	.131	.142	.081	.288	.255	.426	.440	.550	.670
11	.274	.083	.027	.139	.177	.168	.167	.238	.218	.331	.322	.251	.131	.142	.081	.288	.255	.426	.440	.550	.670
5+	.101	.026	.024	.072	.100	.142	.169	.240	.214	.343	.285	.167	.137	.224	.110	.153	.190	.241	.306	.267	.327
	.202	.051	.022	.078	.102	.123	.170	.205	.168	.288	.283	.209	.166	.219	.124	.271	.237	.314	.306	.325	.469

B)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.001	.000	.004	.001	.000	.002	.000	.000
3	.064	.001	.001	.001	.000	.001	.000	.003	.000	.001	.001	.000	.005	.006	.003	.004	.006	.007	.006	.017	.004
4	.054	.018	.003	.018	.005	.003	.019	.008	.010	.022	.006	.012	.012	.035	.008	.013	.012	.017	.018	.014	.043
5	.076	.031	.050	.029	.011	.021	.043	.018	.017	.023	.021	.019	.043	.029	.042	.009	.030	.011	.067	.033	.024
6	.211	.028	.070	.031	.051	.040	.136	.028	.023	.045	.039	.022	.036	.067	.028	.050	.020	.013	.022	.025	.029
7	.282	.067	.012	.055	.068	.192	.068	.122	.059	.046	.057	.034	.022	.040	.066	.030	.038	.014	.055	.034	.042
8	.168	.070	.023	.045	.051	.224	.357	.042	.120	.100	.067	.032	.030	.024	.036	.084	.018	.021	.023	.035	.032
9	.281	.026	.051	.046	.061	.083	.409	.321	.033	.130	.173	.082	.021	.023	.018	.032	.064	.028	.039	.037	.077
10	.115	.033	.023	.040	.069	.079	.103	.108	.088	.088	.114	.142	.026	.015	.012	.033	.027	.038	.057	.040	.053
11	.115	.033	.023	.040	.069	.079	.103	.108	.088	.088	.114	.142	.026	.015	.012	.033	.027	.038	.057	.040	.054
6+	.136	.034	.027	.040	.066	.092	.133	.106	.083	.084	.077	.053	.033	.039	.033	.037	.027	.029	.047	.035	.047
	.192	.046	.027	.045	.063	.131	.208	.140	.078	.090	.105	.086	.025	.023	.029	.042	.035	.028	.046	.037	.051

Table 26. Projected estimates of population numbers, mid-year biomass, fishing mortality and catch biomass for spring-spawning herring in NAFO division 4R assuming a constant catch of 11,000 t in 1994 and 1995.

POPULATION NUMBERS ('000)

	1993	1994	1995
2	49727	49727	49727
3	40603	40642	39358
4	7188	31808	26922
5	18651	2500	14411
6	53112	12201	1596
7	5995	37379	82089
8	6389	3556	21999
9	7023	3339	1510
10	6252	3322	1376
11+	19695	10867	5121
2+	214636	195341	174702
4+	124305	104972	85617
5+	117117	73164	57064

MID-YEAR POPULATION BIOMASS (t)

	1993	1994	1995
2	5180	5180	5180
3	5347	5352	5183
4	1272	5627	5051
5	4212	565	3896
6	13452	3090	404
7	1737	10830	2378
8	2244	1249	7726
9	2591	1232	557
10	2406	1278	529
11+	7822	4316	2034
2+	46262	38718	32938
4+	35736	28187	22576
5+	34464	22560	17525

FISHING MORTALITY

	1993	1994	1995
2	.002	.034	.040
3	.044	.153	.180
4	.856	.412	.484
5	.224	.249	.292
6	.151	.196	.231
7	.322	.330	.388
8	.449	.656	.771
9	.549	.686	.806
10	.670	.819	.962
11+	.670	.819	.962
5+	.469	.536	.630

CATCH BIOMASS (t)

	1993	1994	1995
2	9	173	202
3	231	763	857
4	741	1915	1956
5	851	125	993
6	1897	554	84
7	482	3066	771
8	819	609	4212
9	1106	620	313
10	1190	726	333
11+	3870	2450	1279
2+	11198	11000	11000
4+	10958	10065	9941
5+	10215	8149	7985

Table 27. Projected estimates of population number, mid-year biomass, fishing mortality and catch biomass for spring-spawning herring in NAFO division 4R assuming a fully recruited fishing mortality rate of 0.3 in 1994 and 1995.

POPULATION NUMBERS ('000)

	1993	1994	1995
2	49727	49727	49727
3	40603	40642	40212
4	7188	31808	31461
5	18651	2500	22396
6	53112	12201	1869
7	5995	37379	9296
8	6389	3556	27118
9	7023	3339	2290
10	6252	3322	2126
11+	19695	10867	8606
2+	214636	195341	195100
4+	124305	104972	105161
5+	117117	73164	73700

MID-YEAR POPULATION BIOMASS (t)

	1993	1994	1955
2	5180	5180	5180
3	5347	5352	5295
4	1272	5627	5565
5	4212	565	5058
6	13452	3090	473
7	1737	10830	2693
8	2244	1249	9523
9	2591	1232	845
10	2406	1278	818
11+	7822	4316	3418
2+	46262	38718	38869
4+	35736	28187	28394
5+	34464	22560	22829

FISHING MORTALITY

	1993	1994	1995
2	.002	.012	.012
3	.044	.056	.056
4	.856	.151	.151
5	.224	.091	.091
6	.151	.072	.072
7	.322	.121	.121
8	.449	.240	.240
9	.549	.251	.251
10	.670	.300	.300
11+	.670	.300	.300
5+	.469	.196	.196

CATCH BIOMASS (t)

	1993	1994	1995
2	9	64	64
3	231	272	289
4	741	791	782
5	851	49	442
6	1897	215	33
7	482	1238	308
8	819	268	2046
9	1106	275	189
10	1190	334	213
11+	3870	1126	892
2+	11198	4653	5259
4+	10958	4297	4906
5+	10215	3506	4123

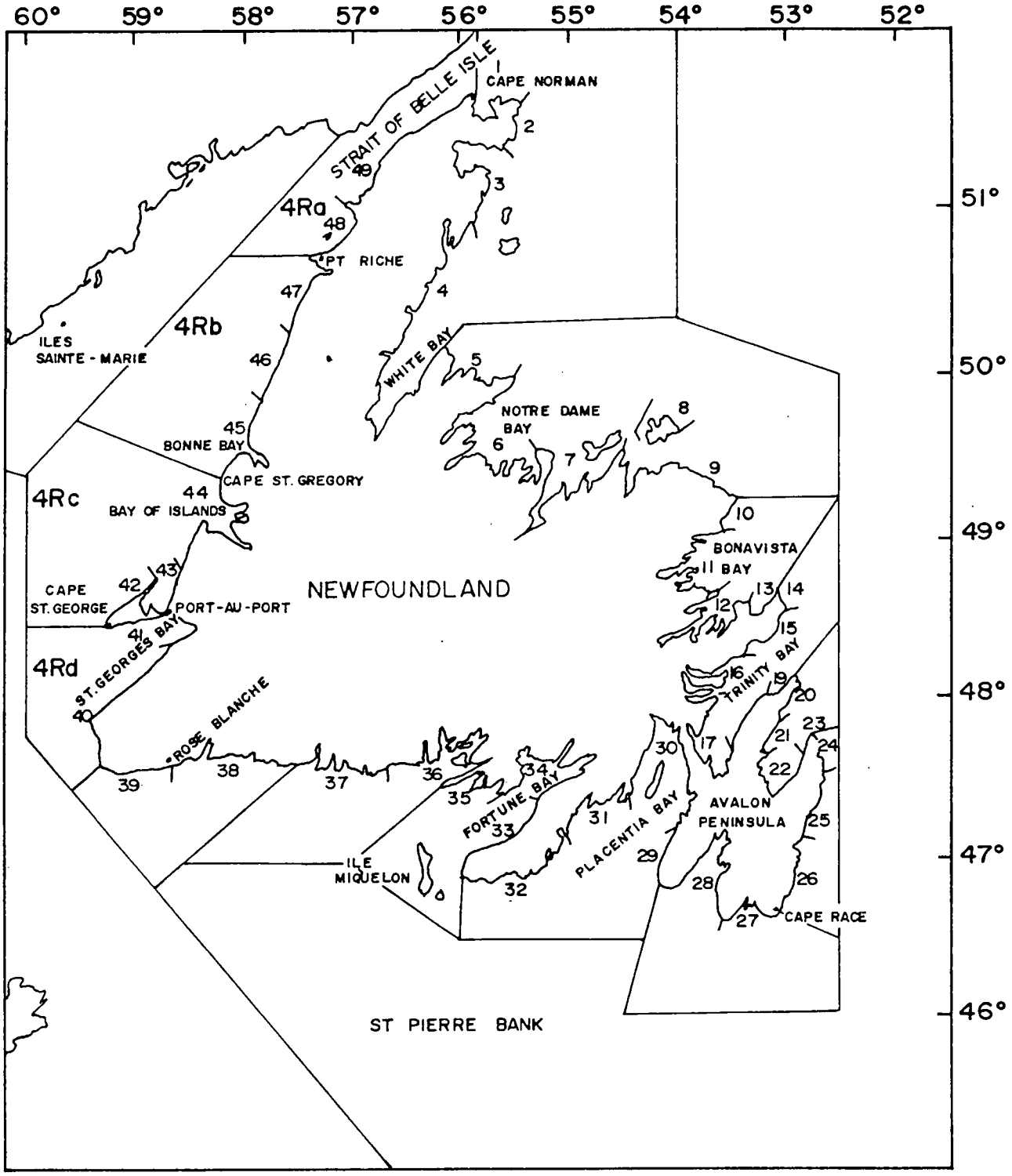


Figure 1. West coast of Newfoundland unit areas and statistical districts.

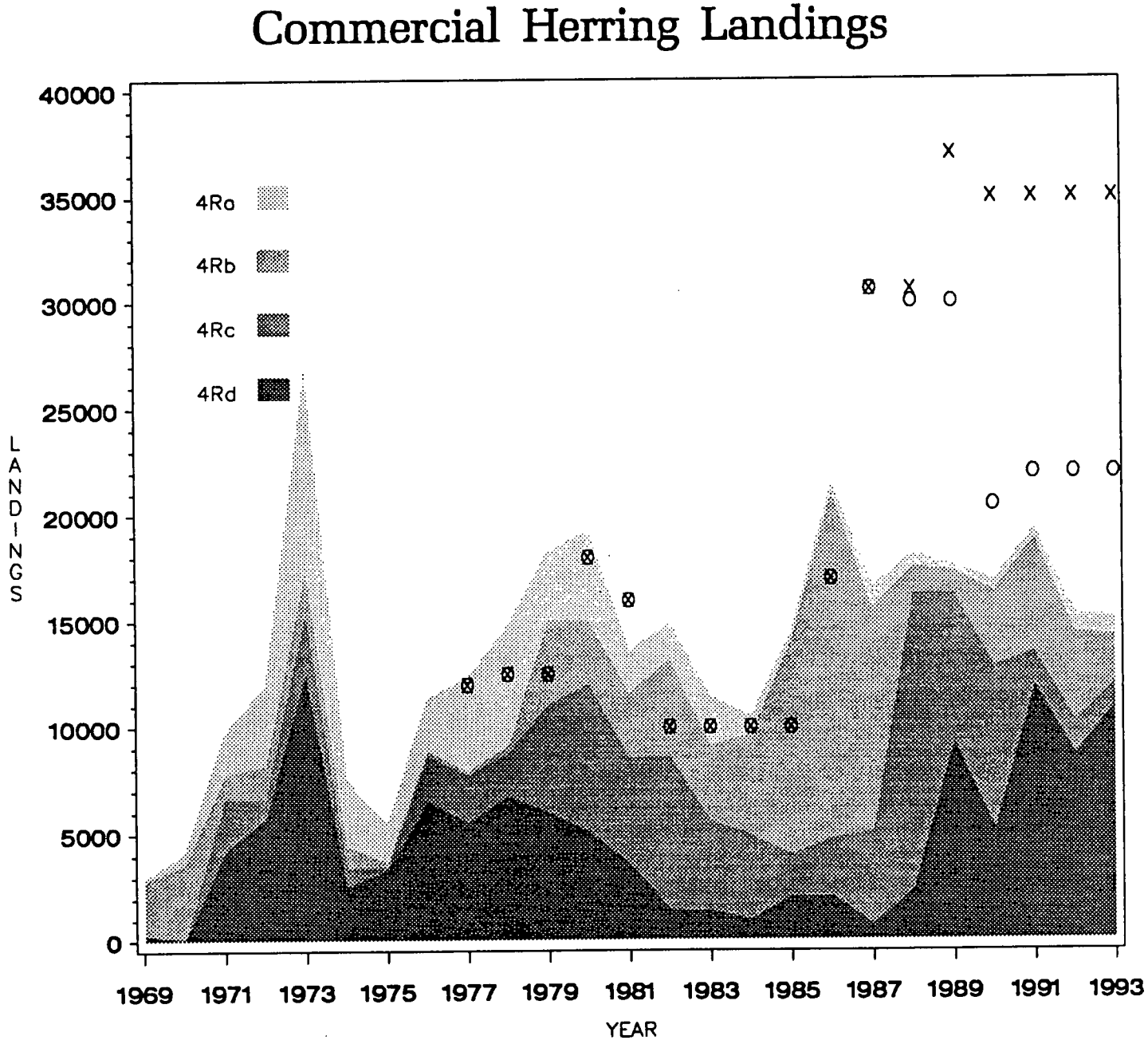


Figure 2. Cumulative commercial herring landings (t) by fishing area in NAFO Division 4R from 1969 to 1993."X" indicates annual TAC; "O" indicates assessment advice.

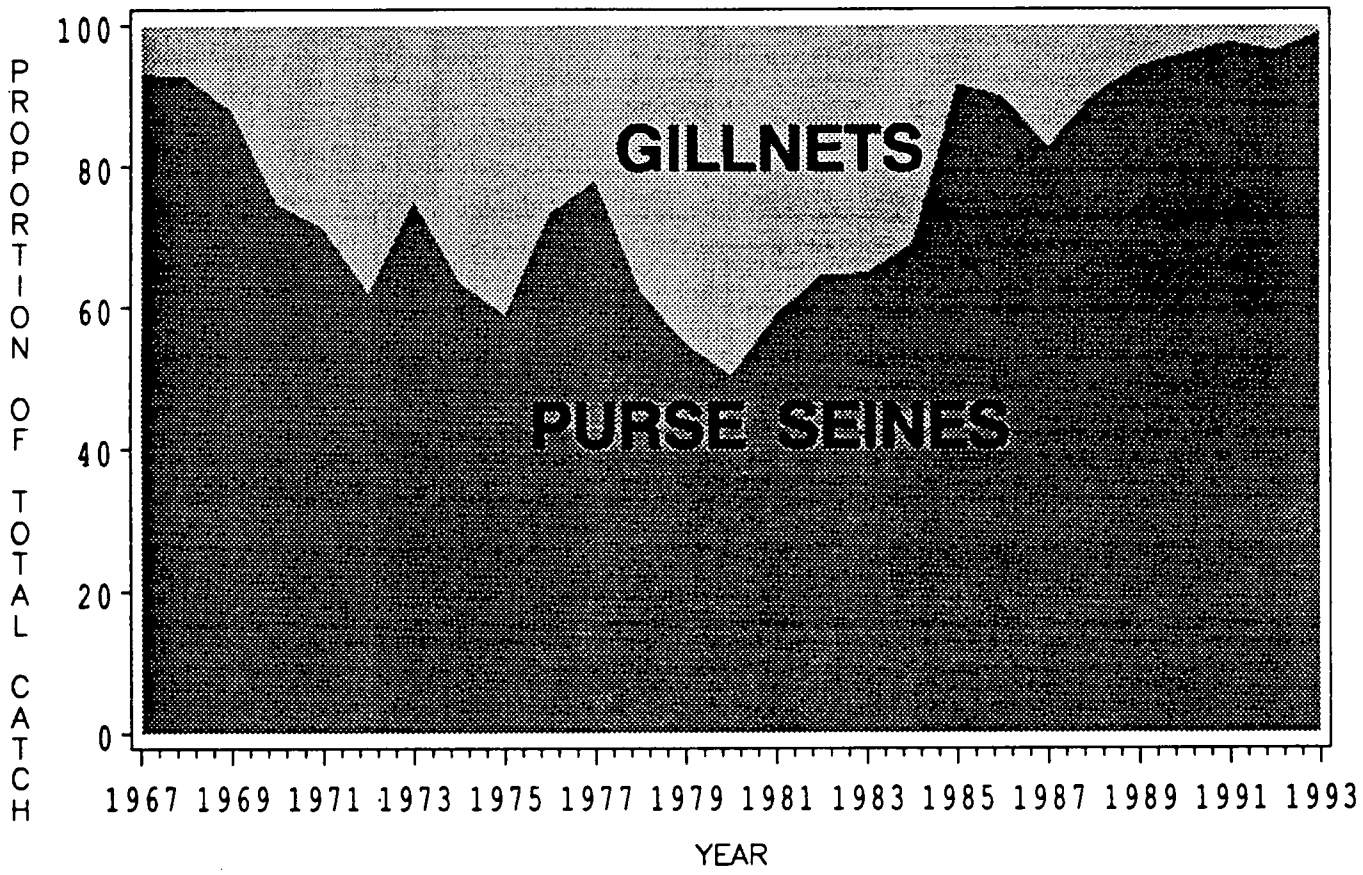
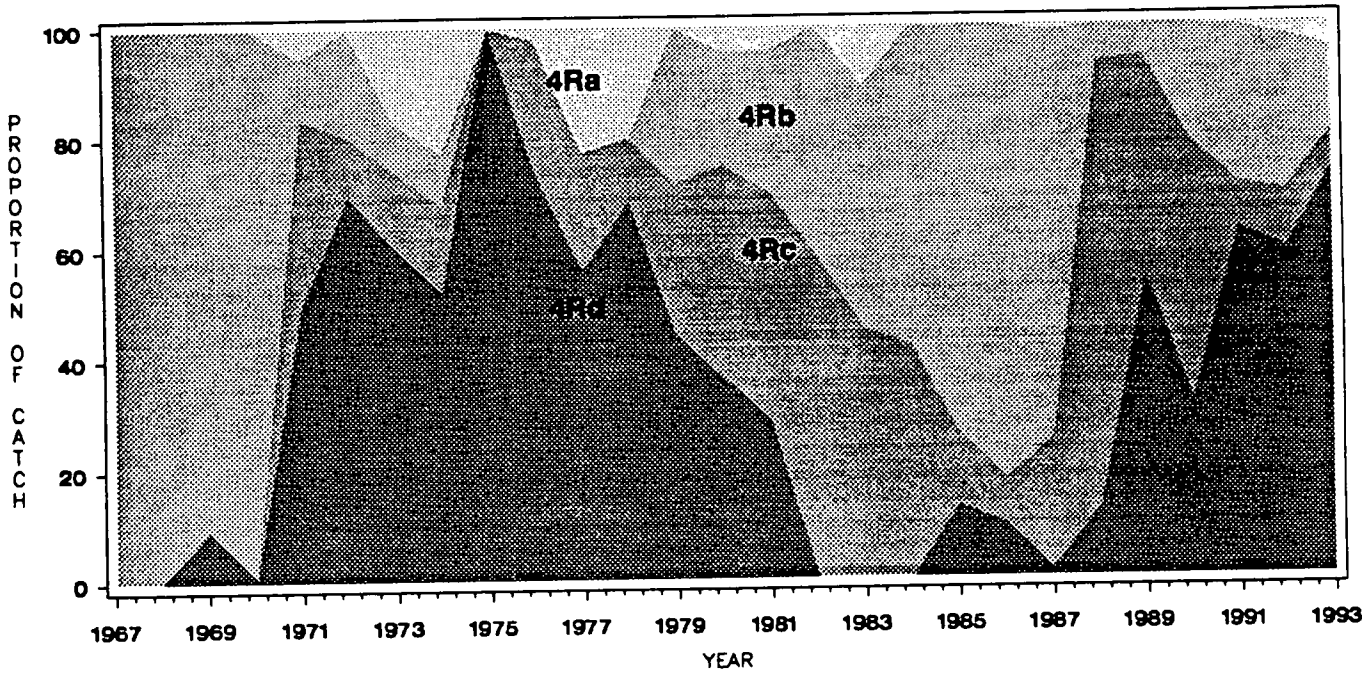


Figure 3. Proportion of total herring landings taken by gillnets and purse seines in NAFO Division 4R from 1967 to 1993.

A) PURSE SEINES



B) GILLNETS

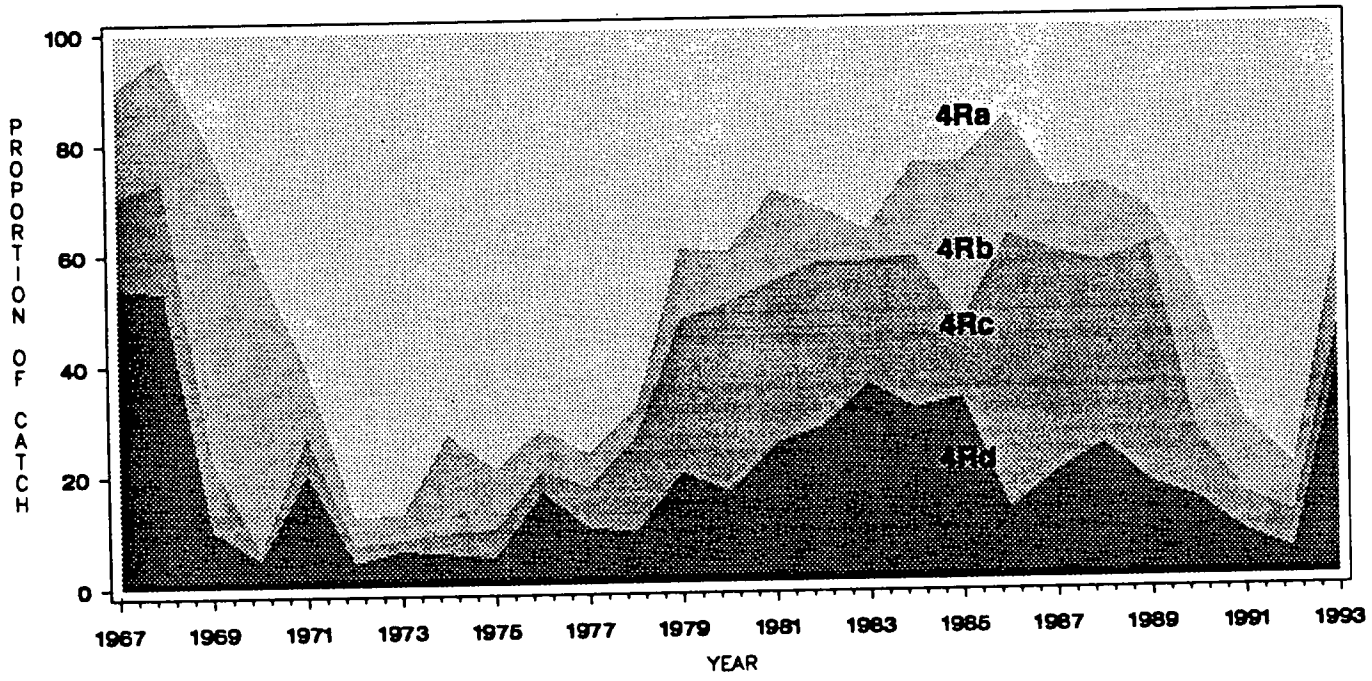


Figure 4. Proportion of (a) purse seine and (b) gillnet herring landings by fishing area in NAFO Division 4R from 1967 to 1993.

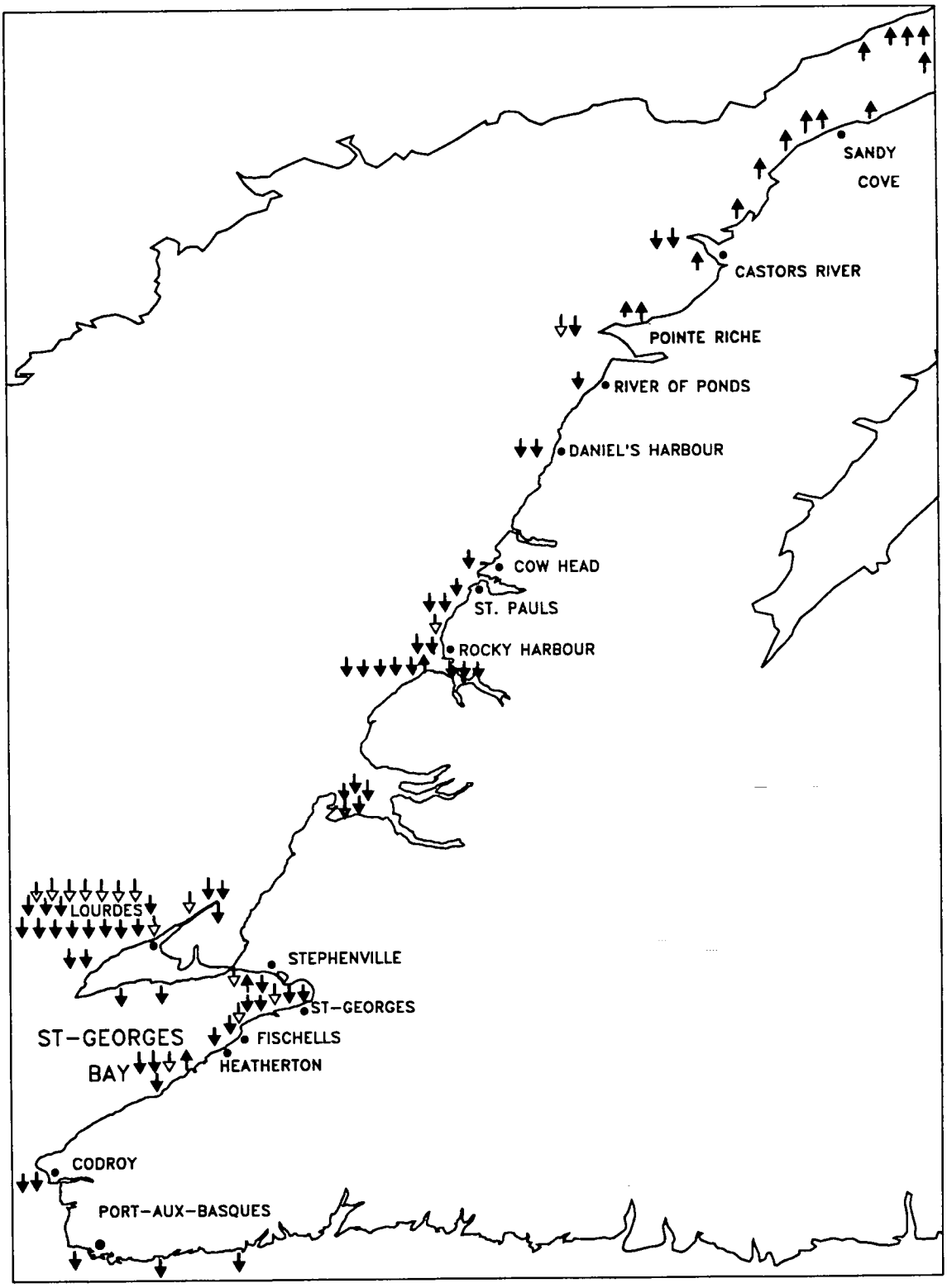


Figure 5. Distribution of inshore fishermen's opinions concerning the state of herring stocks and spawning in NAFO division 4R from written questionnaires [↑ = stock in good shape, ↓ = stock in decline, ↓ = spawning in decline].

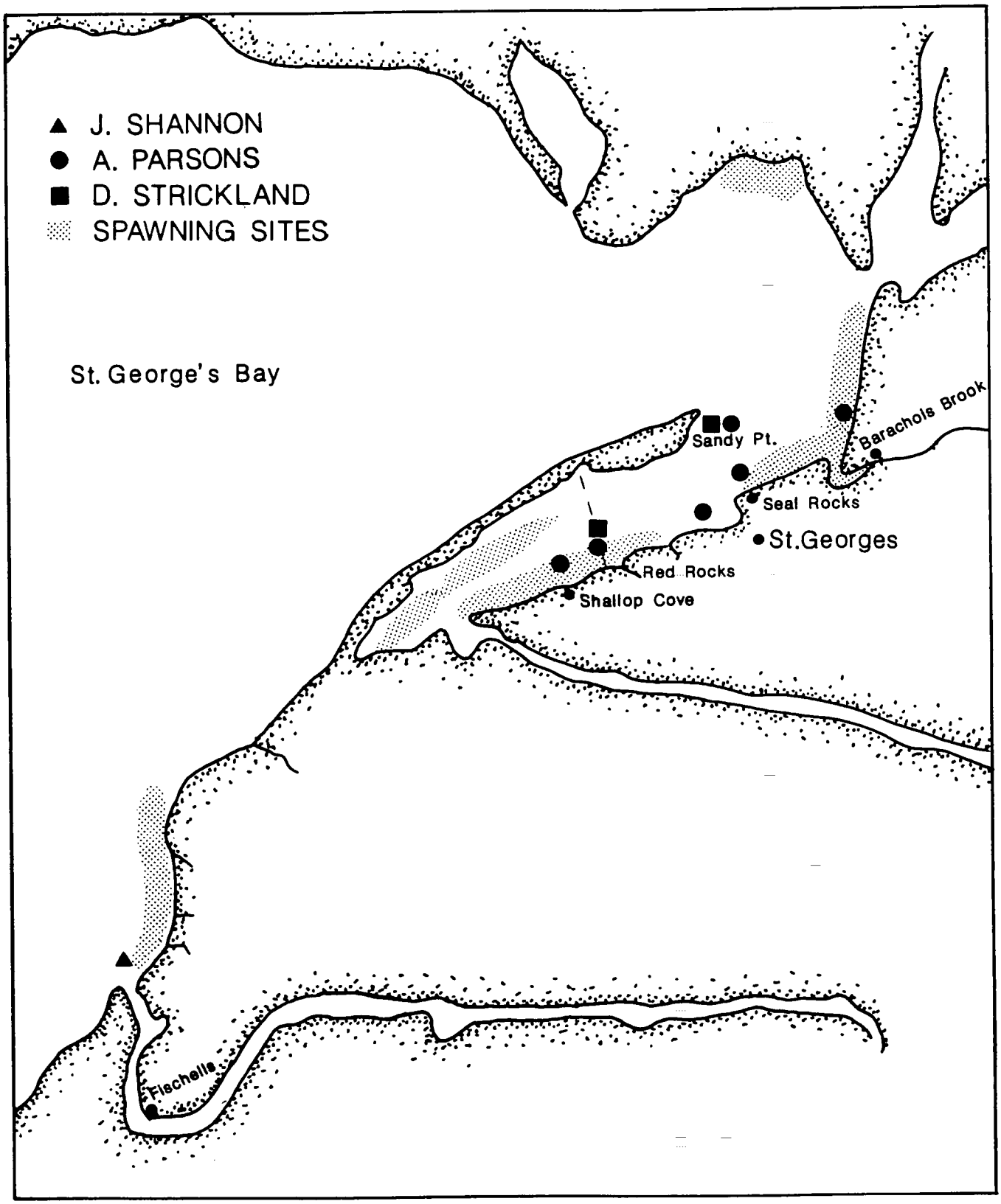


Figure 6. Location of the major spawning sites of spring herring and fishing sites of index fishermen in St. Georges Bay.

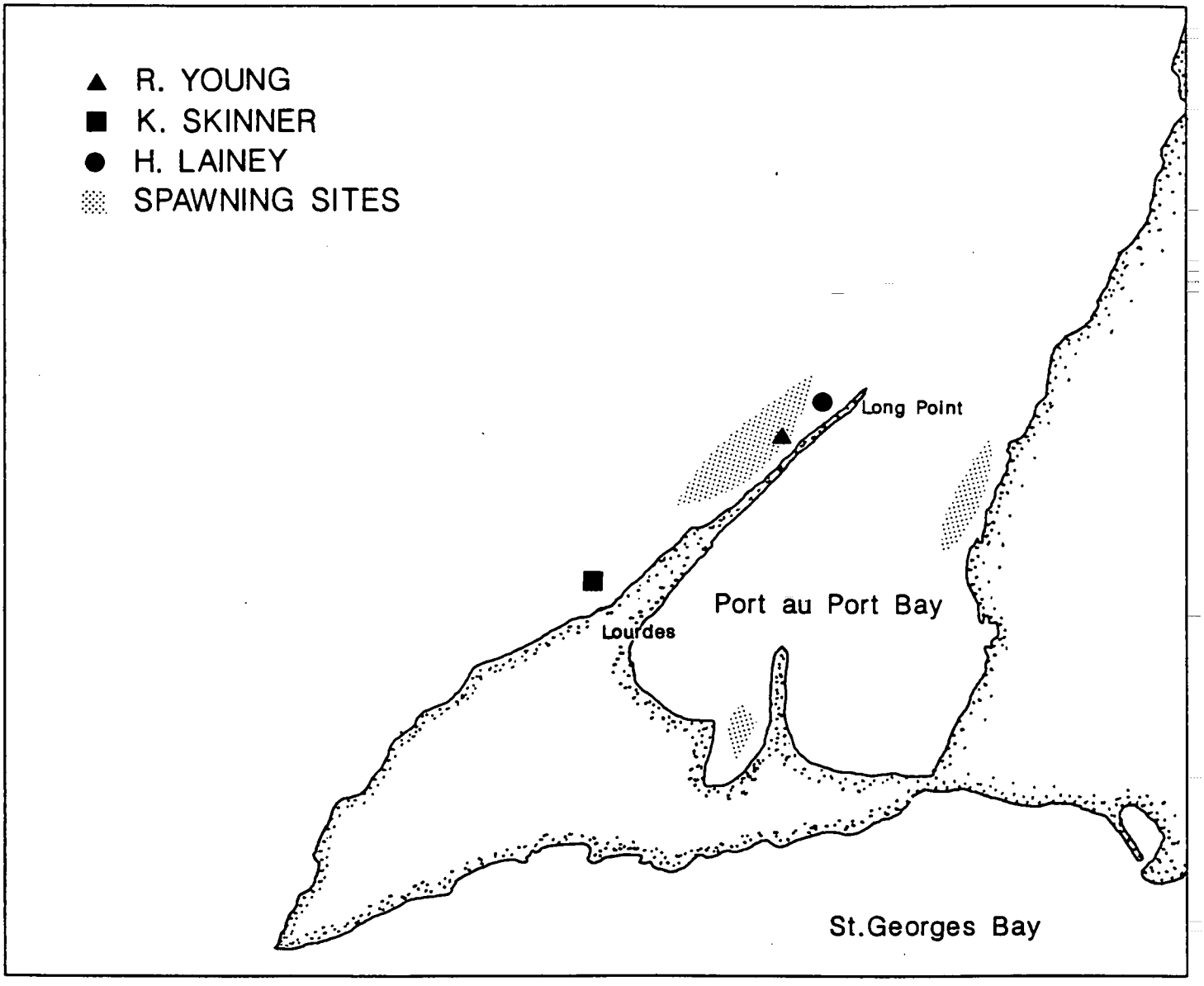


Figure 7. Location of the major spawning sites of spring herring and fishing sites of index fishermen in and around Port-au-Port Bay.

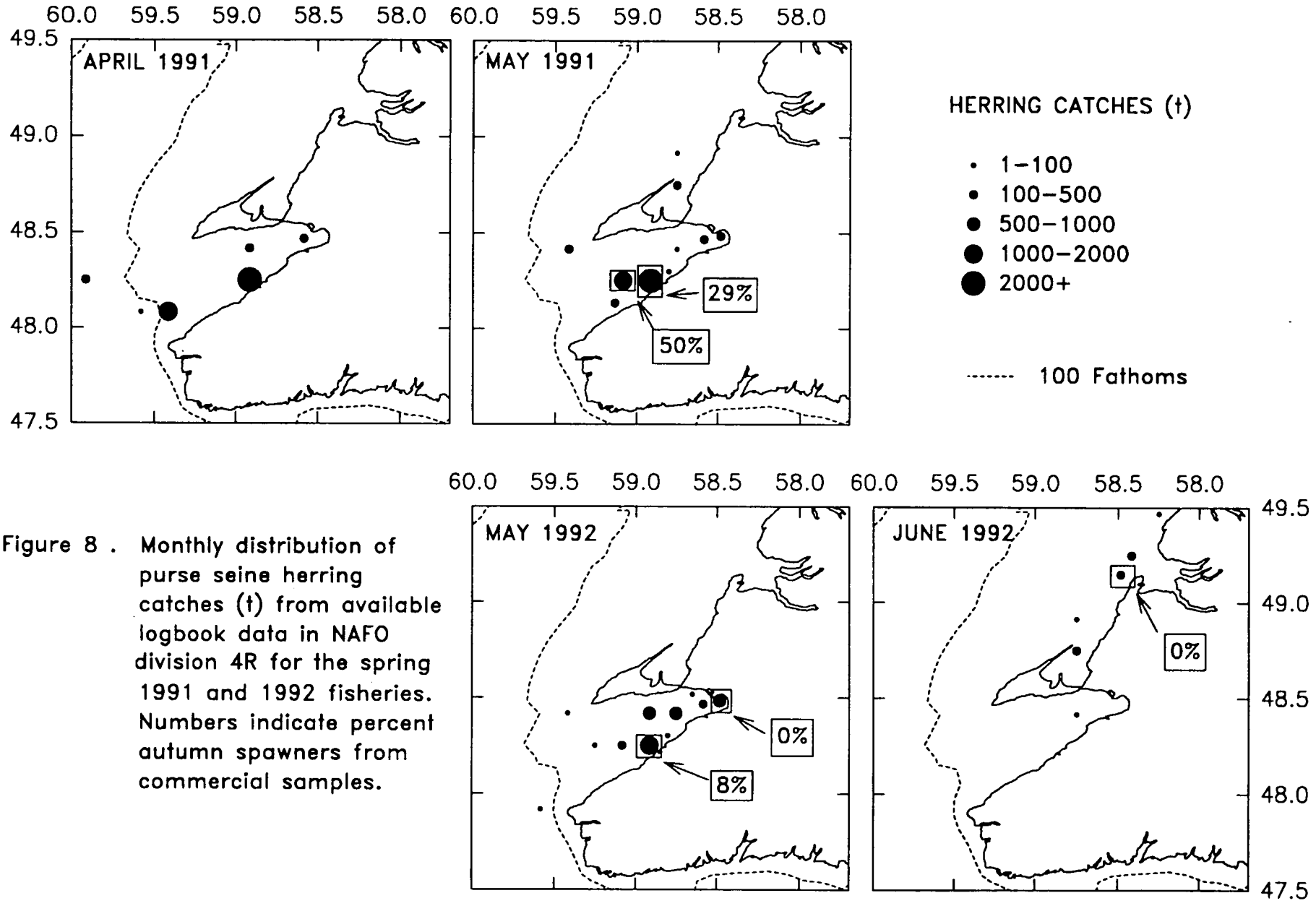


Figure 8 . Monthly distribution of purse seine herring catches (t) from available logbook data in NAFO division 4R for the spring 1991 and 1992 fisheries. Numbers indicate percent autumn spawners from commercial samples.

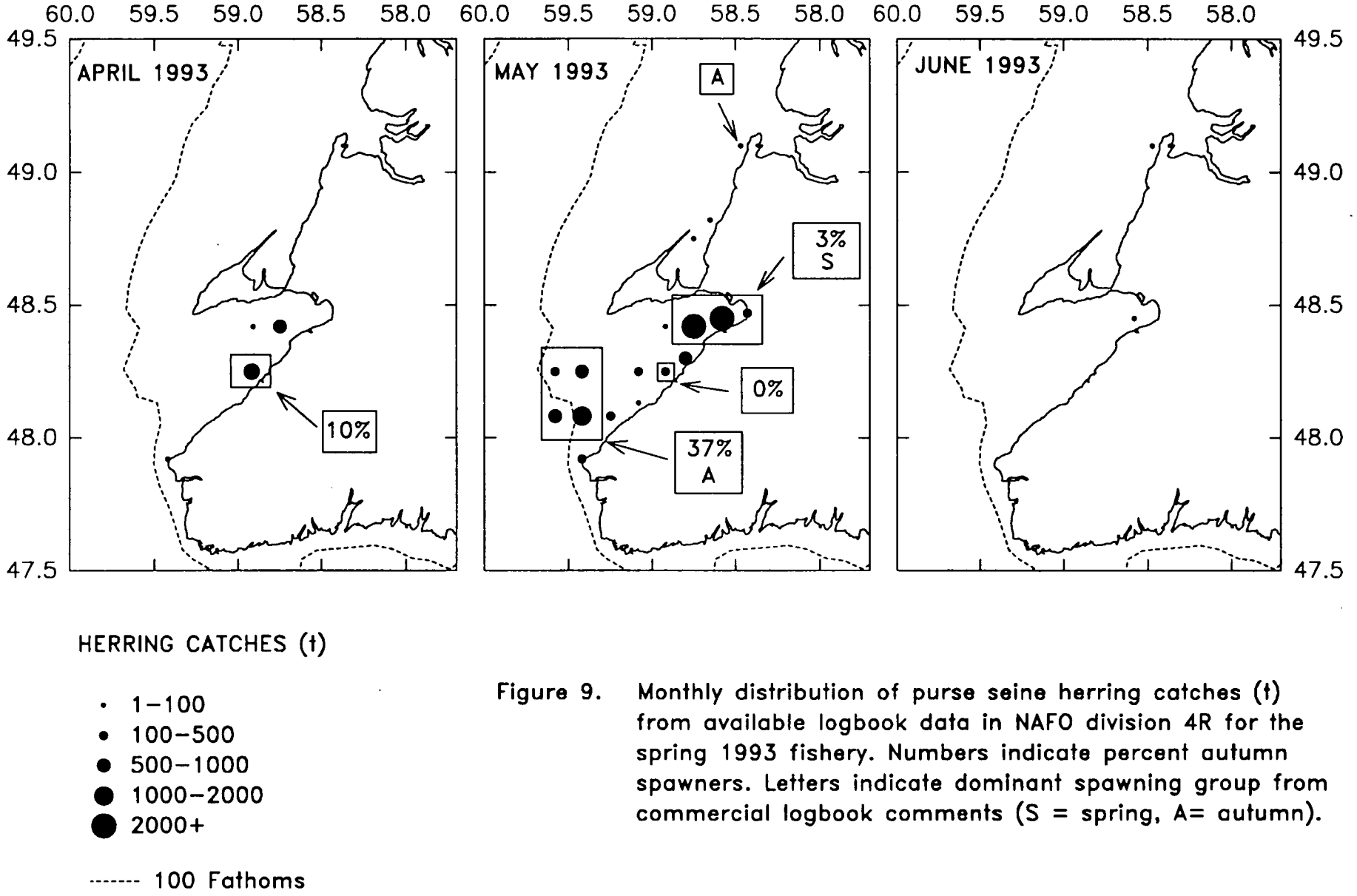


Figure 9. Monthly distribution of purse seine herring catches (t) from available logbook data in NAFO division 4R for the spring 1993 fishery. Numbers indicate percent autumn spawners. Letters indicate dominant spawning group from commercial logbook comments (S = spring, A= autumn).

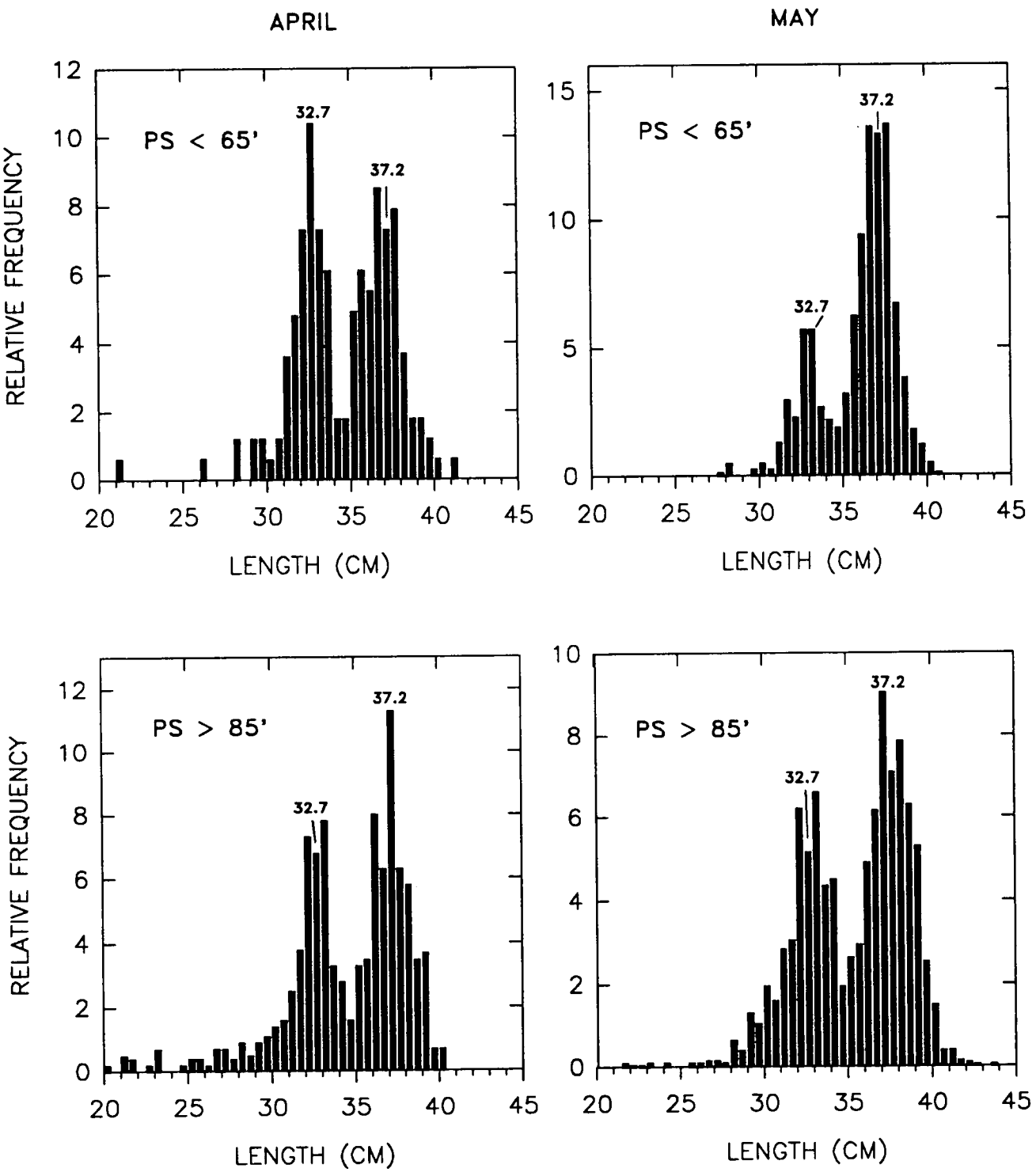


Figure 10. Length frequency distributions of herring sampled from small and large purse seines in 4Rd during the 1993 spring fishery.

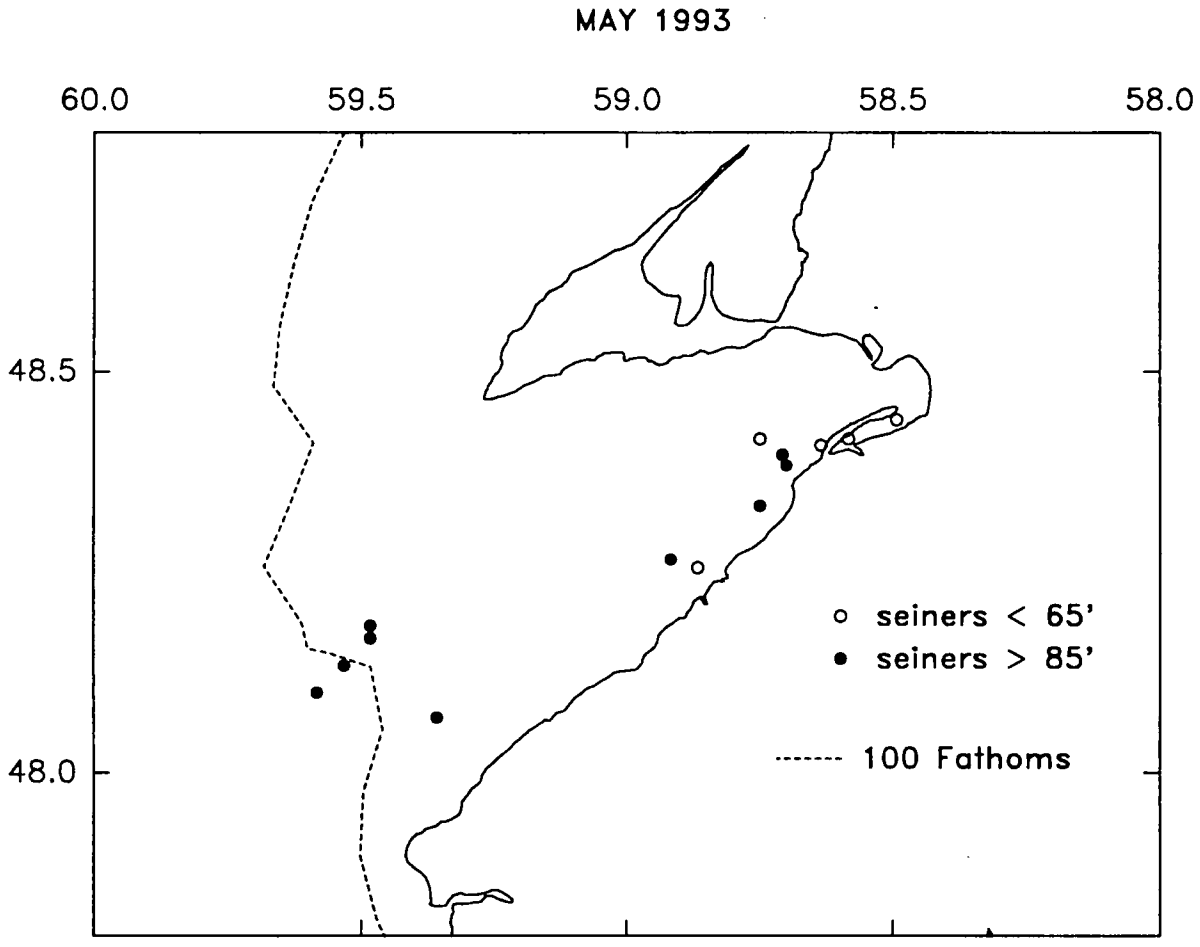


Figure 11. Positions of samples from small and large purse seiners in St. Georges Bay during May 1993.

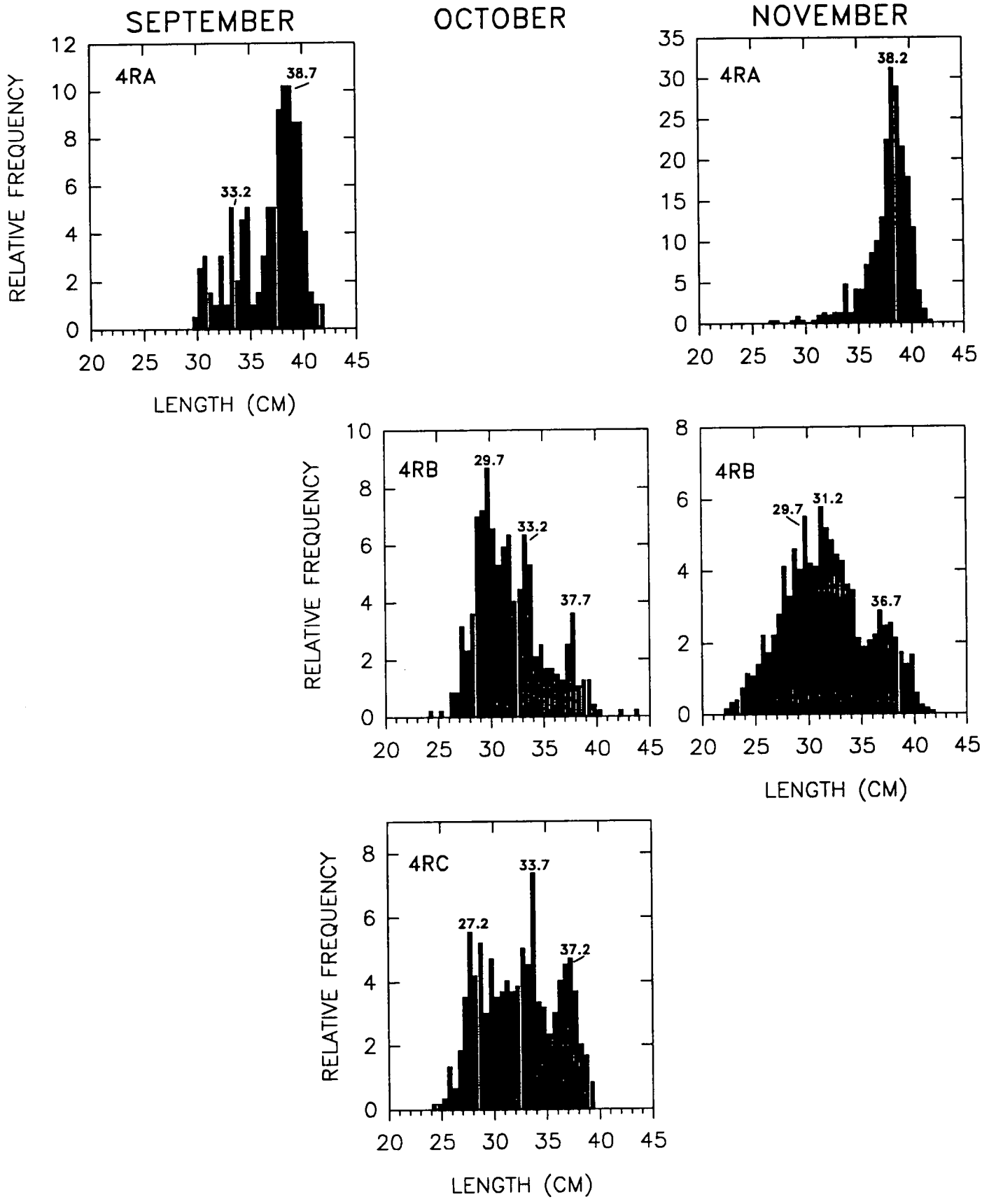


Figure 12a. Length frequency distributions of 4R herring by month and unit area sampled from purse seines during the 1993 fall fishery.

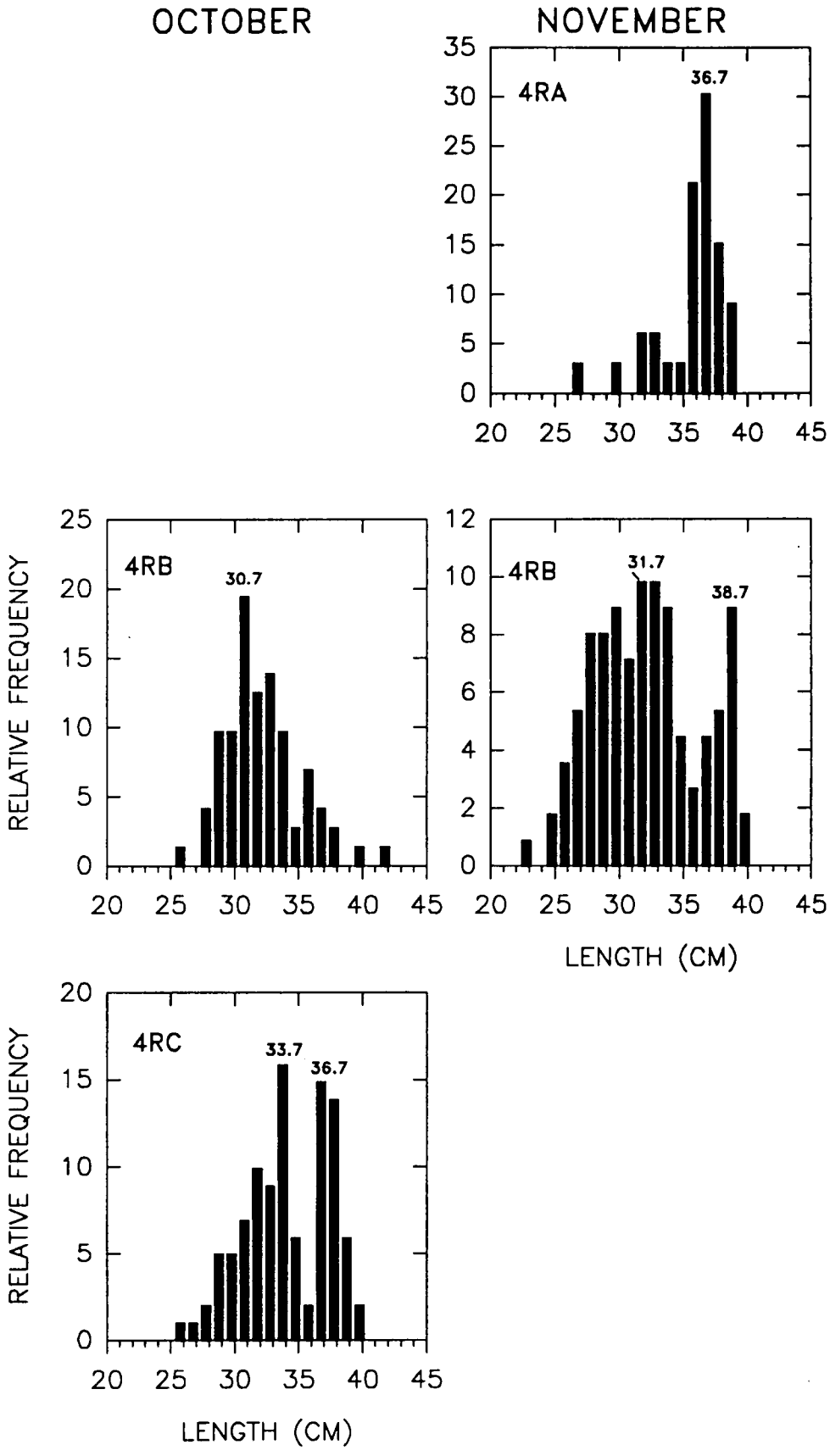


Figure 12b. Length frequency distributions of 4R spring-spawning herring by month and unit area sampled from purse seines during the 1993 fall fishery.

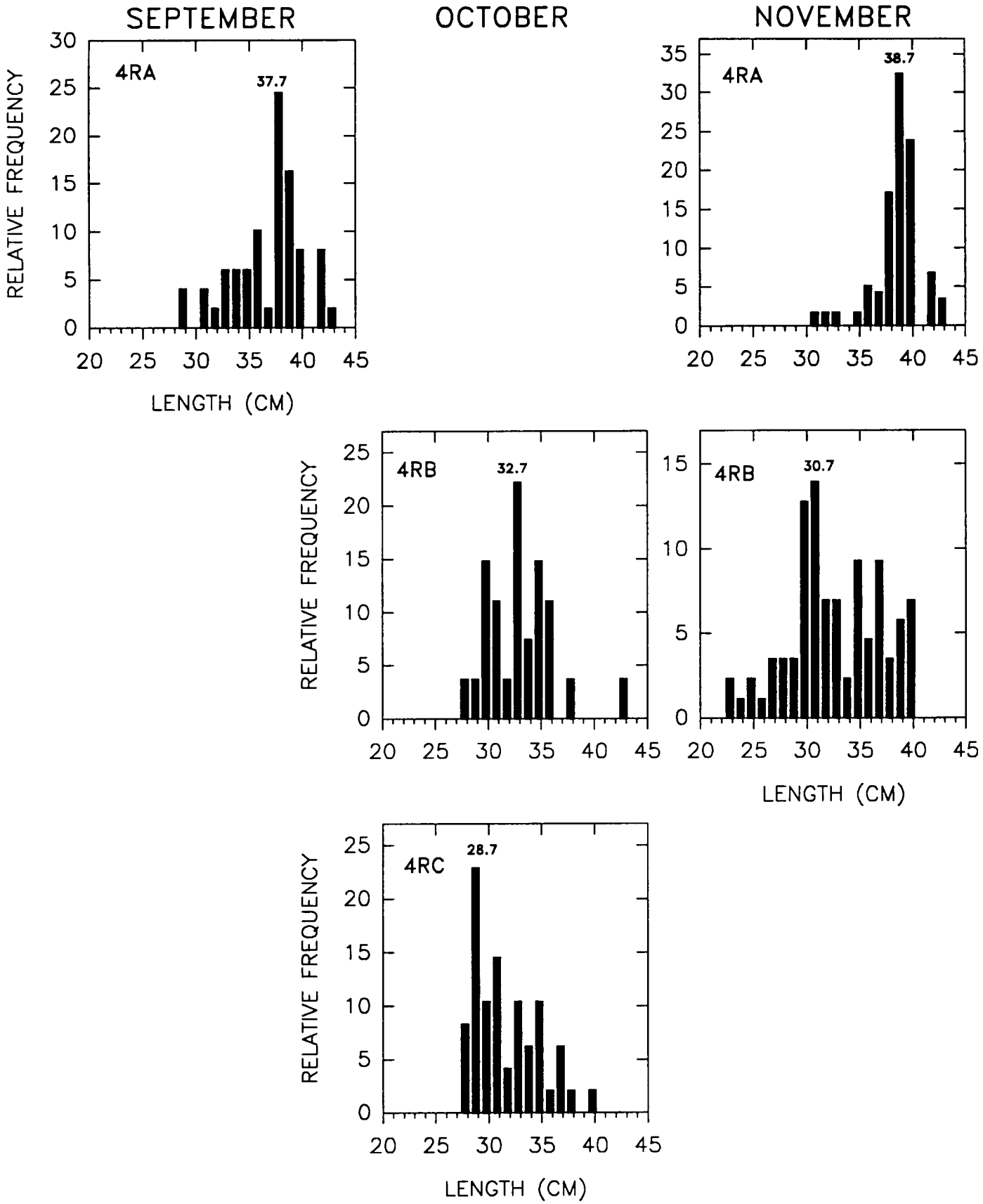


Figure 12c. Length frequency distributions of 4R autumn-spawning herring by month and unit area sampled from purse seines during the 1993 fall fishery.

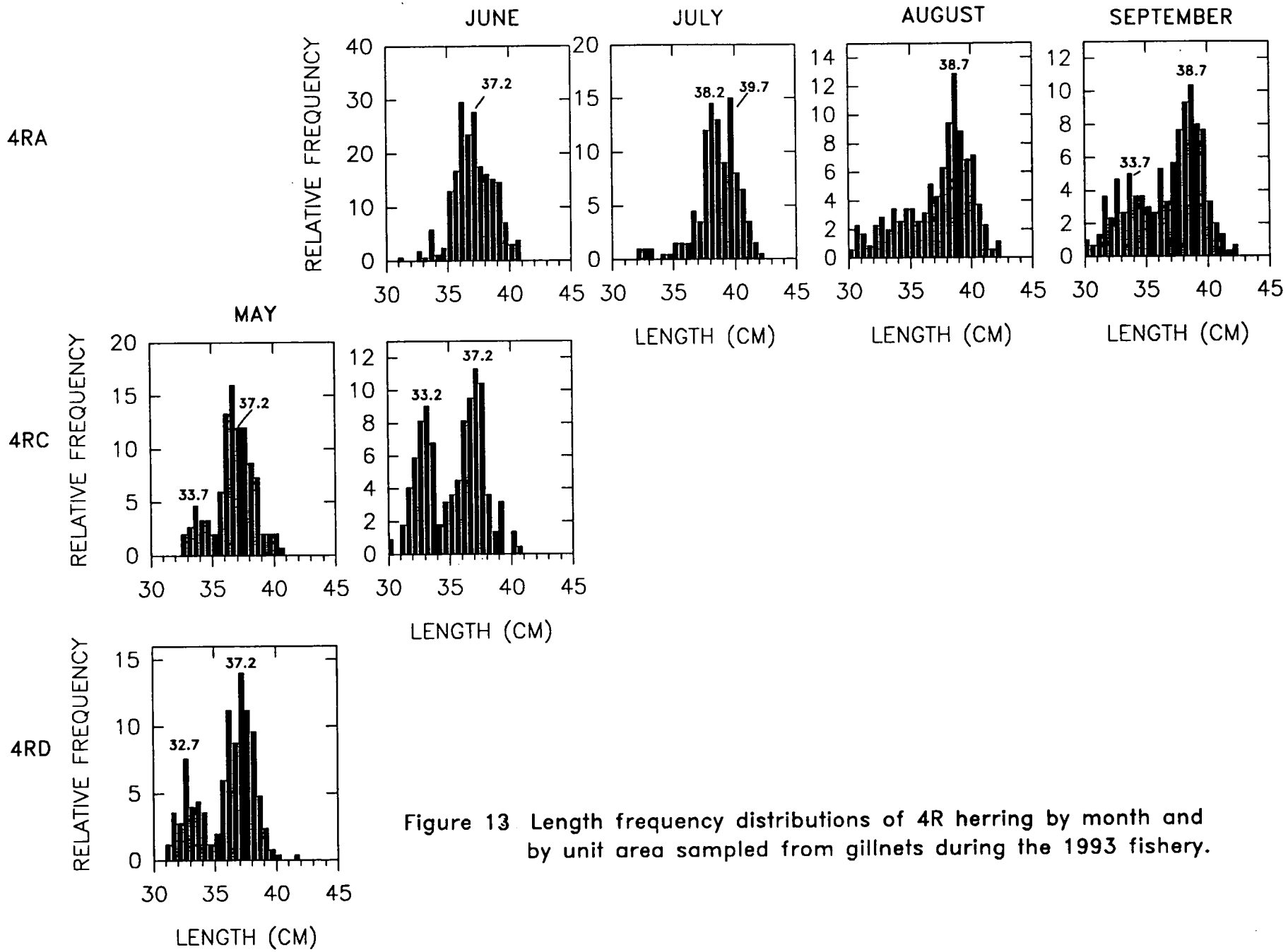


Figure 13 Length frequency distributions of 4R herring by month and by unit area sampled from gillnets during the 1993 fishery.

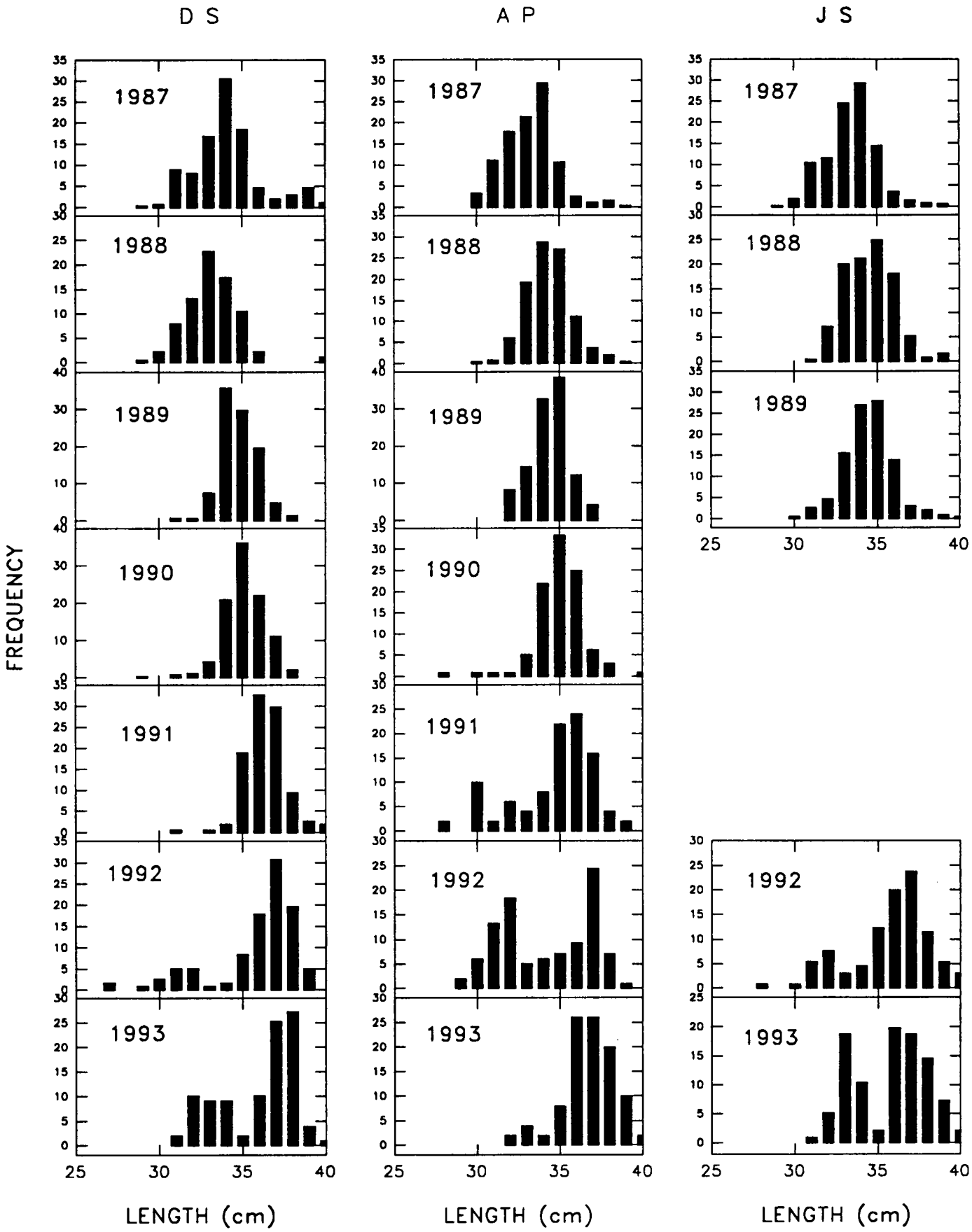


Figure 14. Length frequency distributions of 4R spring-spawning herring from index fishermen in St. Georges Bay between 1987 and 1993.

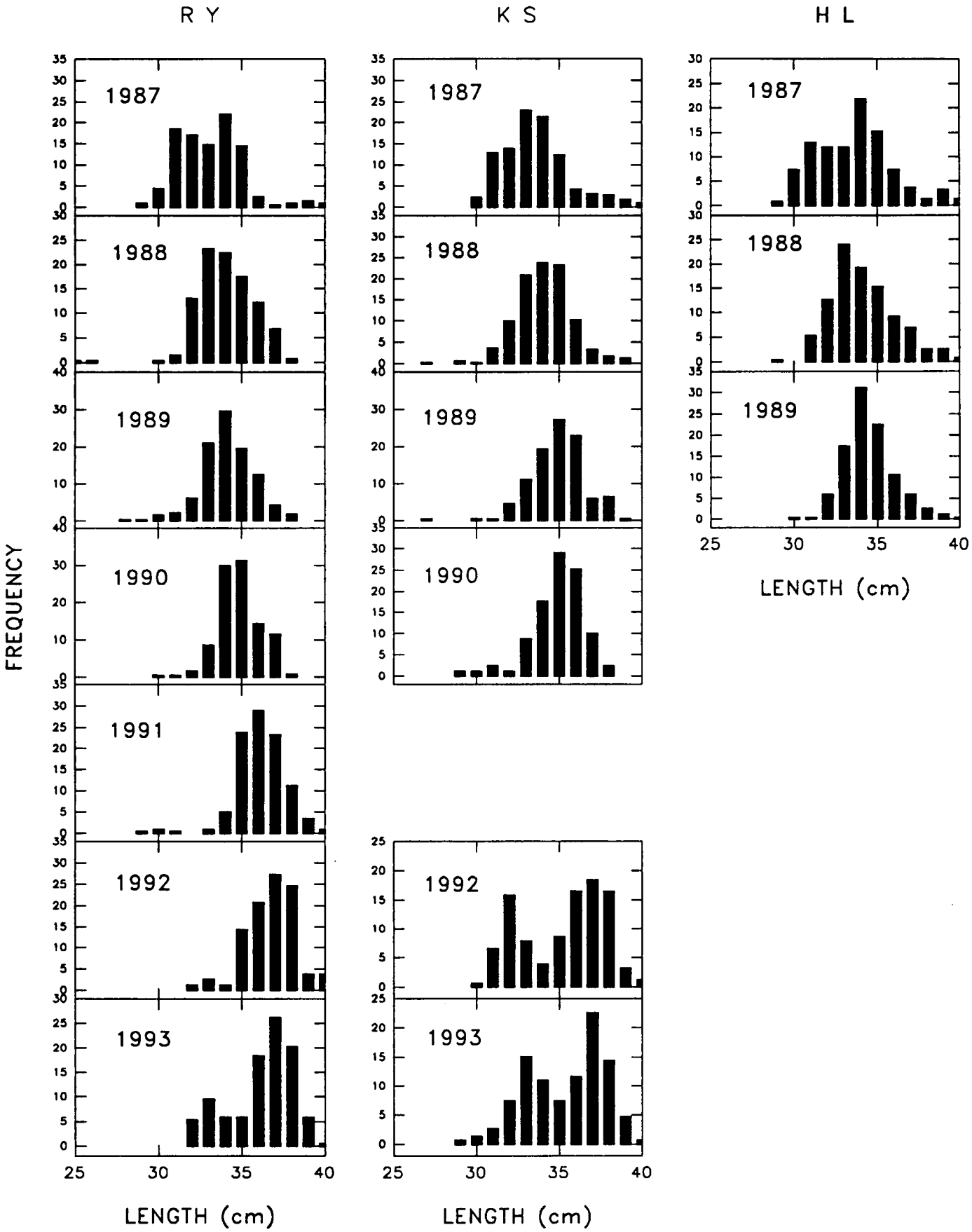


Figure 15. Length frequency distributions of 4R spring-spawning herring from index fishermen in and around Port-au-Port Bay from 1987 to 1993.

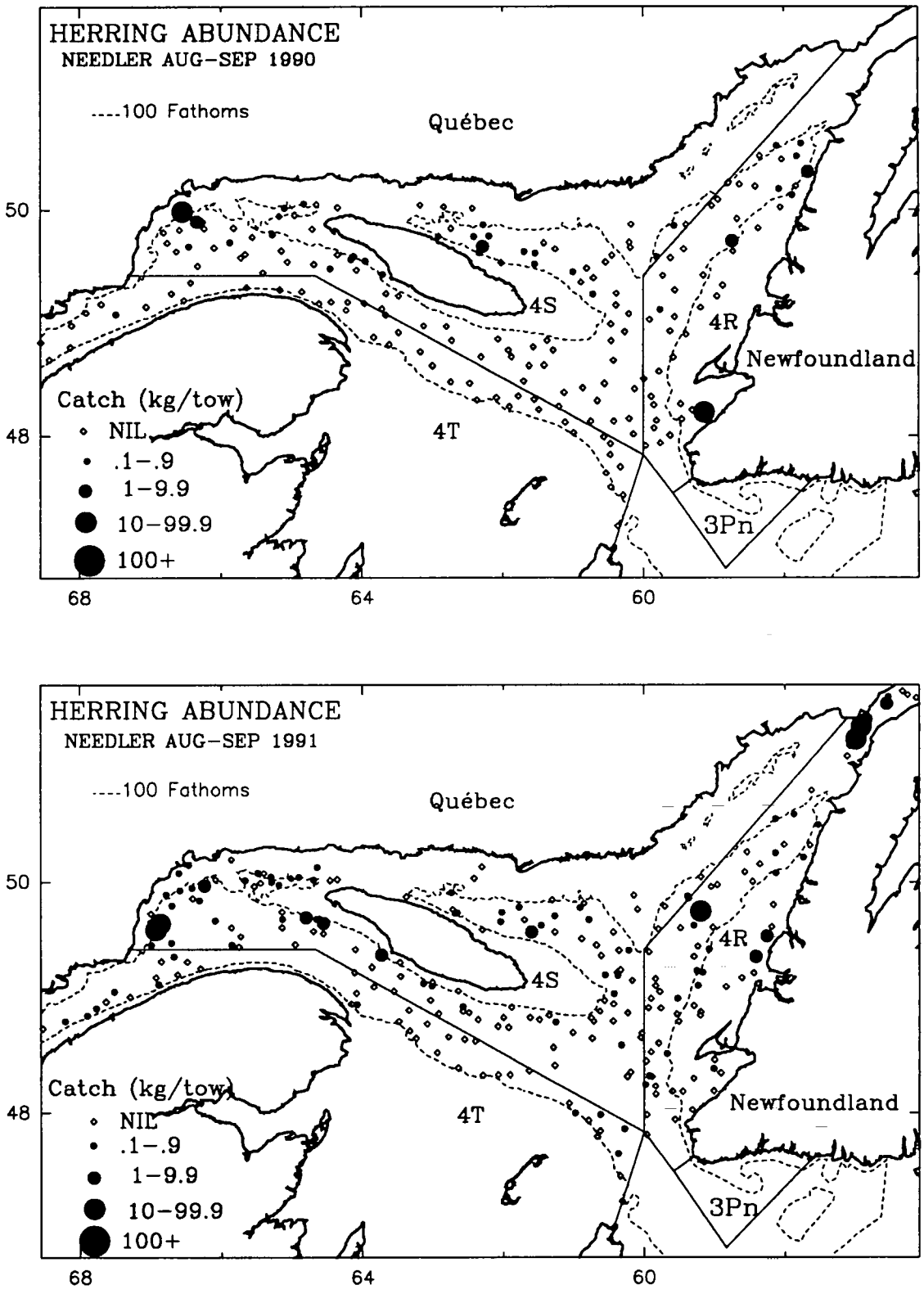


Figure 16. Herring catch rates from 1990-1991 summer Needler survey in the Gulf of St.Lawrence.

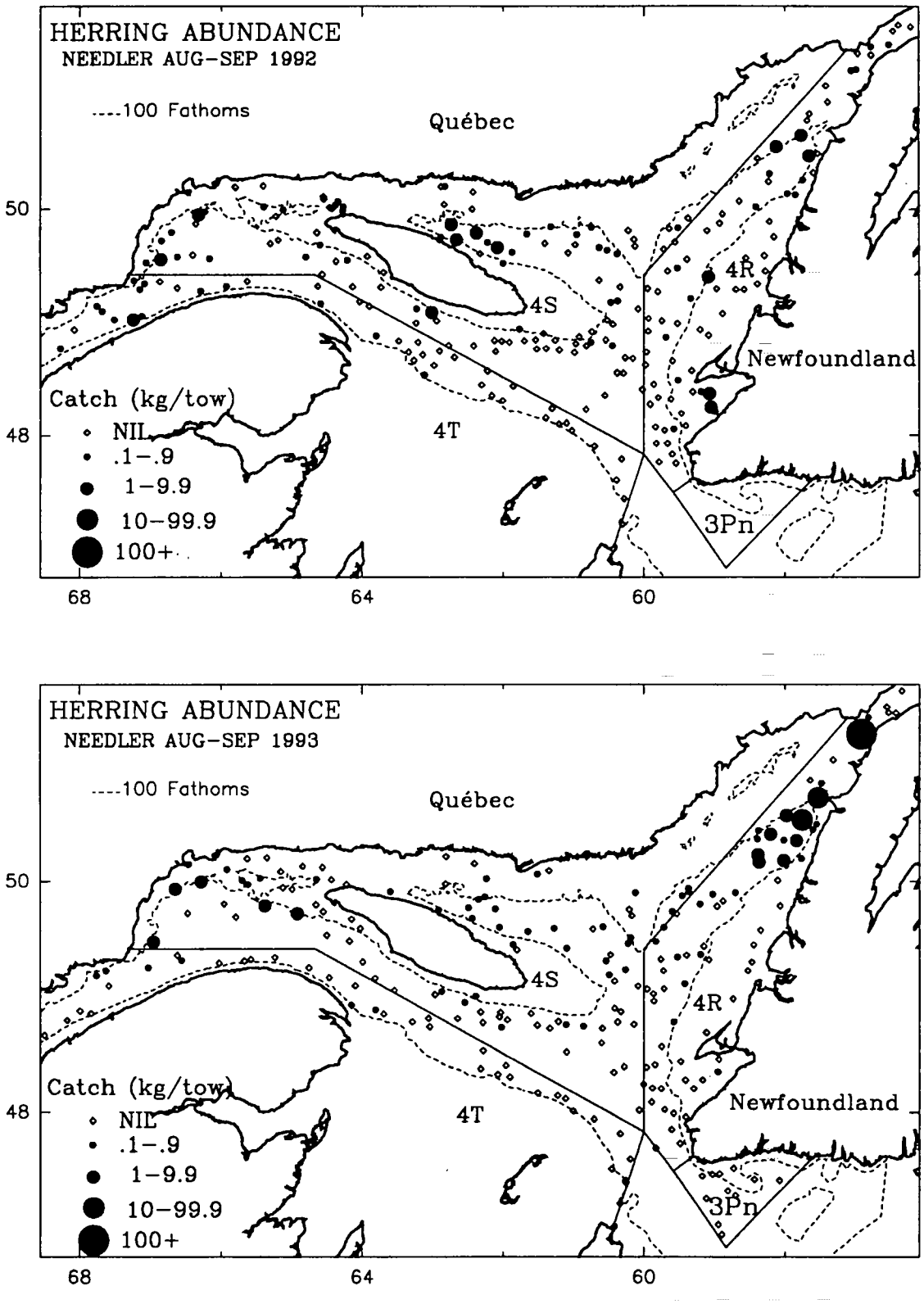


Figure 17. Herring catch rates from 1992-1993 summer Needler survey in the Gulf of St. Lawrence.

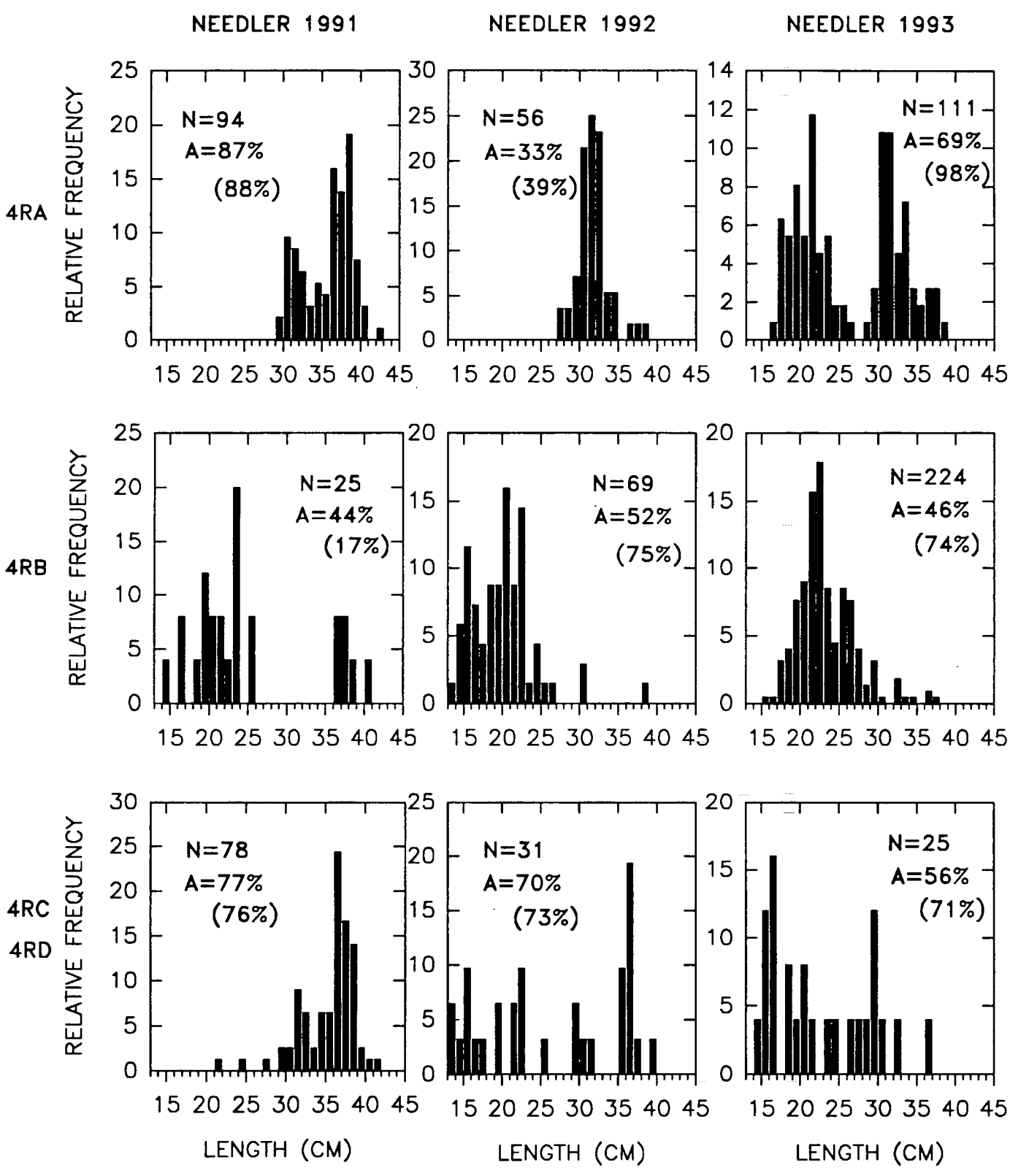


Figure 18. Length frequency distributions of 4R herring by unit area sampled in August and September from the 1991, 1992 and 1993 Needler summer surveys (A indicates percent autumn spawners for entire sample; for adults only in parentheses).

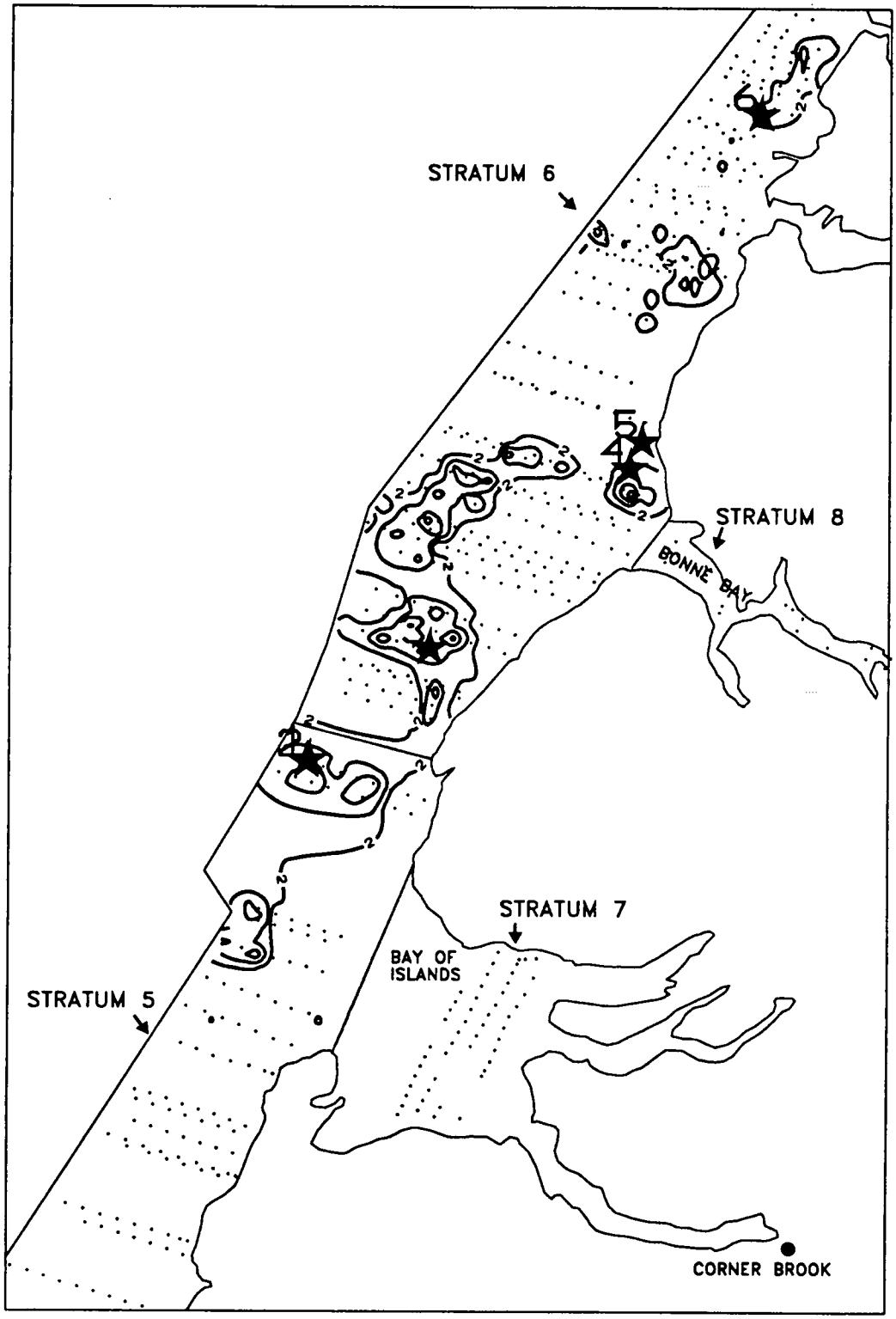


Figure 19. Herring density contours from November 1993 acoustic survey in strata 5, 6, 7 and 8 from the West Coast of Newfoundland (Dotted lines indicate acoustic transects, stars indicate trawl set positions).

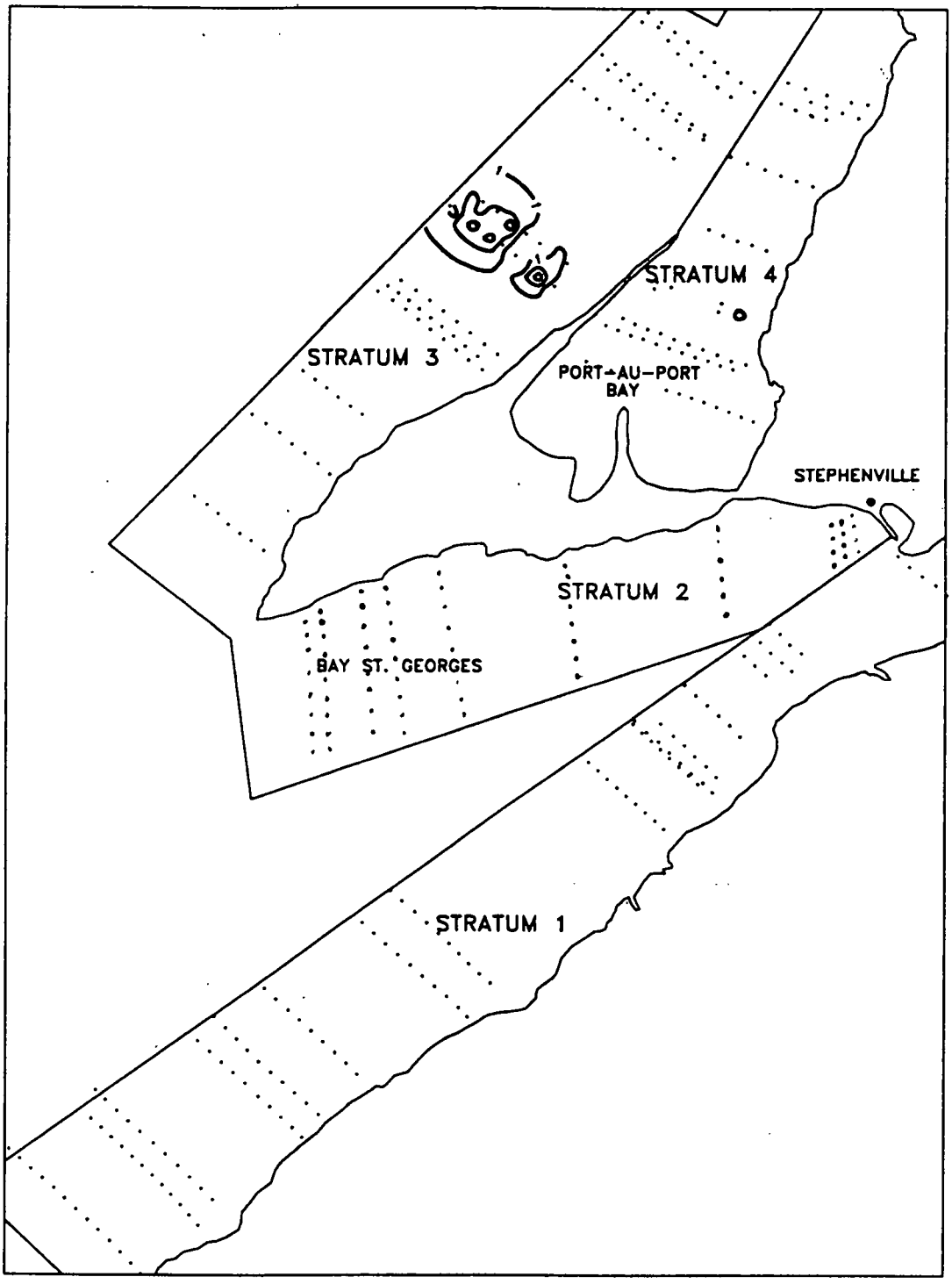


Figure 20. Herring density contours from November 1993 acoustic survey in strata 1,3 and 4 from the West Coast of Newfoundland (dotted lines indicate acoustic transects).

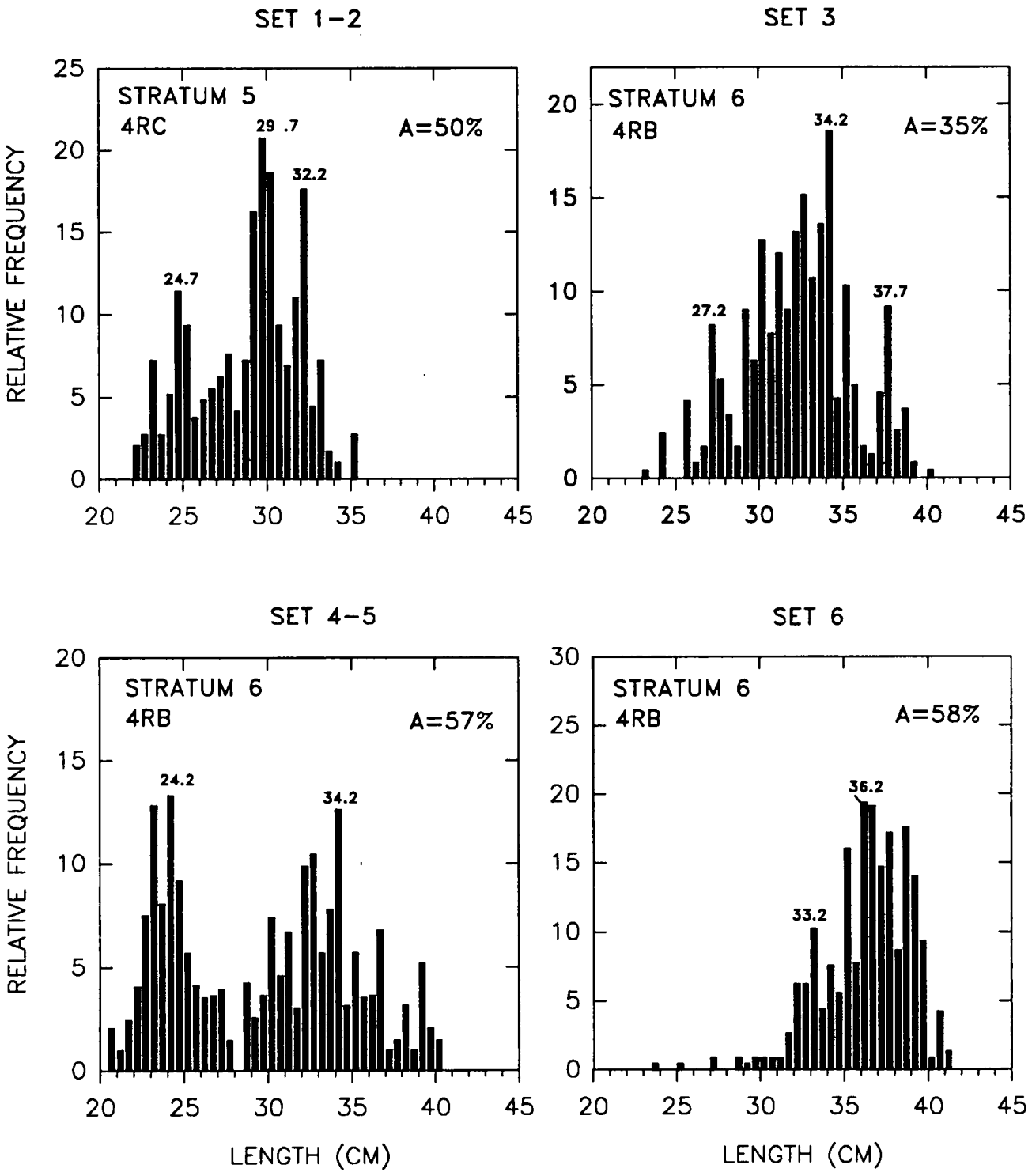


Figure 21. Length frequency distributions of herring sampled in November 1993 during the acoustic survey along the West Coast of Newfoundland (A indicates percent autumn spawners).

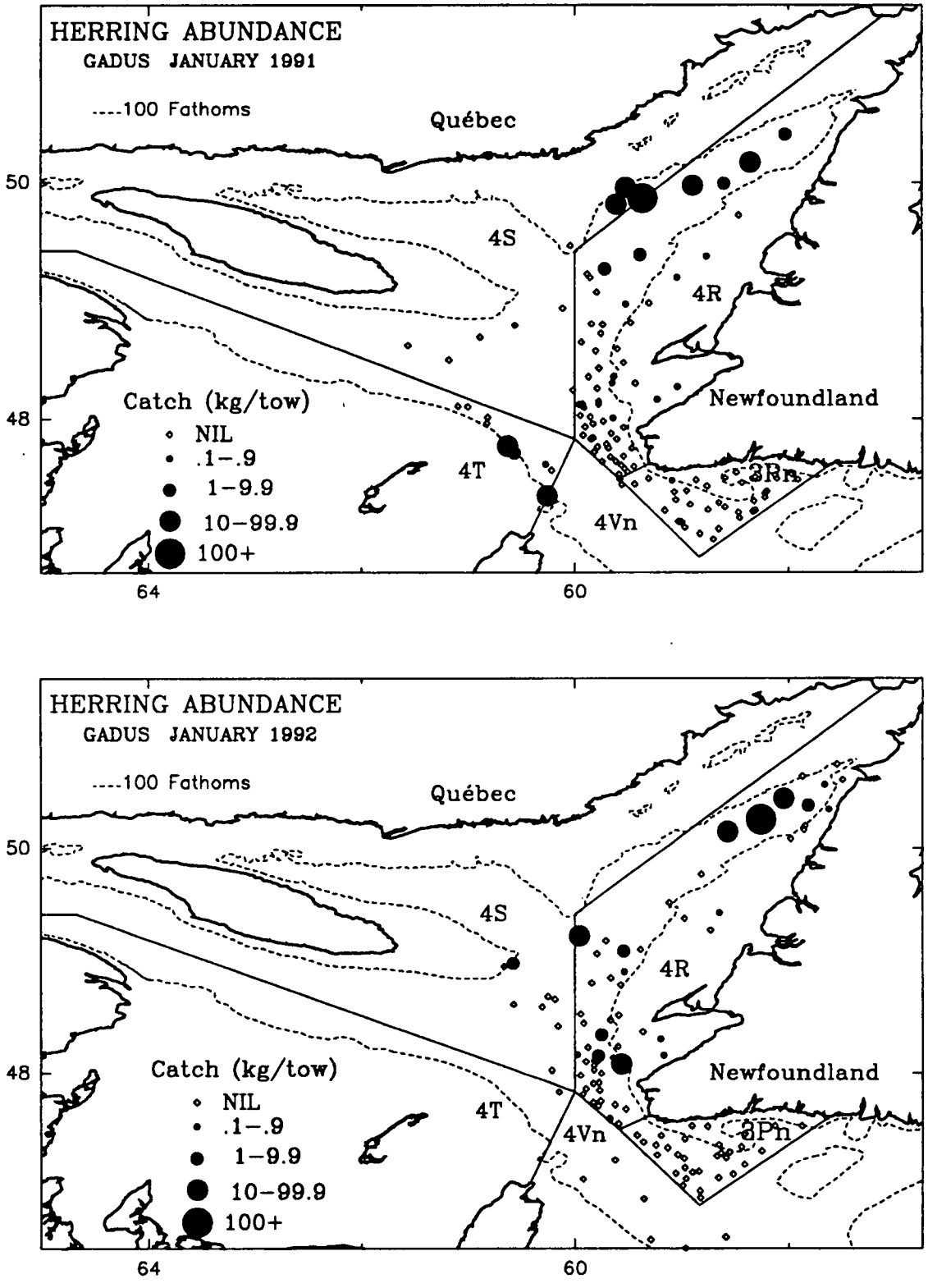


Figure 22. Herring catch rates from 1991–1992 winter Gadus survey in the Gulf of St. Lawrence.

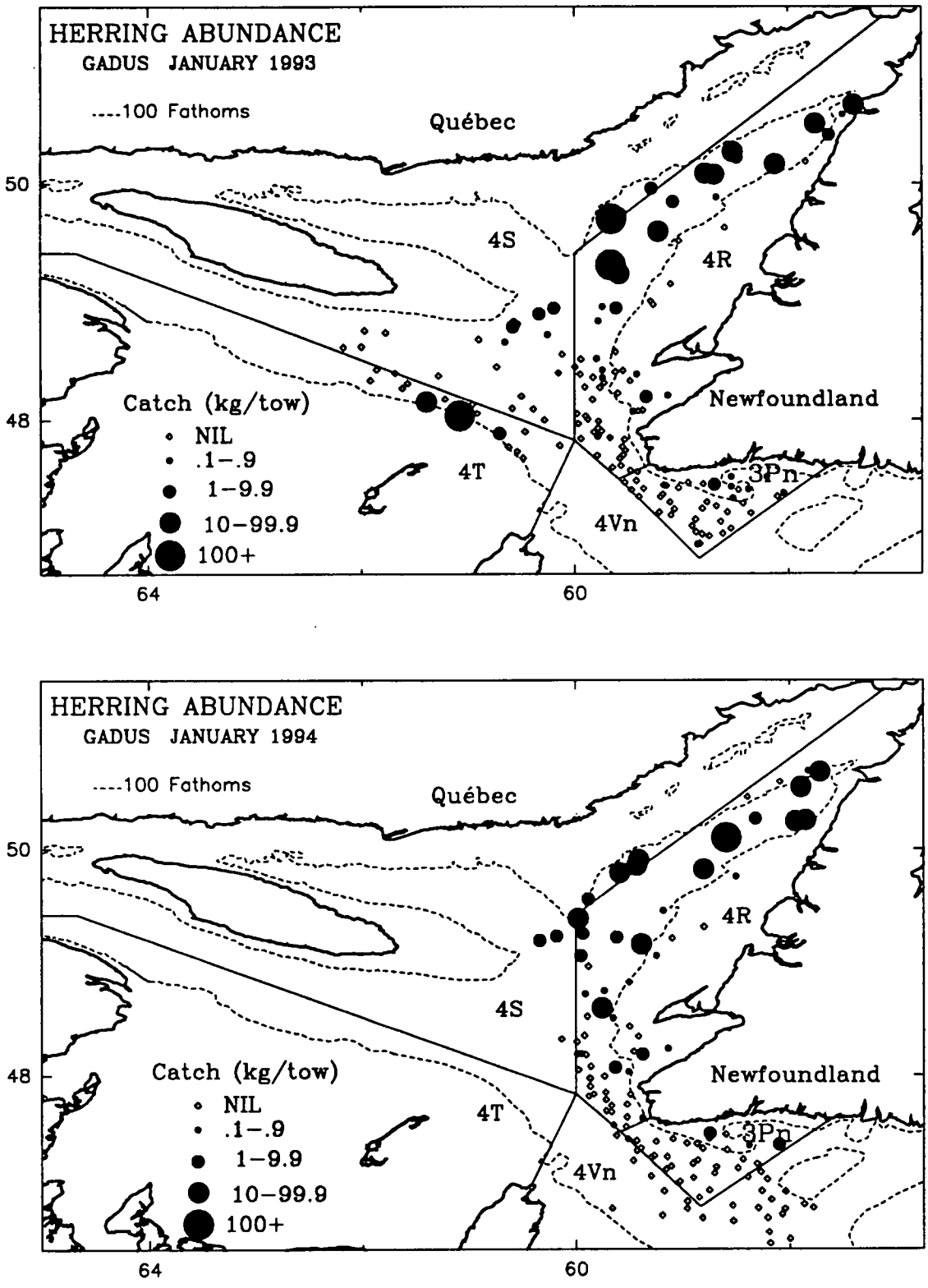


Figure 23. Herring catch rates from 1993-1994 winter Gadus survey in the Gulf of St. Lawrence.

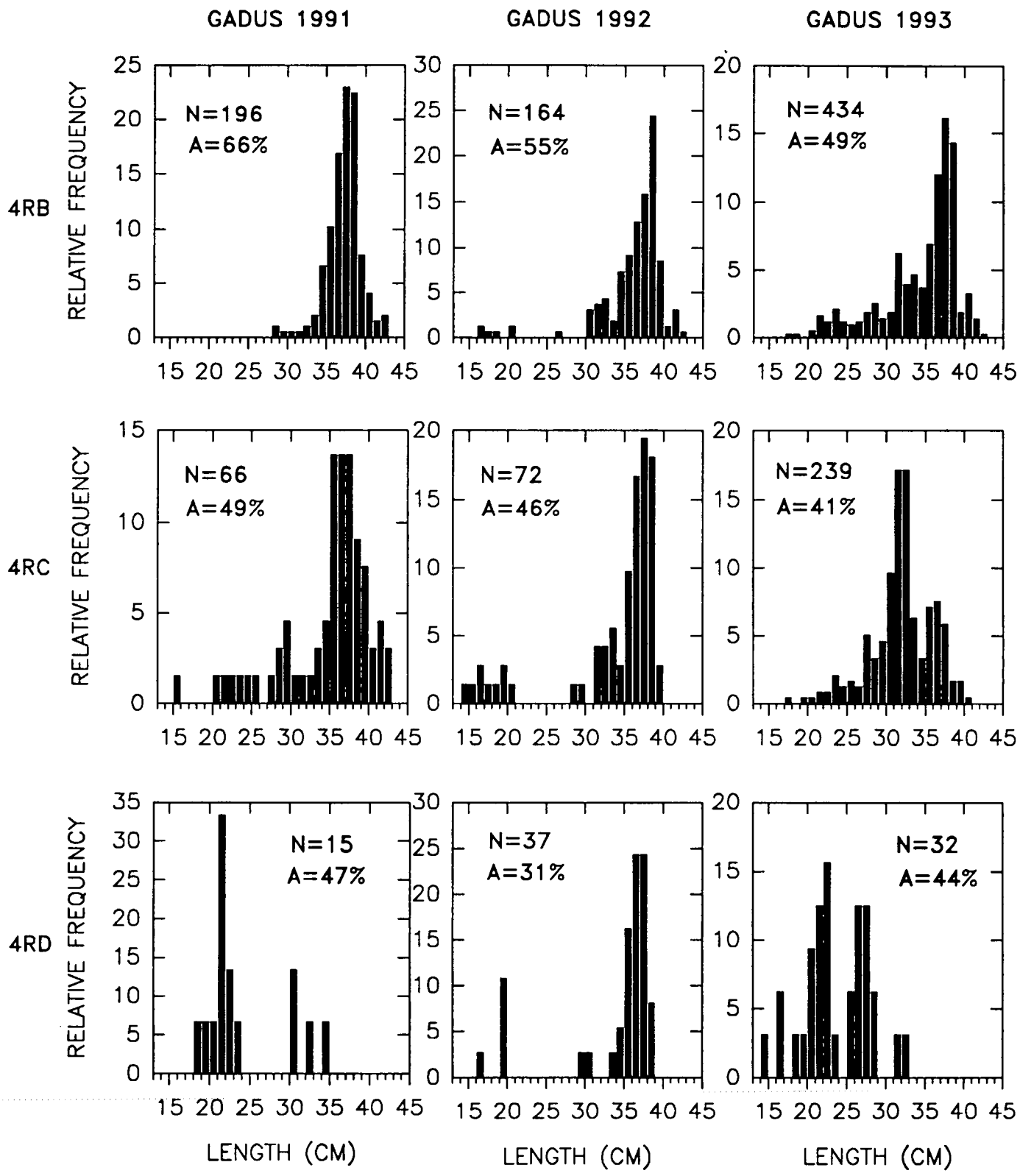


Figure 24. Length frequency distributions of 4R herring by unit area sampled in January from the 1991, 1992 and 1993 Gadus winter surveys (A indicates percent autumn spawners).

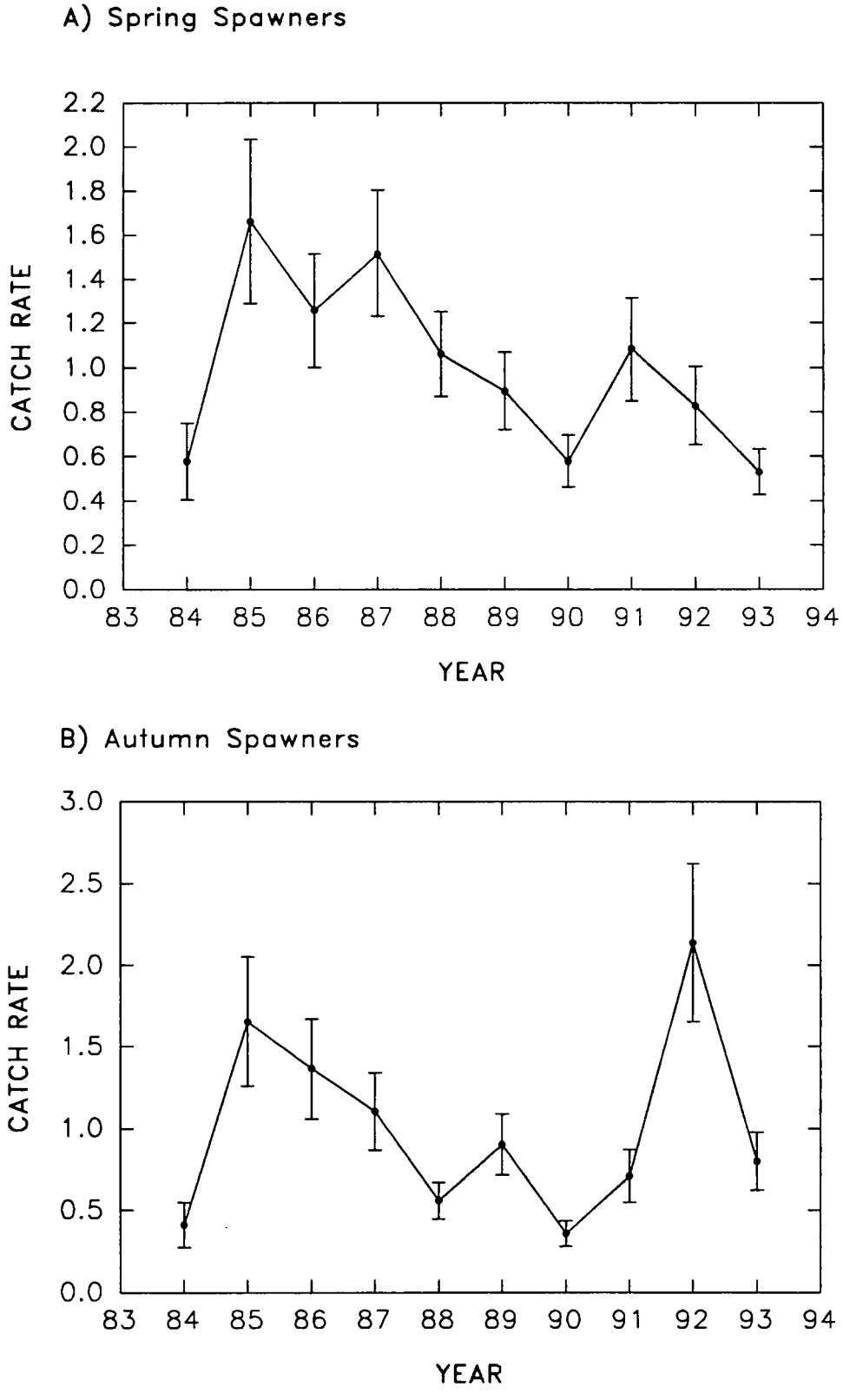


Figure 25. Standardized gillnet catch per unit effort and 2xS.E. for (a) spring-spawning and (b) autumn-spawning herring in NAFO Division 4R as calculated from index-fisherman logbook data.

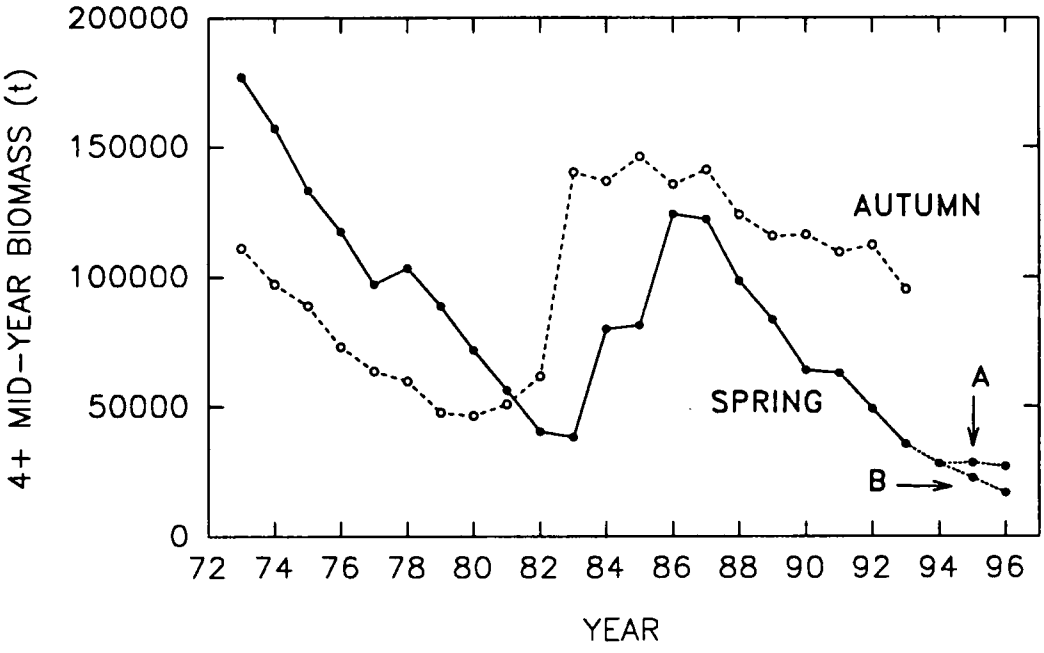


Figure 26. Mid-year population biomass (4+) for 4R spring- and autumn-spawning herring from 1973 to 1993 with projection scenarios assuming (A) F=0.3 and (B) constant catches at 11,000 t in 1994 and 1995.

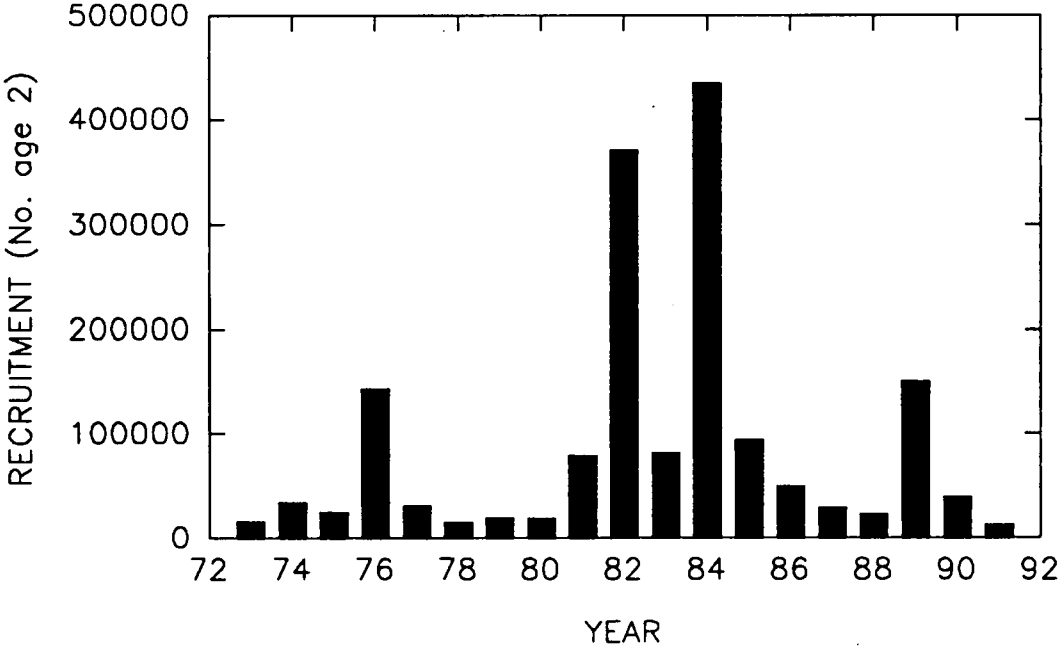


Figure 27. Year-class size at age 2 (recruitment) as estimated by cohort analysis for 4R spring-spawning herring from 1973 to 1991.

Annex 1. Number of herring otoliths read (**bold print**) and commercial landings (t) in NAFO division 4R by gear, area and month in 1993. (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						1 **50** 6	2 **200** 103	3 **350** 45	4 **300** 5			
	4Rb						10	2	1		4	4	
	4Rc					5 **150** 4	6 **221** 3	1	1	3	3	1	
	4Rd				7 6	**250** 38	1	1	2	2	5	1	

GEAR	AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PS	4Ra					11	127	1 78	51	**50** 5		2 **150** 423	
	4Rb		3 15			**50**			57	62	4 **100** 824	5 **305** 1241	
	4Rc								6 9	2	**150** 764	67	
	4Rd				7 **148** 1253	8 **531** 7347					78	431	