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# Discrimination of Spawning Groups of Herring, *Clupea harengus*, Along the Coast of Maine

by

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## Abstract

This paper illustrates the importance to management of discriminating among individual spawning groups within the herring population of the Maine coast. The spawning success of coastal adult herring was monitored by sampling larval herring in the Sheepscot River estuary in central-western Maine and in the Sullivan Harbor embayment of eastern Maine. Data from coastal surveys and larval birth dates determined from larval otoliths supported the information obtained from monitoring. Three spawning areas were extant along the coast after 8-9 years; located from west to east, 1) off Saco Bay, 2) off Boothbay and 3) off the Machias Bay - Cutler Harbor area. The Sullivan Harbor embayment received larvae hatched from the eastern area, and the Sheepscot River estuary received larvae from both that distant spawning area and from the nearby Boothbay area. After hatching in coastal waters, larval catch rates peaked in the inshore waters during autumn to early winter. Peak catch rates varied from 17-80 larvae per 100 $m^{-3}$ of water strained by nets during 1964, 1966-69 and 1973-77. In contrast, rates varied only from 3 to 9 during 1978-81. The lower catch rates coincided with unusually large harvests of adult herring during or just prior to the summer-fall spawning period. The possibility that spawning groups from individual areas declined to near or below their minimum viable size is discussed, and the importance to management of discriminating among these groups is emphasized.

## Introduction

The results of two recent investigations on herring suggest that the discrimination of spawning groups is necessary for reliable herring management. Anthony and Waring (1980) attribute the demise of the herring stock on Georges Bank to overfishing within individual spawning areas progressively from east to west across the bank. They substantiate this claim by pointing out the associated severe drop in egg deposition and the east to west decline in larval production. Iles and Sinclair (1982) hypothesize that the maximum size of a given stock

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of herring is dependent upon the retention area available to its larvae. Because there is probably more than one spawning unit within a given retention area, they suggest that fishing might have to be managed according to the smallest spawning unit which otherwise might not survive fishing of mixed units.

This paper illustrates the importance to management of discriminating among spawning groups of the herring on the Maine coast. It does so through studies of their production of larvae and discusses the possibility that in recent years they individually and independently reached their minimum viable size.

## Methods

Collections of larval herring have been made along the Maine coast from tidal flows with buoyed and anchored nets since the early 1960's to anticipate recruitment to the sardine fishery, and in recent years, to evaluate the status of the spawning populations (Graham, 1982). Surveys of recently hatched larvae in coastal waters with towed nets also have been used to infer the distribution of spawning groups and their sizes. Recruitment has been anticipated using data collected in winter with buoyed and anchored nets and in spring with towed nets. This paper is concerned with data collected primarily in the autumn during the spawning season of the coastal herring.

### Sampling with buoyed and anchored nets:

Buoyed and anchored nets (Graham and Venno, 1968) were used to determine the abundance of larval herring within 2 inshore areas of coastal Maine: the Sheepscot River estuary of central-western Maine and the Sullivan Harbor embayment of eastern Maine (Fig. 1). Within the estuary, 2 to 3 lines of 4 nets each were fished at 2 locations (landward and seaward) shown in Figure 2 (Table 1). On each line, 2 "shallow" nets were placed above mid-depth, one near the surface and the other at 10 m; 2 "deep" nets were placed below mid-depth at 15 m and near the bottom (20 m). Mid-depth was approximately the level of no-net-motion between a shallow residual flow seaward and a deep residual flow landward (Graham and Davis, 1971; Graham, 1972). This two-layered flow was less pronounced following the removal of a causeway during 1974 from an adjacent bay causing an increased flow through the estuarine channel (McAlice and Jaeger, In Press). Within Sullivan Harbor, 4 lines of 4 nets each fished the harbor channel at 2 locations (landward and seaward) shown in Figure 2. Two shallow nets fished above the edge of the subtidal channel, one near the surface and the other at 3 m; two deep nets fished below the edge, one at 10 m and the other near the bottom (14-20 m). Two additional lines of 2 nets each were positioned laterally to the channel at the entrances to the eastern and western subtidal flats. One net fished near the surface (shallow) and the other, at 3-4 m near the bottom (deep). The shallow nets fished a residual flow departing the harbor while the deep nets fished a residual flow confined to the channel and directed landward (Graham and Joule, 1981). The nets were set at dusk and retrieved at dawn, sampling larvae from the ebb and flood phases for a complete semidiurnal tidal cycle. In 1965-67, the tidal phases within the Sheepscot estuary were fished separately, but these data were treated as overnight sets for the purposes of this paper.

The relative abundance of the larval herring from an overnight set was determined as the number captured per 100 $m^{-3}$ of water sampled by the nets. For each area, the total number of larvae captured was divided by the volume of water sampled measured by flow meters, and then multiplied by 100 to obtain the mean catch per unit effort. To compare peak autumn catch rates in the estuary over a number of years, the data were partitioned according to the sampling design in Table 1 and applied to a Kruskal-Wallis test (Zar, 1974) followed by Dunn's (1964) multiple comparison test. The total number of larvae captured was divided by the total volume of water sampled for each pair of shallow and deep nets, then multiplied by 100 to provide 8 catch rates expressed as number per

100 $m^{-3}$ (Table 1). Another line of nets was added to each location during 1974-81 increasing the number of catch rate estimates from 8 to 12. In one instance an error in setting of the nets in October 1976 reduced the number to 2, although an overall mean was feasible for the sampling period.

Sampling with towed nets

During the 1960's and 1970's, larval surveys were made along the western coast of the Gulf of Maine, which included the coastal waters of Maine (Graham et al., 1972a). During autumn of 1971 and 1972, a large array of stations was sampled during four consecutive cruises providing relatively detailed distributions of the larvae (Graham et al.; 1973, 1972b). Such an array and consecutive cruises were not feasible in eastern Maine during 1980, when only a portion of the array of 1972 was sampled during a single cruise (Fig. 1). In 1981, a large portion of the array was sampled, but again, during a single cruise. Larvae were captured with metered 61 cm bongo nets having a mesh opening of .505 mm. The nets were towed at four knots (ca. 200 cm/sec.). At each station in the eastern coastal sector, two 7.5 minute oblique tows were stepped with 2.5 minutes near the surface, 10 m and 20m. During 1981, towing was similar to that of 1980, except that tows were stepped near the surface, 20 m and 40 m. Larvae were preserved in 5% formalin and later measured. The number measured did not exceed 100 in a given sample.

During the 1980 survey for larval herring, stations were sampled in the area of Frenchman Bay (Fig. 1). The tows were made to evaluate how representative the data were from the buoyed and anchored nets, set in Sullivan Harbor at the head of the bay, to that of the surrounding region. Such an evaluation was made previously for data from the Sheepscot estuary and the results were favorable (Graham et al., 1972a).

Aging with otoliths

During the autumn and winter of 1980-81 and 1981-82, samples from buoyed and anchored nets were placed on ice and brought to the laboratory where the larval herring were sorted from them. Usually, 10 larvae were removed from each net sample and frozen, but this number varied considerably with the size of the catch. The remaining larvae were preserved in 5% formalin for later measurement. Procedures for processing and reading the otoliths were those reported by Townsend and Graham (1981).

## Results

Larval catch rates during 1978-81 were especially low compared to those of previous years. Information from coastal cruises and aging of the larvae indicated that these low catch rates emanated from larvae hatched in the same area as in previous years and that they coincided with unusually high harvests in the adult fishery of Maine.

Inshore catch rates

Peaks in larval abundance are reached inshore within a few weeks after the herring eggs begin hatching during late August and early September along the Maine coast. Table 2 lists peak catches in the Sheepscot estuary for years 1964, 1966-69 and 1973-81, when sufficient data were available for determination. Figure 3 illustrates the considerable fluctuation in the size of peak catch rates. A Kruskal-Wallis test (Zar, 1974) suggested that the magnitudes of peak catch rates differed statistically ($x^2 = 58$, $P_{.01} = 26$). Examination of the differences, using Dunn's (1964) multiple comparison test demonstrated that the statistical difference was related to rates of the later years 1977-81 (Table 3). In 1977, the peak rate exceeded all others appreciably and was followed by an extreme low in 1978. Some recovery occurred in 1979, but in 1980, there was no autumn peak in relative abundance. Instead, the peak was reached in early December apparently by larvae hatched later than those that would have contributed to an autumn peak. In 1981, a new low occurred. In the years 1974-76 and 1978-81 the autumnal catch rates were reinforced by late spawning with hatching in November and December (Graham 1982; Townsend and Graham, 1981). These hatchings produced smaller, additional peak catch rates in winter, which were generally smaller than those in the autumn (Fig. 4). The rather large increase in catch rates of the 1980 year class in February was probably not related to late spawning (Graham and Joule, 1981) as indicated in the section on larval sources. When the peak catch rates were grouped chronologically and according to the presence or absence of late spawning, the series of low catch rates were not compatible statistically with the other groups (Table 3). Larvae of the Sullivan Harbor embayment exhibited a change in autumnal catch rates similar to that of larvae from the Sheepscot estuary, although only four years of data were available. Sampling was less frequent in 1973-74 than in 1980-81, but it was sufficient to indicate peaks in autumnal catch rates that were large compared to the 1980's when no larvae were captured in September, 1980 and only a few in 1981 (Fig. 5). In 1980, larval catch rates rose only slightly during October and November, reaching a low in the latter month. In 1981, the rates rose to a peak in November exceeding the values of the 1970's during that month and maintaining a relatively high level in December. Some late spawning was evident in 1974 from the presence of traces of recently hatched larvae in the embayment as late as December (Graham and Joule, 1981).

## Coastal catch rates

The absence of larvae during September, 1980 within Sullivan Harbor prompted an October cruise along the eastern coast to determine whether this area was still utilized appreciably by the herring as a spawning ground. The relatively high catch rates in the vicinity of Machias Bay and Cutler Harbor indicated that the area was still an important ground (Fig. 6). A comparison of the contours of catch rates along the coast in 1980 was made with 1 of 4 cruises completed in the autumn, 1972 (Graham, 1982). Both cruises occurred approximately one month after hatching began. Although sampling techniques differed between cruises, some agreement in relative larval distribution and abundance was apparent. These were: 1) recently hatched larvae (< 10 mm) were concentrated in the area off Machias Bay and Cutler Harbor, 2) fewer recently hatched larvae occurred west of Frenchman Bay, 3) larger larvae (10-15 mm) were distributed somewhat similarly to those recently hatched, but were more abundant in the offing of Penobscot Bay, and, 4) the largest larvae (> 15 mm) were relatively abundant near the entrances to coastal embayments and in the offing of Penobscot Bay. Essentially, the patterns of dispersal suggested by the isolines of catch rate were very similar for the two cruises conducted eight years apart.

During the October cruise of 1980, we also sampled larvae from the Frenchman Bay area (Fig. 1) to compare them with those captured in buoyed and anchored nets at the head of the bay in Sullivan Harbor (Fig. 2). The number per 100 $m^{-3}$ captured in the harbor (1.2) on 28 October was close to that estimated (1.0) for towed nets. It was slightly under the average rate for the entire bay area, which was 3.0, with extremes of .1 and 6.3 (N=519). The lengths of larvae from the harbor and bay area were compared by adjusting the former for growth that ensued between 21 October when the nets were set and 28 and 30 October when the bay area was sampled. Age data from larvae of Sullivan Harbor were not sufficient to determine the growth of individual cohorts so the growth rate of 2.1 mm per week, obtained from the Sheepscot River estuary (Townsend and Graham, 1981), was used to adjust the larval lengths. The addition of 3 mm for the ensuent 9-day period of growth produced an excellent agreement between the length frequency distributions of larvae from the harbor and bay area (Fig. 7) with a single modal length, 15 mm. However, the modal length of larvae east and west of Frenchman Bay along the coast was 18 mm, although the coastal and inshore frequency curves greatly overlapped. Whether the slightly larger modal length was related to faster growth or greater age could not be determined.

A second coastal cruise was pursued in the autumn (27 Oct.-6 Nov.), 1981 in central-western coastal water to ascertain the degree of larval hatching in that area. The results of this cruise were compared with those of the last of the 4 cruises conducted in 1972, although the latter occurred about one week later than the former (Fig. 8). As in eastern waters during 1980 (Fig. 6) some agreement was evident between data from the two cruises made 9 years apart (Fig. 8). Recently hatched larvae (< 10 mm) were present as traces off Casco and Saco Bays and, larger larvae (10-15 mm) were most abundant to the westward within the area surveyed. Disagreement between the results of the two cruises were also apparent. The larger larvae (10-15 mm) were concentrated near Boothbay in 1981 and near Saco Bay in 1972. However, this difference in areal concentration was probably related to the interaction of the timing of inshore larval migration and the cruise rather than to any major change in distribution. An earlier cruise (18-22 Oct.) in 1972 revealed larger larvae concentrated in both areas (Graham, 1982). The largest larvae concentrated at the offing of Frenchman and Penobscot Bays during both years, but there were no concentrations of larvae west of Penobscot Bay in 1980.

## Larval sources

Data collected from coastal larval distributions in 1972 (Graham, 1982) showed that three hatching areas were present along the coast. These were; in eastern Maine 1) the area off Machias Bay and Cutler Harbor, and in central-western Maine, the areas off 2) Boothbay and 3) Saco Bay (Fig. 1). The inshore movement of larvae from these coastal spawning areas was documented by an examination of changes in their distributions with time (Graham, 1982; Graham et al., 1972a). Hatching began earlier over the egg beds in eastern Maine (late August to early September) than in central-western Maine (mid to late September)and larvae from eastern Maine appeared to move westward with the coastal currents, mixing with larvae from western Maine. Larvae which hatched off Boothbay and Saco Bay moved shoreward apparently through a complexity of currents. Further confirmation of the mixing of larval cohorts from eastern Maine with those from western Maine was possible in 1980 through the determination of larval birthdates from enumeration of growth increments in their otoliths (Townsend and Graham, 1981). These increments or rings, as they appeared in the otolith, were assumed to be deposited daily and to be initiated about 5 days after hatching.

Aging larvae of the 1980 year class revealed that initial increment or ring formation in the otolith occurred throughout the period from 18 August to 13 December with larval cohorts generated either by hatching pulses or differential mortality over this extended period. In Sullivan Harbor, one cohort was evident in mid September from samples collected on 8 October and another in early October from collections on 21 October. A remnant of the first cohort was apparent on the latter date. Only a few larvae were available for aging in November and December. In the Sheepscot estuary, initial ring formation occurred from late August to early October as indicated by October sampling. A cohort was present in early October according to November sampling and December and January samplings revealed cohorts in early November and late November respectively. Most of the otoliths collected from larvae, in February were unusable for various reasons and the ages of the larvae forming the increase in larval catch rate on 24 February (Fig. 4) were not obtained. The few otoliths read on that date suggest that the larvae comprised the cohorts remaining from early October to late November. One explanation for the increased catch rate in late February (Fig. 4) is that larvae overwintering in the Boothbay coastal area began their spring aggregation and movement into the estuary earlier than usual. Usually, this event occurs in early March (Graham et al., 1972a; Graham and Joule, 1981).

These data from eastern and western Maine are summarized in Figure 9 (right panel) where the two cohorts of Sullivan Harbor and perhaps as many as five from the estuary are apparent. The group of larvae from the estuary with initial ring formation in November and December would be considered the product of late spawning (Graham, 1982). The presence of larvae which formed their first ring in August and early September both from Sullivan Harbor and the Sheepscot estuary suggest that those in the estuary hatched along the east coast and drifted westward within the prevailing currents, since larvae usually do not hatch that early in western Maine (Graham et al., 1972a). The similarity in frequency between the cohorts in early October from the two areas is also evidence of this drift. There was no comparison of the November cohorts between areas because the numbers of larvae were few in Sullivan Harbor in December (Fig. 4) and sampling in the harbor during January was not feasible.

Preliminary data from samples of the 1981 year class display a broad range in initial ring formation, from August to January (Fig. 10). Dates of ring formation in February from the Sheepscot estuary include almost all of those evident in previous months of sampling. Individual cohorts are not apparent in the monthly data, perhaps because of the few larvae examined. However, a summary of the data in Figure 10 shows two cohorts, one in September and a second in October. The proportionately few records of ring formation in November and later supports the catch data in Figure 4, which suggests that late spawning was considerably reduced in 1981 as compared to 1980.

The data from Sullivan Harbor were too few to indicate cohorts of larvae. However, groupings of ring formation data were similar to those of 1980 and covered approximately the same range in date of initial ring formation.

Coastal harvests

The present coastal fishery for juvenile herring (ages 1-3) in the Gulf of Maine began in the late 1800's; that for the adult herring (age 4+) was a more recent development. During the 1950's, harvests of juveniles varied from 34,411 MT to 90,557 MT, but in the 1960's, the harvest declined reaching a low of 6,478 MT by 1971. During the past 9 years, the annual harvest fluctuated between 12,785 MT and 37,351 MT (Table 4). Anthony and Waring (1980) reported that the fishery for adult herring in the Gulf of Maine began with a catch of 7,000 MT in 1967 and then rose sharply to average 38,500 MT from 1969 to 1972, as the accumulated stock was harvested. Harvests then declined and averaged 18,700 MT from 1972 to 1977. The primary site of the fishery for adult herring in the Gulf of Maine was in the area of Jeffrey's Ledge (Fig. 1).

The harvest along the Maine coast did not show a dramatic increase in the 1970's. Harvests varied from 679 in 1973 to 9,306 MT 1980 (Table 4). The harvest in 1978 was especially unusual because the largest contributor to the harvest was the 1970 year class at age 8. During the 1970's, most harvests were largely composed of fish 4 and 5 years old. The contibution of the 1970 year class is underlined in Table 4 and its percent yield to harvests and age groups from 1970-78 is given. The relative yield was always appreciable, especially at age 8. During the 9 years of fishing, the 1970 year class supplied almost 30% of the total harvest of herring from ages 4 through 8. Anthony and Waring (1980) offered an explanation for the late abundance of the 1970 year class, indicated by the harvests. Fishermen reported that this year class tended to remain offshore as juveniles and was not available to their fixed inshore gear (stop seines and weirs). Obviously, these herring became especially availably in 1978 to the mobile gear (purse seines) resulting in a relatively large harvest in the adult fishery. The large harvest of the 1970 year class at age 8, as well as other year classes, coincided with the initial reduction in larval production shown in Figures 3 and 4. Some recovery occurred in 1979 when the harvest was considerably reduced. The large harvests of 1980 and 1981 coincided with severe reductions in larval production indicated by the larval catch rates from Sullivan Harbor and the Sheepscot estuary, respectively.

It cannot presently be determined whether the location of the adult harvest along the coast affects larval production in specific areas. In 1978, over 80% of the adult harvest was obtained from the Boothbay area near the Sheepscot estuary. In the next three years the percentage in this area dropped from 11% to 0, and from 55-70% was from the eastern area near Machias Bay with the remainder primarily from the vicinity of Penobscot Bay (Fig. 1).

## Discussion

Observations on animals suffering extinction suggest that for a given species, there is a minimum viable population that can exist under average environmental conditions, but which may succumb to calamities from various environmental perturbations (Shaffer, 1981). When fishing mortality is one of these perturbations, a population may not become extinct, but it may still be reduced to a size at which commercial fishing is no longer economically sound. An example of such a population is that of the herring on Georges Bank in the northwestern North Atlantic (Anthony and Waring, 1980).

Reaching a minimum viable population along the Maine coast would involve some complexities within the population dynamics of the herring. There is little relationship between the number of spawning adults and recruitment to the juvenile fishery. Recruitment in the 1970's was equivalent to that of the 1960's when spawning populations were relatively large. Recent evidence suggests that recruitment is often a function of larval survival rather than the abundance of spawning populations (Graham, 1982). Ideally, at some lower abundance continued reduction of the spawning populations leads to a proportional decline in recruitment. However, a minimum viable population of adults could be restored to a higher level through appreciable larval survival and subsequent recruitment.

Larval herring data from inshore sampling areas (Figs. 3-5) and coastal cruises (Figs. 6 and 8) suggested that larval production was low after 1977. The concurrence of large harvests (Table 4) with low larval production indicated a direct relation between the size of the spawning populations and the production of larvae and these populations were either near or below their minimum size. If so, the minimum was not necessarily reached simultaneously by the various spawning groups from the persistent spawning grounds along the coast.

Data from the Sheepscot River estuary and the Sullivan Harbor embayment suggested that during the years of low larval production (1978-81), the contributions of larvae from the eastern and Boothbay spawning areas were not similar from year to year. The 1974 year class had a large December peak catch rate in the Sheepscot estuary (Fig. 4) which was not evident in the eastern embayment (Fig. 5). In 1980, catch rates in Sullivan Harbor were consistently low while those in the estuary showed considerable recovery by December. This situation was reversed for the two sampling areas in 1981. Of special note was the scarcity of recently hatched larvae in late November, 1981, along the coast and its similarity to the larval distribution of 1972 (Fig. 8), when late spawning did not occur. Although some late spawning was indicated for larvae from the estuary (Fig. 10), their numbers were few; and possibly some originated from the spawning beds of eastern Maine and drifted westward to the estuary.

Collectively, low larval production and no late spawning might lead to a recruitment failure from herring spawning in one part of the coast, but not necessarily in another. According to Iles and Sinclair, this could occur by fishing on concentrations of spawning adults from several spawning grounds within the retention area of their larvae. They suggested that to prevent such an occurrence, management could be based on the weakest spawning group from a given ground. Another approach would be to discriminate among the spawning populations which could lead to management based on spawning groups rather than on larger management units. To this end, Maine scientists will continue coastal cruises and inshore monitoring of larval abundance and a study of the biology of the adult herring (D. Stevenson, personal communication). Priority for this research has been given to the eastern spawning ground, because the westward drift of larvae from this ground and their wide dispersal inshore may be an important element in the success of the coastal fishery (Graham, 1982). This research will be in cooperation with

Canadian scientists, with the concord of the U.S. National Marine Fisheries Service, because of juxtaposition of the Maine and New Brunswick fisheries.

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Table 1. Number and location of samples obtained in buoyed and anchored nets from the Sheepscot River estuary and Sullivan Harbor embayment.

| Area | Depth m | Seaward | Landward | Flats | Total |
|---|---|---|---|---|---|
| Sheepscot Estuary | Shallow 0-10 | 4-6 | 4-6 | - | 8-12 |
| | Deep 15-20 | 4-6 | 4-6 | - | 8-12 |
| Total samples | | 8-12 | 8-12 | - | 16-24 |
| Sullivan Harbor | Shallow 0-3 | 4 | 4 | 2 | 10 |
| | Deep 14-20 | 4 | 4 | 2 | 10 |
| Total samples | | 8 | 8 | 4 | 20 |

Table 2: Summary of peak catch rates of larval herring from the Sheepscot River estuary.

| Year Class | Date of Peak | No. of Larvae | No. per 100 $m^{-3}$ |
|---|---|---|---|
| 1964 | 22 Oct. | 2057 | 16.15 |
| 1966 | 21 Nov. | 3056 | 17.30 |
| 1967 | 8 Nov. | 3829 | 19.71 |
| 1968 | 29 Oct. | 4387 | 55.27 |
| 1969 | 23 Oct. | 3679 | 20.28 |
| 1973 | 8 Nov. | 5068 | 23.11 |
| 1974 | 30 Oct. | 3997 | 18.63 |
| 1975 | 6 Nov. | 9194 | 32.50 |
| 1976 | 18 Oct. | 2234 | 14.00 |
| 1977 | 20 Oct. | 32645 | 79.38 |
| 1978 | 16 Nov. | 1133 | 3.81 |
| 1979 | 8 Nov. | 3148 | 9.56 |
| 1980 | 11 Dec. | 2251 | 8.56 |
| 1981 | 19 Oct. | 590 | 2.84 |

Table 3. Dunn's multiple comparison test on the mean ranks of peak catch rates obtained from 14 years of sampling in the Sheepscot River estuary. Tests were made on individual and grouped year classes. ___ indicates no significant difference at the 5% probability level.

Year Classes

| 1981 | 1978 | 1980 | 1979 | 1966 | 1973 | 1967 | 1968 | 1969 | 1974 | 1976 | 1975 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24.0 | 27.8 | 46.7 | 47.8 | 60.0 | 60.6 | 61.0 | 61.9 | 65.9 | 66.8 | 70.0 | 93.2 | 110.8 |

| | Grouped Year Classes | Mean Ranks |
|---|---|---|
| Late spawning | 1978-81 | 37.2 |
| No late spawning | 1966-73 | 61.9 |
| Late spawning | 1974-76 | 79.2 |
| No late spawning | 1977 | 110.8 |

Table 4. Harvests in metric tons of juvenile and adult herring at age along the coast of Maine, 1970-80. Harvests of the 1970 year class (Y.C.) are underlined and their percent contributions to the harvests at age are given for fishery years 1970-78.

JUVENILES

| Fishery Year | Age (Years) 1 | 2 | 3 | Total |
|---|---|---|---|---|
| 1970 | 294 | 6258 | 4422 | 10974 |
| 1971 | 1909 | 2838 | 1731 | 6478 |
| 1972 | 3 | 17360 | 833 | 18196 |
| 1973 | 164 | 8100 | 7456 | 15720 |
| 1974 | 486 | 9074 | 5489 | 15049 |
| 1975 | 796 | 9451 | 2538 | 12785 |
| 1976 | 478 | 13228 | 12740 | 26446 |
| 1977 | 1316 | 18541 | 8022 | 27879 |
| 1978 | 242 | 12398 | 8025 | 20665 |
| 1979 | 27 | 25839 | 11485 | 37351 |
| 1980 | 1012 | 9051 | 26538 | 36601 |
| 1981 | 120 | 39575 | 1627 | 41322 |
| % Y.C. | 33.6 | 17.8 | 14.5 | 17.3 |

ADULTS

| Fishery Year | Age (Years) 4 | 5 | 6 | 7 | 8 | 8+ | Total |
|---|---|---|---|---|---|---|---|
| 1970 | 2673 | 513 | 726 | 294 | 265 | 118 | 4589 |
| 1971 | 3388 | 1793 | 409 | 127 | 126 | 86 | 5929 |
| 1972 | 492 | 242 | 318 | 264 | - | - | 1316 |
| 1973 | 193 | 164 | 80 | 121 | 55 | 66 | 679 |
| 1974 | 3780 | 230 | 75 | 9 | - | - | 4094 |
| 1975 | 924 | 1249 | 96 | 8 | 120 | - | 2397 |
| 1976 | 1203 | 1122 | 1390 | 11 | 6 | 16 | 3748 |
| 1977 | 2161 | 535 | 381 | 1358 | 3 | 40 | 4478 |
| 1978 | 1816 | 2969 | 388 | 739 | 3055 | 210 | 9177 |
| 1979 | 1708 | 191 | 329 | 196 | 104 | 179 | 2707 |
| 1980 | 8606 | 442 | 24 | 101 | - | 133 | 9306 |
| 1981 | 2586 | 3815 | 366 | 20 | 20 | 120 | 6927 |
| % Y.C. | 22.7 | 14.1 | 35.9 | 46.3 | 84.2 | | 29.9 (Ages 4-8) |

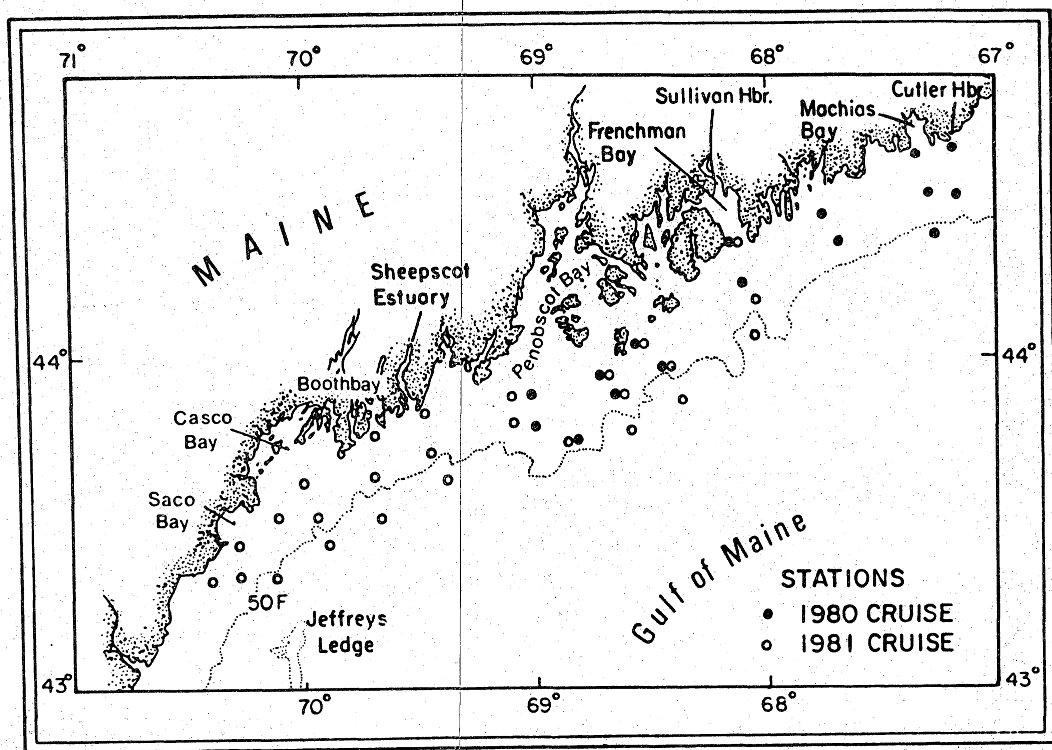
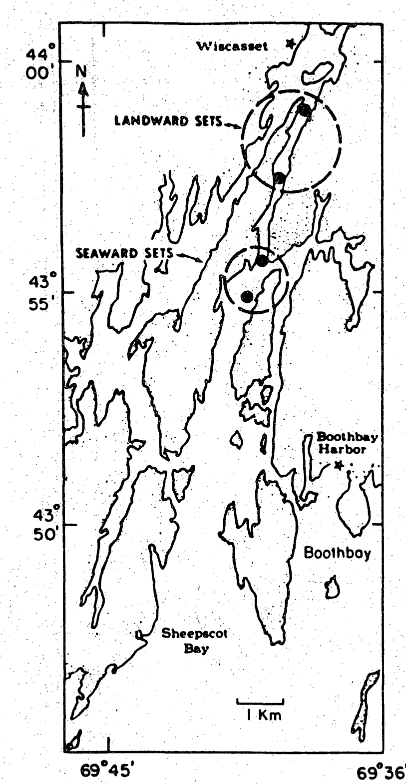



Figure 1. The coastal Maine region showing station positions for 1980-81 larval herring surveys and the locations of sampling areas, the Sheepscot River estuary and Sullivan Harbor embayment.



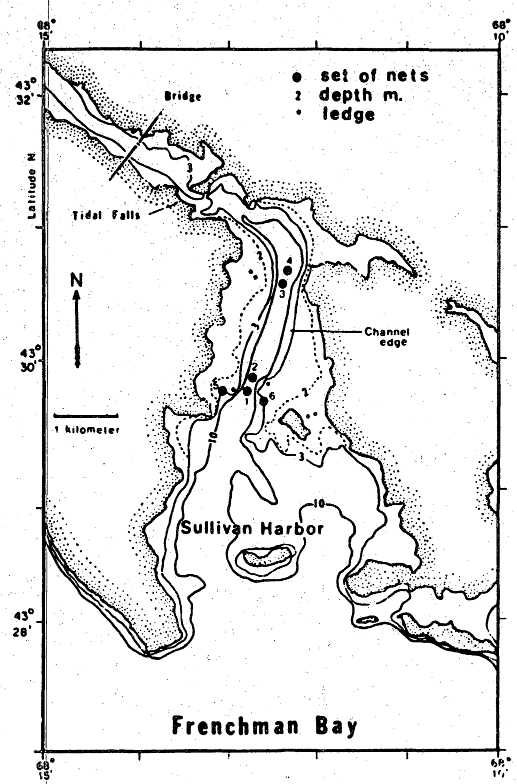




Figure 2. Station locations of buoyed and anchored nets in the Sheepscot River estuary and the Sullivan Harbor embayment.

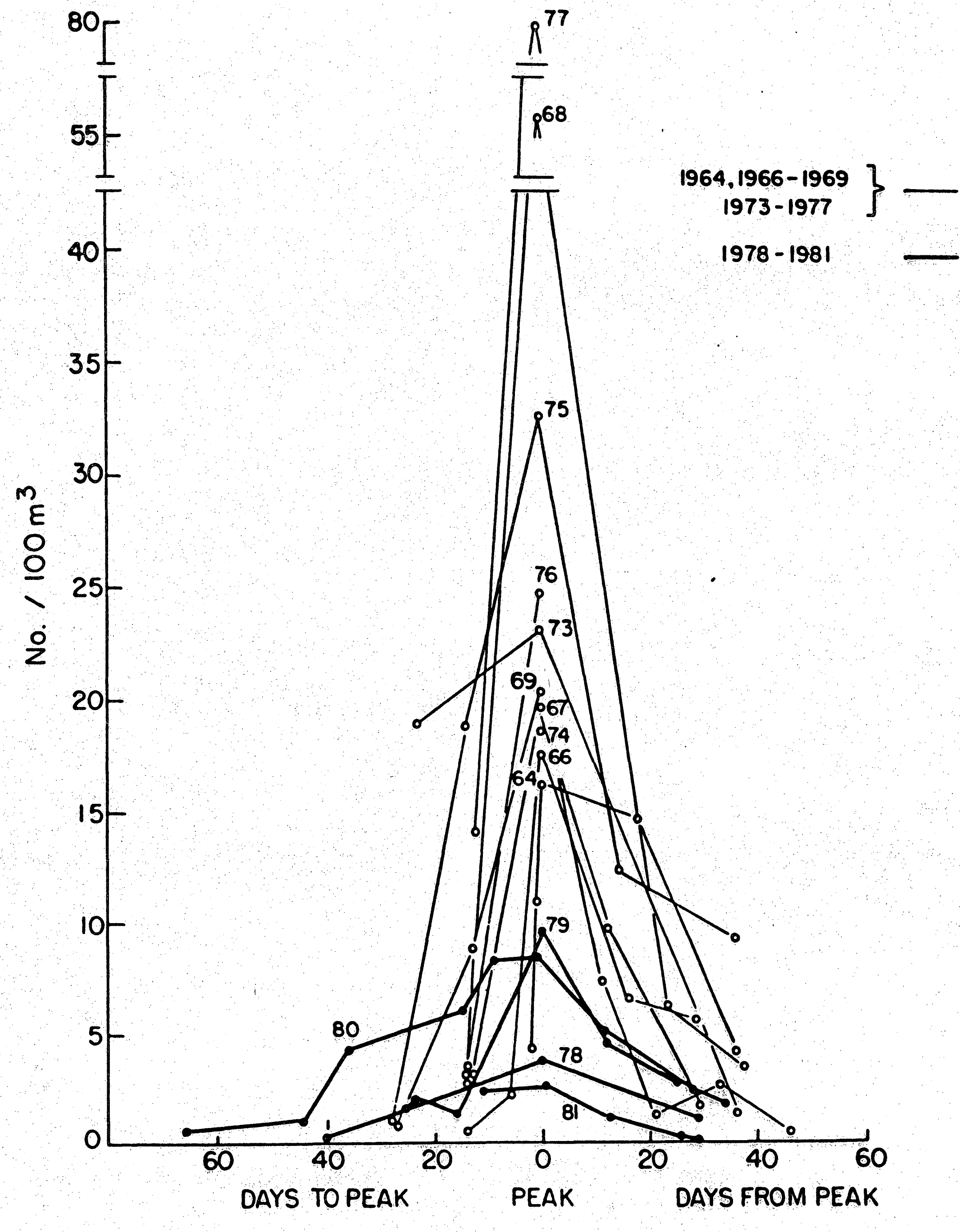



Figure 3. Peak larval catch rates from the Sheepscot River estuary. For comparison, the date of each peak catch rate is set at zero, and rates preceding and subsequent to each peak are plotted in days. The date of each peak catch rate is given in Table 2.

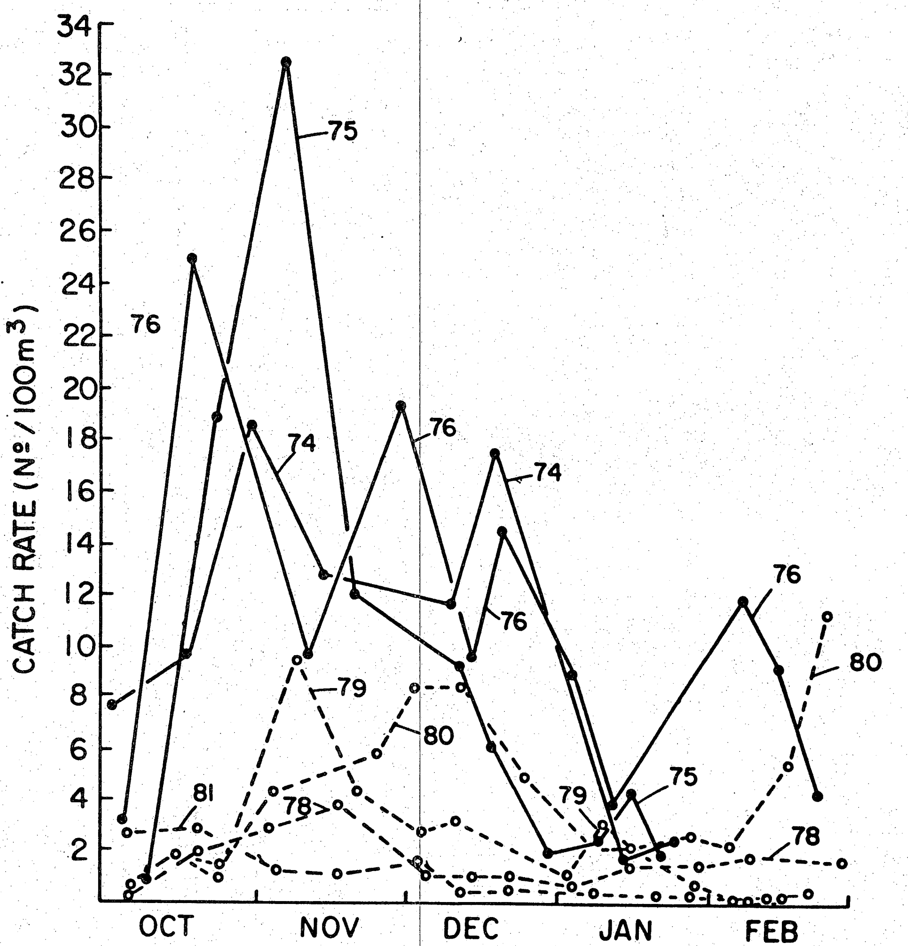



Figure 4. Larval catch rates during the autumn and winter in the Sheepscot River estuary when late spawning (November) occurred. Dashed lines indicate years of relatively low larval production.

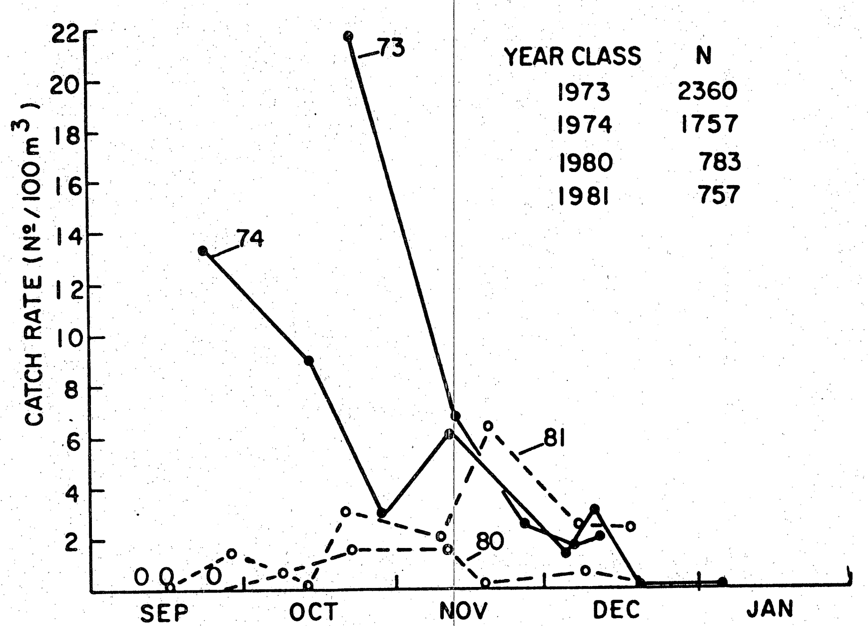



Figure 5. Catch rates of larval herring in the Sullivan Harbor embayment during the autumn and winter of the 1970's (solid line) and the 1980's (dashed line).

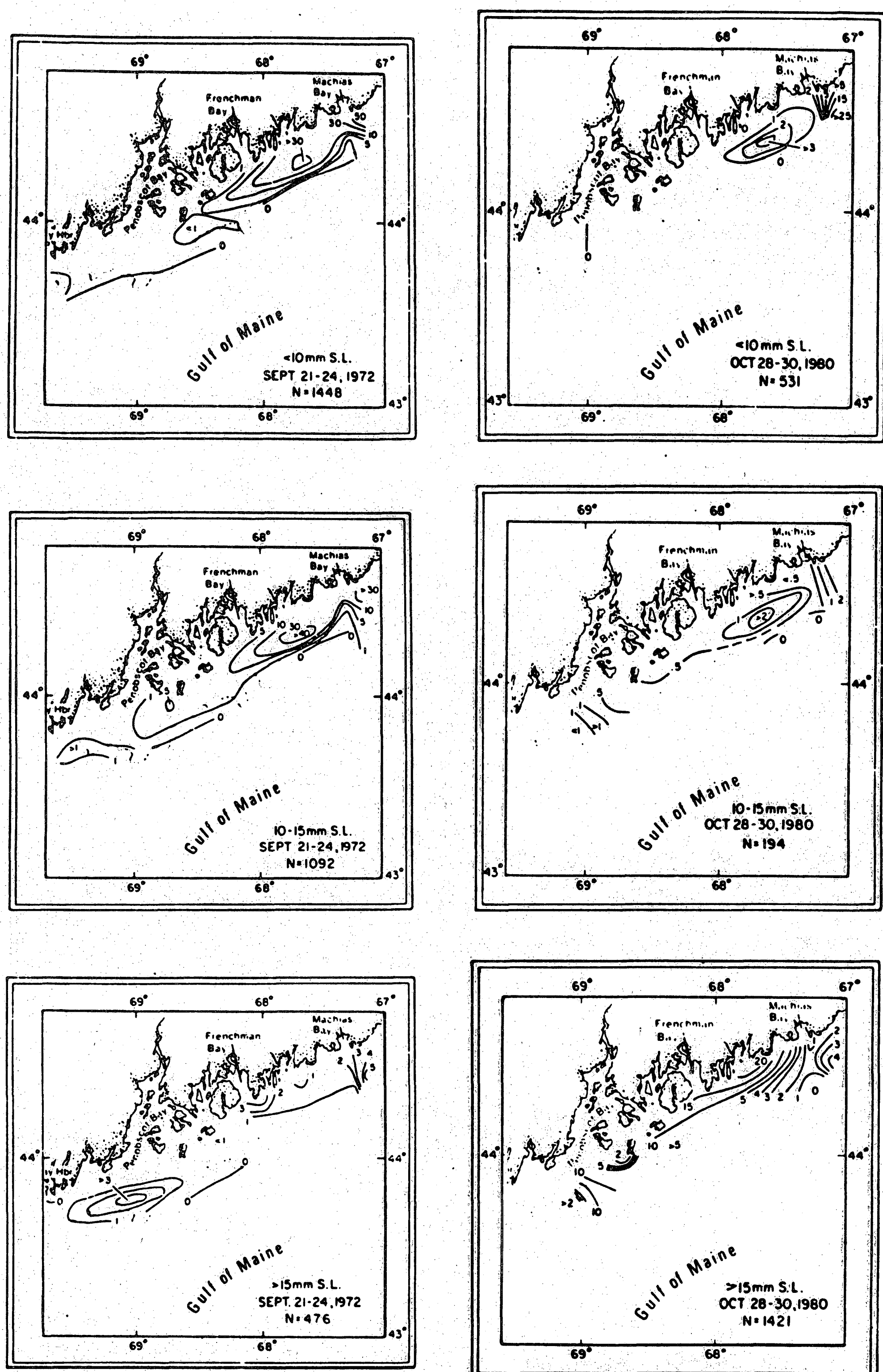



Figure 6. Contoured distributions of larvae along the Maine coast during cruises in eastern Maine. (The values for 1972 represent the numbers of larvae under a $m^{-2}$ of sea surface; those for 1980, per $m^{-3}$.)

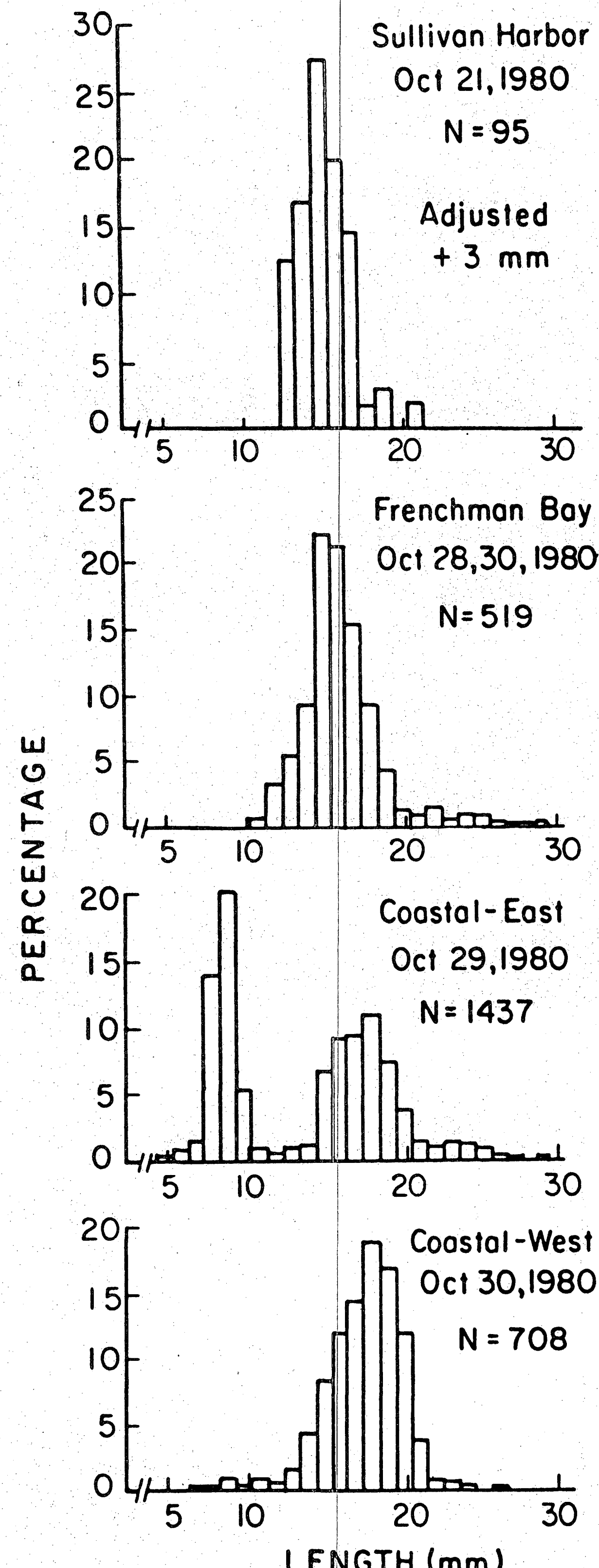



Figure 7. Length frequencies of larval herring captured during October, 1980 in Sullivan Harbor with buoyed and anchored nets, Frenchman Bay and the coastal area with towed nets. Coastal data are grouped east and west of Frenchman Bay. Sullivan Harbor data are adjusted for larval growth between October 21 and 28 as described in the test.

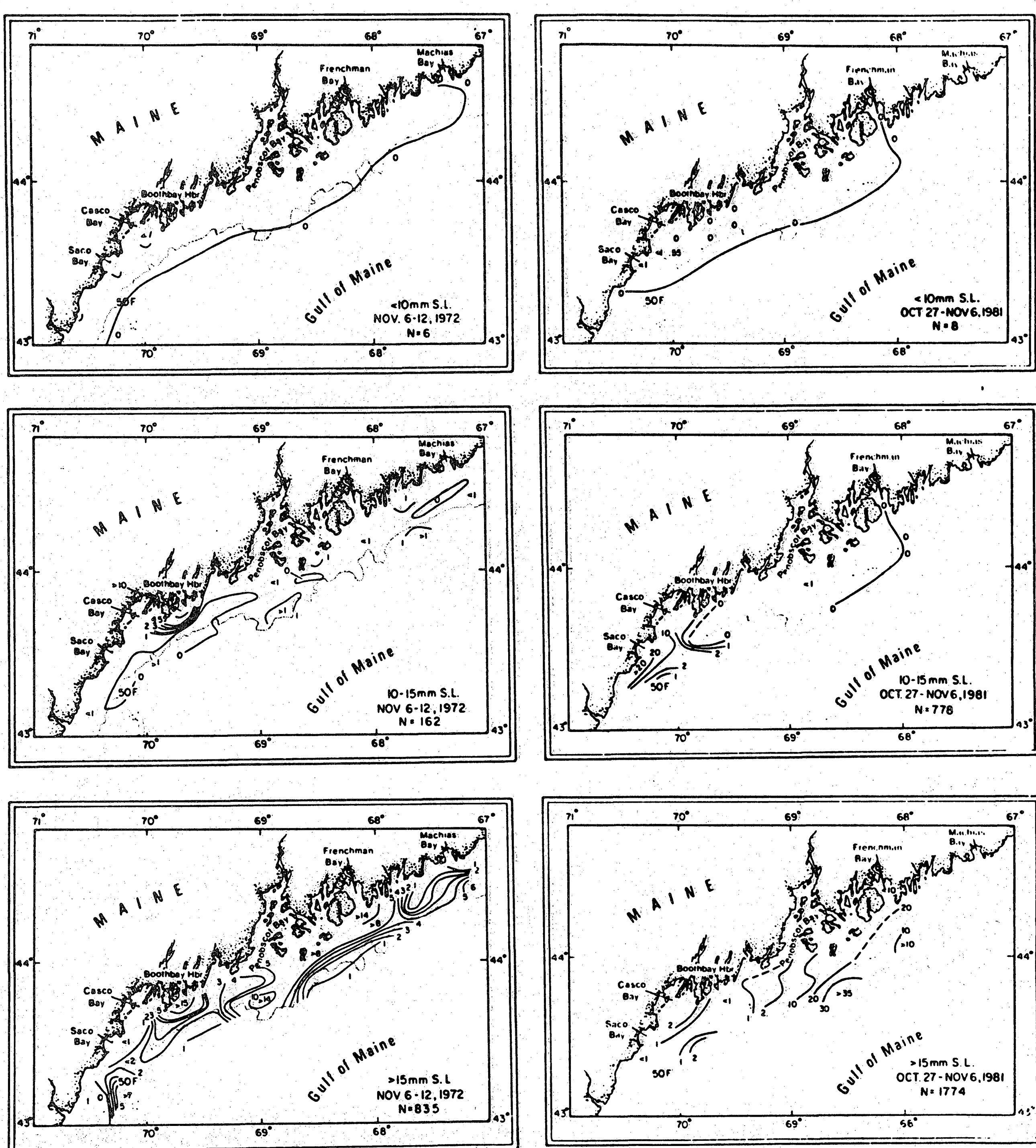



Figure 8. Contoured distributions of larvae along the Maine coast during cruises in central-western Maine. (The values for 1972 represent the numbers of larvae under a $m^{-2}$ of sea surface; those for 1981, per $m^{-3}$.)

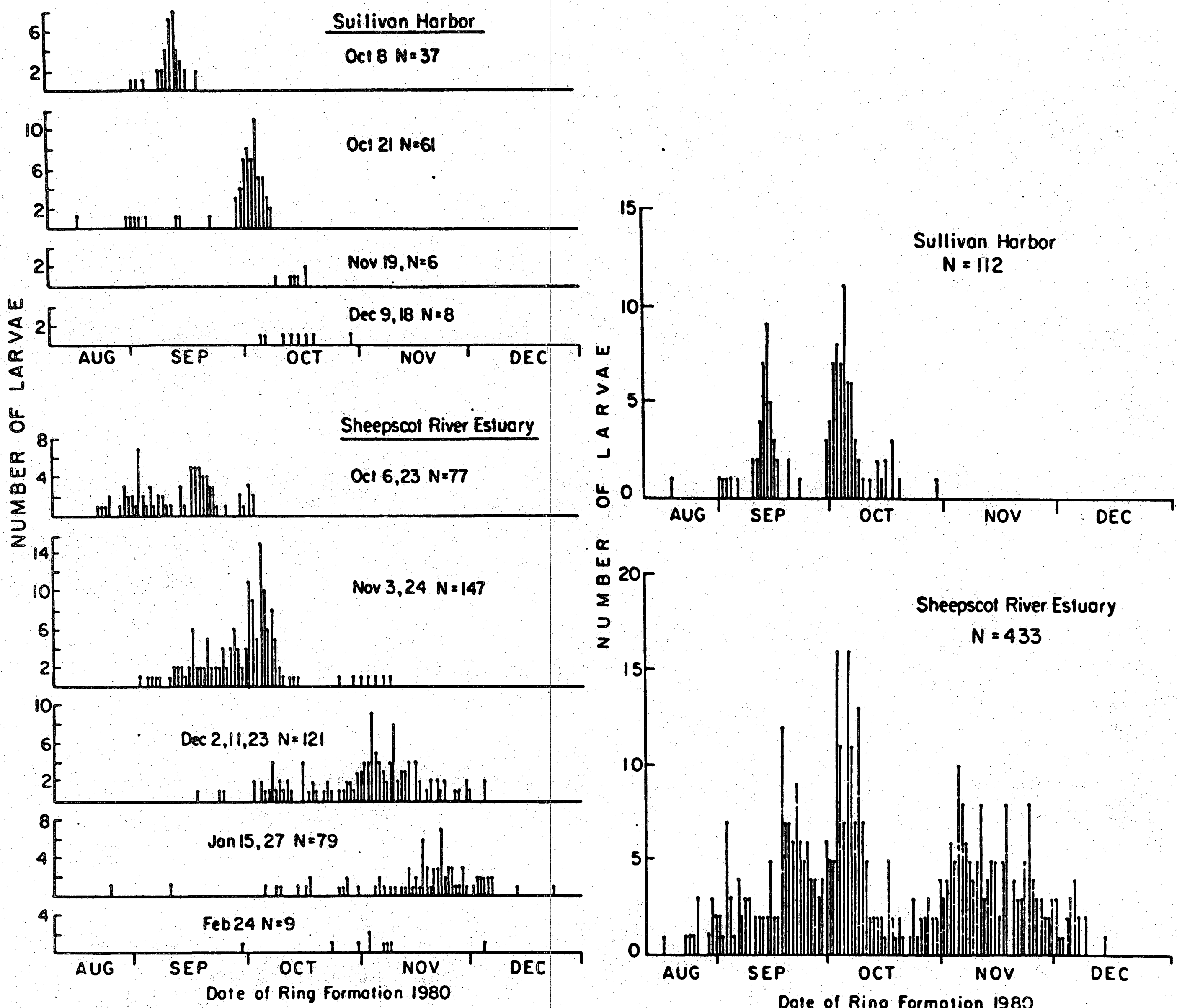



Figure 9. (Left Panel) Dates of initial ring or increment formation in otoliths of larval herring from Sullivan Harbor and the Sheepscot River estuary. (Right Panel) Summary of ring formation data.

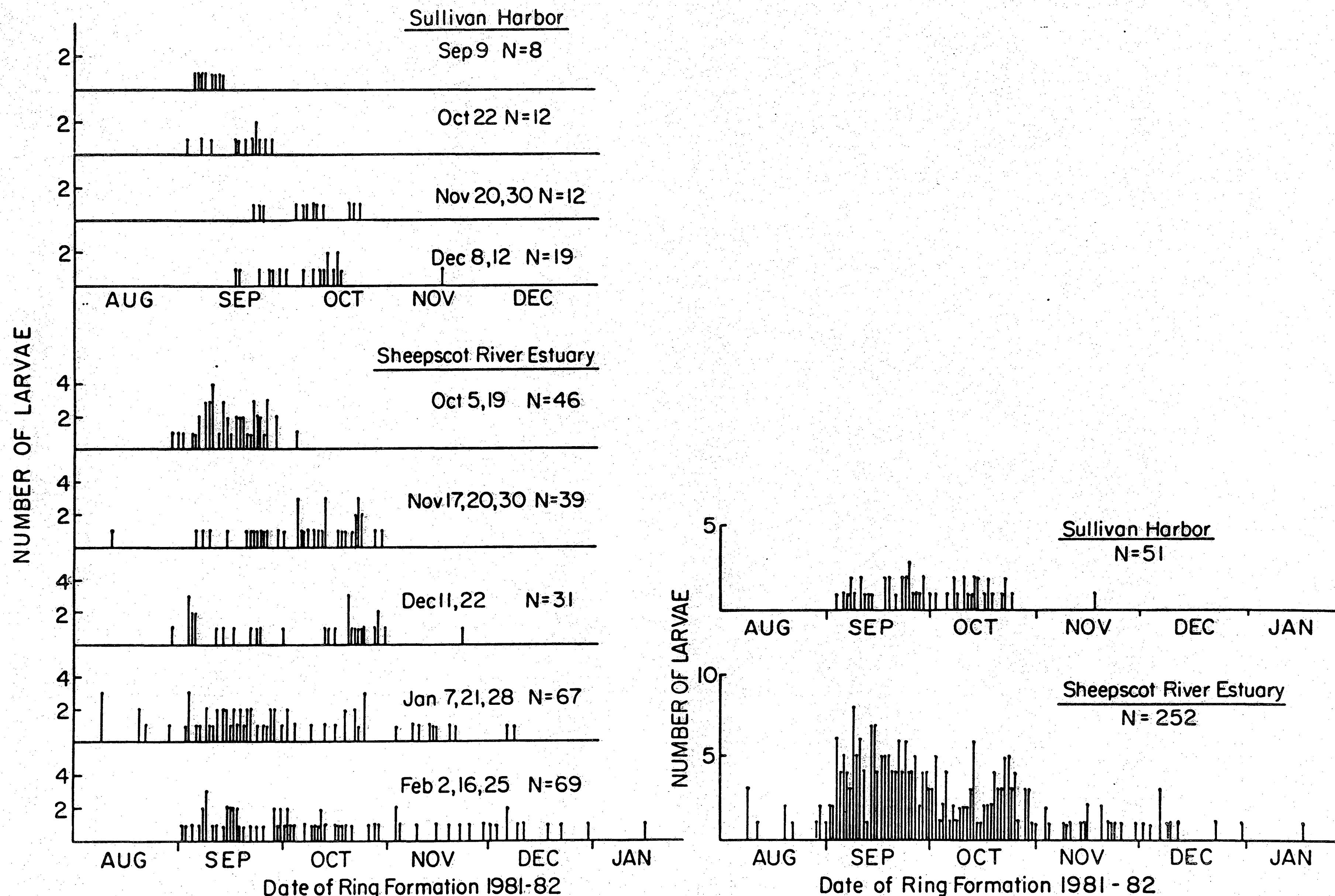



Figure 10. Dates of initial ring or increment formation in otoliths of larval herring from the Sheepscot River estuary during winter months, 1981-82.