RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 2575
(D.c.9)

ICNAF Res.Doc.71/98

ANNUAL MEETING - JUNE 1971

The retention inside the Bay of Fundy of herring larvae spawned off the southwest coast of Nova Scotia

by T. D. Iles

Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

Introduction

The seasonal distribution of larval herring in relation to the physical and biological environment in the Bay of Fundy-Gulf of Maine region for the years 1967 to 1969 as shown by cruises at three month intervals has been described by Tibbo and Lauzier (1970). Three additional short cruises at approximately fortnightly intervals were carried out in the fall of 1969 to follow in more detail the dispersal of larvae from spawning grounds off the S.W. Nova Scotia coast, this being one of the major sources of larvae in the region (Tibbo et al. 1958). The area studied is now the scene of a large fishery for pre-spawning and spawning adults (Iles and Tibbo 1970) but the extent to which the stock contributes to the juvenile fisheries for herring in the Bay of Fundy and Gulf of Maine is not known with certainty and more detailed knowledge of larval movement from the spawning area was thought likely to make a contribution towards the solution of this problem.

Methods

The cruises were undertaken from the St. Andrews Biological Station of the Fisheries Research Board of Canada on M.V. E.E. Prince during the periods October 7-10, October 28-30 and November 14-17. The two October cruises covered the entrance to the Bay of Fundy and an area off the Nova Scotia coast north of latitude 44°32'; the November cruise surveyed the southern side of the entrance and much of the Bay of Fundy itself.

As far as possible sampling was based on a rectangular grid, station distances varying with circumstances from about five to about ten miles. An Isaacs-Kidd 2m trawl (1.6 mm cod-end mesh) was towed at 5 knots and most of the water column was sampled.

A telemetering device on the trawl allowed the calibration of gear depth to warp length so as to estimate the lee-way required to avoid bottom contact. About 5 m was allowed in shallow water and a little more than 10 m for deeper water.

It was assumed that the water column above these depths was adequately sampled. The gear was lowered rapidly to the maximum depth of the tow and hauled step-wise during the 30 minute towing period to approximate an oblique tow.

Bathythermograph records were taken at each station and surface temperatures and salinities measured.

Plankton samples were sorted and analysed at the St. Andrews laboratory. Fish larvae were identified and counted and total lengths of herring larvae were measured on the whole of small samples and on at least 100 of larger samples. Estimates of numbers of invertebrates in broad systematic categories were made for each station.

Larval escapement from gear

The high towing speed was designed to reduce larval avoidance of gear to a minimum. Such avoidance is usually demonstrated by markedly increased catches at night compared with day-time catches, (Bridger 1956). Table 1 lists day and night catches (numbers per tow) for each of the three cruises and for all taken together. There were no systematic differences that cannot be easily explained on the basis of differences in larval abundance in areas sampled at day and at night time.

TABLE 1. Comparison of day and night catches of herring larvae

		DAY		NIGHT		
Cruise		Tows	Average No/Tow	Tows	Average No/Tow	Total Number of Larvae
October	7-10	28	465	22	283	19,242
	27-30	30	126	16	468	10,318
November	14-17	18	191	10	282	6,307
All cruises together		76	266	48	324	35,867

That larval escapement was certainly reduced for the Isaccs-Kidd trawl is indicated by comparison of catches made at the same day-time station by a 1 m (60 mesh/inch) net hauled vertically (and thus more slowly) and the Isaccs-Kidd trawl hauled at 5 knots. Only larvae less than 14 mm total length were caught in the 1 m net whereas a full size range up to 26+mm was caught in the Isaccs-Kidd.

Herring larvae develop considerable short-burst swimming power at 15 mm as the caudal fin develops (Blaxter 1962).

Results

Larval distribution and abundance

Larval numbers were plotted for each station and contour lines drawn at different levels of abundance to give results shown in Figures 1-3 for the three cruises separately.

The results for the first cruise showed two areas of concentration of larvae, a small one at the south-west end of the Grand Manan Channel and a much larger and more dense one off the south-west coast of Nova Scotia which blankets the known spawning grounds of the Nova Scotia fall spawners (Tibbo et al. 1958, Das 1968). Within this area the highest concentrations occurred a few miles to the northwest of Trinity Ledge and a similar distance from Lurcher Shoal.

The westerly and southerly limits of this larval concentration were clearly delimited; if, as is thought likely, the main spawnings occur on Trinity Ledges and Lurcher Shoals then there was a general dispersion from this area but movement out of the area was restricted to the north and east; towards St. Mary's Bay and, on the outside of this bay, along the north shore of Digby Neck into the Bay of Fundy proper. There is little evidence of larval movement across the entrance of the Bay of Fundy towards Grand Manan, nor on the northern side, of larvae moving out of the bay along the New Brunswick coast towards the Grand Manan channel. It should be noticed that relatively few larvae were found at the head of St. Mary's Bay itself.

By the end of October larval numbers had declined sharply (Fig. 2) both because of mortality and movement out of the area, but it is not possible to estimate the effect of each of these separately. The areas of high concentration had contracted, and the one immediately off the Nova Scotia coast had split up into northerly and southerly components. The reduction in larval numbers was much more marked in the Lurcher Shoals area and the western section of the survey area. An overall increase in density at the head of St. Mary's Bay towards its north side was indicated however, suggesting a net accumulation of larvae there.

Again there was little sign of transport across the entrance of the Bay of Fundy and the concentration of larvae at the southwest entrance to the Grand Manan channel was still evident and had moved only a very short distance.

The November cruise, extending into the Bay of Fundy, completed the pattern suggested by the two earlier cruises. The path of transport of larvae along the northern shore of Digby neck could be seen as confluent with a large area of concentration centered at a point 15 miles south-west of Saint John and extending northwards and eastwards, up to Chignecto Bay and Minas Basin. (Fig. 3) Densities were relatively high, implying an accumulation and retention of larvae in the area. There was also indication of a more even spatial dispersal of larvae in this area which is demonstrated in Figure 4. This compares, for the three cruises, the frequency distribution of numbers of larvae/tow, divided into conveniently grouped cells. A higher proportion of the tows for the November cruise has high numbers of larvae and the frequency distribution was less asymmetric than for the two October cruises.

The westward limit of distribution was a little west of Saint John; no larvae were recorded west of Point Lepreau, so that again, there was no indication of transport of larvae out of the Bay of Fundy along the northern side.

Larval length distributions

Inspection of length-frequency distributions of larvae from individual tows for the first October cruise indicated size differences between areas. Five areas were separated; around Grand Manan, the southern part of the area off the southwest Nova Scotia coast, the entrance to St. Mary's Bay, the southern entrance to the Bay of Fundy and lastly, the head of St. Mary's Bay, i.e. above the passages connecting the bay to the Bay of Fundy. Similar area differences were found for the results of the second October cruise and data for both cruises are presented for each area in Fig. 5.

The smallest larvae were found near the entrance to St. Mary's Bay, i.e. near Trinity Ledges; most were below 13 mm total length at the beginning of October and represent, probably, the products of a recent spawning in the vicinity. Larvae to the south and west of St. Mary's Bay were larger and those nearer the entrance to the Bay of Fundy and around Digby neck larger still. Considering these three groups together there was a suggestion, at least, of three modes each, possibly, representing larvae spawned at different times during the season. For the first October cruise larvae at the head of St. Mary's Bay were distinctly larger than those at the mouth; very few were smaller than 15 mm total length.

Finally larvae in the Grand Manan area were larger on average than in the other areas and showed a much wider range of size, from 11 mm to 34 mm total length.

By the end of October larvae in each of the areas were larger, although only marginally so for those at the head of St. Mary's Bay. The differences in average size for the other areas varied from about 3 mm to about 7 mm which is consistent with larval growth rates given by Tibbo et al (1958) and Das (1968) for larvae from the same general region. The shape of the frequency distributions had also changed in that they were skewed more towards the larger fish. This could have been the effect of differential mortality for length during the period between the two cruises, the larger larvae having a higher survival rate. This would be expected if competition for food occurred at this stage of the life history.

There was no indication of an influx of smaller larvae in any area so that it is highly improbable that any new spawning had occurred.

The length distribution for the November cruise had a wide range, from about 10 mm to about 40 mm and had also a more even spread of length (Fig. 5); this is consistent with the hypothesis that these larvae represented accumulation of larvae transported into the Bay from Nova Scotia spawnings over the spawning season as a whole, or over a large part of it.

Discussion

Evidence has been steadily accumulating that larvae from fall spawnings off the south west Nova Scotia coast are transported northwards and thence northeast along the southern side of the Bay of Fundy along a non-tidal inflow associated with the Gulf of Maine eddy (Tibbo et al. 1958, Tibbo and Legaré 1960, Das 1968, Tibbo and Lauzier 1970).

This study demonstrates such a transport and indicates that the path of transport might be quite narrow (Fig. 2). However, a corresponding transport out of the bay along the northern New Brunswick side, which would be associated with the same current system (Tibbo and Lauzier 1970) is not indicated by these results. Instead there is evidence, both from the distribution and abundance of larvae and from length frequency distributions, that larvae transported into the bay on the southern side are retained in the shallow areas of the upper part of the bay. This could be the result of a slackening off of the current system which begins in the fall (Bumpus and Lauzier 1965), and results in almost a closed circulation within the Bay of Fundy during the winter. It is now suggested that larvae retention inside the Bay of Fundy may involve larval behavioural and activity patterns of the kind described by Graham (in press) to account for overwintering larval concentrations in estuaries along the Maine coast.

That such mechanisms may exist is suggested by the retention of larvae at the head of St. Mary's Bay. It was shown above that in early October most of the larvae at the head of this bay exceeded 15 mm in length, the same length at which the development of the caudal fin confers a marked increase in swimming ability, whereas larvae at the entrance to the bay were smaller, implying that maintainance of position is a function of swimming ability. This does not imply that St. Mary's Bay is itself a major overwintering area for the larvae of the Nova Scotia stock, neither its size nor the density of larvae found there match up with the size of the stock or of the fishery it supports (Iles and Tibbo 1970), although it is not excluded as a possibility that larger densities of larvae may occur in the bottom 5 m, not sampled by these surveys.

The occurrence of larval concentrations during the fall, at the south-west end of the Grand Manan channel might be construed as evidence of transport out of the Bay of Fundy but the similarility in length distributions between early and late October samples (and allowing for intervening growth) noted above makes it far more likely that these represent a relatively stationary population originating in the area itself. Das (1968) cites instances of spawning being recorded in this area.

On the other hand, larvae have been reported well inside the Bay of Fundy during the fall and winter on many occasions. Tibbo et al. (1958) record such occurrences in the fall of 1956 and in the fall and winter of 1957-58, Tibbo and Legaré (1960) in the fall and winter of 1958-59, Das (1968) in early 1961 and in the fall of 1962 and Tibbo and Lauzier (1970) in the autumn and winter of 1967-68 and 1968-69.

The question then arises whether the upper part of the Bay of Fundy is the major area for overwintering larvae from the Nova Scotia spawnings and if so what is the pattern of movement of post larval fish after their first winter. It is assumed by Das (1968) that the movement of these post larvae will be dictated by the non-tidal drift current system set up in the area which, as it develops in the spring, would carry any overwintering larvae out along the New Brunswick coast. It is suggested now that passive drift by larvae, although undoubtedly important during the early stages of development, becomes less important as they develop even relatively modest swimming powers, so that the dispersal of the young of the Nova Scotia stock may not be as widespread as has been supposed. Certainly "brit" (yearling) herring were also caught during the November cruise well inside the Bay of Fundy and that a return of brit and sardine (two year old) herring may be in the direction of the Nova Scotia side of the entrance to the Bay of Fundy cannot be excluded. Iles (1970) produced some evidence to question the commonly held hypothesis that the Nova Scotia spawning provides recruits to the sardine fishery of the New Brunswick-Maine coast, suggesting that sardine populations on both sides of the Bay of Fundy are distinct. While neither that evidence, nor the implications of this study are in any way conclusive, they do suggest that more detailed study of the overwintering larval populations of the Bay of Fundy and attempts to complete the life cycle by adequate sampling of later stages are likely to contribute much to what is still the major herring problem in the region - the origin of the sardines of the Bay of Fundy-Gulf of Maine.

If the hypothesis suggested by this study can be substantiated it will have important implications.

The Nova Scotia fall spawning stock would neither contribute to nor be directly affected by the Gulf of Maine-New Brunswick fisheries for brit (yearling) and sardine fisheries and could be treated as a convenient unit for management purposes. Again, if the Bay of Fundy is a major overwintering area for larval herring opportunity is created for the study of larval ecology of a discrete population, and the possibility of estimating total abundance at late larval or subsequent stages, if these can be adequately sampled, might allow prediction of subsequent recruitment levels.

Acknowledgments

This study was carried out with support provided by the Industrial Development Branch of the Department of Fisheries and Forestry, which is gratefully acknowledged. Thanks are due also to S. N. Tibbo, Head of the Pelagic Programme, St. Andrews Biological Station for his advice and assistance and to his staff who took part in the field work. Miss Gretchen Markel analysed the plankton samples while working as a summer student and did this efficiently and accurately.

References

Blaxter, J.H.S. 1962. Herring rearing - IV. Rearing beyond the yolk sac stage. Mar. Res. Scotland. 18pp.

Bridger, J.P. 1956. On day and night variation in catches of fish larvae. J. Conseil. Explor. Mer, 22(1): 42-57.

Bumpus, D. F. and L. M. Lauzier. 1965. Surface circulation on the Continental Shelf. Folio 7. Serial Atlas of the Marine Environment. American Georgraphical Society (New York).

Das, N. 1968. Spawning distribution, survival and growth of larval herring (Clupea harengus L.) in relation to hydrographic conditions in the Bay of Fundy. Tech. Rept. No. 88. (F. R. B.).

Graham, J.J. (In press). Aggregations and movements of larval herring in the Sheepscot Estuary in Maine.

Iles, T. D. 1970. Vertebral numbers of the Bay of Fundy Herring and the Origin of New Brunswick Sardines. ICNAF Redbook 1970 Part III: 148-150.

Iles, T. D. and S. N. Tibbo. 1970. Recent events in Canadian Atlantic herring fisheries. ICNAF Redbook 1970 Part III: 134-147.

Tibbo, S. N. and L. M. Lauzier. 1970. Seasonal distribution of larval herring in the Bay of Fundy and Gulf of Maine. ICNAF Res. Doc. 70/52.

Tibbo, S. N. and J.E.H. Legaré. 1960. Further study of larval herring (Clupea harengus L.) in the Bay of Fundy and Gulf of Maine. J. Fish. Res. Bd. Canada, 17(6): 933-942.

Tibbo, S. N., J. E. H. Legaré, L. W. Scattergood and R. F. Temple 1958. On the occurrence and distribution of larval herring (Clupea harengus L.) in the Bay of Fundy and Gulf of Maine. J. Fish. Res. Bd. Canada 15(6): 1451-1469.

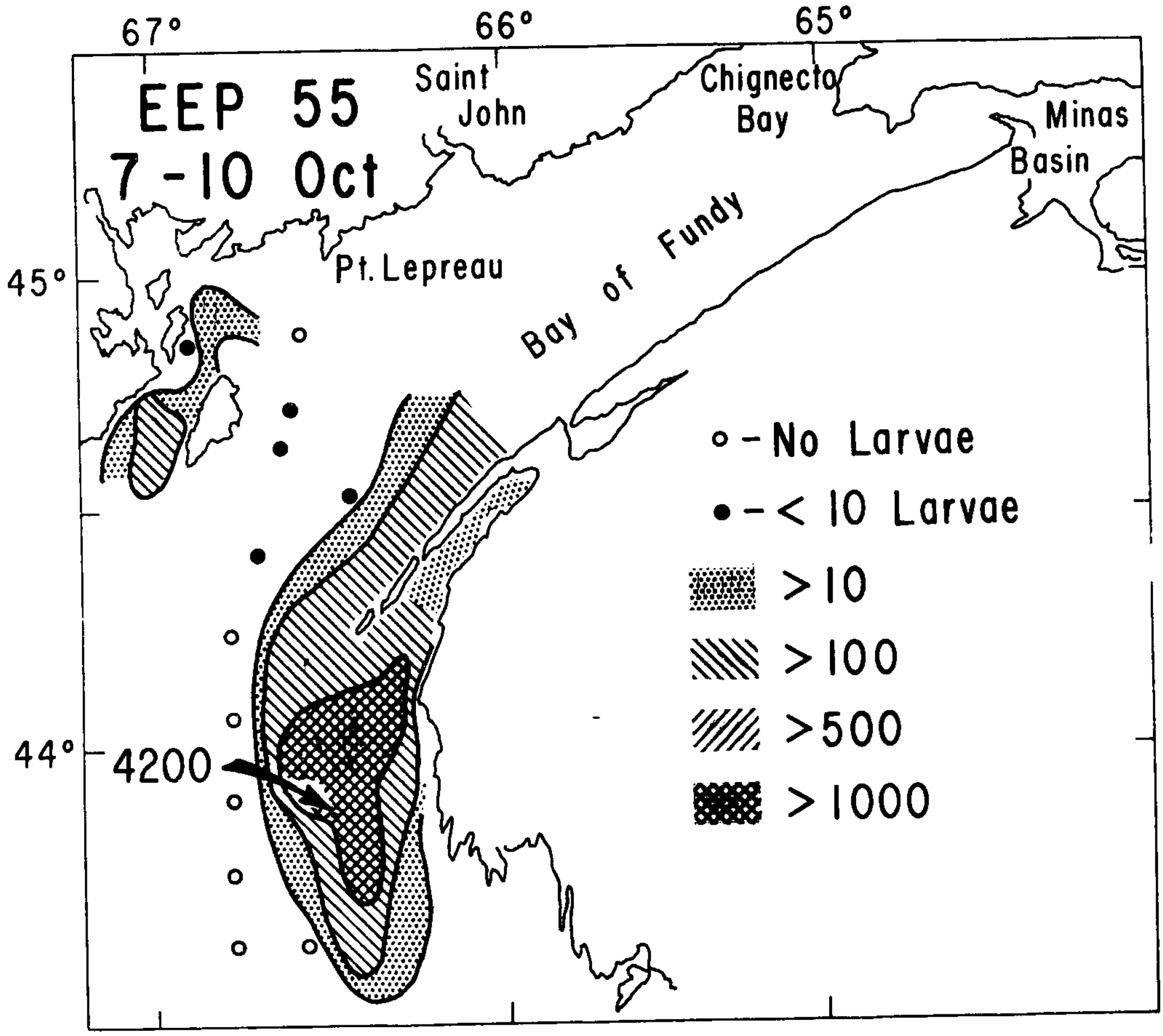

Figure 1.: Herring larval distribution and abundance in the Bay of Fundy - Nova Scotia southwest coast area. October 7 - 10, 1969.

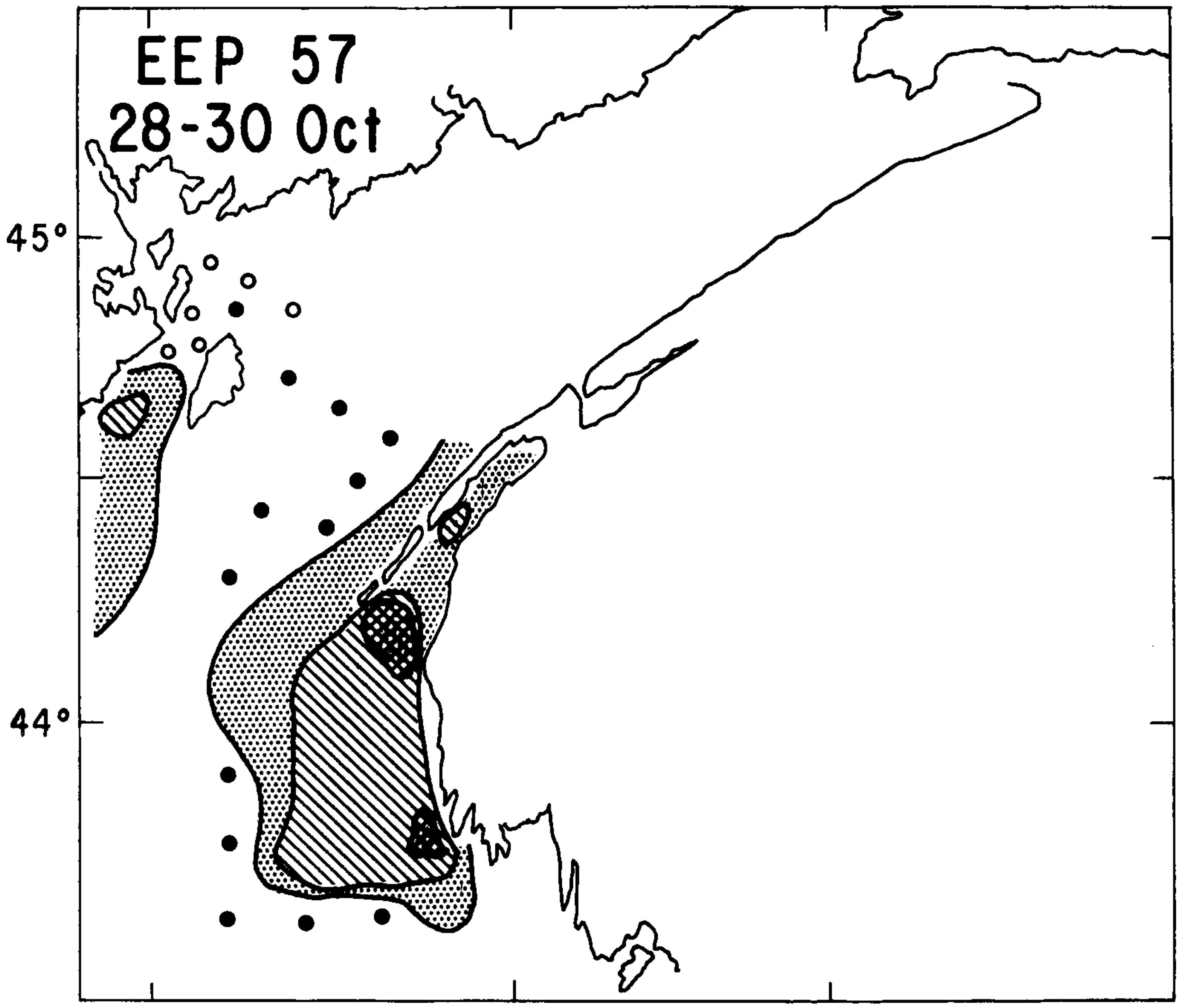

Figure 2.: Herring larval distribution and abundance in the Bay of Fundy - Nova Scotia southwest coast area. October 28 - 30, 1969.

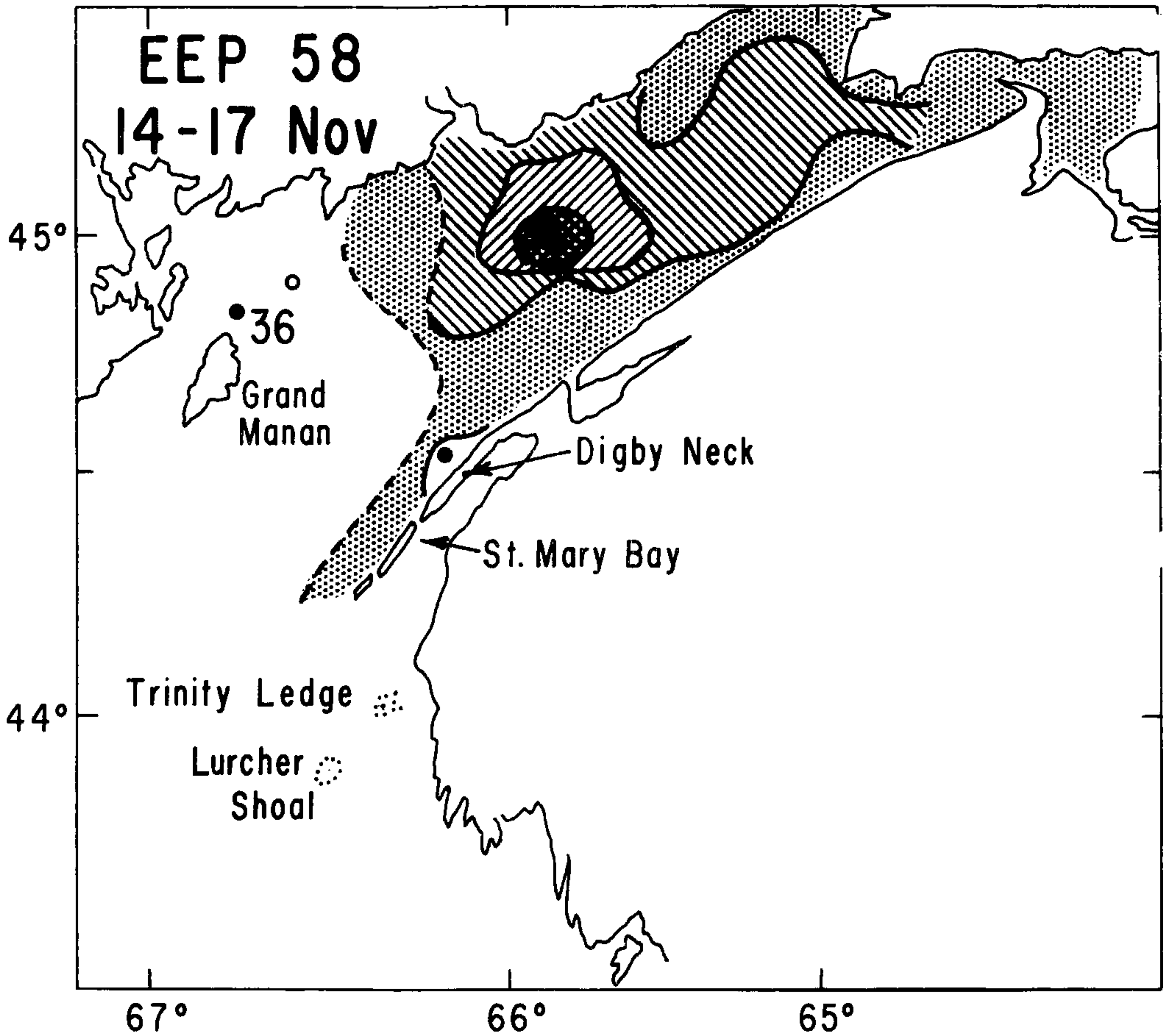

Figure 3.: Herring larval distribution and abundance in the Bay of Fundy - Nova Scotia southwest coast area. November 14 - 17, 1969.

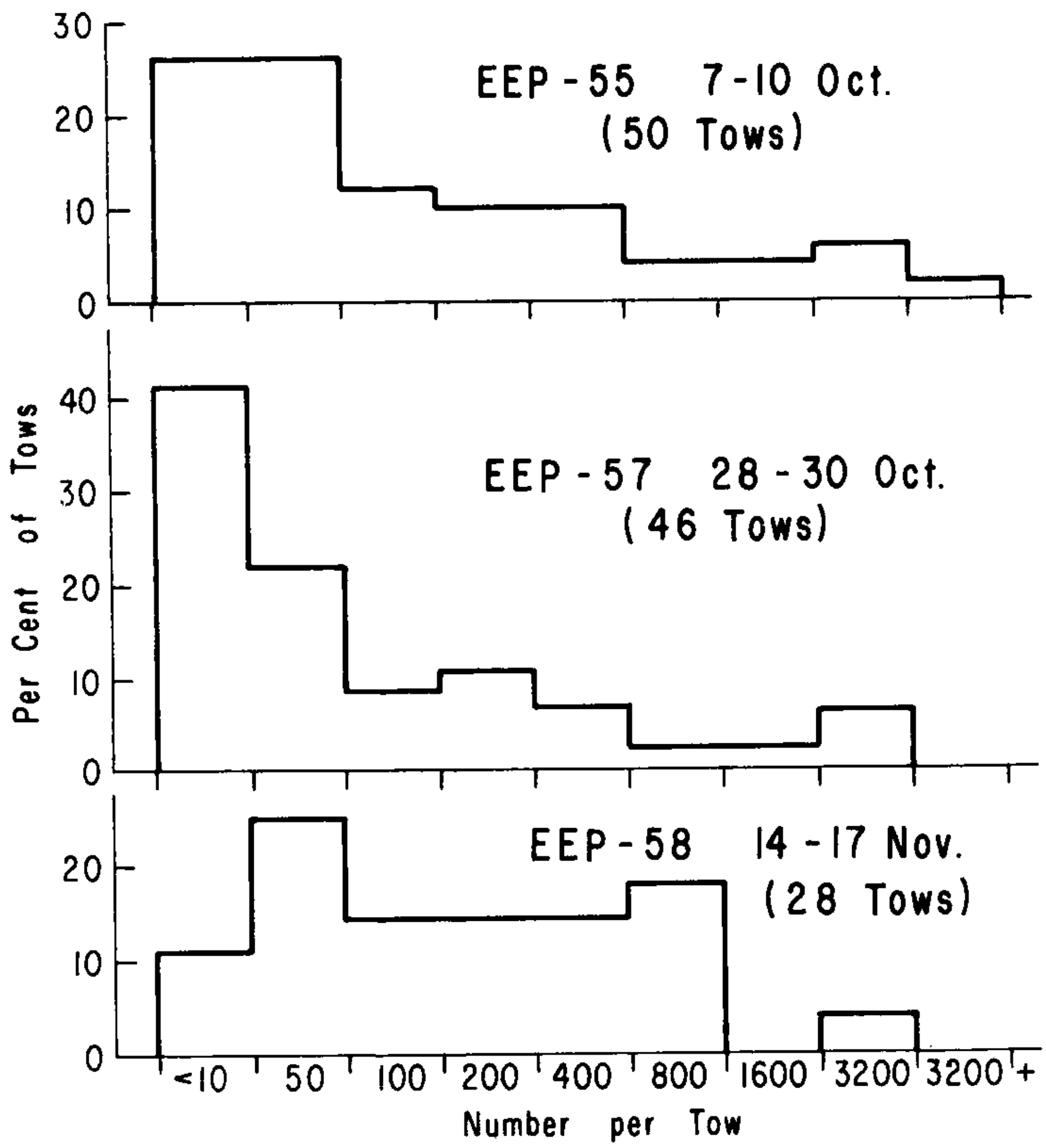

Figure 4.: Frequency distribution of number of larvae per tow for the three cruises.

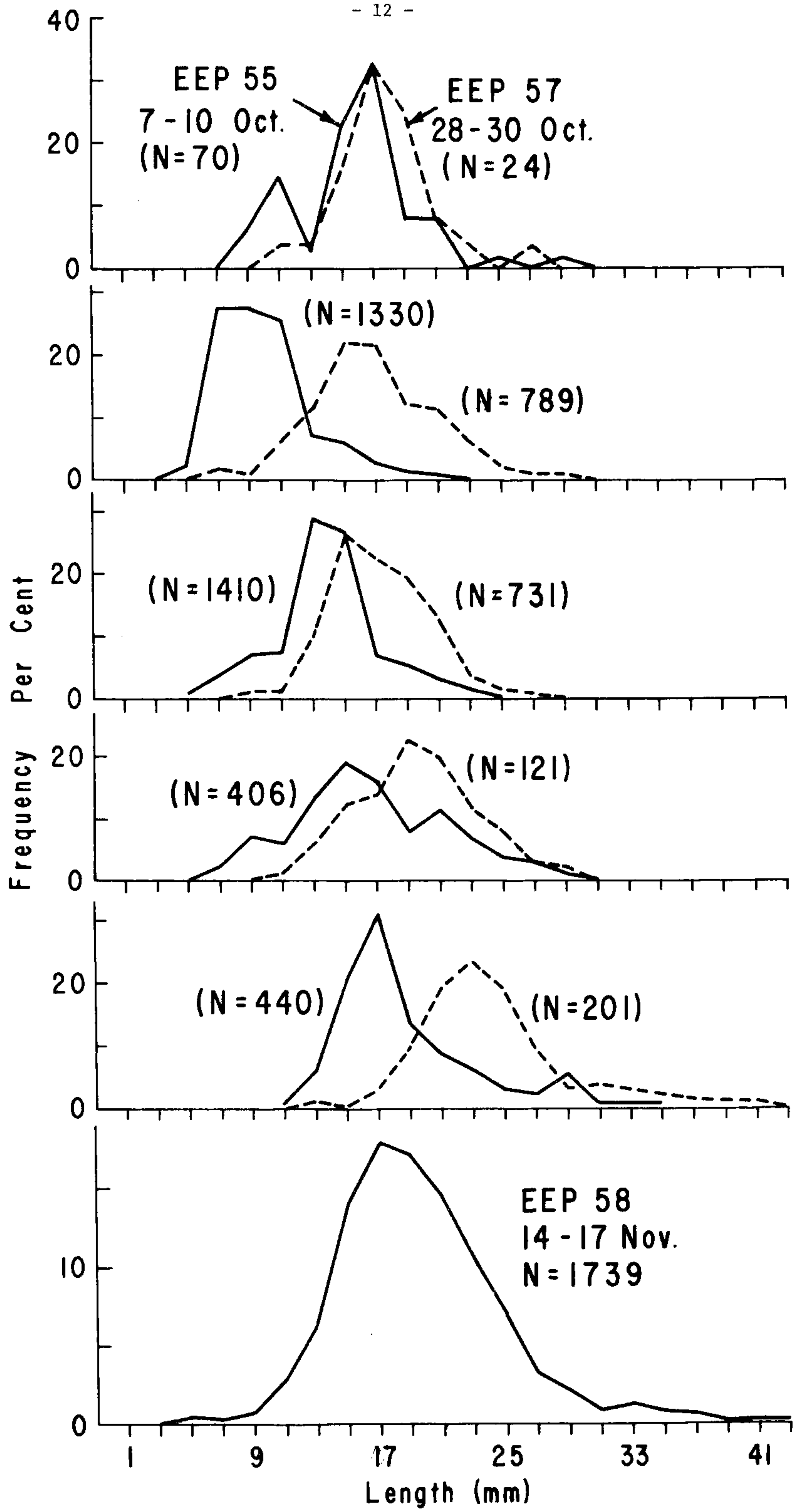

Figure 5.: Comparison of larval length frequency distributions for the three cruises (see text).