Analysis of juvenile Atlantic herring catches in the southern Gulf of St. Lawrence September groundfish surveys

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ABSTRACT

Catches of juvenile Atlantic herring (Clupea harengus harengus) in the annual fall groundfish bottom trawl surveys between 1984 and 1993 were analysed. The catch-at-age analysis, available since 1988 with the advent of biological samples, has demonstrated that it can detect strong age-classes which later became predominant cohorts in the fishery landings. The geographical distribution of juvenile herring catches indicates a shallow coastal area distribution with the two youngest and smaller-sized age-classes (0P and 1A) distributed mostly in depths of less than 25 meters, aggregating in size-specific schools. Paired comparisons of juvenile herring age-class catch rates by depth gradient resulted in age-specific differences in depth distribution, suggesting that the spatial distributions among the different age-classes have more to do with depth gradients than with geographic area. Before 1990, day versus night variations in catches indicated that a higher percentage of September bottom-trawl tows catching juvenile herring were daytime tows. This trend did not persist after 1990, and the 1988 to 1993 catch-at-age time series analysis showed no statistically significant differences in juvenile herring catches between day and night sets. As the data time series becomes longer, the groundfish survey juvenile herring catch rates could be used as an index of abundance of prerecruits, especially the older age 2 juveniles which seem to be fully accessible to the bottom trawl gear in September.

RÉSUMÉ

Les captures de harengs juvéniles de l`Atlantique (Clupea harengus harengus) pendant les relevés annuels d`automne de poissons de fond entre 1984 et 1993 furent analysées. Les captures-à-l`âge, disponibles depuis 1988 avec le début de la collecte d`échantillons, démontrent qu'il fut possible de détecter des classes-d`âge de juvéniles supérieures à la moyenne qui se sont révélées d`importantes cohortes dans les débarquements de la pêcherie comme adultes. La distribution géographique des harengs juvéniles se situait plutôt dans les régions côtières peu profondes, les deux classes-d`âge les plus jeunes (0P et 1A) étant distribuées dans des profondeurs inférieures à 25 mètres. Une comparaison jumelée des taux de captures entre classes-d`âge par gradient de profondeur indique une différence spécifique par âge, suggérant que la distribution est plutôt reliée à la profondeur qu'à la région géographique. Avant 1990, une plus grande proportion des traits de chalut capturant du hareng juvénile était de jour. Cette différence n'a pas continué après 1990, et la série de captures-à-l`âge disponible entre 1988 et 1993 n'a donné aucune différence significative entre les captures de jour et de nuit. Avec la collecte d`échantillons additionnels au cours des années récentes, les captures de harengs juvéniles lors des relevés de poissons de fond pourraient être utilisées comme indices d`abondance et de pré-recrutement, surtout pour les captures-à-l`âge des juvéniles de 2 ans qui semblent être pleinement accessibles au chalut de fond en septembre.

INTRODUCTION

In the southern Gulf of St. Lawrence (NAFO Division 4T), the Atlantic herring population (*Clupea harengus harengus*) is divided into two spawning stocks, spring and fall; the date that marks the division between the two is July 1st. For both seasons, large-scale fluctuations in recruitment are indicated by the presence of strong year-classes in the commercial fishery (Claytor et al., 1995). Juvenile abundance has been used as a recruitment indicator in various exploited clupeid populations (Winters, 1976; Chenoweth et al., 1980; Graham, 1982; Koeller et al., 1986; Jessop and Anderson, 1989).

Standardised, stratified random bottom trawl inventory surveys for demersal fish species have taken place in early fall (September) in the southern Gulf of St. Lawrence since 1970. Since 1982, improvements in data collection, recording, and storage resulted in a data set of herring catches and length frequency measurements being available, with the most recent years having also collected samples for detailed laboratory analysis and age determination.

Comparative fishing experiments in Chaleur Bay indicated that juvenile herring were catchable by bottom trawls in the fall, with catchability to bottom trawls greater than that to midwater trawls (Dupuis et al., 1997). Our aim was to investigate whether the juvenile herring catches in the September bottom trawl survey could be used to determine the spatiotemporal distribution of juvenile herring and to develop indices of abundance and recruitment.

METHODS

The sampling protocol used for the annual groundfish surveys in the southern Gulf of St. Lawrence has changed very little since the early 1970s (Hurlbut and Clay, 1990). It follows a standard form of random survey, stratified by depth, with 30 minute bottom trawl tows (Fig. 1). The 1984 inclusion of three additional inshore strata in Northumberland Strait, northern Prince Edward Island and Georges Bay (strata 401 to 403) extended coverage in areas known to harbour juvenile herring. These surveys are conducted in September, before the winter migration period of various groundfish species, and cover all of NAFO Division 4T. For our analysis, this Division was split into four areas: North (4Tm, 4Tn and 4To), Mid (4Tl), South (4Tg, 4Th and 4Tj), and East (4Tf and 4Tk) (Fig. 2). These areas are consistent with those used to summarise fishery data, and correspond roughly to the following strata of the groundfish survey; strata 417-419 (North area), 420-422 (Mid area), 401-403, 429, 431-434 (South area) and all other strata (East area) (Fig. 1).

Prior to the inclusion of the three additional inshore strata in 1984, juvenile herring catches in the south area were minimal. Since 1984, adequate data was available in all coastal areas of NAFO Division 4T. The annual groundfish surveys recorded the total weight of the catch and length frequencies for up to 200 herring per tow. In addition, individual biological subsamples, stratified by length intervals, have been collected since 1988 and used in the laboratory to provide data on length/weight ratio, sex, maturity stage, gonad weight, age and season of birth or hatching.

Three different vessels have been used to conduct the annual groundfish surveys in the southern Gulf of St. Lawrence since 1984: the *E.E. Prince* in 1984 and 1985, the *Lady Hammond* from 1985 to 1991, and the *Alfred Needler* since 1992. The *E.E. Prince* used a Yankee 36 bottom trawl with a 6 mm mesh size in the codend liner, while the *Lady Hammond* and the *Alfred Needler* used a Western IIA bottom trawl with a 19 mm mesh size in the codend liner (Hurlbut and Clay, 1990). Until 1985, with the *E.E. Prince*, the surveys were conducted in daylight hours between 7:00 a.m. and 7:00 p.m.; the change of vessel in 1985 extended the survey period to 24 hours a day. Comparative studies on the fishing efficiency of the research vessels were carried out in 1985 (the *E.E. Prince* vs. the *Lady Hammond*) and 1992 (the *Lady Hammond* vs. the *Alfred Needler*). In the course of these paired comparisons involving simultaneous tows, no significant differences in herring catches were observed (Nielsen, 1994).

Juvenile herring were defined as herring with a maximum total length of 25 centimetres, corresponding to mostly immature herring between the ages of 0 and 2 years. The percentage of tows containing juvenile herring, together with the mean depth of the tows, were determined for each area and time of day (i.e. daylight or night). The age and length data from the laboratory samples provided a mean length at age by season of hatching. Hereafter, the term "age-class" will denote both age and season of hatching: in all cases the season of hatching, spring (P for "Printemps") or fall (A for "Automne"), is paired with the age to classify juveniles in one of five age-class designations, i.e. 0P, 1A, 1P, 2A or 2P. The age-class 0A is not available to the bottom trawl in September as they have yet to undergo metamorphosis.

Analysis of variance (ANOVA) using the SAS general linear model procedure (GLM), (SAS Institute Inc., 1989) was used to test for differences in mean length among age-classes and for differences in spatial and temporal distributions. The geographical distribution analysis was done by NAFO 4T areas as defined earlier, while depth distribution was analysed by 25 and 10 meter depth zones, and temporal distribution included variations between day and night.

To generate the abundance indices, it was necessary to combine the North and Mid areas due to the small number of samples available, resulting in age-specific comparisons between the North/Mid and the South areas. Ages 0P and 1A herring were identified by length intervals for the period 1984-1993. This identification was possible by the distinct separation of mean lengths at age for these age-classes, resulting in a length-based catch index. This index provided mean catch per tow by area for the 0P and 1A age-classes, plus the 1+ age-group, which included lengths between 17 and 25 cm., corresponding to individuals in the 1P, 2A and 2P age-classes combined. With the information obtained from the biological samples, catch-at-age was calculated for each tow using a research vessel analysis (RVAN) software package (Clay, 1989). A mean catch per tow was then calculated for all the groundfish survey strata included in the North/Mid area (strata 417 to 422), as well as for all the strata included in the South area, namely strata 401 to 403, 429, 431 to 434.

The length-based index obtained from the length frequency distributions and the RVAN catch-at-age index were compared in a correlation analysis. These two groundfish survey indices were also compared with fishery-based catch-at-age data, using ANOVA in a lagged SAS GLM procedure, lagging a specific groundfish survey age time series (i.e. age 1's from 1988 to 1992) with a specific fishery-based age+t (i.e. age 4's from 1991 to 1995). The spring fishery catch per effort data was obtained from index fisher information and daily landings at Escuminac, New Brunswick. The data from the fall fishery originated from numbers-at-age generated by a virtual population analysis (VPA). (Claytor et al., 1995).

RESULTS

Distribution of catches

The percentage of groundfish survey sets with juvenile herring catches varied among areas, the mean percentages from 1984 to 1993 were highest in the South and Mid areas, 46% and 51%, followed by the North area with 21% and the East area with 3% (Table 1). The very small proportion of tows with juvenile herring catches in the East area is noteworthy. This area is characterised by deeper water and few inshore areas (Fig. 2), and accounts, on average, for 46% of the tows made in the course of the September groundfish survey. We decided to exclude the East area from subsequent analysis. Among the remaining areas, the proportion of sets containing juvenile herring varied annually, with more interannual variation in the Mid area (Fig. 3A).

Since 1985, the groundfish surveys have been conducted 24 hours a day. Day/night variations in the proportion of tows with juvenile herring catches were observed among areas and years. The North and Mid areas had a higher percentage of sets catching juvenile herring in daytime hours until 1991, while the South area had a more evenly distributed number of sets catching juvenile herring between day and night (Table 1, Fig. 3B).

Preliminary observations of the three areas combined showed that the percentage of sets catching juvenile herring in one 24 hour period was generally higher during daytime hours. The overall percentage of sets catching juvenile herring during daytime hours between 1985 and 1993 was 61%. In 1985, 76% of the total number of sets catching juvenile herring were day tows, the minimum being 45% in 1991 (Fig. 4). Taking into consideration these possible differences in catchability between day and night, and also wanting to retain as long a time series as possible by including pre-1986 daytime surveys and wanting to compare with results from the December daytime juvenile herring survey (LeBlanc et al., 1995b), we decided to consider only daytime tows in this analysis.

From 1984 to 1993, the median depth of tows with juvenile herring catches was between 35 and 41 m, with 50% of these tows being mostly between 30 and 50 m (Fig. 5). Overall, juvenile herring have been caught in tows at depths ranging from 13 and 140 metres, but with little variation in the mean annual depth, except for 1988, where one deep set was recorded at 257 meters in the North area (Table 2).

Size and age distribution

Between 1984 and 1988, the length frequency distributions were bimodal, with one mode under 15 cm and a second between 18 and 25 cm. (Fig. 6). In 1989 and 1990 the smaller-sized juvenile herring were a small fraction of the catch. The 1991 and 1992 distributions were unimodal, with the 1991 mode at 12 cm. and the 1992 mode between 18 and 19 cm., while the 1993 distribution is mostly of smaller-sized juveniles, with a mode at 14 cm.

The biological samples collected between 1988 and 1993 enabled us to determine a length interval for the 0P and 1A age-classes. The results obtained by grouping all the available samples indicated that the mean lengths of juvenile herring in the 0P age-class were between 8 and 11.9 cm (within 2 standard deviations), while the mean lengths of juveniles in the 1A age-class were between 12 and 16 cm. These two length frequency distributions can be clearly separated with virtually no overlap. For the 1P, 2A and 2P age-classes, lengths ranged between 18 and 25 cm. (Table 3, Fig. 7). The confidence intervals associated with the mean lengths of these three age-classes overlap. Further analysis with a SAS GLM procedure revealed a significant difference between the mean lengths of all the age-classes (Table 4).

Abundance indices

A length-based abundance index was calculated from the 1984 to 1993 juvenile herring length frequency distributions (<26 cm). Broken down by age-class, it indicated substantial differences between years and areas. In the case of the 0P and 1A age-classes, abundance was higher in the South area, except for 1991, whereas the 1+ age-class abundance fluctuated annually between the North/Mid and South areas (Table 5, Fig. 8).

A catch-at-age index was obtained from the detailed 1988 to 1993 biological samples, using RVAN generated mean numbers per set by area. The index for spring juveniles indicates that the 0P age-class abundance was very high in the North/Mid area in 1991, as well as in the south area in 1993. The 1P and 2P age-classes were found in varying proportions in both areas since 1989 (Table 6, Fig. 9). For the fall juvenile catch rates, the 1991 1A age-class abundance was also high in the North/Mid area, while the 2A age-class was distributed in varying yearly proportions between the two areas. As with the 0P age-class, this high 1A abundance in the North/Mid area in 1991 was the result of high catches in sets between Escuminac and north-western Prince Edward Island, on the boundary between the North/Mid and South areas. The catch-at-age data by groundfish survey stratum are summarised for the North/Mid area (Appendix 1) and the South area (Appendix 2).

Analysis of paired correlations between the groundfish survey length-based and RVAN catch-at-age indices resulted in a highly significant correlation between the two indices for the 0P and 1A age-classes (the only age-classes common to both indices). This correlation was observed for both North/Mid and South areas, with all correlation r values higher than 0.9.

Comparisons with fishery-based indices

Lagged fishery-based indices (i.e. age 4's from 1991 to 1995) were compared with groundfish survey age time series (i.e. age 1's from 1988 to 1992). In the case of spring-spawned herring, neither the groundfish survey length-based index nor the RVAN catch-at-age index showed significant correlations with the two fishery-based indices, i.e. 4T spring index gillnetter catch per unit effort and Escuminac spring catch rates as recorded by dockside observers (Table 7). Nonetheless, the RVAN catch-at-age index age-class 0P had a high correlation with both fishery-based age 3 indices.

For the fall herring, the groundfish survey length-based numbers-at-age index for age-class 1A was not correlated with fishery-based VPA population numbers. However, the RVAN catch-at-age index for age-class 2A in the North/Mid area was significantly correlated with the fishery-based 4T Division VPA numbers at age 2, as well as lagged ages 3, 4 and 5. In addition, the groundfish survey RVAN age-class 1A numbers for the South area were highly correlated with the VPA numbers (Table 7).

Spatiotemporal distribution

Between 1988 and 1993, groundfish survey age-specific distribution maps of juvenile herring catches indicate that most catches were in shallow inshore waters. Spring juveniles of the youngest age-class (0P) were observed almost exclusively near and/or inside the Northumberland Strait, in water less than 35 m deep (Fig. 10). Older age-classes 1P and 2P were distributed over a larger area, with high concentration areas inside Chaleur Bay and to the north-west and south-east of Prince Edward Island. In general, the water depth in these areas ranges between 20 and 50 m. Fall spawned juvenile herring were distributed similarly to spring juveniles, with the 1A age-class having a more limited distribution than 2A (Fig. 11).

Age-specific analysis of variance in the geographic distribution of juvenile herring catches was done by area, as well as age-specific distribution comparisons by depth, pooling the available data into three zones; 14 to 24 meters, 25 to 44 meters and 45 to 76 meters. Results of age-specific catch rate distributions by depth zones and area indicated that the 0P and 1A age-classes had significantly different distributions by area and/or depth zone (Table 8a). Further analysis revealed that, for these two age-classes, catch rate distributions varied significantly by depth rather than by area; they both had significantly higher catch rates in the 14 to 24 meter depth zone than in the deeper ones (Fig. 12a). The older age-class catch rates were more evenly distributed among the two shallower depth zones, while age-class 2P catch rates were also recorded in the deeper 45 to 76 meter zone (Fig. 12b).

Pooling all 1988 to 1993 groundfish survey juvenile herring RVAN catch rates, comparisons of paired age-class distributions by 10 meter depth gradients, weighted by their respective catch rates, showed significant differences in distribution between most age-classes (Table 8b). However, the differences were not significant for two pairs of age-class comparisons; between the 0P and the 1A age-classes, as well as between the 1P and the 2A age-classes. Both of these comparisons are between spring spawned juveniles and the previous year's fall spawned age-class.

For the same combined data among all age-classes, no statistically significant differences were found between daytime and night time RVAN catch rates from 1988 to 1993 (Table 8C).

DISCUSSION

Between 1985 and 1990, preliminary observations of daytime versus night-time differences in September bottom-trawl survey tows catching juvenile herring indicated that a higher percentage of tows catching juvenile herring were done during daytime hours (Figure 4). For reasons mentioned earlier, only daytime sets were included for the comparisons made in this study. However, this analysis has shown that these differences did not persist from 1991 to 1993. Furthermore, the 1988 to 1993 RVAN catch-at-age time series analysis showed no statistically significant differences in catch rates of juvenile herring between day and night sets. Subsequent analysis of juvenile herring catch rate data from September groundfish surveys should include both daytime and night-time sets.

The two juvenile herring indices of abundance derived from the groundfish survey data, the length-based index and the RVAN catch-at-age index, are significantly correlated for the 0P and 1A age-classes. Both indices indicate increased abundance for these two age-classes in 1991; this corresponds to the fall 1990 and spring 1991 cohorts. Similar results were obtained from the bottom trawl juvenile herring surveys conducted in December (LeBlanc et al., 1995b). In addition, these same cohorts appear to be strong in the samples taken during acoustic herring surveys conducted in October (LeBlanc et al., 1995a). Both groundfish survey indices also indicate a strong increase in 1993, corresponding to the fall 1992 and spring 1993 cohorts.

The longer time series length-based index, which is restricted to the 0P and 1A age-classes, did not detect the presence of the large fall 1987-spring 1988 cohorts, which were the major contributing cohorts in the commercial fishery landings beginning in 1991, and were still abundant in the 1994 landings (Claytor et al., 1995). However, the RVAN catch-at-age index does detect the passage of these large cohorts. For spring herring, they were noticeable as 0P in the South area in 1988, as 1P in both areas in 1989, and as 2P in the North/Mid area in 1990. For the fall herring, the large fall 1987 year-class was not detected in 1988 at age 1, but the 2A age-class in 1989 was the strongest index in the time series for the North/Mid area (Fig. 9). The failure of the length-based index to detect the large fall 1987-spring 1988 cohorts at ages 0P and 1A in 1988, as well as the RVAN catch-at-age index failure to detect fall juveniles at age 1's in 1988 but to detect them as age 2's in 1989, would suggest that the smaller, younger juvenile herring might not be fully accessible to the groundfish survey bottom trawl.

When the length-based and catch-at-age indices obtained from groundfish surveys were compared with indices obtained from the fishery, no significant correlation was found in the case of spring indices. For the fall RVAN catch-at-age index, age 2's were significantly correlated with the numbers-at-age generated by the fall VPA. These findings concur with other observations that larger juveniles are most often caught with adults, whereas younger juvenile fish seem to aggregate in size-specific schools (Dupuis et al. 1997). This also indicates that the older fall spawned age 2's could be more accessible to the bottom trawl survey than the younger age-classes.

The geographical distribution of juvenile herring catches in the 1984 to 1993 September groundfish surveys shows that catches are mainly located in the shallower coastal areas of the survey area. The groundfish survey coverage does not include all of the western end of Chaleur Bay, where young juveniles are present during the December juvenile herring surveys (LeBlanc et al., 1995b).

Using the 1988 to 1993 RVAN catch-at-age data, age-specific distribution comparisons by area (North/Mid and South) did not show any significant differences. However, age-specific differences in distribution by depth zone were significantly different for the 0P and 1A age-classes, their catch rates being higher in the shallow 14 to 24 meter depth zone. These results also indicate that the two youngest and smaller-sized age-classes are distributed in the shallower coastal waters of the southern Gulf.

The paired comparisons of juvenile herring catch rates between age-classes by depth gradient were statistically different between most age-classes, showing age-specific differences in depth distribution. The exceptions were for comparisons between the 0P and 1A age-classes as well as the 1P and 2A age-classes. These two pairs of age-classes have similar early-life cycles, as their larval metamorphosis take place on average within 5 to 7 months of each other in the same year. Fall larvae undergo metamorphosis in late winter or the early spring (Messieh et al. 1987, Sinclair and Tremblay 1984). The similarity in distribution of these two pairs of age-classes reflects the preference of the younger 0P and 1A age-classes for shallower depths, while the older 1P and 2A age-classes are also similarly distributed by depth, their distribution including deeper areas. The southern Gulf groundfish survey distribution maps by age-class confirm this. They show that the youngest age-classes, 0P and 1A, are found in shallow coastal waters (< 35 metres) for the most part, while the older age-classes are also caught in deeper water, at depths ranging between 20 and 50 metres. These observations suggest that the spatial distribution among the different age-classes have more to do with depth gradients than with geographic area.

September groundfish surveys in the southern Gulf have proven to be an important source of data, one that has helped to further our understanding of the distribution and abundance of juvenile herring in the southern Gulf of St. Lawrence. Divergences noticed in the spatiotemporal distribution of juvenile herring may reflect actual differences in the geographic and/or vertical distribution at this specific time of the year, or they may be due to differences in fishing gear selectivity, sampling intensity and area or other factors that may affect catchability.

The RVAN catch-at-age, available since 1988 with the advent of biological samples, has demonstrated that it can detect strong cohorts which later became predominant in the fishery, although data available is limited and the time series is short. Older age 2 fall spawned herring catch rate trends from the survey were the best indicator from the RVAN data, and were similar to the trends seen in the fishery VPA numbers. As the data time series becomes longer, the groundfish survey juvenile herring catch rates could prove to be a useful index of abundance of prerecruits for the southern Gulf herring stocks.

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REFERENCES

Chenoweth, S.B., M.A. Hunter and G.D. Speirs. 1980. Seasonal migrations and recruitment patterns of juvenile herring in the Gulf of Maine. Maine Dept. Mar. Resour. Lab. Res. Doc. 80/14.

Clay, D. 1989. RVAN: Research vessel analysis programs. Can. Man. Rep. Fish. Aquat. Sci. 2044: 133p.

Claytor, R., H. Dupuis, F. Mowbray, G. Nielsen, C. LeBlanc, L. Paulin, C. Bourque and C. MacDougall. 1995. Assessment of the NAFO Division 4T southern Gulf of St. Lawrence herring stock, 1994. DFO Atl. Fish. Res. Doc. 95/69.

Dupuis H.M.C., S.C. Courtenay, and E.M.P. Chadwick. 1997. Distribution of juvenile Atlantic herring in the southern Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2141:19p.

Graham, J.J. 1982. Production of larval herring, Clupea harengus, along the Maine coast, 1964-78. J. Northw. Atl. Fish., 3:63-85.

Hurlbut, T. and D. Clay. 1990. Protocols for research vessel cruises within the Gulf Region (demersal fish) (1970 - 1987). Can. Man. Rep. Fish. Aquat. Sci. 2082: 143p.

Jessop, B.M. and W.E. Anderson. 1989. Effects of heterogeneity in the spatial and temporal pattern of juvenile alewife (Alosa pseudoharengus) and blueback herring (A. aestivalis) density on estimation of an index of abundance. Can. J. Fish. Aquat. Sci., vol. 46, no. 9: 1564-1574.

Koeller, P.A., P.C.F. Hurley, P. Perley and J.D. Neilson. 1986. Juvenile fish surveys on the Scotian Shelf: implications for year-class size assessments. J. Cons. Int. Explor. Mer, 43: 59-76.

LeBlanc, C., J. Dale and L. Mello. 1995a. Distribution and acoustic backscatter of herring in NAFO division 4T, October 1994. DFO Atl. Fish. Res. Doc. 95/128: 33p.

LeBlanc, C., L. Mello, H.M.C. Dupuis and J. Dale. 1995b. Results of the December juvenile herring surveys from 1991 to 1994, and an overview of some other juvenile indices. DFO Atl. Fish. Res. Doc. 95/135: 31p.

Messieh, S.N., D.S. Moore and P. Rubec. 1987. Estimation of age and growth of larval Atlantic herring as inferred from examination of daily growth increments in otoliths. p. 433-442 in R.C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State Univ. Press, Ames, Iowa.

Nielsen, G. 1994. Comparison of the fishing efficiency of research vessels used in the Southern Gulf of St. Lawrence groundfish surveys from 1971 to 1992. Can. Tec. Rep. Fish. Aquat. Sci. No 1952: 56p.

SAS Institute Inc. 1989. SAS User's Guide, version 6, fourth edition. SAS Institute Inc., Cary, N.C., USA.

Sinclair, M. and M. J. Tremblay. 1984. Timing of spawning of Atlantic herring (Clupea harengus harengus) populations and the match-mismatch theory. Can. J. Fish. Aquat. Sci., 41: 1055-1065.

Winters, G.H. 1976. Recruitment mechanisms of Southern Gulf of St. Lawrence Atlantic herring (Clupea harengus harengus). J. Fish. Res. Board Can., 33: 1751-1763.

Table 1. Summary of September groundfish survey set distributions, by area and period of day.

YEAR	AREA	SET DISTRIBUTION						
		Total number of sets during September groundfish survey			Number of sets with juvenile herring catches			Percent of total number of survey sets with juvenile herring catches
		day	night	total	day	total	percent day sets	
1985-1993	North	15	13	28	4	6	64	21
24 hour	Mlid	9	6	15	4	6	66	51
surveys	East	40	36	76	1	1.5	64	3
MEAN	South	23	23	47	12	20	59	46
*1984	North	20	-	20	3	3	100	15
	Mlid	13	-	13	8	8	100	62
	East	38	-	38	3	3	100	8
	South	37	-	37	24	24	100	65
1985	North	16	-	16	4	4	100	25
	Mlid	9	-	9	9	9	100	100
	East	32	-	32	2	2	100	6
	South	27	-	27	16	16	100	59
**1985	North	16	13	29	4	6	67	21
	Mlid	8	4	12	8	10	80	83
	East	39	20	59	0	0	0	0
	South	25	15	40	16	21	76	53
1986	North	15	16	31	4	5	80	16
	Mlid	8	6	14	5	8	63	57
	East	33	28	61	0	1	0	2
	South	34	33	67	14	21	67	31
1987	North	13	16	29	4	6	67	21
	Mlid	7	7	14	4	7	57	50
	East	31	38	69	3	5	60	7
	South	26	24	50	19	31	61	62
1988	North	20	18	38	2	4	50	11
	Mlid	9	7	16	2	3	67	19
	East	31	28	59	2	2	100	3
	South	23	18	41	8	15	53	37
1989	North	15	14	29	5	7	71	24
	Mlid	13	2	15	9	11	82	73
	East	33	50	83	0	0	0	0
	South	22	20	42	11	17	65	40
1990	North	11	8	19	4	5	80	26
	Mlid	9	2	11	2	2	100	18
	East	38	40	78	0	0	0	0
	South	18	21	39	9	14	64	36
1991	North	17	6	23	4	5	80	22
	Mlid	9	8	17	3	5	60	29
	East	43	51	94	1	1	100	1
	South	24	32	56	5	17	29	30
***1992	North	14	12	26	1	4	25	15
	Mlid	7	9	16	3	8	38	50
	East	52	32	84	1	2	50	2
	South	19	23	42	14	24	58	57
1993	North	13	14	27	6	10	60	37
	Mlid	7	10	17	2	4	50	24
	East	57	41	98	0	0	0	0
	South	20	24	44	9	17	53	39

* 1984-85 E.E. Prince **1985-91 L. Hammond ***1992-93 A. Needler

Table 2. Mean depth (m) of daytime sets with juvenile herring catches in September groundfish surveys, 1984 - 1993.

YEAR	AREA												
	ALL AREAS				NORTH			MID			SOUTH		
	mean depth	SD	min. depth	max. depth	mean depth	SD	number of sets	mean depth	SD	number of sets	mean depth	SD	number of sets
1984	37	13.3	15	71	24	23.8	3	33	9.8	8	38	13.1	24
1985	40	13.2	16	68	43	11.6	4	43	12.0	9	37	14.2	16
1985	39	12.5	16	64	42	11.6	4	38	12.0	8	39	14.2	16
1986	35	9.7	15	60	42	11.1	4	37	7.7	5	32	9.4	14
1987	39	13.4	15	64	38	14.0	4	37	7.8	4	40	13.7	19
1988	53	65.2	16	257	144	122.8	2	40	8.1	2	34	13.4	8
1989	40	13.0	23	76	53	18.1	5	35	6.6	9	38	9.2	11
1990	35	12.7	16	57	35	22.4	4	34	7.8	2	36	13.0	9
1991	37	12.1	17	55	46	11.1	4	27	10.4	3	34	8.4	5
1992	40	16.2	13	71	71	18.3	1	29	12.4	3	40	14.2	14
1993	41	18.6	17	140	59	35.6	6	31	9.8	2	34	8.9	9
all years mean depths	40	4.7	35	53	54	30.7	----	35	4.5	----	37	2.6	----

Table 3. Mean length-at-age of juvenile herring by area, September groundfish survey catches, 1988 - 1993.

YEAR	AGE	LENGTH (cm)														
		SOUTH					MID					NORTH				
		mean	n	SD	min	max	mean	n	SD	min	max	mean	n	SD	min	max
1988-1993	0P	10	280	0.7	5	16	-	0	-	-	-	-	0	-	-	-
all years	1A	14	32	1.1	11	22	-	0	-	-	-	-	0	-	-	-
MEANS	1P	19	214	0.9	14	23	20	72	1	16	23	21	84	0.4	18	24
	2A	20	104	1.5	15	23	21	51	1.5	18	25	22	50	0.9	20	25
	2P	22	167	1.5	17	29	23	42	2	17	29	23	118	1.3	19	28
1988	0P	9	89	1.6	6	14	-	0	-	-	-	-	0	-	-	-
	1A	14	7	1.1	12	15	-	0	-	-	-	-	0	-	-	-
1989	0P	11	42	1.5	8	13	-	0	-	-	-	-	0	-	-	-
	1A	16	10	3.2	12	22	-	0	-	-	-	-	0	-	-	-
	1P	19	41	1.3	17	23	21	55	1.4	16	23	21	61	1.4	18	24
	2A	22	15	1	20	23	23	43	1.1	21	25	23	37	1	20	24
	2P	23	35	3.7	17	29	25	26	2.6	20	29	25	63	1.6	20	28
1990	0P	10	28	2.3	7	16	-	0	-	-	-	-	0	-	-	-
	1A	13	4	1.7	11	15	-	0	-	-	-	-	0	-	-	
	1P	18	86	1.5	14	21	-	0	-	-	-	21	4	0.5	20	21
	2A	21	14	0.8	20	22	-	0	-	-	-	21	7	0.8	21	23
	2P	20	12	6.3	17	24	-	0	-	-	-	22	9	1.7	20	25
1991	0P	9	39	1.9	5	13	-	0	-	-	-	-	0	-	-	-
	1P	20	19	0.7	19	22	-	0	-	-	-	21	15	0.9	20	24
	2A	21	5	1.1	20	23	-	0	-	-	-	23	6	1.3	21	25
	2P	24	20	1.4	20	26	-	0	-	-	-	24	33	1.2	21	26
1992	1P	18	50	1.4	14	21	19	17	0.9	17	21	20	4	1.3	18	21
	2A	18	70	1	15	22	20	8	1.5	18	22	-	0	-	-	-
	2P	21	57	2.7	17	25	21	16	2.7	17	25	22	13	2.4	19	25
1993	0P	10	82	2.3	6	16	-	0	-	-	-	-	0	-	-	-
	1A	15	11	1.4	13	17	-	0	-	-	-	-	0	-	-	-
	1P	20	18	0.9	18	21	-	0	-	-	-	-	0	-	-	-
	2P	23	43	0.8	21	25	-	0	-	-	-	-	0	-	-	-

Table 4. SAS GLM results from correlation analysis of length at age of juvenile herring catches, September groundfish surveys, 1988 -1993.

Dependent Variable: LENGTH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	34838.99	8709.75	1515.96	0.0001
Error	1389	7980.29	5.75		
Total	1393	42819.29			

R-Square	C.V.	RMSE	LENGTH Mean
0.81	13.02	2.4	18.41

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AGE-CLASS (0P, 1P, 2P, 1A, 2A)	4	34838.99	8709.75	1515.96	0.0001

Contrast	DF	Mean Square	F Value	Pr > F
1A vs 0P	1	950.67	165.47	0.0001
1A vs 1P	1	867.54	151	0.0001
1A vs 2A	1	1438.09	250.31	0.0001
2A vs 1P	1	317.01	55.27	0.0001
2A vs 2P	1	1085.59	188.95	0.0001

Table 5. Length-based mean number of juvenile herring per daytime tow by area and age-class, September groundfish surveys, 1984 - 1993.

Age-Class	Area	Mean Number Per Tow									
		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Spring spawned (P)											
0P	North/Mid	0	0	0	0	0	0	0	45	0	0
	South	39	49	35	4	13	2	4	0	0	124
	All areas	21	25	21	2	6	1	2	23	0	62
Fall Spawned (A)											
1A	North/Mid	0	1	1	0	0	0	0	861	0	0
	South	1	11	60	44	2	2	23	0	8	134
	All areas	0	6	36	25	1	1	11	448	4	67
Spring/Fall Combined											
1P,2A,2P	North/Mid	38	142	214	96	2	166	101	11	18	36
	South	56	22	6	129	5	44	174	80	93	44
	All areas	48	81	90	115	3	113	135	44	54	40

Table 6. RVAN catch-at-age mean number of juvenile herring per daytime tow, by area, September groundfish surveys, 1988 - 1993.

Area	Age-Class	Mean Number Per Tow					
		1988	1989	1990	1991	1992	1993
Spring spawned (P)							
North/Mid	0P	0	0.01	0	517	0	0
	IP	0	64	12	44	5	1
	2P	0	51	46	17	10	26
South	0P	22	2	4	0.1	0	150
	IP	0	33	95	49	22	19
	2P	0	8	10	19	20	8
Fall Spawned (A)							
North/Mid	1A	0	1	0	118	0	0
	2A	0	58	22	1	9	0.5
South	1A	2	2	1	0.04	0.4	22
	2A	0	2	11	6	26	0.5

Table 7. SAS GLM lagged comparison of September groundfish survey juvenile herring abundance indices with fishery-based spring and fall spawner abundance or population number estimates.

Groundfish Survey dependent variable	Age	Gulf Area	Fishery-based independent variable	Age	Gulf Area	SAS GLM Results df	r	Pr>F
SPRING (P)								
length-based	0	South	Index Gillnetter	2	4T	6	0.15	NS
catch per tow	0	South	Index Gillnetter	3	4T	5	0.15	NS
	0	South	Index Gillnetter	4	4T	4	0.64	NS
RVAN	0	South	Index Gillnetter	2	4T	4	0.16	NS
catch-at-age	0	South	Index Gillnetter	3	4T	3	0.91	0.09
	0	South	Escuminac	2	South	4	0.01	NS
	0	South	Escuminac	3	South	3	0.85	NS
FALL (A)								
length-based	1	South	VPA	2	4T	7	0.29	NS
catch per tow	1	South	VPA	3	4T	7	0.29	NS
	1	South	VPA	4	4T	6	0.37	NS
	1	South	VPA	5	4T	5	0.58	NS
RVAN	1	South	VPA	2	4T	4	0.82	0.08
catch-at-age	1	South	VPA	3	4T	4	0.83	0.08
	1	South	VPA	4	4T	3	0.79	NS
	2	North/Mid	VPA	2	4T	5	0.92	0.001
	2	North/Mid	VPA	3	4T	5	0.92	0.001
	2	North/Mid	VPA	4	4T	4	0.91	0.007
	2	North/Mid	VPA	5	4T	3	0.92	0.01
	2	South	VPA	2	4T	5	0.21	NS
	2	South	VPA	3	4T	5	0.21	NS
	2	South	VPA	4	4T	4	0.41	NS
	2	South	VPA	5	4T	3	0.11	NS

NS = not significant

Table 8. Analysis of variance (ANOVA) on spatial (A and B) and temporal (C) distributions of juvenile herring catches in the Southern Gulf of St. Lawrence September groundfish surveys, 1988-1993.

A. Dependent Variable: RVAN Catch rate **Classes:** Area (North/Mid and South) Depth Zone (16-24m, 25-44m, 45-76m)
Model : Catch rate = Depthzone Area

Age-Class	Source	DF	R^2	F Value	Pr > F	
0P	Model	3	0.104	3.73	0.0138	Significant
1P	Model	3	0.036	1.19	0.3178	NS
2P	Model	3	0.051	1.73	0.1651	NS
1A	Model	3	0.087	3.08	0.0311	Significant
2A	Model	3	0.035	1.17	0.3261	NS
	Error	96				
	Corrected Total	99				

B. Dependent Variable: DEPTH Class (10m intervals) **Weight:** RVAN Catch Rate **Class:** Age-Class (0P,1A,1P,2A,2P)
Model : Depth Class = Age : Weigh Catch rate, Contrast among Age-Classes

Source	DF	R^2	F Value	Pr > F
Model	4	0.517	68.41	0.0001
Error	256			
Corrected Total	260			

Source	DF	F Value	Pr > F	
Age-Class	4	68.41	0.0001	
Contrast				
0P vs 1A	1	0.06	0.8062	NS
0P vs 1P	1	103.03	0.0001	
0P vs 2A	1	46.29	0.0001	
0P vs 2P	1	196.46	0.0001	
1A vs 1P	1	45.41	0.0001	
1A vs 2A	1	28.48	0.0001	
1A vs 2P	1	110.19	0.0001	
1P vs 2A	1	0.01	0.9236	NS
1P vs 2P	1	28.01	0.0001	
2A vs 2P	1	18.34	0.0001	

C. Dependent Variable: RVAN Catch rate **Classes:** Age-Class (OP, 1A, 1P, 2A, 2P) Period (Day, Night)
Model : Catch rate = Age Period

Source	DF	R^2	F Value	Pr > F	
Model	5	0.0094	0.94	0.4522	NS
Error	494				
Corrected Total	499				

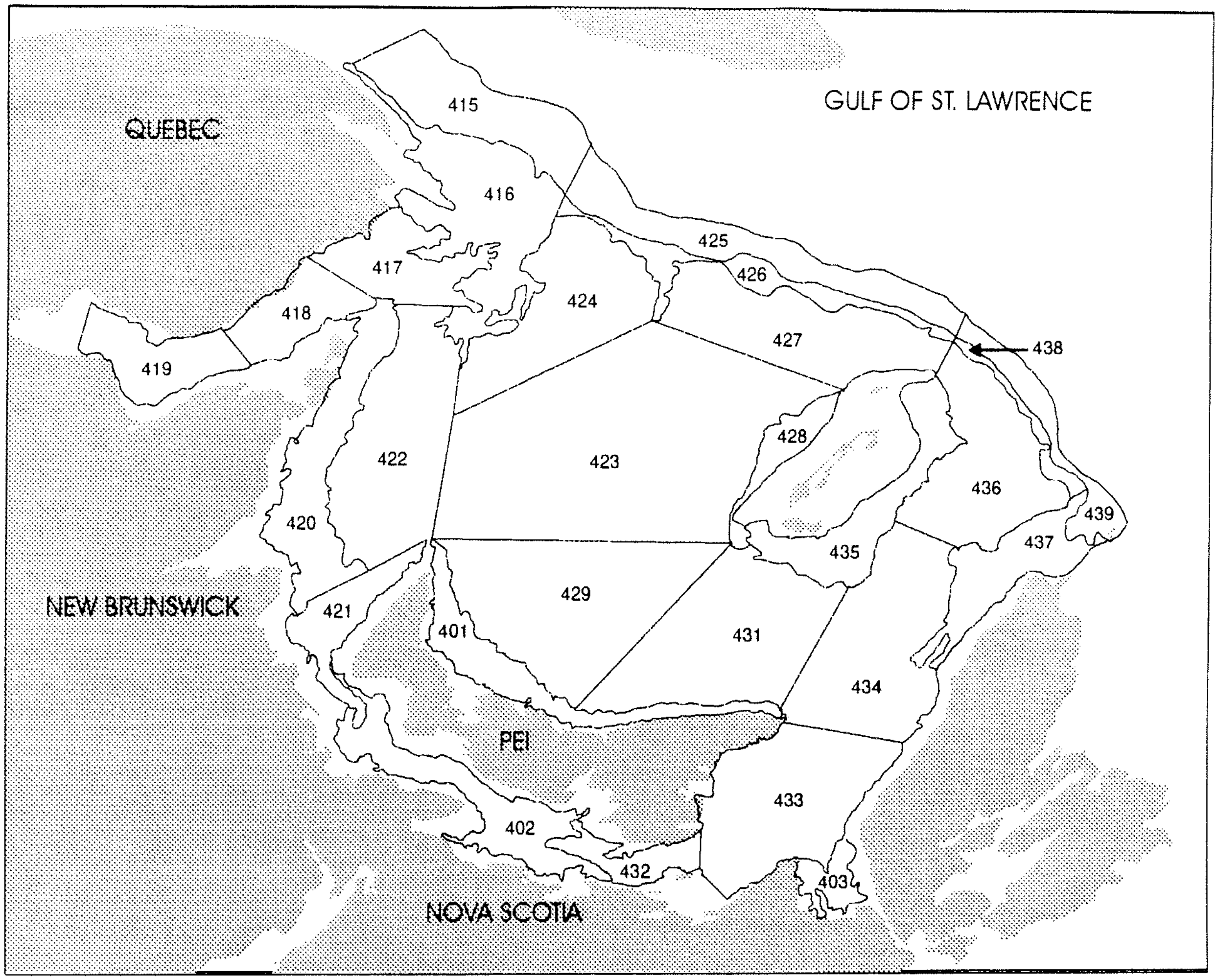


Figure 1. Strata covered in the southern Gulf of St. Lawrence September groundfish surveys

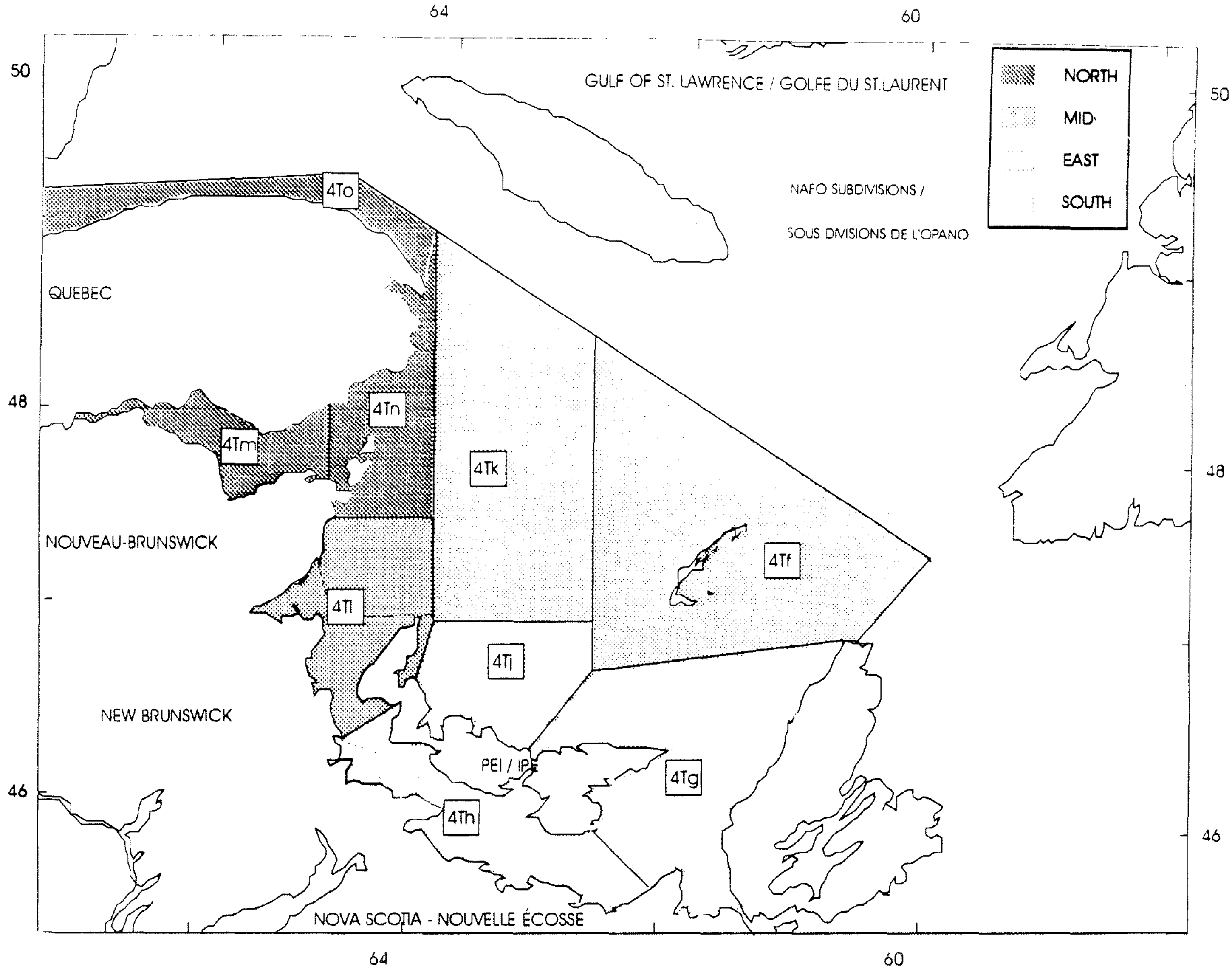


Figure 2. Northwest Atlantic Fisheries Organisation (NAFO) 4T unit areas in the southern Gulf of St. Lawrence.

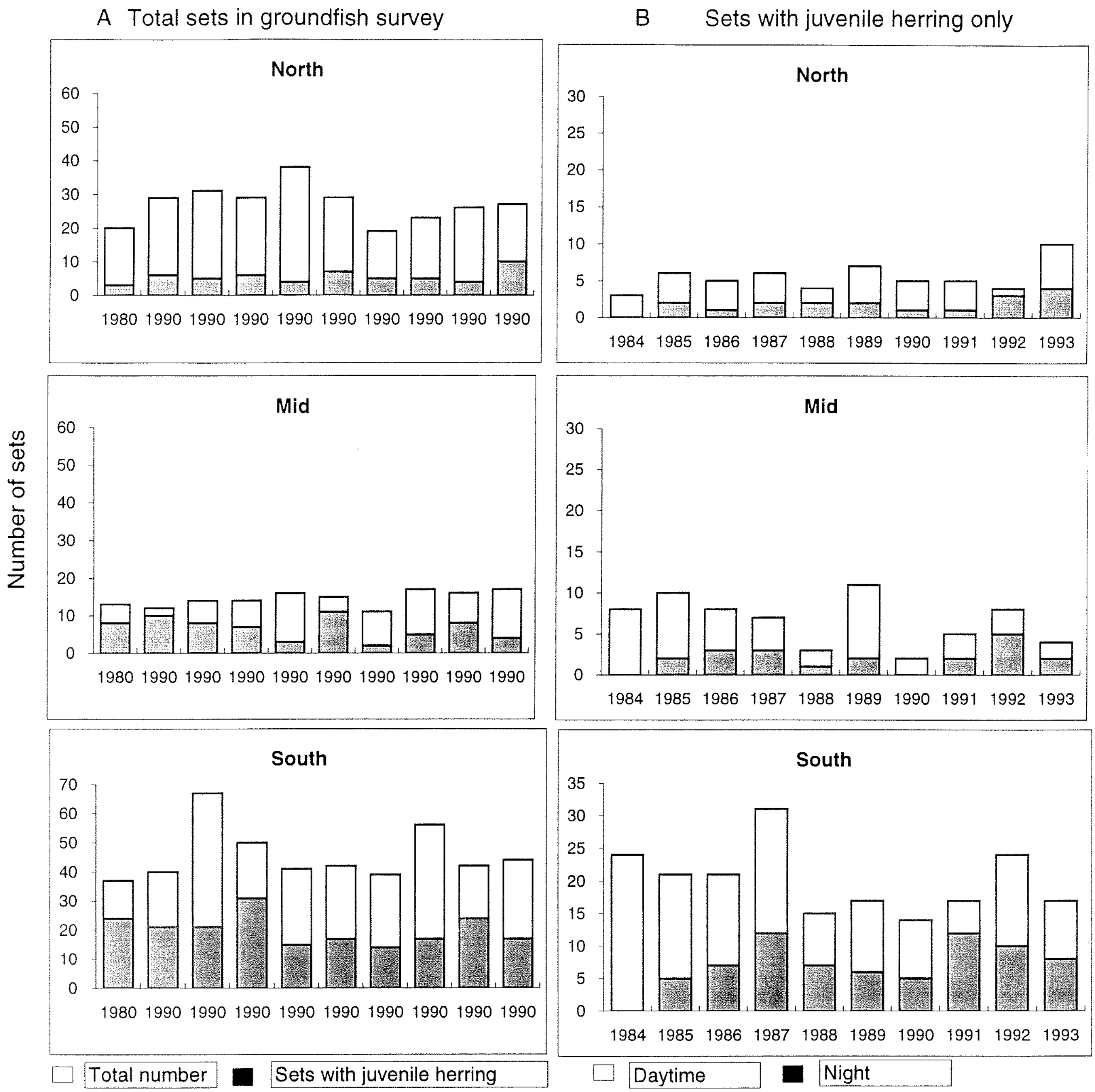


Figure 3. (A) Total number of groundfish survey sets and proportion thereof with juvenile herring catches (B) Proportion of day and nightime sets with juvenile herring catches by area.

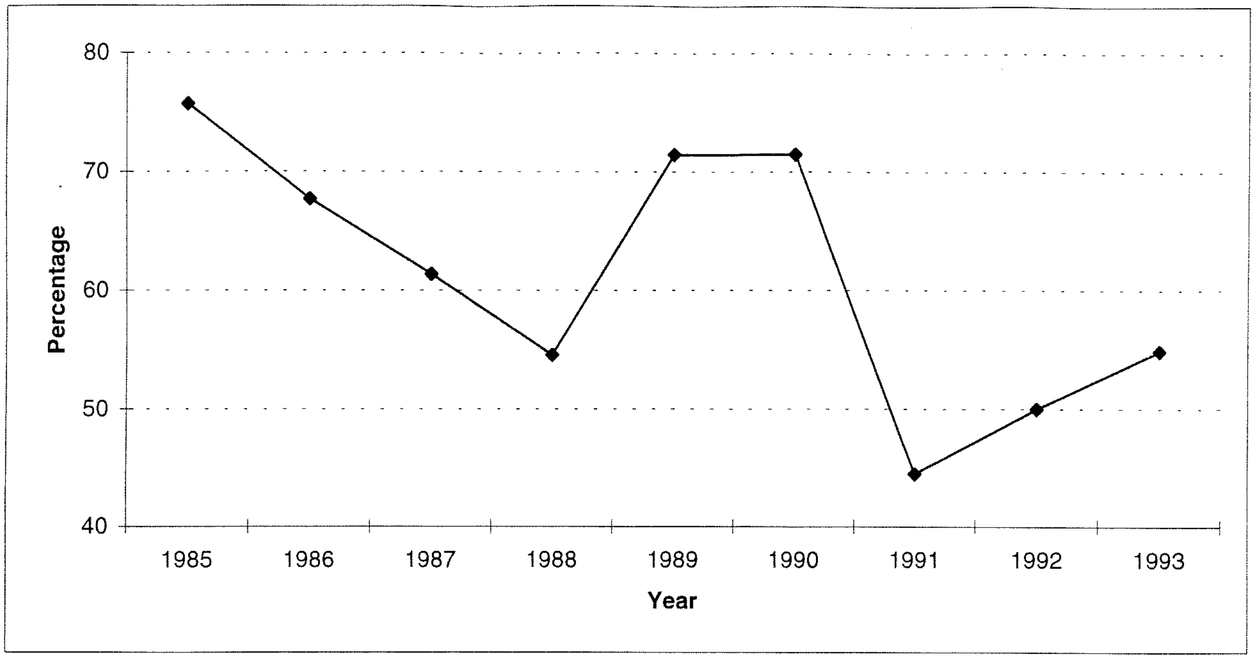


Figure 4. Percentage of sets catching juvenile herring done during daytime hours, North, Mid and South areas combined, September groundfish surveys.

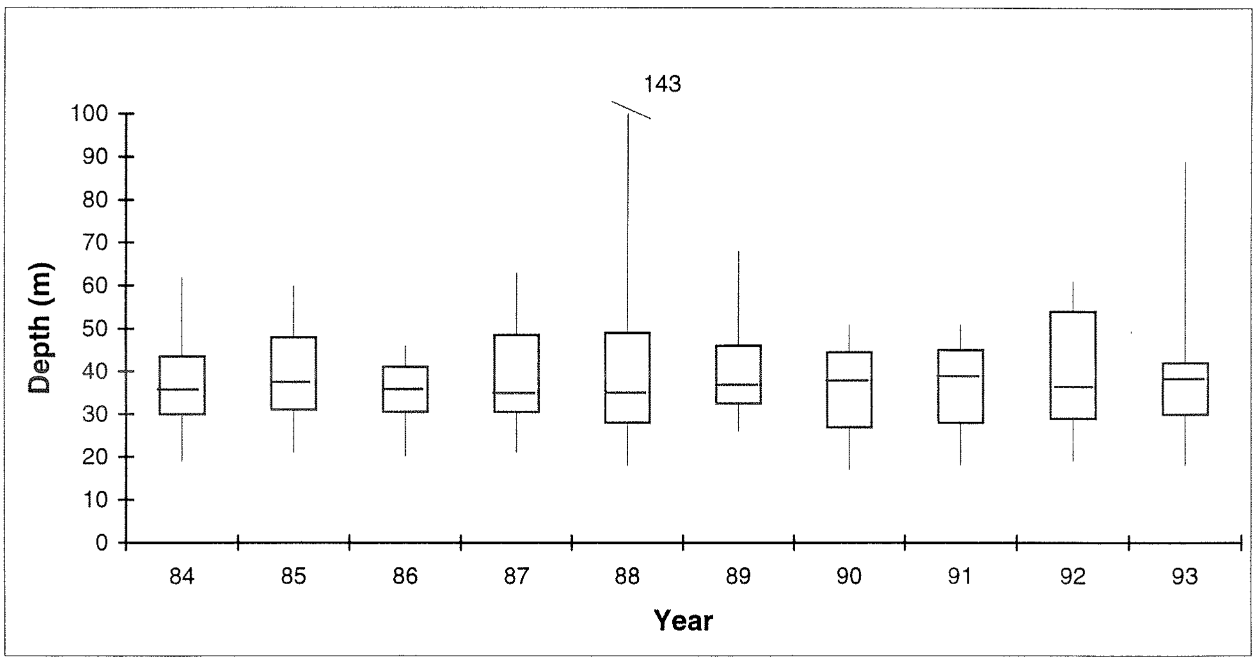


Figure 5. Depth of daytime sets with juvenile herring catches, September groundfish surveys, 1984-93. The boxes delimit the 25 and 75 percentile, the inside line the median, and the end whiskers the 5 and 95 percentiles.

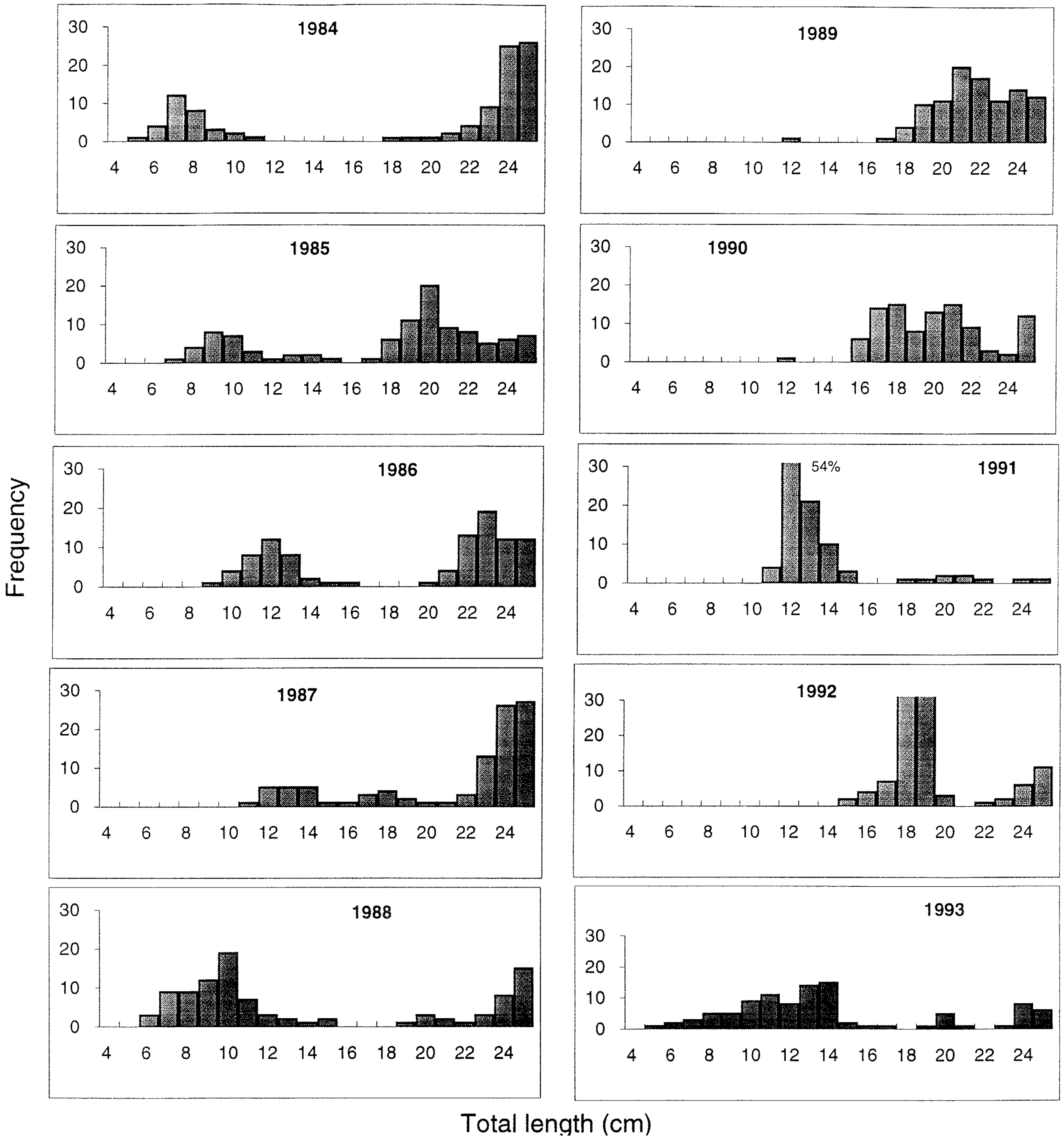


Figure 6. Length frequency distribution of juvenile herring caught in daytime sets, in the southern Gulf of St. Lawrence 1984 to 1993 groundfish surveys.

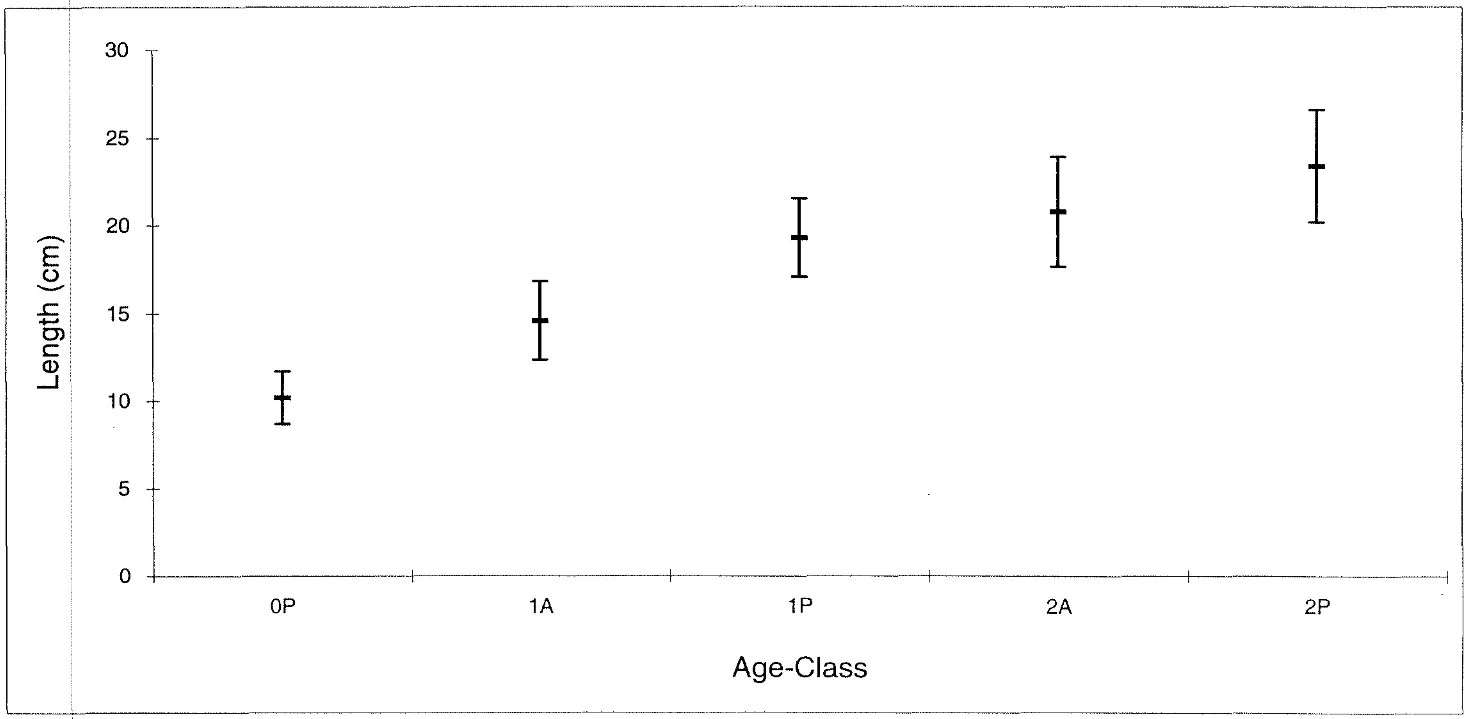


Figure 7. Mean length-at-age of juvenile herring caught in September groundfish surveys, 1988 to 1993 samples combined. Error bars represent +or- 2 standard deviations (SD) from the mean.

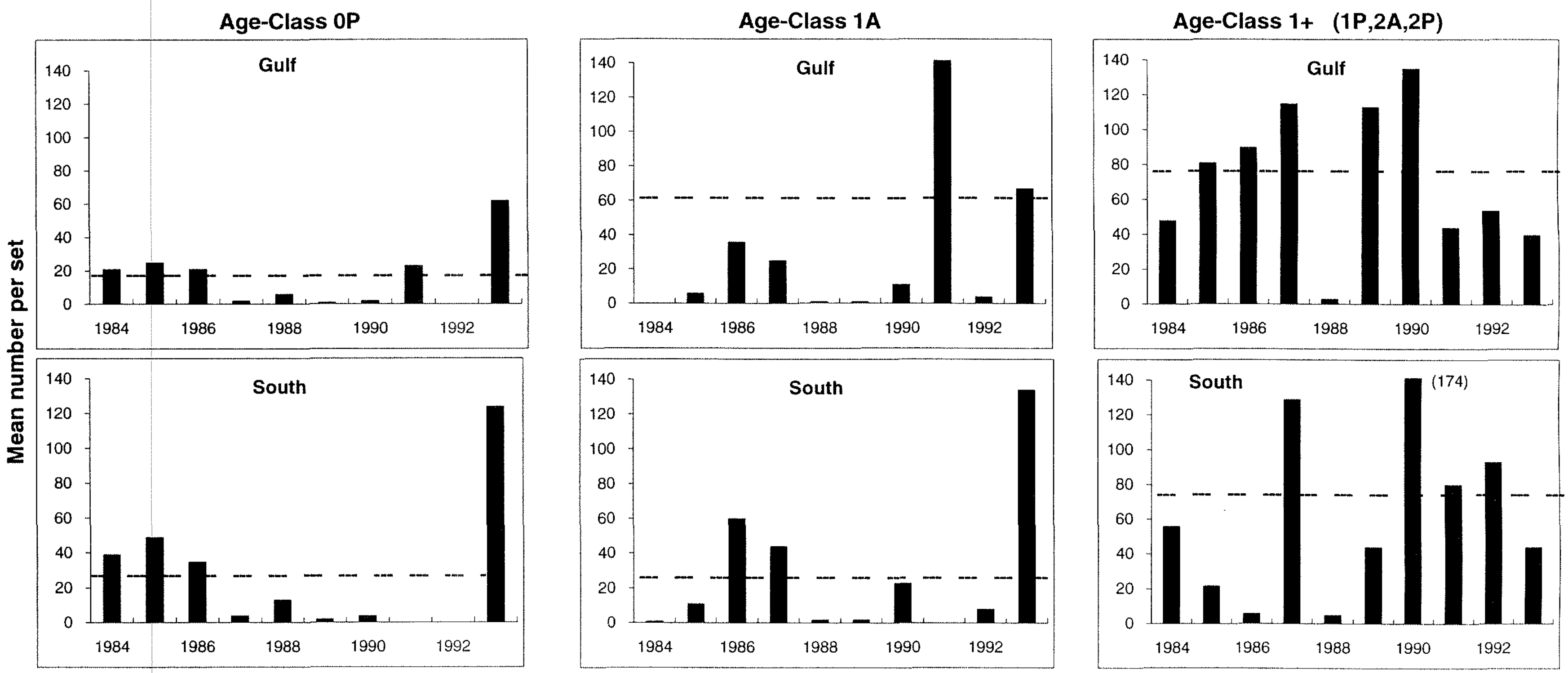


Figure 8. Length-based mean numbers-at-age of juvenile herring caught in daytime sets, entire southern Gulf and south area, September groundfish surveys. Dashed line represents the 1984 to 1993 average number per set.

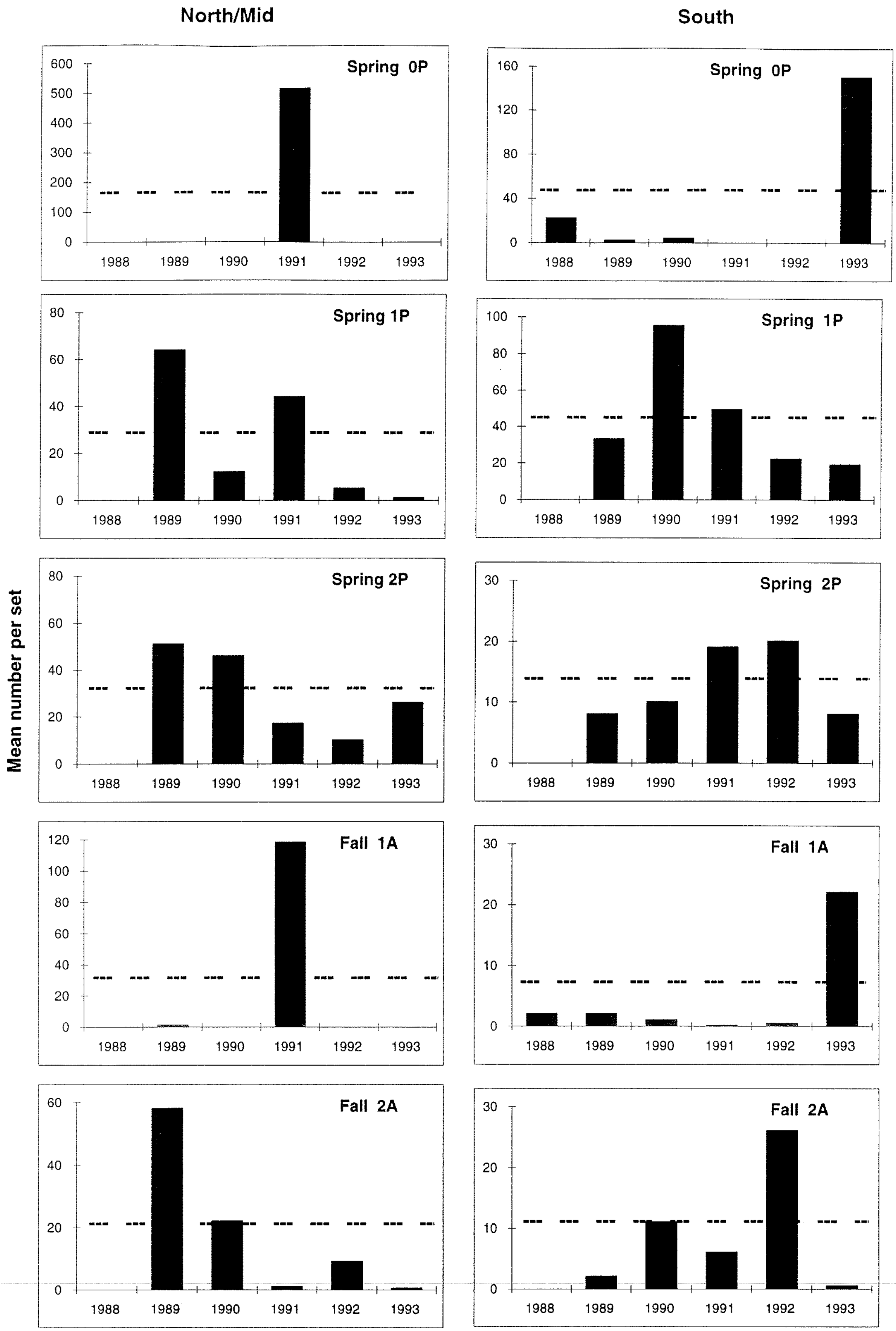


Figure 9. RVAN mean numbers-at-age of juvenile herring caught in day sets, by area. September groundfish surveys. Dashed line represents the 1988 to 1993 average number per set.

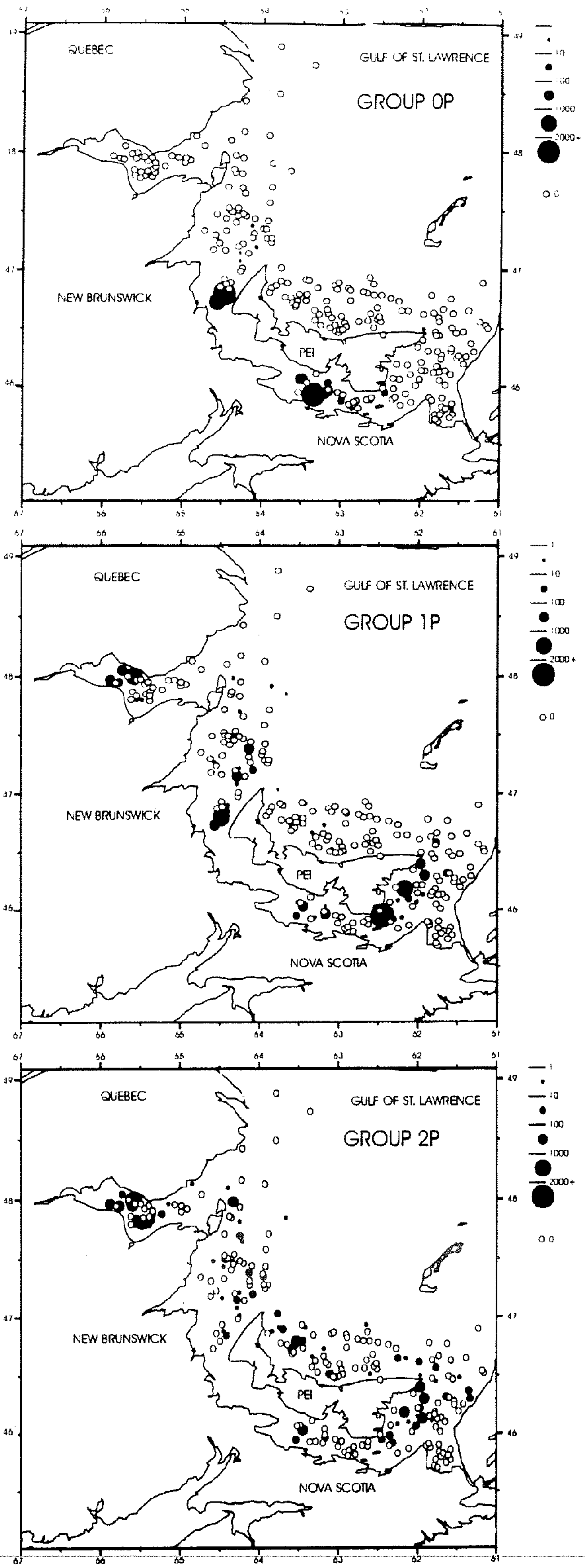
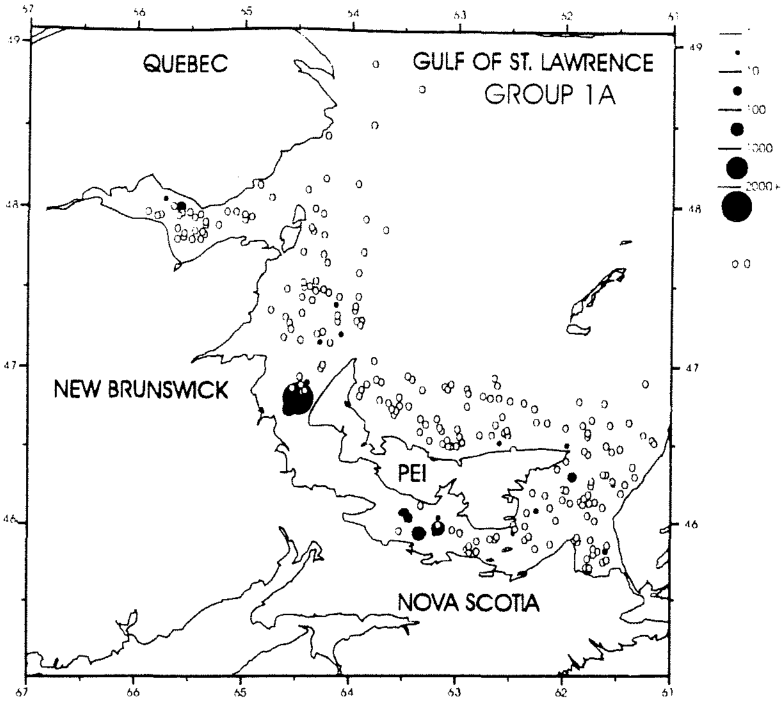


Figure 10. RVAN mean numbers-at-age per tow of Spring (P) juvenile herring in daytime sets, 1988 to 1993 September groundfish surveys combined.



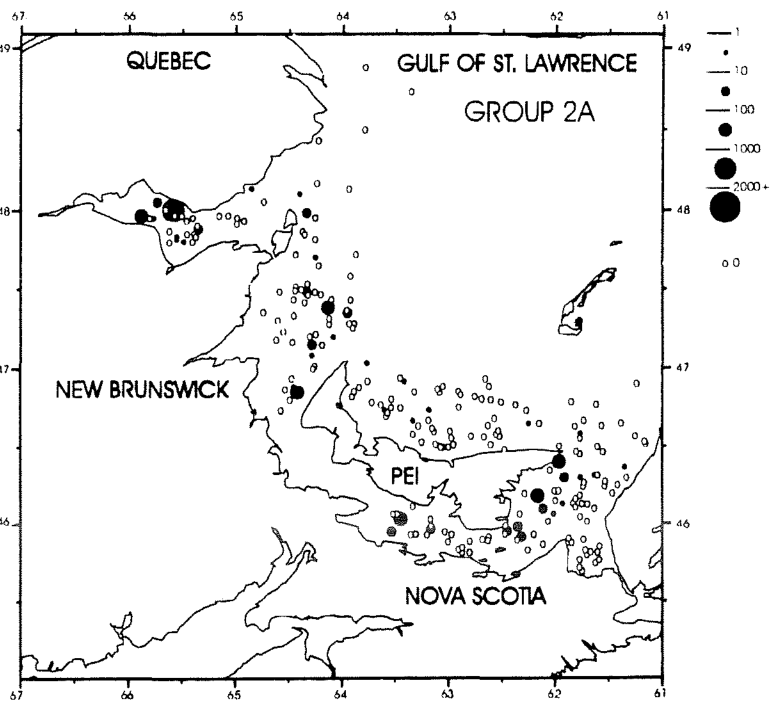


Figure 11. RVAN mean numbers-at-age per tow of Fall (A) juvenile herring in daytime sets, 1988 to 1993 September groundfish surveys combined.

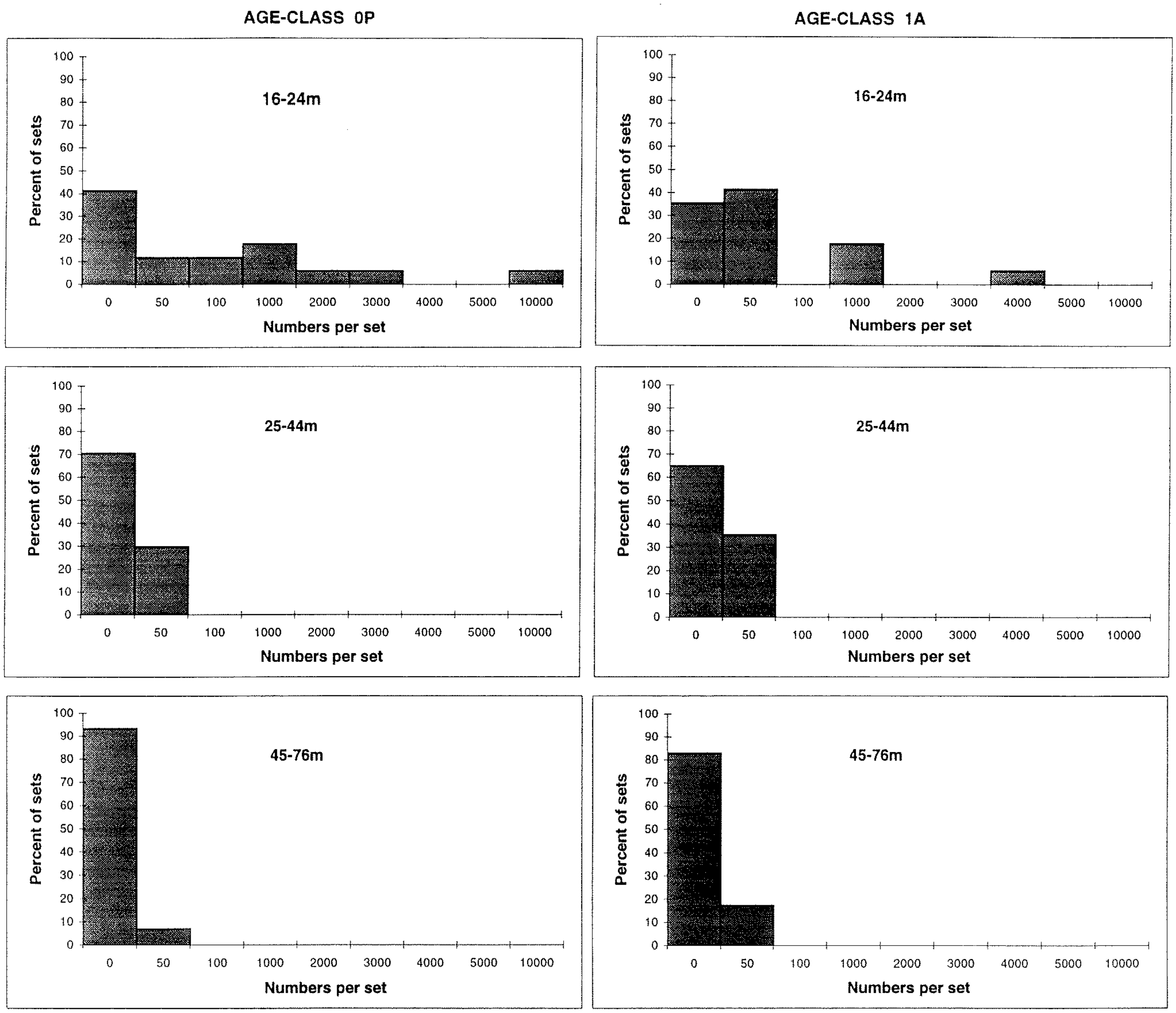


Figure 12a. RVAN catch-at-age numbers per daytime set by depth zone in the September 1988 to 1993 groundfish surveys combined.

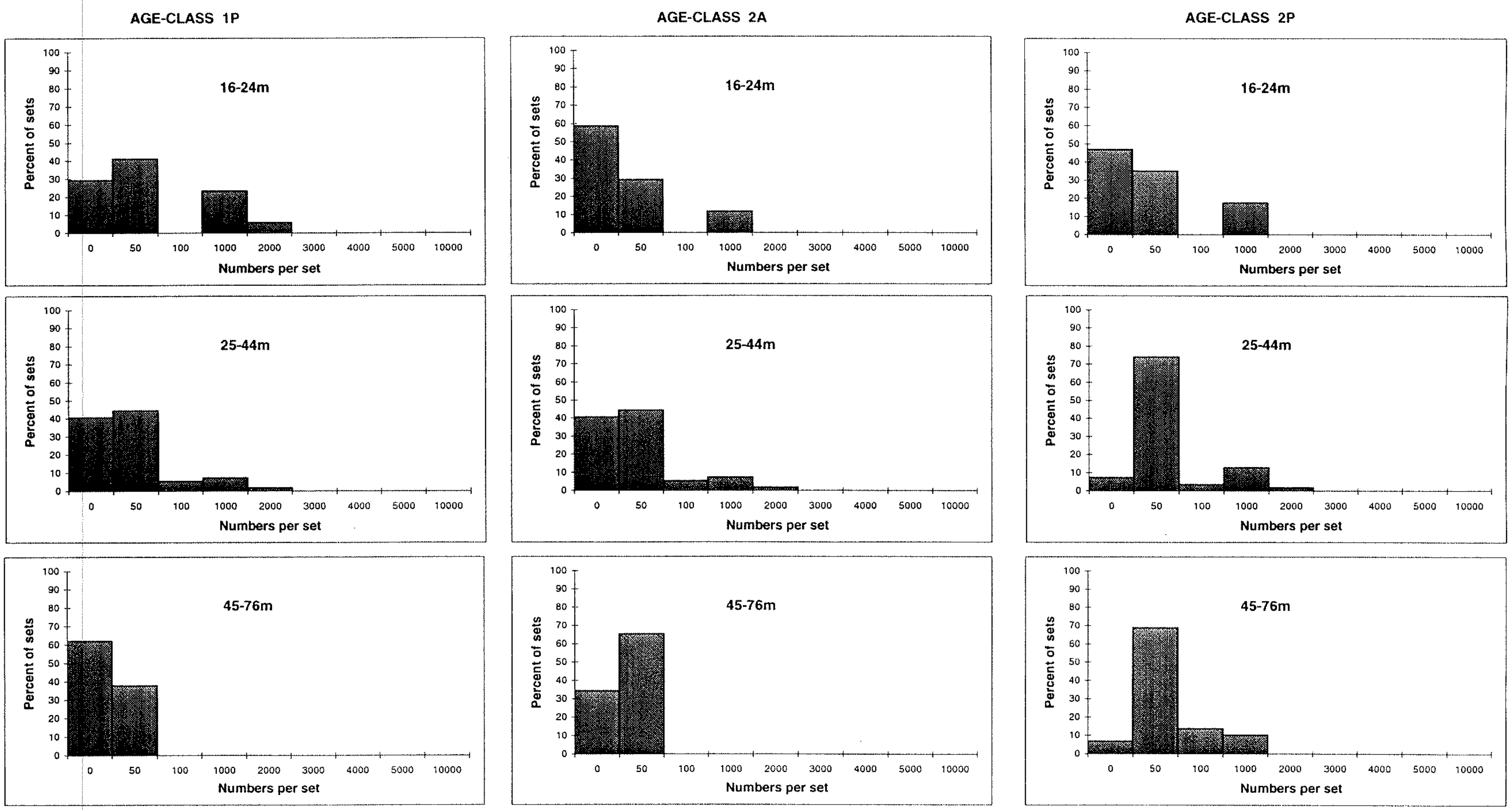


Figure 12b. RVAN catch-at-age numbers per daytime set by depth zone in the September 1988 to 1993 groundfish surveys combined.

Appendix 1. North/Mid area RVAN juvenile herring catch-at-age mean numbers per daytime tow, by age-class and strata, in the southern Gulf groundfish surveys, 1988 - 1993.

Year	Strata	Mean Number per Tow				
		Fall Spawned		Spring spawned		
		1A	2A	0P	1P	2P
1988	417	0	0	0	0	0
	418	0	0	0	0	0
	419	0	0	0	0	0
	420	0	0	0	0	0
	421	0	0	0	0	0
	422	0	0	0	0	0
	All Strata Mean	0	0	0	0	0
1989	417	0	0	0.01	0	0
	418	0	0	0	0	0
	419	5	359	0	338	337
	420	0	0.1	0.01	0.1	0.13
	421	0.3	1.5	0.01	2	1
	422	1	27	0.15	49	16
	All Strata Mean	1	58	0.01	64	51
1990	417	0	0	0	0	0
	418	0	0	0	0	0
	419	0	179	0	100	305
	420	0	4	0	1	43
	421	0	0.3	0	0	0.3
	422	0	0	0	0	0.2
	All Strata Mean	0	22	0	12	46
1991	417	0	0	0	0	0
	418	0	0	0	0	0
	419	0	3	0	5	120
	420	0	0	0	0	0
	421	1335	0	5831	483	0.5
	422	0	0.4	0	0.5	8
	All Strata Mean	118	0.5	517	44	17
1992	417	0	0	0	0	0
	418	0	0.4	0	0	3
	419	0	0	0	0	0
	420	0	0	0	0	0
	421	0	63	0	41.5	31
	422	0	6	0	3	16
	All Strata Mean	0	9	0	5	10
1993	417	0	0	0	0	0
	418	0	0	0	0	0
	419	0	4	0	9	214
	420	0	0.2	0	0	2
	421	0	0	0	0	0
	422	0	0	0	0	1
	All Strata Mean	0	0.5	0	1	26

Appendix 2. South area RVAN juvenile herring catch-at-age mean number per daytime tow, by age-class and strata, in the southern Gulf groundfish surveys, 1988 - 1993.

Year	Strata	Mean Number per Tow				
		Fall Spawned		Spring spawned		
		1A	2A	0P	1P	2P
1988	401	0	0	0	0	0
	402	19	0	322	0	0
	403	2	0	1	0	0
	429	0	0	0	0	0
	431	0	0	0	0	0
	432	0	0	1	0	0
	433	1	0	0	0	0
	434	0	0	0	0	0
All Strata Mean		1.5	0	22	0	0
1989	401	0.24	0	0.1	0	0.15
	402	0	0	0	0	0
	403	0	0	0	0	0
	429	0.1	1	0.1	1	9
	431	0	0.4	0	0.1	1
	432	3	0	35	0.1	0
	433	7	8	0.1	166	28
	434	0.5	0.2	0.3	3	2
All Strata Mean		2	2	2	33	8
1990	401	0	0	0	0	0
	402	5	0	51	1	0
	403	0	0	0	0	0
	429	0	0.2	0	0.03	2
	431	0	0	0	0	0
	432	6	0	4	266	3
	433	0	59	3	464	50
	434	0	1	0	0	5
All Strata Mean		1	11	4	96	10
1991	401	0	0	0	0	0
	402	0	0	0	0	0
	403	2	0.1	4	1	0.1
	429	0	0.1	0	0.1	1
	431	0	0.01	0	0.01	1
	432	0	0	0	0	0
	433	0	29	0	233	86
	434	0	0	0	0	0
All Strata Mean		0.04	6	0.1	49	19
1992	401	0	3	0	1	10
	402	6	275	0	254	122
	403	0	0	0	0	0
	429	0	0.1	0	0.1	4
	431	0	3	0	0	23
	432	0	0	0	0	0
	433	0	29	0	19	14
	434	0	0	0	0	11
All Strata Mean		0.4	26	0	22	20
1993	401	0	0	0	0	0.5
	402	225	0	1808	3	0
	403	0	0	0	0	0
	429	0	0	0	0	18
	431	0	0	0	0	2
	432	153	11	572	410	13
	433	0.1	0	0.1	0	9
	434	0	0	0	0	1
All Strata Mean		22	0.5	150	19	8