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OBSERVATIONS ON THE EARLY STAGES OF SEBASTES FROM CONTINUOUS PLANKTON RECORDS

by

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ABSTRACT.

Young Sebastes are the predominant fish larvae over a wide area of the North Atlantic and the majority can be referred to S. mentella Travin. The pattern of abundance, the distribution of larvae with sub-caudal pigmentation and the timing of extrusion in different regions all indicate the occurrence of fairly well defined populations. These include the huge oceanic stock in the Irminger Sea, a separate population over the shelf and slope from Labrador to northeast Newfoundland and another in the Nova Scotia - Gulf of Maine area. To these may be added a population in the vicinity of Flemish cap, similar in some respects to the oceanic stock.

The timing of the occurrence of larvae of the different populations would appear to be linked with the timing of the average seasonal cycle of Copepoda in the areas they occupy. The larval phase of each population is closely associated with the period of the year when suitable food organisms are normally available in greatest concentrations. Within the Irminger Sea the "spawning" of Sebastes has been most regular in timing compared with a relatively erratic seasonal cycle of plankton production. It is suggested that the very long life span of the fish providing opportunities for reproduction over many years might be advantageous in this situation.

INTRODUCTION

The Continuous Plankton Recorder Survey, which covers a vast area of the North Atlantic at approximately monthly intervals, offers a unique opportunity for studies on the distribution of fish larvae. When the Survey was extended westwards from European waters in the late nineteen fifties, large numbers of Sebastes larvae were encountered in the central and western North Atlantic. Investigations on the seasonal and geographical distributions of these larvae formed the subject of a series of papers by Henderson (for example, 1961, 1965a, 1965b and 1968). With the build up of sampling over the open ocean and North American shelf in recent years, more extensive information has become available on certain aspects of the biology of the larvae.

MATERIAL AND METHODS

Details of the Continuous Plankton Recorder, the logistics of the Survey and the methods of analysis are provided by Glover (1967) q.v. for further references. In this interim report it is necessary to draw attention only to those features of the survey which are important in assessing the data on fish larvae.

Recorders are towed by selected merchant ships and ocean weather ships at a depth of 10m and at monthly intervals when practicable. The single sampling depth, the wide network of routes (Fig. 1) and the small samples (ca. 3 m^3 of water filtered per 10 miles of tow) impose limitations on the treatment of the young fish data. Nevertheless in the North Sea and adjacent waters, where sampling extends over 20 years, some promising relationships have emerged between fluctuations in the abundance of the larvae and the catch per unit effort of fisheries for herring, mackerel, coalfish and whiting. The basic data for fish larvae, as for all zooplankton species in the survey, are expressed as mean numbers per statistical rectangle of 1° latitude by 2° longitude for each month. From the appropriate rectangle means averages can be obtained for particular months, years, sub-areas or any combinations of these.

THE FISH LARVAE OF THE NORTH ATLANTIC /

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The relative abundance and general composition of the young fish population at 10 m depth in the open Atlantic and over the North American shelf are illustrated in Figure 2. The results were obtained by first calculating averages in each statistical rectangle ($2^{\circ} \times 1^{\circ}$) for each month over all years, then the annual mean for each rectangle and finally average numbers within the areas delimited in the figure. It should be noted that the averages refer to more then two decades of sampling in the north-east Atlantic but only between five and ten years off North American coasts.

Marked differences are evident in the fauna of young fish between the eastern and western sectors of the Atlantic. Fig. 2 shows that the blue whiting (Micromesistius poutassou, Risso) is dominant in the east and redfish (Sebastes spp.) in the central and western regions. Fish with luminescent organs tended to be most frequent in the southern oceanic sectors of the survey area. This group is a rather diverse assemblage of several families of small oceanic fishes including the Gonostomatidae (e.g. Maurolicus spp.), Stomiatidae (mainly Stomias spp.) and Myctophidae (e.g. Myctophum sp.). All three families were well represented in the south-eastern area but elsewhere the Stomiatidae were scarce. In the north-eastern area Maurolicus was the principal genus and in the south central area Myctophum, although many of the myctophids were metamorphosed specimens reaching up to 50 mm in length.

Fish larvae were less abundant in the areas sampled over the North American shelf and Slope than in the shelf seas around the British Isles, the Faroes and Iceland (which are not shown in Figure 1). Young Ammodytidae were particularly abundant over the Grand Banks and were also prominent in the Nova Scotia - Gulf of Maine area. In view of the study by Scott (1968) it seems likely that the main species present is the offshore sand launce, Ammodytes dubius Reinhardt rather than the inshore launce, A. hexapterus, Pallas. Gadidae, mostly Gadus morhua L., provided the outstanding group of larvae off the coast of Labrador while the larvae of the Clupeidae, presumed to be entirely those of the Atlantic herring, Clupea harengus L., were common in the Nova Scotia-Gulf of Maine area as well as over the southern section of the Grand Banks. The early stages of Sebastes /

Sebastes were present in all three sectors of the North American Shelf and Slope shown in Fig. 2.

THE DISTRIBUTION OF YOUNG SEBASTES

Fig. 3 shows the wide spread distribution of the young stages of Sebastes within the survey area. The centre of abundance of the oceanic population lies in the vicinity of the Reykjanes ridge with numbers decreasing to the south-west leaving the populations of larvae over the North American shelf and slope well defined, although not separated, from the oceanic population. There appear to be three centres of larval concentrations over the shelf and slope; one off the coast of Labrador, another in the vicinity of Flemish Cap and a third in the Nova Scotia-Gulf of Maine region.

Henderson (1965 and 1968) has drawn attention to the different characteristics of the oceanic type of young Sebastes, found almost entirely over depths exceeding 1000 fathoms, and the coastal type of the North American shelf and slope, found mainly over depths of less than 250 fathoms. All specimens of the oceanic type were without subcaudal melanophores (referred to by Henderson as "non-pigmented") while most specimens of the coastal type possessed from one to three, but mainly two melanophores (described as "pigmented" young). Henderson also noted differences in the seasonal distribution of the two types. The greatest numbers of newly 'extruded' young of the oceanic type were present in April and May while small specimens of the coastal type were most frequent in June and July.

Some finer details of the distribution of the two forms are now available and Fig. 4 gives the percentage of pigmented young by statistical rectangles. Off Labrador and the north-eastern coast of Newfoundland the percentage of pigmented larvae was generally between 81 and 90%. The patch of larvae in the vicinity of Flemish Cap consisted almost entirely of non-pigmented individuals; larvae with subcaudal pigmentation in this region were limited to two rectangles where they constituted under 10% of the total. The highest percentages of pigmented young, from 91 to 100%, were found in the Gulf of Maine and off the coast of Nova Scotia.

Differences in the month of first occurrence of newly extruded Sebastes larvae (i.e. from 5 to 7mm in length) shown in Fig. 5 indicate a clear pattern of spawning /

spawning. At the centre of distribution of the oceanic population in the Irminger Sea, the extrusion of young was first evident in April and around the periphery of this area in May. Along the North American Shelf, extrusion first occurred in April around Flemish Cap, in June off Labrador and the north-east coast of Newfoundland, and in July off Nova Scotia and the Gulf of Maine.

Figures 3, 4 and 5 are complementary and suggest that three distinct populations of larvae exist off the North American seaboard with the population near Flemish Cap morphologically identical as well as "spawning" at the same time as the enormous oceanic population centred in the Irminger Sea. The distributions of the three populations of larvae in North American waters substantiate the concensus of opinion of other workers as given by Mean and Sindermann (1961) and quoted below:

> "The commercial American fishery for redfish in the north-west Atlantic is based upon the mentella-type of redfish which may constitute three stocks for assessment purposes. The first of these lives in waters comprising ICNAF sub-areas 4 and 5, and Division 3 O and 3 P (the south-west Grand Banks and westward to the Gulf of Maine and including the Gulf of St. Lawrence). The second area is ICNAF Division 3 K, 3 L and Sub-area 2 (the northern Grand Banks, the Newfoundland shelf and the coast of Labrador). These two groups intermingle in Division 3N, the south-eastern Grand Banks, in which the situation is not yet clear. The third area is Division 3 M (Flemish Cap)".

There is some confusion over the taxonomic position of the various members of the genus so it is not surprising that doubts exist as to the specific determination of the larvae. The young stages of *Sebastes viviparus* Kr. are reasonably distinct and the larvae of this species were limited to the Norwegian Sea with a few specimens in Icelandic coastal waters. However, the vast majority of the larvae present cannot be ascribed definitely to the other two species of *Sebastes* in the North Atlantic, *S. marinus* L and *S. mentella* Travin. Results of angling trials for adult redfish at Weather Station Alfa given by Jones (1969) suggest that the parent stock of the oceanic larvae in the Irminger Sea consists entirely of *S. mentella*. All the larvae found in the ovaries and oviducts of the female *S. mentella* were like the free living young of the area in /

in being entirely without any sub-caudal pigmentation (Henderson and Jones 1964). This conflicted with the results of an investigation on the sub-caudal pigmentation of pre-extrusion redfish larvae from the Newfoundland area by Templeman and Sandeman (1959). They found sub-caudal pigmentation in 97.7% of the larvae of S. mentella (usually two melanophores) and in 23.9% of the larvae of S. marinus (usually single melanophores). Considering only the newly "extruded" larvae in the Recorder collections (i.e. those from 5 to 7 mm in length) 87.5% of those off Labrador and the North-east coast of Newfoundland showed sub-caudal pigmentation and 90.5% of those from the Nova Scotia - Gulf of Maine region. Two sub-caudal melanophores were usually present in the larvae from both areas. Taking these results on their face value, the pigmentation of the larvae of S. mentella must vary in different parts of the Atlantic - a possibility suggested by Templeman and Sandeman (1959) - and the majority of the larvae taken by the Recorder off the North American coast as well as in the Irminger Sea may be associated with this species.

The timing of extrusion

Figure 5, which gives the month of first occurrence of the early larvae throughout the area of distribution, shows the progression of extrusion from north-east to south-west. By contrast, the timing of the first appearance of the early larvae of Micromesistius poutassou and other oceanic fish of the north-east Atlantic indicate a south to north pattern of spawning. Cushing (1967) has shown that differences in the spawning time of herring populations can be linked to differences in the production cycle of different areas and this may also apply to the redfish populations. In Fig. 6 the average numbers of young Sebastes and copepods each month are compared for selected areas. The seasonal development of Copepoda in the Nova Scotia - Gulf of Maine area as well as off Labrador is clearly two months later than in the Irminger Sea and, in each of these regions, the occurrence of Sebastes larvae is closely associated with the cycle of copepod abundance. The area chosen off the north-east slope of the Grand Banks includes two populations of Sebastes young, but there is again some correspondence between the two variables which are intermediate in timing between those of the shelf and oceanic regions.

Newly /

Newly extruded *Sebastes* larvae are known to feed on the early stages of copepods, principally the eggs and nauplii of *Calanus* (Bainbridge and MacKay 1968). The results therefore imply that the larvae of the different "spawning stocks" are extruded at the time when, under average conditions, food organisms are most plentiful.

Figure 7 allows a comparison of the average percentage length distribution each month of young *Sebastes* from the Labrador area with that of the population in the Irminger Sea. The histograms show that the main period of extrusion is about two months later in the Labrador area, but the apparent growth rate - a compound effect of extrusion, mortality, dispersion and true growth - is similar in the two areas. Insufficient data are available for comparisons with other regions.

DISCUSSION

Data reviewed in the preceding section suggest that the different "spawning" seasons of *Sebastes* have evolved so that larvae are extruded at the period when food for them is usually most plentiful. The implication is that planktonic conditions have been a major influence in the formation of separate "spawning" stocks.

Cushing (1969) has pointed out that fish can only link their times of spawning to production cycles in an indirect manner; that is, by spawning at a fixed season. In high latitudes the timing, amplitude and spread of the production cycle of the plankton is variable and, in the absence of any known mechanism for a fish to vary its time of spawning in relation to the oncoming cycle it must, perforce spawn at a fixed season. Although this is a "hit or miss" process, Cushing considers that it allows fish the best chance of profiting from the variability of the production cycle. The "spawning" of *Sebastes* appears to be extremely regular since, within the Irminger Sea as a whole (areas B6, B7 and C7 combined), the highest numbers of newly extruded young have always been found in samples collected during the first half of May. Cushing suggests that the fixity of spawning season may be a corollary of the variability of the production cycle and the dependence of the fish populations upon it during their larval /

larval lives.

The productive season for phytoplankton in the Irminger Sea area is much shorter than it is over the continental shelf and slope off Europe and North America (Robinson, in press). The development of copepods in the area is likewise very restricted seasonally and is highly variable (Colebrock, 1965). Calanus is by far the dominant member of the zooplankton and newly extruded Sebastes larvae have to rely on the eggs and nauplii of this species for food (Bainbridge, 1965). Taking all these observations into consideration, the Irminger Sea would indeed appear a precarious environment for fish larvae. Could the key to the dominant position and success of the Sebastes population in the Irminger Sea lie partly in longevity and iteroparity? Murphy (1968) has advanced the argument that evolutionary pressure for long life, late maturity and many reproductions may be generated by an environment in which density independent factors cause wide variations in the survival of the early stages. He used computer simulation to test different models and drew examples from various plankton feeding fish to show there is a trend towards high variability of year-class strength being associated with fish stocks which both mature late and have a long reproductive life. Sandeman (1969) found female Sebastes from Hamilton Inlet Bank, Labrador, matured at 10-12 years of age and attained ages to 40 years. For the oceanic stock at Weather Station Alpha, Jones (1969) reported ages ranging from 15 to 57 years with sexual maturity in females occurring at 15-25 years of age. It is possible that Sebastes may provide an extreme example of the necessity for multiple reproductions in a highly unpredictable environment for the planktonic larvae with the huge area occupied by the "spawning" stock in the Irminger Sea offering additional "biological insurance". As Murphy (1968) has theorized, a population of this type cannot withstand very great predation pressure - if it did develop both the population and the predators would be unobservable because of extinction. The Greenland Shark and the Sperm Whale are known to include Sebastes in their diet (Roe, 1969) but we have no evidence of any common predators on the pelagic stock of Sebastes in the Irminger Sea and as yet no fishery exists.

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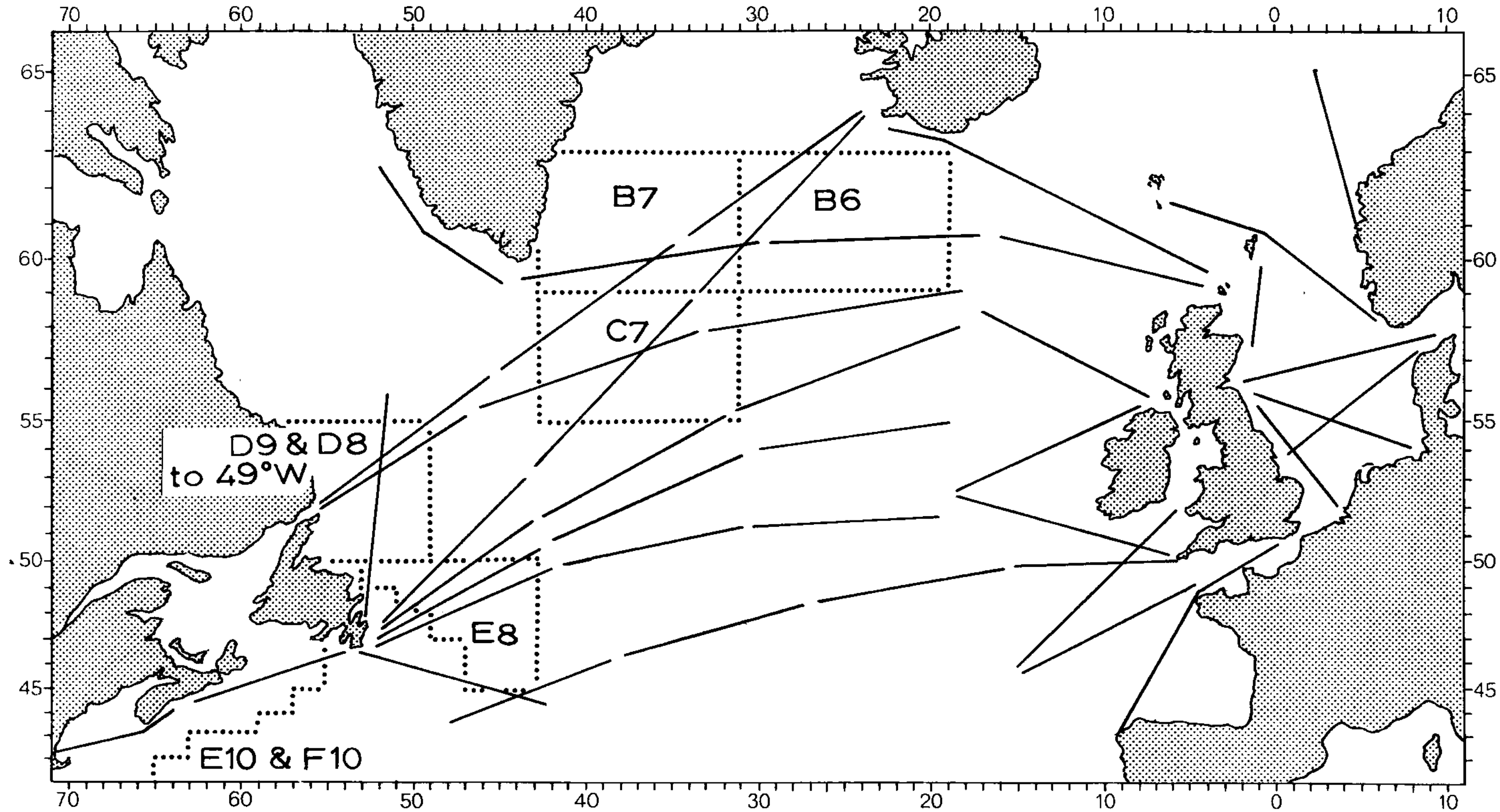

Fig. 1. Chart showing the routes included in the Continuous Plankton Recorder Survey in 1963 and the sub-areas referred to in the Text.

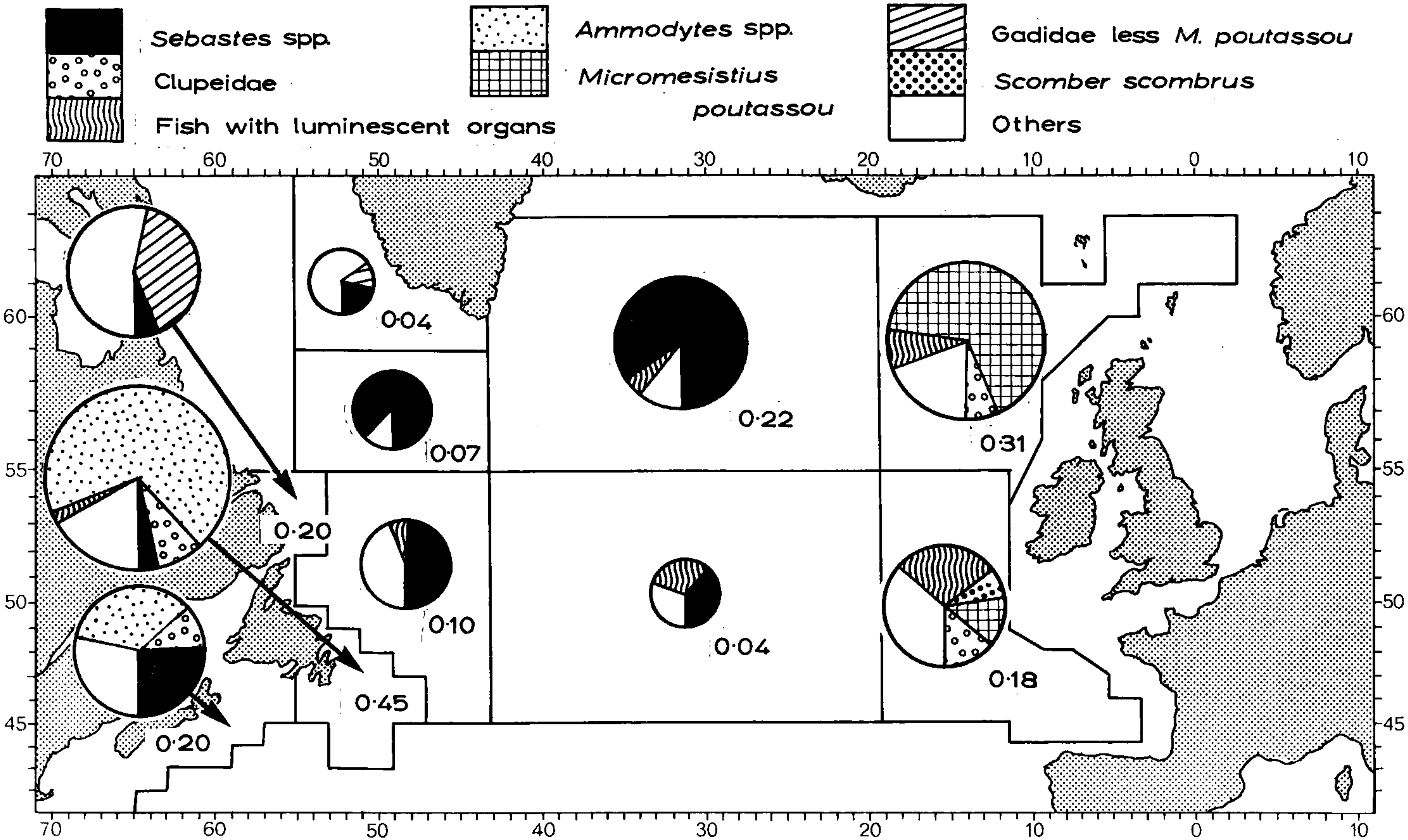

Fig. 2. The Young fish of the open Atlantic and the North American Shelf as sampled by the Continuous Plankton Recorder at a depth of 10m. The area of the circles is proportional to the average numbers per sample over all months and years within the areas delimited on the chart. Each circle is subdivided to show the relative numbers of some major taxonomic groups of young fish (see key).

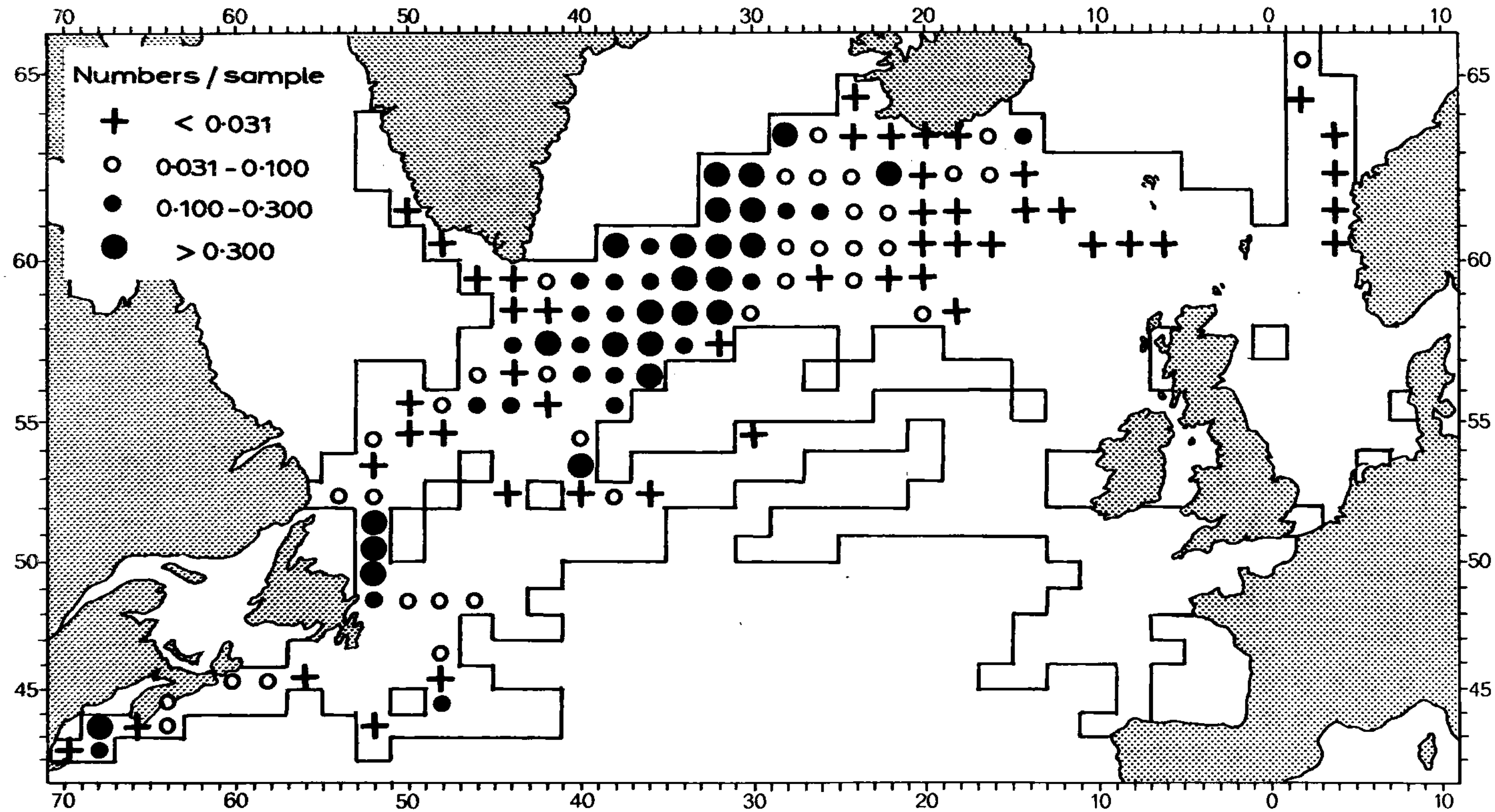

Fig. 3. Chart showing the distribution and abundance of young Sebastes at a depth of 10m. Abundance was obtained by first calculating the average numbers in each statistical rectangle by calendar months over all years of sampling from 1948 to 1967 and averaging these monthly means to give an annual mean. Only rectangles sampled for at least six of the twelve months have been included within the outlined sampled area.

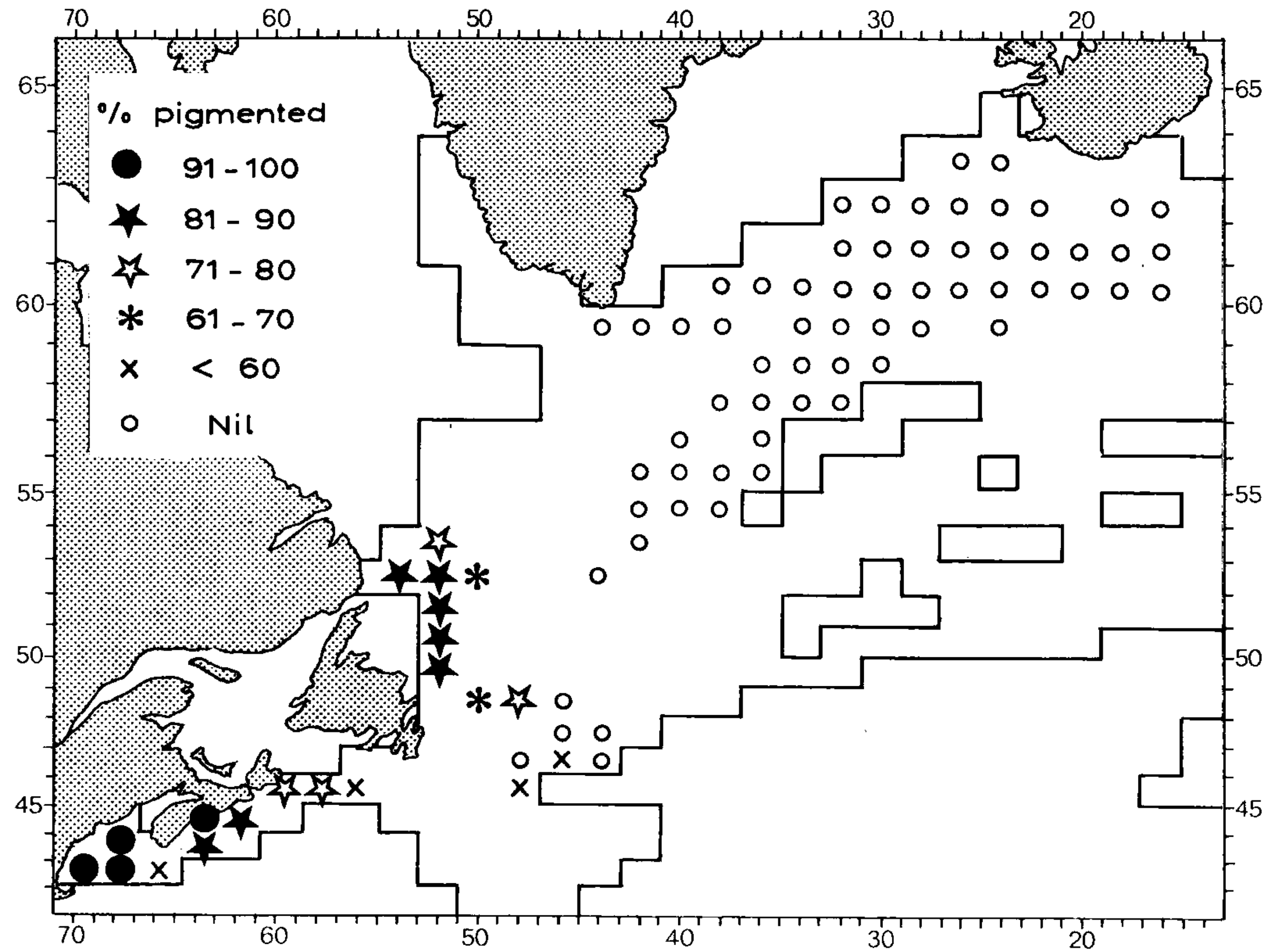

Fig. 4. Chart showing the percentage of young Sebastes with sub-caudal melanophores. All rectangles sampled three or more times in the period April to August 1960 to 1967 are included in the sampled area.

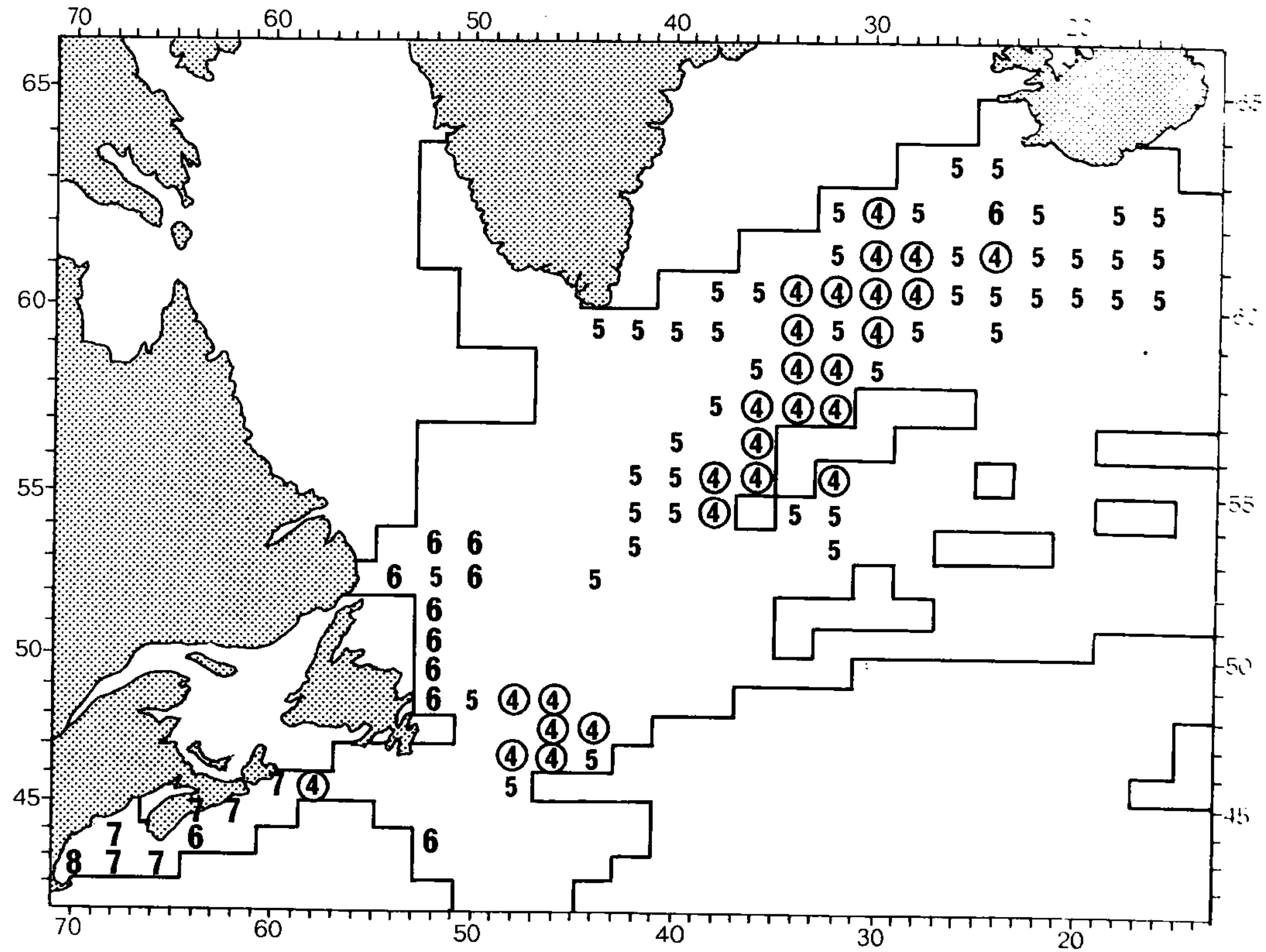

Fig. 5. Chart showing the month of first occurrence of newly extruded young *Sebastes* (5 to 7 mm in length) within each statistical rectangle. Months are numbered consecutively from April-4 to August-8. All rectangles sampled three or more times in the period April to August 1960 to 1967 are included in the sampled area.

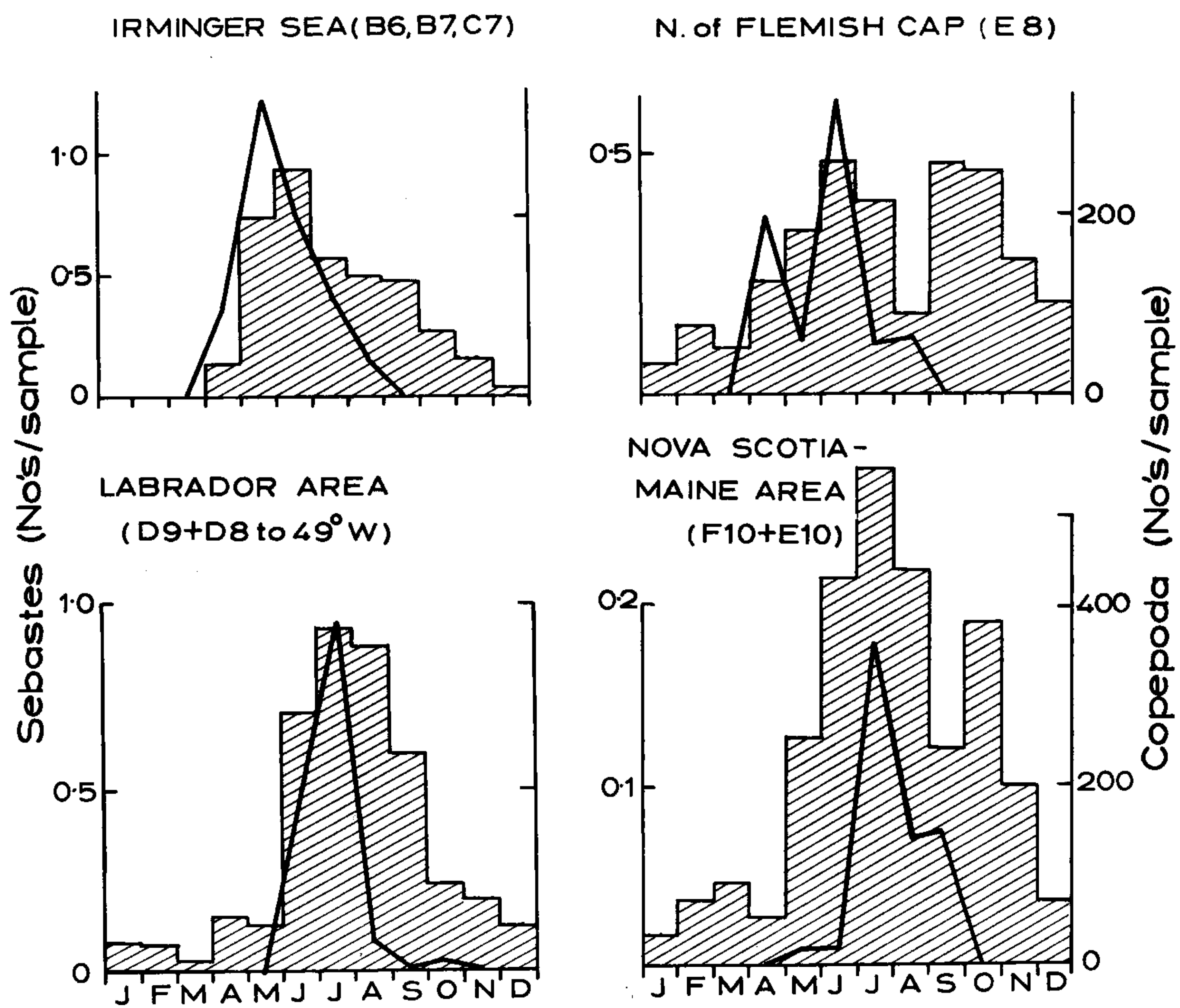

Fig. 6. Histograms representing the average numbers of Copepoda per Recorder sample in selected areas (right hand scale) with line graphs showing the average numbers of young Sebastes (left hand scale). Data are averages for the years 1957 to 1963 in the Irminger Sea and for the years 1960 to 1968 in the other three areas.

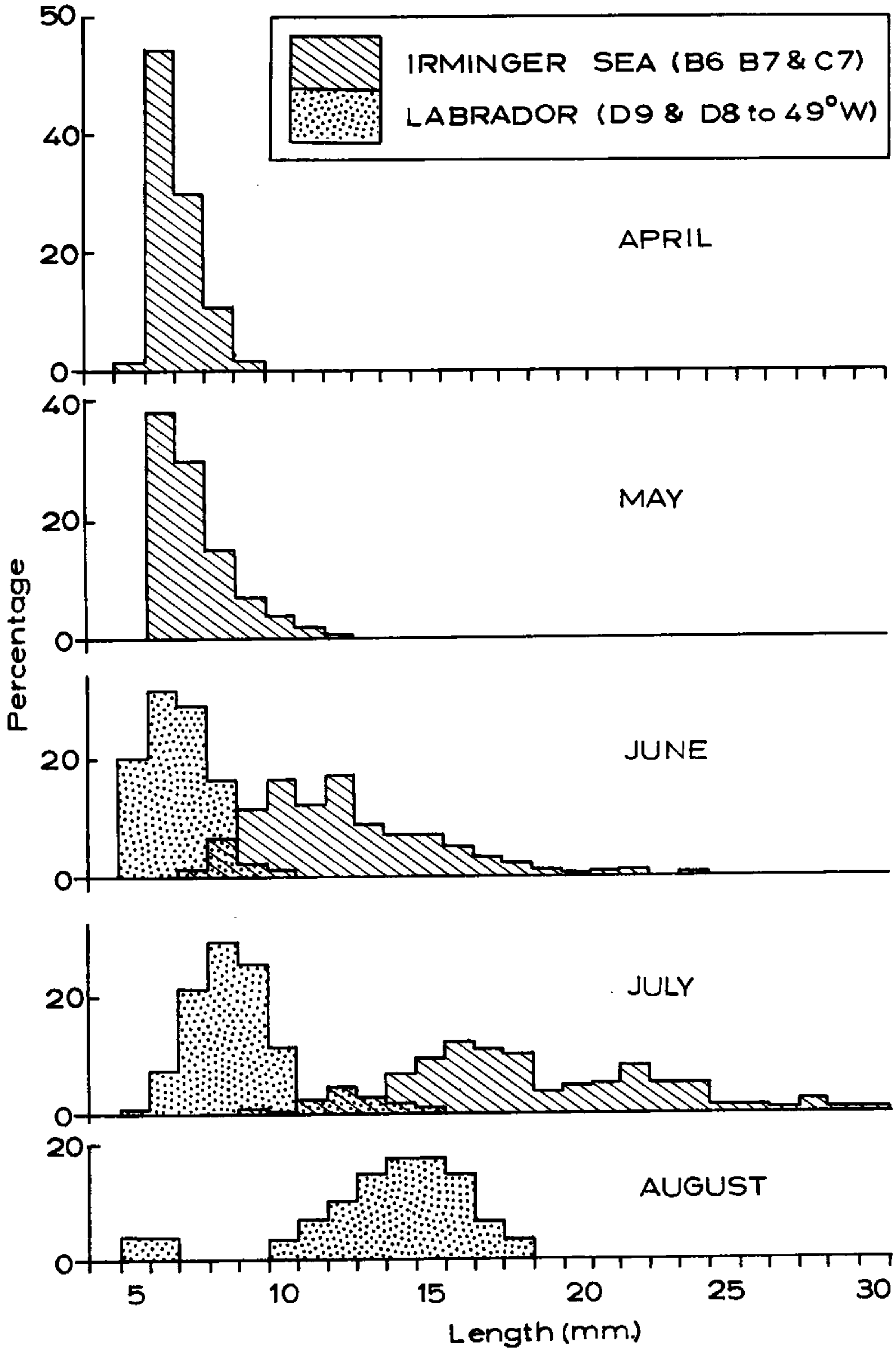

Fig. 7. Histograms showing the percentage size frequency composition of young Sebastes in the Irminger Sea area (hatched) and off Labrador (stippled). Percentages for each month refer to all larvae taken over the years 1960 to 1968.