Distribution of juvenile Atlantic herring in the southern Gulf of St. Lawrence

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DISTRIBUTION OF JUVENILE ATLANTIC HERRING IN THE SOUTHERN GULF OF ST. LAWRENCE

by

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ABSTRACT

The distribution of juvenile Atlantic herring (*Clupea harengus harengus*) in the southern Gulf of St. Lawrence was surveyed by means of echosounders, midwater- and bottom trawls and by sampling the bycatch of the winter smelt fishery. Surveys and smelt gear revealed that juvenile herring are benthic in winter. Spring-spawned juveniles appeared to overwinter within Chaleur Bay and were most easily sampled during winter. Although not all areas of the southern Gulf were surveyed, few fall-spawned juveniles were located, a surprising finding given the preponderance of adult fall spawners. Single-beam echosounders did not reliably detect juvenile herring, even when the latter were well off the bottom. Annual bottom-trawl surveys are now being conducted in December to develop pre-recruit abundance indices.

RÉSUMÉ

La distribution du hareng atlantique (*Clupea harengus harengus*) juvénile à l'intérieur du sud du golfe du Saint-Laurent est délimitée à l'aide de sondeuses, de chaluts pélagiques et de fond, ainsi que par l'échantillonnage des prises accessoires de la pêche hivernale à l'éperlan. Les missions de recherche et les filets à éperlan révèlent que le hareng juvénile est benthique en hiver. Les juvéniles nés au printemps semblent hiverner à l'intérieur de la baie des Chaleurs et sont plus facilement prélevés à ce moment. Quoique le golfe n'ait pas été prélevé en entier, peu de juvéniles d'automne sont repérés, fait surprenant compte tenu de la prépondérance des géniteurs d'automne. Les sondeuses à rayon simple ne décèlent pas le hareng juvénile de façon fiable, même lorsque ce dernier est bien dégagé du fond marin. Des relevés annuels à l'aide de chaluts de fond se poursuivent maintenant en décembre afin de développer des indices d'abondance de pré-recrues.

INTRODUCTION

In Canada's southern Gulf of St. Lawrence Atlantic herring, *Clupea harengus harengus*, spawn either in the spring or in the fall, although the degree of reproductive allopatry between the two spawning groups (or the extent of cross-recruitment) remains unquantified (Messieh and Tibbo 1971). Both groups are exploited commercially, generally recruiting at Age-2 for spring spawners and Age-3 for fall spawners (Claytor et al. 1995). Both spring and fall spawners are subject to large fluctuations in recruitment. Since 1978, the proportion of recruits in the annual catch has fluctuated between 0 and 15% for spring spawners and 0 and 39% for fall spawners.

Pursuing research on the factors that influence year-class strength is the best approach to improve our understanding of recruitment mechanisms. In the meantime, monitoring the abundance of pre-recruits could improve the predictive power of herring stock assessments and allow a more judicious exploitation of the resource (Doubleday 1985; Jakobsson 1985; Smith 1985). At present, however, there is no measure of pre-recruit abundance for any Canadian Atlantic herring stock (McQuinn and Lefebvre 1994; Stephenson et al. 1994; Wheeler et al. 1994; Claytor et al. 1995). Instead, projected recruitment is estimated by averaging its historical levels as derived from virtual population analysis (Claytor et al. 1995). Winters and Wheeler (1987) showed that recruitment co-varies among several NW Atlantic herring stocks, and presented evidence that year-class strength is related to water temperature and salinity. However, their model applied to spring spawners only and left a substantial amount of variation unexplained, which limits its applicability to southern Gulf stocks.

Although several spawning beds have been identified within the southern Gulf of St. Lawrence (Day 1957; Messieh 1975, 1987, 1988), little is known about the distribution of larvae and juveniles, and there is no fishery on juvenile herring to monitor pre-recruit abundance. Therefore, we aimed our research at delineating the distribution and seasonal movements of spring- and fall-spawned juvenile (sexually immature) herring in the southern Gulf of St. Lawrence, to identify optimal sampling periods and locations for measuring the abundance of each year-class. Based on our knowledge of spawning bed locations and oceanographic features (El-Sabh 1976; Iles and Sinclair 1982; Koutitonsky and Bugden 1991; de Lafontaine et al. 1991) we expected to find several nursery areas within the southern Gulf of St. Lawrence, e.g. near the mouth of Chaleur Bay, the Shediac Valley area and both the NW and SE ends of Northumberland Strait (Fig. 1). This report describes the seasonal geographic distribution of juveniles, as determined from summer and early-winter research surveys and from sampling of the herring bycatch in the winter smelt fishery. It also identifies suitable areas, time of year and sampling gear for monitoring pre-recruit abundance. A subsequent

publication will address the development of a standardised abundance index for spring- and fall-spawned pre-recruits.

METHODS

WINTER DISTRIBUTION

A survey was carried out 2-7 December 1988 in Chaleur Bay (Fig. 1) aboard the 39.6-m Canadian Science Vessel (CSS) EE Prince, using hydro-acoustic gear and an Engel midwater trawl (Table 1). Parallel transects covered all navigable areas of Chaleur Bay west of 65°20'W. Searching was done primarily at night because few fish traces were detected by day. The Engel trawl, towed for 30 min at 6.5 km/h, permitted species identification and biological samples of the fish aggregations recorded by a Simrad® single-beam EK 50 sounder (50 KHz).

The timing of the 26 November - 8 December 1990 survey (Table 1) coincided with a seasonal groundfish survey in the same area. The bottom trawl used for the latter survey was more successful in gathering juvenile herring than was our midwater trawl, and we therefore repeated previous tows, and continued the survey, with a Yankee 36 bottom trawl. A Simrad® EY200 single-beam hydro-acoustic sounder (120 KHz) coupled to a Femto® digitising system recorded the occurrence of fish traces. Most bottom-trawl tows took place between dusk and dawn (1630-0700 hours) unless strong winds precluded night fishing, in which case the schedule was maintained by executing some daylight tows.

To investigate the overwintering behaviour of juvenile herring, sampling of the smelt fishery in Chaleur Bay was undertaken (Table 1), as the bycatch occasionally includes juvenile herring (Cairns 1989). This fishery operates in the fall and winter, normally terminating in early March. On 13-14 February 1990 a fisherman was hired to set smelt gillnets (2.8 and 5.6 cm mesh) in 21 m of water under the ice in Nepisiguit Bay (Fig. 1). In February and March 1990, samples were also obtained opportunistically from smelt bagnets installed in the Restigouche River Estuary. On 12-13 March 1990 a bagnet fisherman from the same area was hired after the closure of the smelt fishery to collect live juvenile herring. The following year, we provided a logbook to smelt fishermen using bagnets and asked them to label and freeze their herring bycatch. Five samples were obtained in this way during February 1991.

On 19-20 April 1990, soon after the ice had broken in the harbours of Chaleur Bay, the 16.8-m fishing vessel (F/V) GCMP was chartered to survey the bay and determine the geographic and vertical distributions of juvenile herring (Table 1). The ship's Furuno® single-beam echosounder (50 KHz) was used to search for

bottom traces and the 30-min bottom-trawl tows were divided approximately evenly between day (0600-1800 hours) and night.

SUMMER DISTRIBUTION

The 19.8-m CSS Navicula, equipped with a Boris midwater trawl, was used 23 July-1 August 1989 to survey Chaleur Bay, Shediac Valley and Northumberland Strait (Table 1). Greater emphasis was placed on Chaleur Bay to compare the summer distribution of juveniles with the December 1988 results. The ship's Elac® single-beam sounder (50 KHz) was used to locate fish aggregations, but because of time constraints, only 11 30-min tows were done to identify species and obtain biological samples. A 24-h day/night comparison of schooling behaviour and vertical distribution was attempted in the western end of Chaleur Bay but the survey was conducted predominantly between dusk and dawn (2100-0530 hours).

On 11-19 July 1990 the 39.6-m CSS EE Prince permitted greater coverage and more systematic searching and pelagic fishing of the southern Gulf than in 1989 (Table 1). The ship's Elac® single-beam echosounder (50 KHz) was used 24 h/day to monitor the presence of fish along pre-selected transects, but 21 of the 26 30-min tows took place between dusk and dawn (2100-0530 hours).

BIOLOGICAL SAMPLING

In all surveys, the number of herring caught in each tow was determined (or estimated for very large sets). Up to 300 fish from each tow were measured (total length, TL) to the nearest 0.5 cm. Depending on the size of the catch, all fish, or a stratified subsample of 3 individuals per 0.5-cm length interval, were frozen for further processing in the laboratory. Total length to the nearest mm, weight, age, season spawned, sex, and gonad weight and maturity stage were then recorded. Season spawned was assigned by evaluating otolith characteristics (Watson 1964; Messieh 1972). Age was determined by counting the number of annuli demarcating wide growth zones on otoliths and using the conventional 1 January birth date, i.e. a wide opaque zone delimited by the edge of the otolith was not counted as a full year until January. Data for fish ≤250 mm only (corresponding to sexually immature Ages 0-3) are presented here.

RESULTS

WINTER DISTRIBUTION

In December 1988, the largest catches of juvenile herring were obtained by towing the midwater trawl within 2 m of the mud bottom, in the western half of Chaleur Bay (Fig. 2a). Almost all herring caught were spring-spawned Age-0, measuring

80-160 mm long (Fig. 3). The shallowest (westernmost) sets contained more smelt than herring. The main species in the three easternmost sets was capelin, *Mallotus villosus*, rather than smelt or herring. The set closest to the mouth of Chaleur Bay was devoid of herring, and the area just west of it produced no fish traces on the echosounder. That area had yielded some larger juveniles (200-250 mm TL) and adults two weeks earlier (Cairns et al. 1989).

All traces detected by the echosounder consisted of an offshore 2-5 m layer of specks spread uniformly over the flat muddy bottom of the Bay. These traces occurred in 19-60 m of water, and disappeared during the day. Trawl tows through this layer always yielded shrimp (Mysid or *Crangon* spp.) and variable proportions of juvenile herring and smelt (*Osmerus mordax*). No dense fish schools were detected by the sounder, even above the near-shore slopes and bottom irregularities with which herring schools are often associated earlier in the fall (H. Dupuis, pers. obs.).

Whereas Chaleur Bay in December 1988 harboured almost exclusively spring-spawned Age-0 juveniles, hardly any were captured there in December 1990. Instead, catches within Chaleur Bay consisted mostly of older juveniles and adults of both spawning groups (Figs. 2c, 4). Other areas surveyed in December 1990 yielded small quantities of primarily Age-0 spring-spawned juveniles (Fig. 4). The age and season of birth of the only juvenile collected to the east of Prince Edward Island could not be identified from its otoliths or its length (155 mm TL).

Bottom-tow locations in December 1990 were, as previously, selected mostly by nocturnal searching using the sounder. However, four sets executed in areas devoid of acoustic traces yielded various benthic and pelagic fish, including juvenile herring in two instances.

The 2.8-cm mesh gillnets set in February 1990 in Nepisiguit Bay caught eight juvenile herring and several smelts. The herring were all spawned in spring 1989 (Age-group 1P, where P stands for Printemps, or Spring). Their total length ranged between 140 and 160 mm, but exact measurements were precluded by sampling damage and predation by crabs. The 5.6-cm mesh gillnets, commonly used in the springtime fishery for adult herring, did not capture any pelagic species, suggesting that there were no larger herring in the vicinity.

All bagnet samples collected in February and March 1990 and February 1991 were very similar to those obtained during the survey in December 1988 in that they consisted almost exclusively of juveniles spawned during the preceding spring (Fig. 5). The bagnet fishermen in the channel of the Restigouche Estuary reported more frequent and larger bycatch of juvenile herring as the winter progressed, while the boxnets anchored along shore rarely caught juveniles, even late in the fishing season (early March).

On 19-20 April 1990 the 15-m flounder drag towed by the F/V GCMP caught only three juvenile (Fig. 6) and five ripe adult herring in Chaleur Bay. All herring were spring-spawned fish. Dense but small midwater schools were seen regularly on the ship's sounder but were not identified for lack of appropriate fishing gear.

SUMMER DISTRIBUTION

The July 1989 survey (Fig. 2b) confirmed that the cohort that prevailed in Chaleur Bay in December 1988 was still abundant. Almost all juveniles in the Bay were spring-spawned, whereas the samples collected south of Shediac Valley and in Northumberland Strait contained more fall- than spring-spawned juveniles (Fig. 7). Herring and smelt were often caught together, but it was not clear from the traces on the sounder whether or not the two species intermingled.

Large quantities of juvenile herring were encountered in most areas searched in July 1990 (Fig. 2d). In Chaleur Bay and around its mouth, Age-2 juveniles were more common than during previous surveys (Fig. 8) and were often caught simultaneously with larger herring. Older juveniles predominated in Shediac Valley as well although most were spring-spawned, in contrast to the juvenile herring caught in Shediac Valley in July 1989. The shift from a preponderance of fall-spawned fish in July 1989 to mostly spring-spawned juveniles in July 1990 was also observed in Northumberland Strait for all three age groups. In fact the majority of juveniles captured in the southern Gulf in July 1990 were spring-spawned, except in north-eastern Prince Edward Island where the converse was true.

DISCUSSION

Our surveys established that spring-spawned herring congregate in Chaleur Bay in December and the Restigouche Estuary throughout winter, and can be conveniently sampled during the winter to derive a relative index of abundance. While overwintering mortality during the larval stage is considered an important determinant of recruitment in herring and other clupeoids (Smith 1985, Graham and Sherman 1987), spring-spawned Age-0 herring in the southern Gulf of St. Lawrence have undergone metamorphosis and attained lengths of 10 cm or more by December (Fig. 3), such that their mortality rate has presumably dropped substantially from that of larvae (Smith 1985).

Our findings are of interest because previous workers have considered juvenile herring to be typically pelagic fish. In the Bay of Fundy for instance, juveniles were well off the bottom (>10m) even by day, as early as March and approached the water surface by night throughout the year (Brawn 1960). Winter water

temperatures are considerably higher in Fundy than in Chaleur Bay, which may allow the fish greater vertical movement. Accumulating evidence suggests that vertical distribution is temperature-dependent (Dupuis and Courtenay, unpubl. data).
Evidence of age-specific differences in migration patterns of juvenile herring within the southern Gulf of St. Lawrence is emerging (Chadwick et al. 1990; this study) and has been noted in other herring stocks as well. Saville (1971) suggested that Age-1 herring migrate into coastal firths in winter from the open Moray Firth (Scotland), and move offshore again in the spring to join the adults. Iles (1967) stated that for East Anglian (North Sea) herring, the Age-0 young remain largely inshore, the Age-1 are found in deeper offshore water, and at least some of the Age-2 juveniles join adult schools further offshore. These findings concur with our observations that larger juveniles (> 20 cm TL) are most often caught with adults rather than by themselves whereas younger fish tend to aggregate in size-specific schools. Because juveniles are found in shallower waters than adults and are more easily collected with bottom, rather than pelagic, trawls, indices of pre-recruit abundance are best developed independently of adult abundance estimates.

Only three spring-spawned Age-1 juvenile herring (but occasionally many smelt) were captured by the bottom trawl in April 1990, which suggests either that the herring do not remain in Chaleur Bay itself throughout winter, or that they have already moved up into the water column by the time the ice cover disintegrates. That small pelagic schools (which may have been herring) were observed on the sounder during the April survey, that spring-spawned juveniles were gillnetted as far east as Nepisiguit Bay in February, and that smelt bagnets catch juveniles throughout winter in the Restigouche Estuary channel supports the latter explanation, i.e. these fish did overwinter in Chaleur Bay but had become pelagic by the time we surveyed the area in April. This hypothesis could be tested by repeating the survey with concurrent bottom- and midwater trawling immediately before and after the presence of ice cover as well as by depth-stratified gillnetting beneath the ice throughout winter.

It became evident by the end of these surveys that: a) juvenile herring in the areas surveyed were not generating echosounder traces typical of adult herring schools, and b) we were unable, especially in July, to differentiate juvenile herring from smelt-, mysid-, or even jellyfish traces. Because the locations of trawl tows in all surveys presented here were based primarily on traces seen on the echosounder (rather than on the systematic sampling of an area), they should be interpreted cautiously when comparing fish distribution or abundance between surveys. We are now certain that juvenile herring are often *not* detected by single beam echosounders, particularly by day in late fall and winter, and that an impracticable number of trawl tows is required to establish the species identity of the fish that are visible (Rose 1992). This finding has led us to abandon the use of such sounders to locate juvenile herring and we have instead developed a bottom-trawl survey

based on a stratified sampling scheme for determining their abundance within the southern Gulf of St. Lawrence. This survey is now carried out during daylight hours in December, when these fish are close to the bottom (Dupuis, unpub. data).

The generally small proportion of fall-spawned juveniles (Table 2) in our samples was unexpected because fall spawners have been the main constituent of the southern Gulf of St. Lawrence herring stock in recent years (Claytor et al. 1995). The dearth of fall-spawned Age-0 young in the winter samples is not surprising as these fish were still in the larval phase or just undergoing metamorphosis (Messieh et al. 1987) and were probably still too small (≈ 4 cm TL) to be retained by the fishing gears used. However, by July they are large enough (≥10 cm TL) to be accessible to the trawls and yet were absent from all but two 1989 samples in Northumberland Strait. Furthermore, the fall-spawned Ages 1 and 2 were not abundant in the December 1990 sets, and the distribution of fall-spawned Age-2 differed dramatically between July 1989 and 1990. A stratified-random survey initiated in December 1991 suggests that eastern Prince-Edward-Island may be an area of high concentration in December (LeBlanc et al. 1995). Furthermore, offshore areas of the southern Gulf of St. Lawrence, as well as those to the N and NE of Prince-Edward-Island, have yet to be adequately surveyed and may harbour large aggregations of these juveniles. Statistical considerations dictate that searching efforts be combined into annual and extensive surveys of the southern Gulf of St. Lawrence rather than seasonal coverage of restricted regions.

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Table 1. Juvenile herring surveys conducted in the southern Gulf of St. Lawrence from December 1988 to February 1991 (net width: for trawls, refers to length of foot-rope; mesh size: mesh of trawl cod-end liner, or of gillnet).

Date	Vessel	Areas surveyed	Fishing gear	Towing speed (km/h)	Net width (m)	Mesh size (mm)
Winter surveys:						
2-7 Dec '88	EE Prince	Chaleur Bay	Engel trawl (midwater)	6.5	17.7	19
26 Nov - 8 Dec '90	EE Prince	Chaleur Bay & mouth Shediac Valley Northumberland Strait E Prince-Edward-Island	Yankee 36 trawl (bottom)	5.6	24.4	6
13-14 Feb '90	---	Nepisiguit Bay	Gillnets	---	30	28, 56
Feb - Mar '90	---	Restigouche Estuary	Bagnets	---	12 - 30	25 - 28
Feb '91	---	Restigouche Estuary	Bagnets	---	12 - 30	25 - 28
19-20 Apr '90	GCMP	Chaleur Bay & mouth	15-m flounder drag (bottom)	5.6	18.9	6
Summer surveys:						
23 Jul - 1 Aug '89	Navicula	Chaleur Bay & mouth Shediac Valley Northumberland Strait	Boris trawl (midwater)	5.6	22.9	20
11-19 Jul '90	EE Prince	Chaleur Bay Shediac Valley Northumberland Strait NE Prince-Edward-Island	Engel trawl (midwater)	6.5	17.7	19

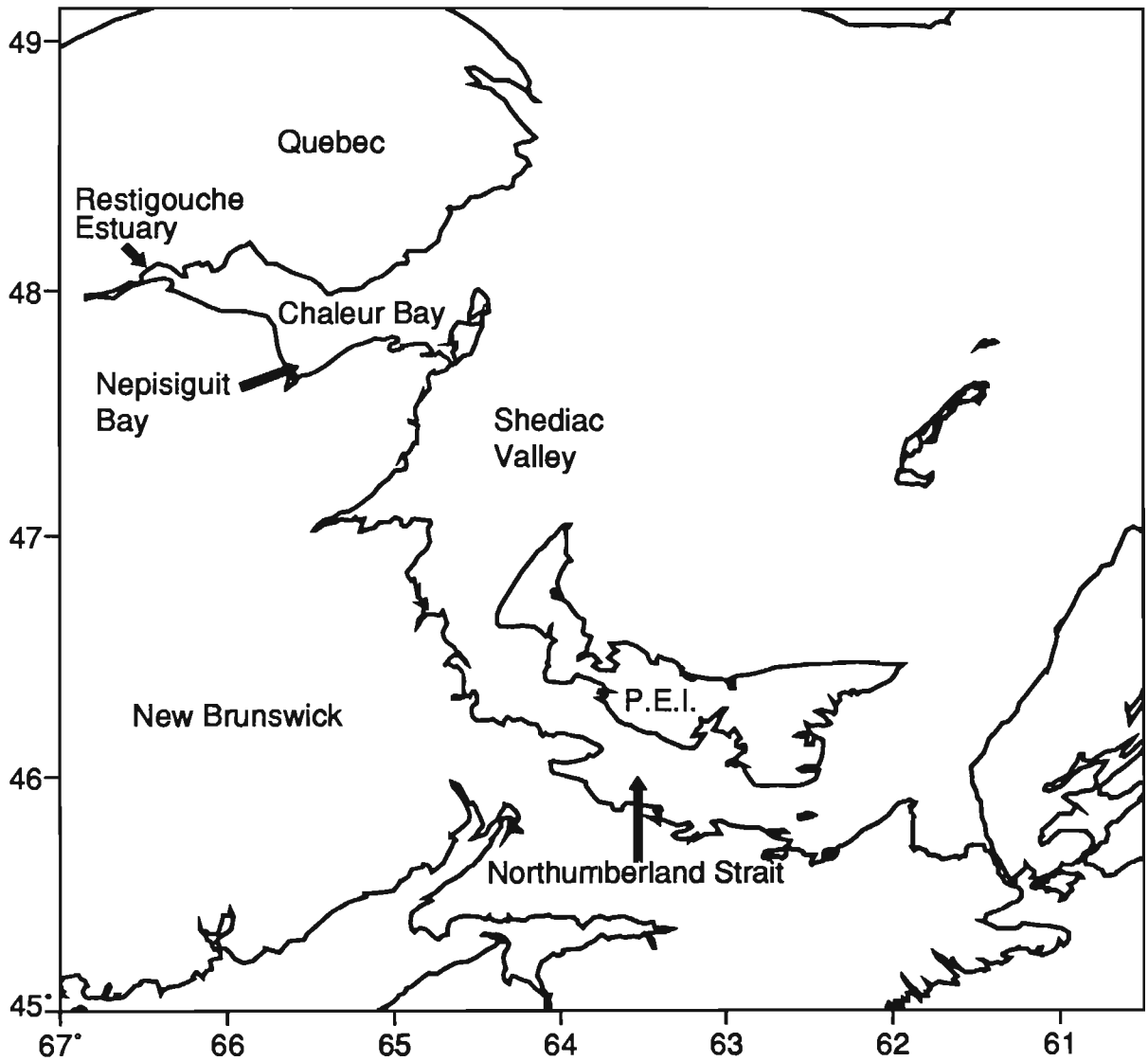

Fig. 1. Areas of juvenile herring surveys within the southern Gulf of St. Lawrence.

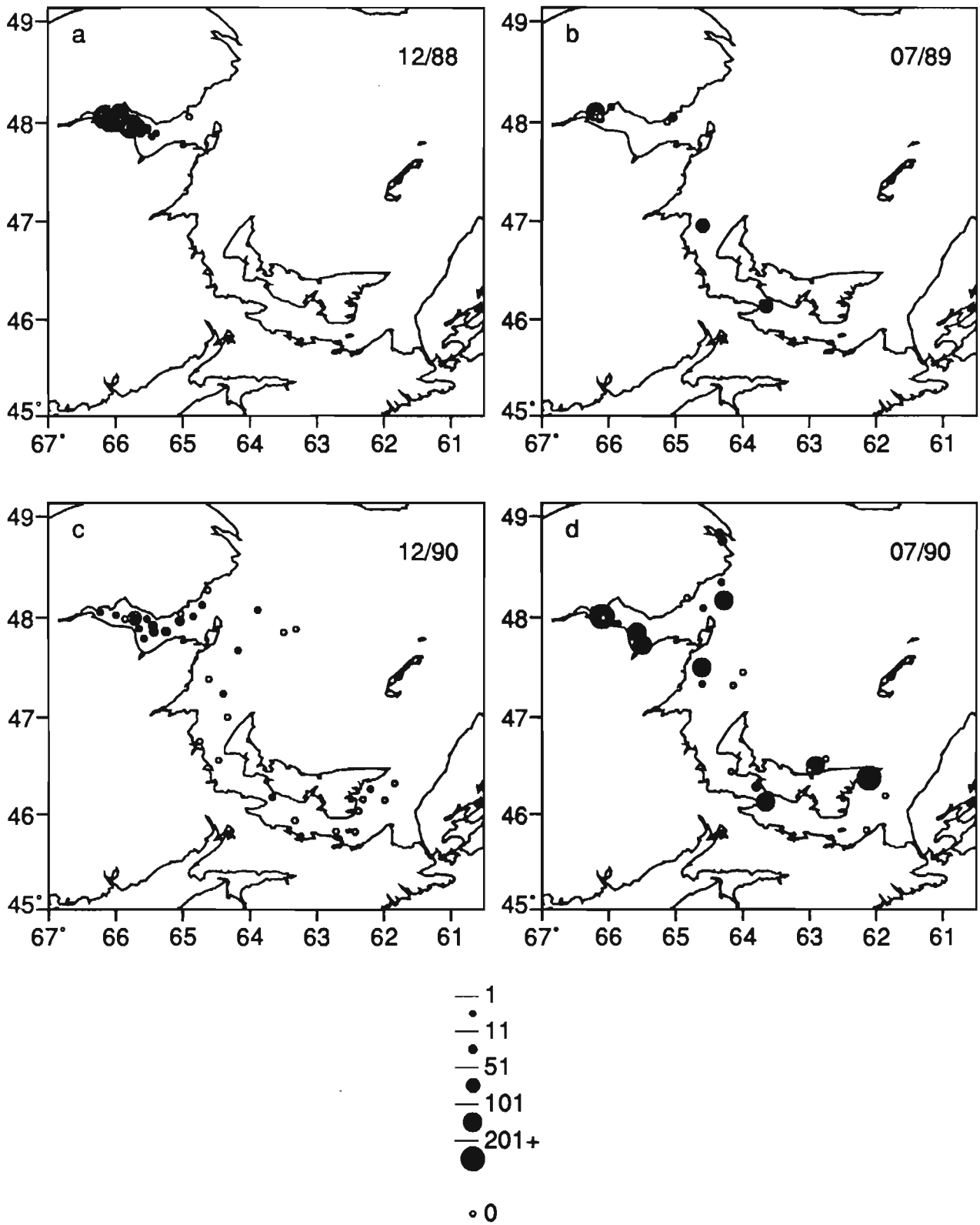

Fig. 2. Abundance of juvenile herring in 30-minute tows of a) a midwater trawl in December 1988, b) a midwater trawl in July 1989, c) a bottom trawl in December 1990, and d) a midwater trawl in July 1990.

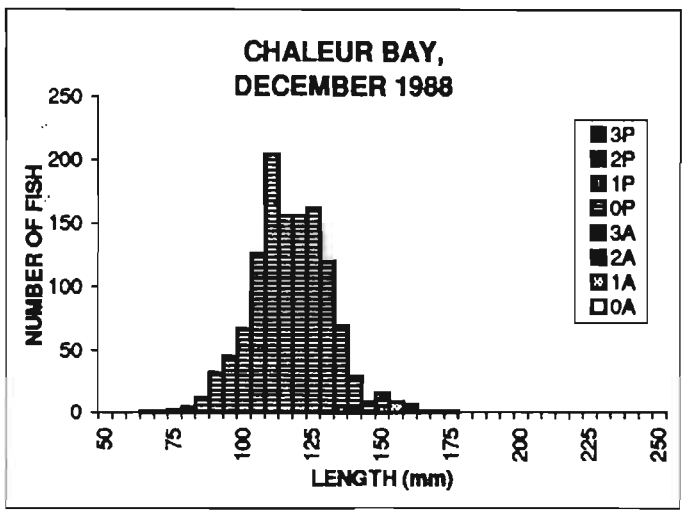

Fig. 3. Size and age distributions of juvenile herring captured with a midwater trawl in Chaleur Bay in December 1988.

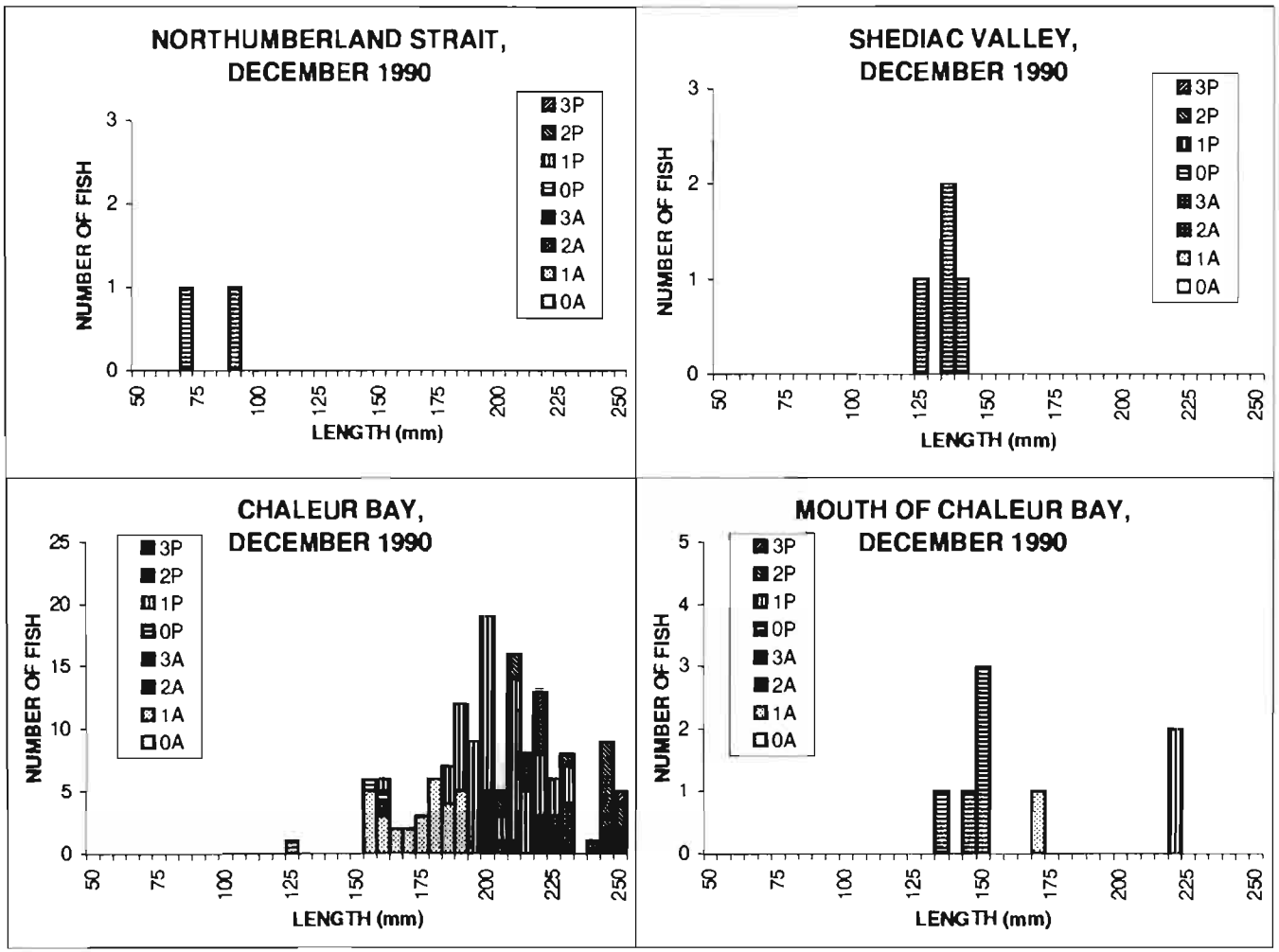

Fig. 4. Size and age distributions of juvenile herring captured with a bottom trawl in the southern Gulf of St. Lawrence in December 1990.

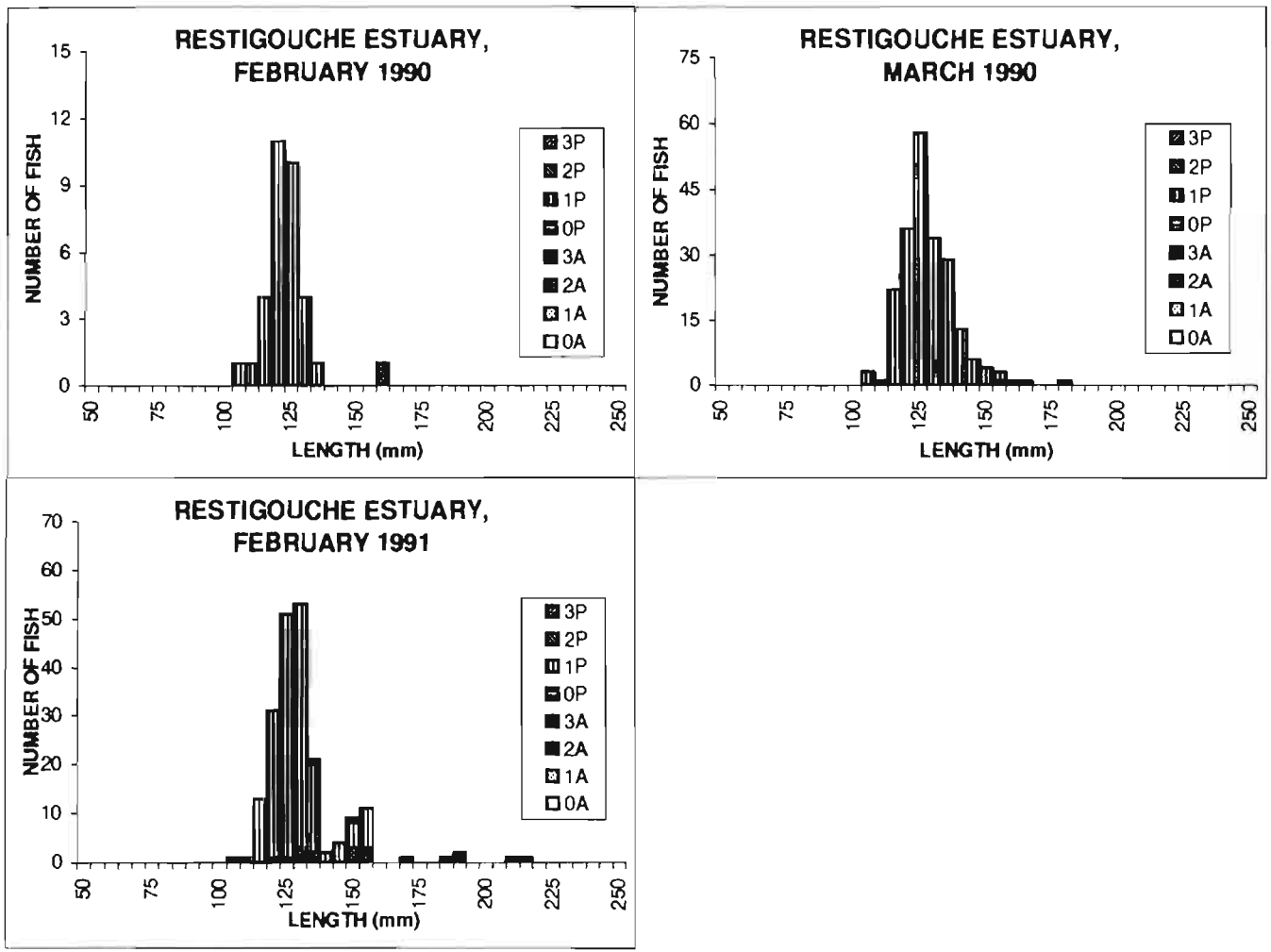

Fig. 5. Size and age distributions of juvenile herring bycatch in smelt bagnets set in the Restigouche estuary in winter 1990 and 1991.

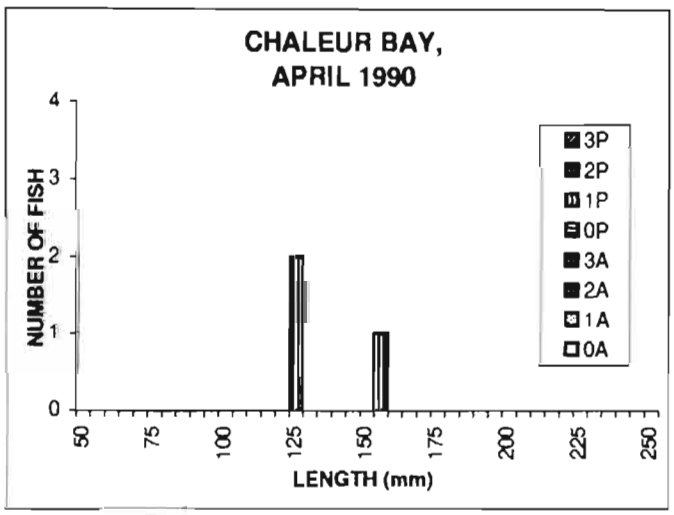

Fig. 6. Size and age distribution of juvenile herring captured with a bottom trawl in Chaleur Bay in April 1990.

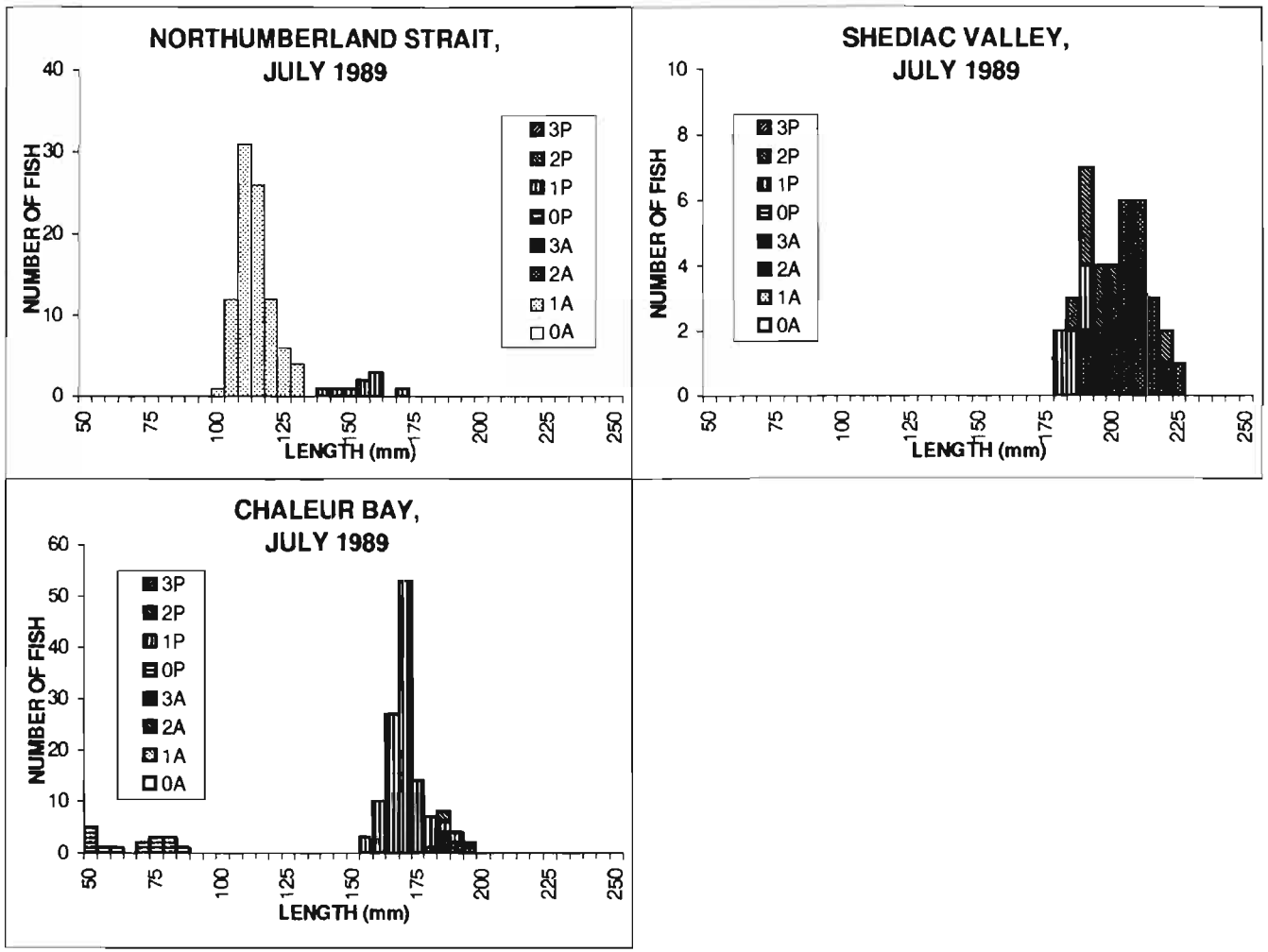

Fig. 7. Size and age distributions of juvenile herring captured with a midwater trawl in the southern Gulf of St. Lawrence in July 1989.

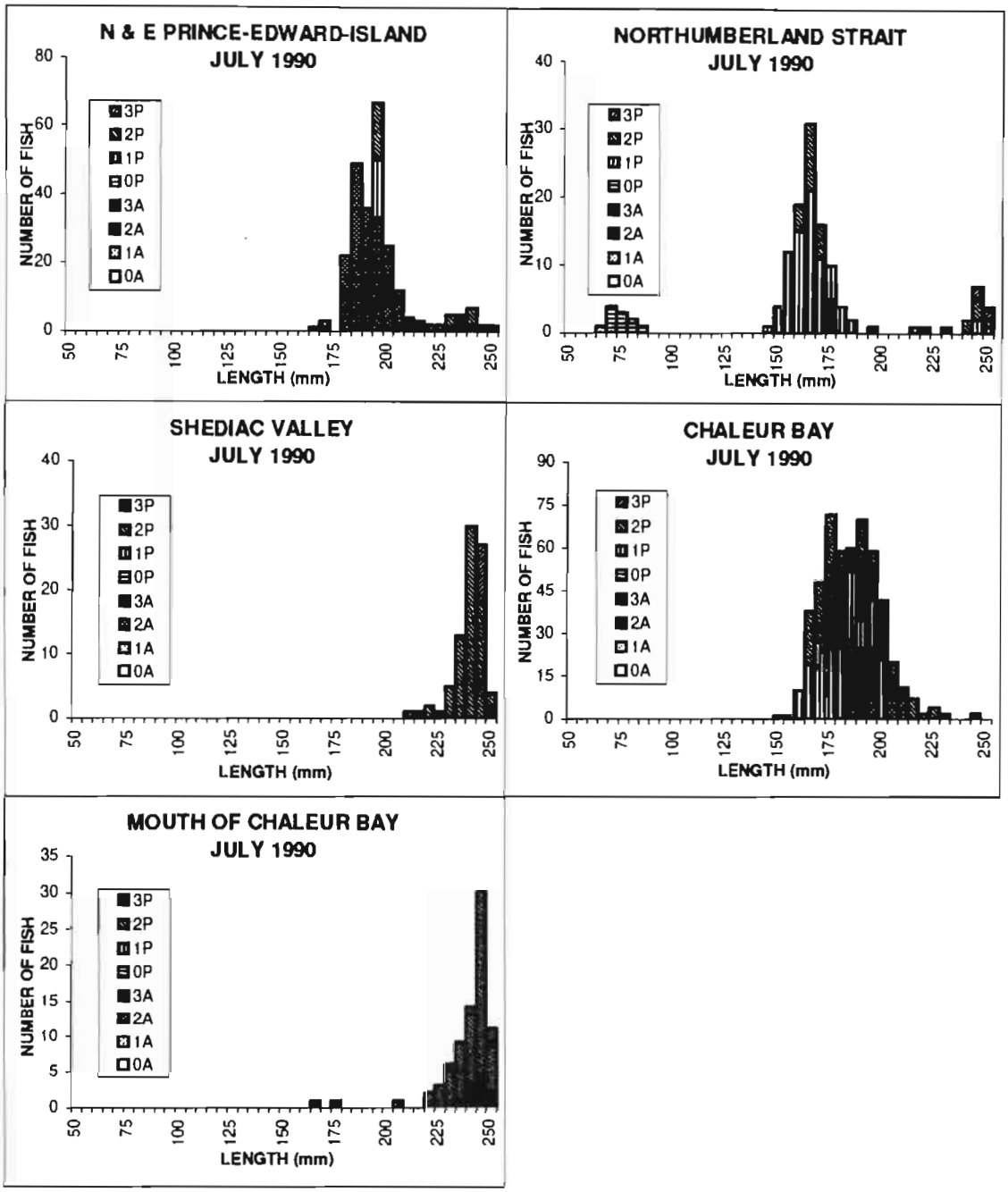

Fig. 8. Size and age distributions of juvenile herring captured with a bottom trawl in the southern Gulf of St. Lawrence in July 1990.