VARIABILITY IN THE OCEANIC CONTENT OF PLANKTON IN THE SCOTTISH AREA

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THE production and survival of plankton is very dependent on its environment, and with changing environment it is only natural to expect changes in the plankton.

In brief these changes are of four main types:

1. Major variability in geographic distribution dependent largely on the temperature *in situ*, thermoclines, and the angle, duration and intensity of light.
2. Major seasonal changes. These are often dependent on the seasonal change in light—e.g. the spring growth of diatoms and the changes in zooplankton content associated with this increase, and they are particularly noticeable in the meroplankton where the bottom living adults have definite spawning seasons and the planktonic larvae are therefore also seasonal.
3. Daily variations produced in the first place by diurnal changes in light intensity—though the vertical distribution of the zooplankton may be dependent on secondary effects such as the distribution of their food species or the more delicate changes in the chemical environment caused by the changed metabolism of other species.
4. Variations in plankton composition in a given locality caused by changes in the environment due to water transport, including variations in the origin of the water masses being moved.

This paper deals only with this last type of variation and within the area of the northern North Sea, Faroe–Shetland Channel and off the Scottish west coast for which in Aberdeen there is a considerable amount of data. This has been collected since about 1920 and analysed in much greater detail since 1935 and especially since 1946. The planktonic fauna in this area is dependent on the topography and current systems, not so much in the North

Sea and in the Faroe–Shetland Channel, but further west whence the current systems that affect these areas have come. A chart illustrating these features is given in FRASER (1961).

Different species of plankton have different optimum conditions and different limiting factors, not necessarily the major physical factors such as $t°$, s‰, though these can often be the dominant ones, but also the organic content. Where the tolerance of the plankton to its environment is adequate to accept a range of physical conditions the limiting factor can be the distribution of food organisms which may not be so tolerant. Planktonic larvae are of course also dependent on the distribution of the adults which may have their own limiting factors. Thus, species are only to be found thriving in waters with the right conditions, and where these boundaries are readily recognisable we use the term "indicator species".

Indicator species can thus be used to indicate the distribution of particular types of water masses. As an individual specimen can be identified until it dies and disintegrates, even after mixing with other species, they have a value not found in the physical and chemical environment—one cannot dilute an organism.

The best known group of indicator species are the Chaetognatha. In the North Sea there are only two abundant species and in the North-east Atlantic only four others and, between them, these six give a convenient coverage of the environmental conditions (FRASER, 1965). In brief, *Sagitta setosa* is indigenous in coastal waters, *S. elegans* is found chiefly in mixed coastal and oceanic water. *S. serratodentata* is an oceanic form, *S. maxima* and *E. hamata* are boreal and *S. lyra* is Lusitanian. Their distribution can be plotted to give an average picture of the distribution of these six species, but it must be emphasised that "average" conditions do not exist as such but they do form a convenient basis for the study of the variations. There are several ways that these can be studied in the area dealt with in this paper.

One simple way is to look at the variations in the degree of penetration of oceanic species into the North Sea—considering other oceanic species as well as *Sagitta serratodentata* (Fig. 1). It will be seen that the years 1946 and 1947 were the years of greatest penetration; 1937 and 1932 were the years of least penetration.

Another way is to study the annual variations of inflow of any one species—such as *Salpa fusiformis* which is very widespread in the oceanic area of the North Atlantic (Fig. 2). It is naturally drifted into the northern North Sea with the oceanic inflow. If conditions are warm enough it will reproduce on the way and it can increase 100-fold in 12 days, thus increasing its chances of a wider distribution before conditions have changed sufficiently to become intolerable. Even then, after death it takes quite a time for individuals to disintegrate to an unrecognisable condition. The figure shows that the

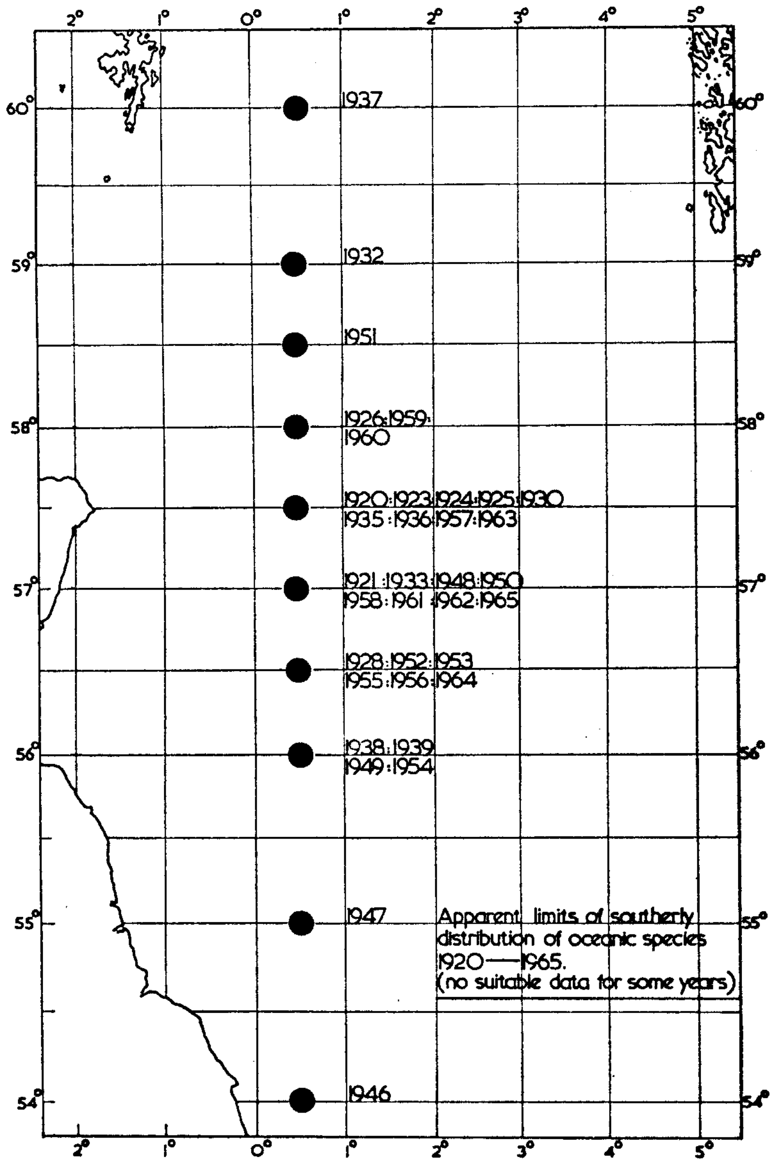

FIG. 1. Approximate limits of penetration of oceanic species into the North Sea, 1920–65 (inadequate evidence some years).

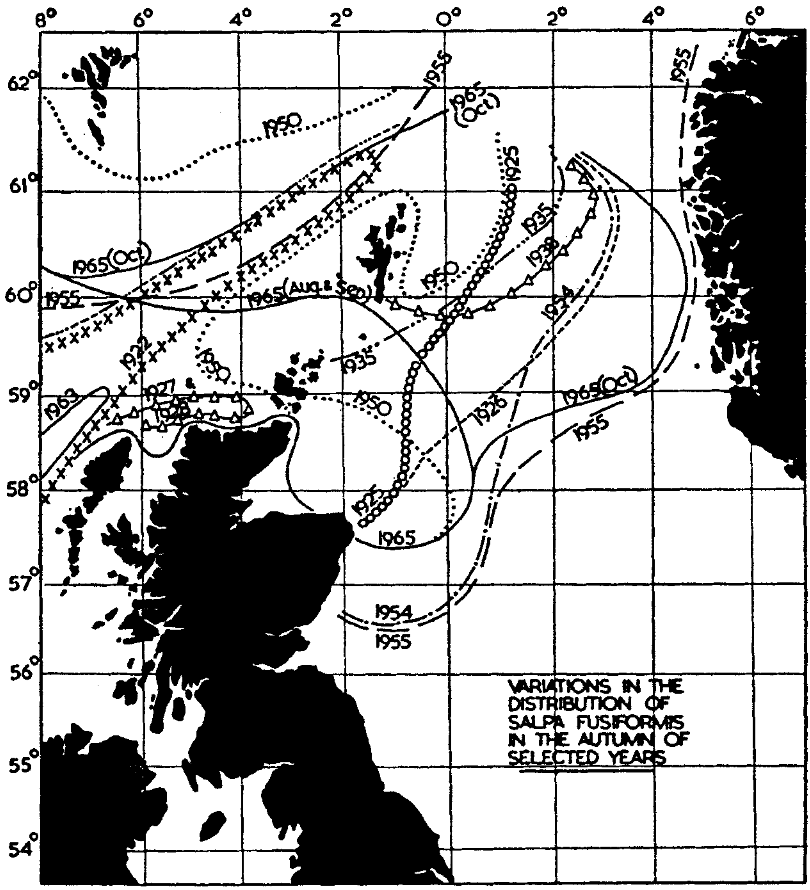

FIG. 2. Variations in the distribution of *Salpa fusiformis* in the northern North Sea in selected years.

variation in the distribution of *Salpa fusiformis* is not only in the degree of penetration but in the total area covered. The influx of *Salpa* is progressive, so that a time scale needs to be added. It occurs first in February to April, west of Ireland; in the summer months it is found over a wide area west of Scotland reaching Shetland and the North Sea in September and October.

Taking a single species like this takes no account of the complications mentioned above—that the optimum conditions are not the same for all oceanic species, even though these are much more rigid than for neritic species. The type of species present will therefore depend on the origins of the water masses, and the degree of penetration of any particular species

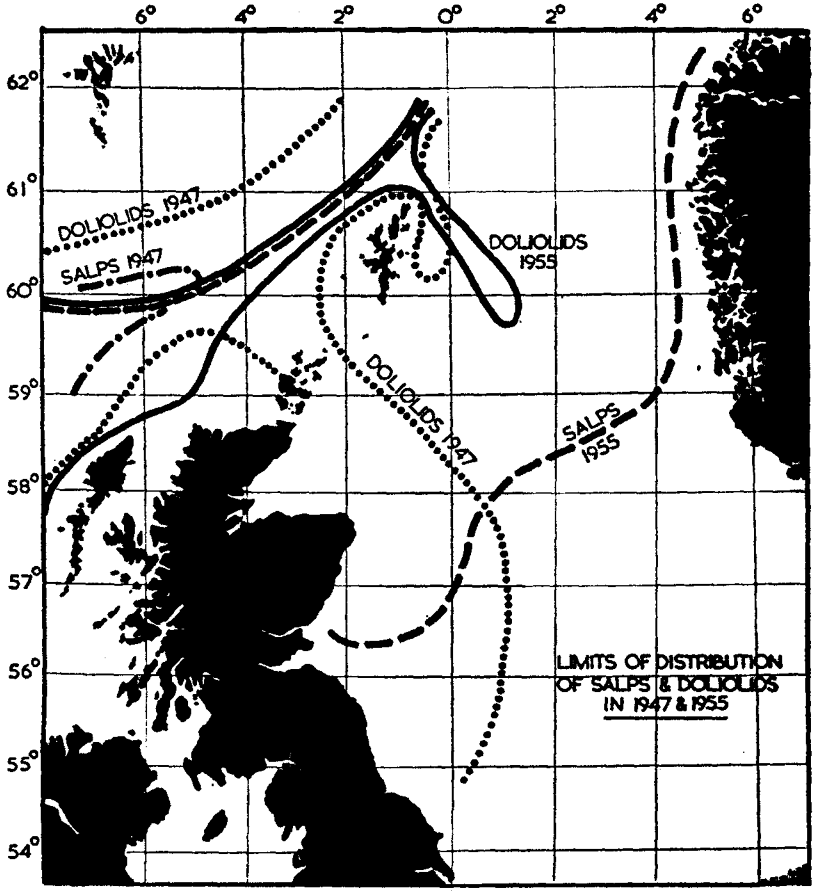

FIG. 3. The limits of distribution of *Salpa fusiformis* and *Dolioletta gegenbauri* in 1947 and 1955.

will depend on how its own limiting factors in the environment have been maintained during the process of the water transport.

This means that the species entering the Faroe–Shetland Channel from the Atlantic will vary not only with the amount of water transport (the larger the volume the longer it will keep its own characteristics) and with its direct physical and chemical characteristics, but also with its organic content which has been dependent on the biological history of the water mass—and this is closely linked with its origin.

Differences can thus be seen between quite closely related species, and as an example we can compare *Salpa fusiformis* with another member of the

Thaliacea, *Dolioletta gegenbauri* (Fig. 3). Each is common and widespread in the northeast Atlantic. To illustrate the point two years with different characteristics can be chosen, 1947 when the doliolids were abundant and 1955 which was a good year for salps. The main environmental difference between these two species is that *Dolioletta gegenbauri* is usually associated with water which is just a shade more southerly in its origin than the salps. In 1947 the salps were very poorly represented and the doliolids reached much further south but not nearly so far as the 1947 southerly limit of oceanic species illustrated in Fig. 1.

It must be emphasised again that although the final distribution of oceanic species in the North Sea is dependent on the water inflow the dominance of one species over another is dependent on conditions well outside the North Sea, and the relevant characteristics would not be at all easy to detect by chemical or physical analysis after much mixing and change during its transit of 500 to 1000 miles or more into the North Sea. That these oceanic plankton species occur so often in the North Sea means that they can withstand the changes and are fairly tolerant. As they cannot withstand the winter conditions they die out, so that each year the influx is a fresh one, uncomplicated by admixture with indigenous individuals.

Not all exotic species are so tolerant, however, and many die out much earlier during the course of their transit and they only reach the North Sea under exceptional circumstances. This is especially true of those species with a distinctly southern origin. Where this southerly origin is relatively near, such as off the Iberian peninsula there is a greater chance of reaching the Scottish area, and the term "Lusitanian" is used to define organisms from this origin.

Can we apply the same principle and use less tolerant species to illustrate the more subtle variations in the environmental conditions in the waters approaching the British Isles, variations which cannot at present be detected by the normal physical and chemical methods used in oceanography?

As an example, the distribution of 32 species of siphonophores can be used. None of these are reported in the literature to occur so far north (except records by FRASER in *Annales Biologiques* and reference to these), the limits otherwise being given are in the order of 10° to 20° further south. Charts illustrating these distributions from 1947–64 are given in Figs. 4–7 and further details of the species concerned are given in FRASER (1967).

The year 1947 was referred to above as a year of peak inflow of oceanic species into the North Sea and when the relatively southern form *Dolioletta gegenbauri* was more abundant and penetrated further than the more northerly *Salpa fusiformis*, yet in 1947 not a single one of these 32 exotic siphonophores was found in the area illustrated in the figures. During the period since 1947 there has been a gradual build up of the records from none

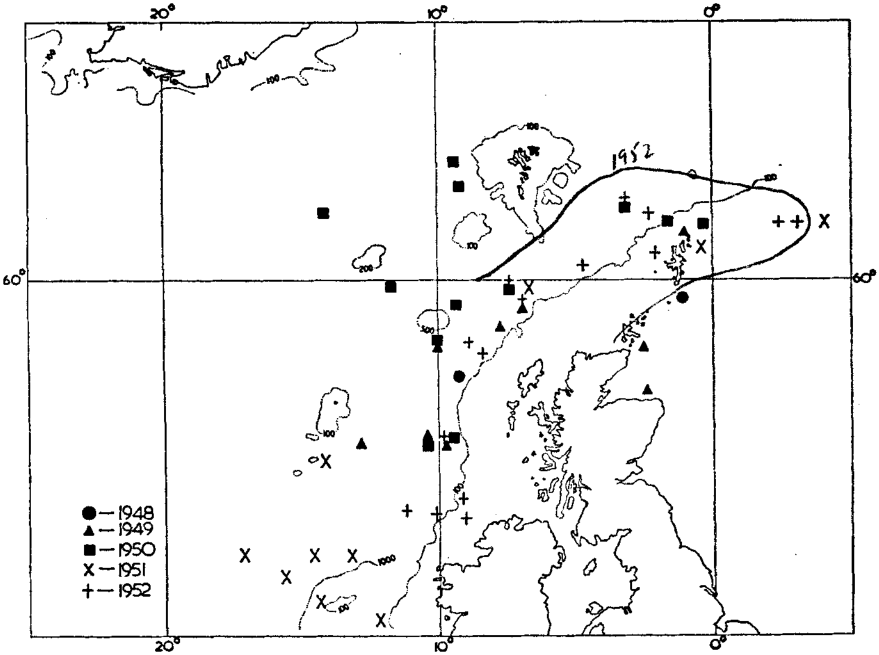

FIG. 4. The distribution of exotic siphonophores, 1948–52.

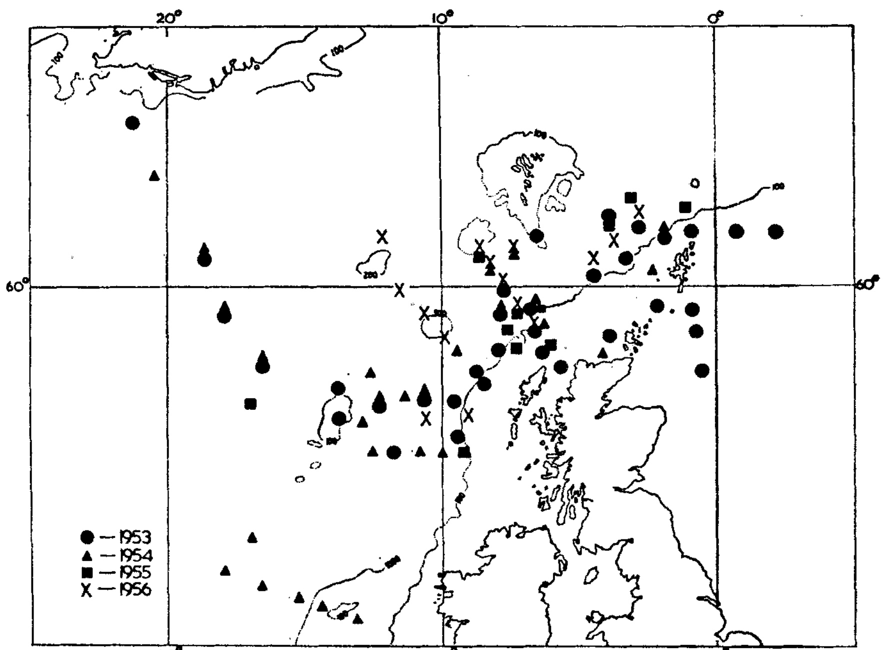

FIG. 5. The distribution of exotic siphonophores, 1953–56.

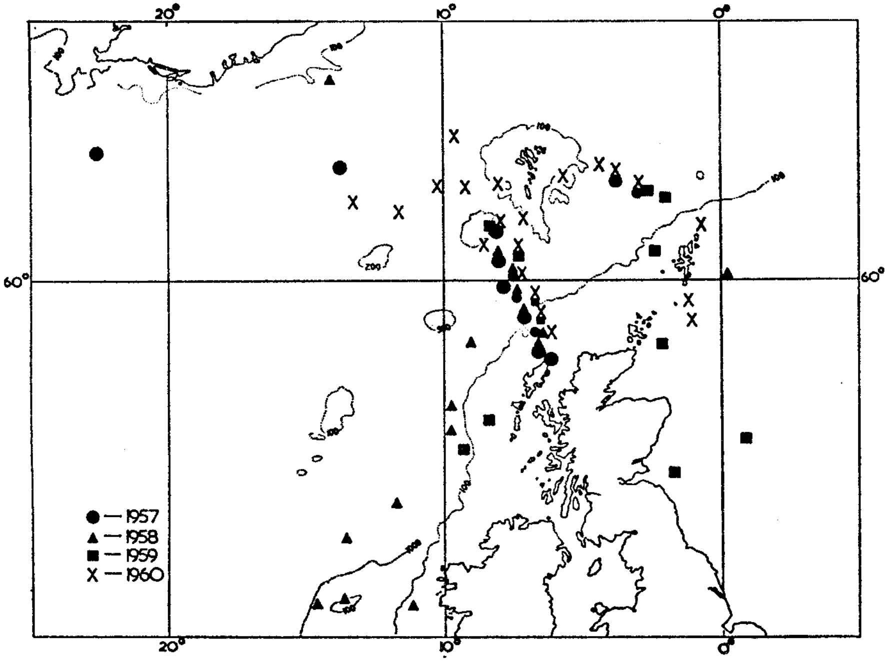

FIG. 6. The distribution of exotic siphonophores, 1957–60.

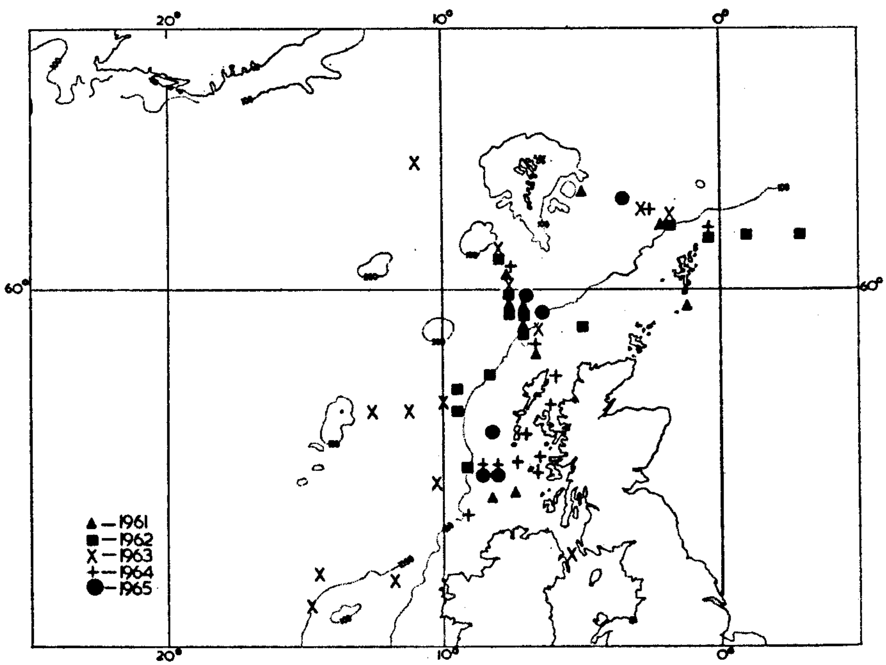

FIG. 7. The distribution of exotic siphonophores, 1961–65.

TABLE 1

	Shelf		S of 60°N		N of 60°N			Shelf		S of 60°N		N of 60°N			Shelf		S of 60°N		N of 60°N	
1947	0	0	0	0	0	0	1953	2	2	4	2	0	0 10	1959	0	0	3	8	2	7
1948	0	0	0	0	0	0	1954	0	0	3	3	1	2 9	1960	1	3	3	5	3	2
1949	0	0	1	2	0	0	1955	1	1	3	5	1	4 15	1961	1	1	3	8	2	3
1950	0	0	1	1	0	0	1956	0	0	3	4	2	3 12	1962	0	0	4	3	1	1
1951	0	0	1	2	0	0	1957	3	3	3	6	3	4 22	1963	1	2	4	6	3	5
1952	0	0	3	2	0	0	1958	3	1	2	4	2	3 15	1964	1	2	0	0	0	0
														1965	2	1	2	4	0	0

in 1947 and very few in 1948 and 1949 to a maximum in 1953 and 1954 which has since largely been retained. It is too early yet to judge whether the decline in 1964 was the beginning of a recession or not. The 1965 data might suggest that 1964 was just an "odd year out" though it could be that 1965 was the odd one. We must wait and see. 1964 was a year when one or two species of these Lusitanian siphonophores overflowed on the Scottish shelf, though in the main the path over the 19 years is clearly revealed to be just beyond the edge of the shelf. The coverage of plankton sampling was not identical during this period so the years are not strictly comparable but the general trends should be adequately illustrated, and sampling in the Faroe Channel and northern North Sea was plentiful each year.

We can look at the line of stations from the Butt of Lewis to Faroe Bank which has been worked fairly regularly by the Scottish research vessels. For convenience we can divide this line into three parts of four stations each, one on the Scottish shelf, one over deep water south of 60° N and one over the deep water between 60° N and Faroe Bank. Using presence or absence of any of the 32 species and ignoring individual or specific frequency we get the first series of figures in Table 1 which give the number of stations—out of four in each column—at which Lusitanian siphonophores were found.

The second series of figures give the number of species—out of a total of 32 identified over the 19 years—in each group of four stations. Both methods give roughly the same results; a build up from nil in 1947 and 1948 to higher figures from 1953 onwards with a reduction in 1964 not maintained in the southern part in 1965. It also shows that 1953, 1957, 1958 and 1965 were years of greater Lusitanian overflow on to the shelf north of Scotland and that over the period 1954 to 1963 there was a more marked northerly distribution.

It ought to be emphasized that the Lusitanian species in these areas form only a very small percentage of the total oceanic fauna which is mainly of Atlantic origin. The variations in the total volume of water transport are mainly of Atlantic water and there is no reason to expect that the Lusitanian content should vary in proportion to the total volume of water transport. It is more likely to be dependent on slight variations of the angle of approach of internal waves against the edge of the continental shelf from the south of the British Isles to Gibraltar (COOPER, 1955). Observations of this kind give no precise measure of variability, but they do suggest that annual and long-term variations exist that could otherwise pass unnoticed.

REFERENCES

COOPER, L. H. N. (1955) Hypotheses connecting fluctuations in arctic climate with biological productivity of the English Channel. *Pap. Mar. Biol. Oceanogr., Deep-Sea Res.* **3** (*Suppl.*), 212–223.

FRASER, J. H. (1961) The oceanic and bathypelagic plankton of the North-east Atlantic. *Mar. Res.* 1961 (**4**), 1–48.

FRASER, J. H. (1965) Zooplankton indicator species in the North Sea. *Am. Geogr. Soc.: Ser. Atlas Mar. Environ.* Folio **8**.

FRASER, J. H. (1967) Siphonophora in the plankton to the north and west of the British Isles. *Proc. R. Soc. Edinb.* **70**, (1), 1–30.