THE SPAWNING OF MACKEREL, *SCOMBER SCOMBRUS* L., AND PILCHARD, *CLUPEA PILCHARDUS* WALBAUM, IN THE CELTIC SEA IN 1937–39

WITH OBSERVATIONS ON THE ZOOPLANKTON INDICATOR SPECIES, *SAGITTA* AND *MUGGIAEA*

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(Text-figs. 1–21)

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INTRODUCTION

Large shoals of mackerel collect each spring in the waters to the south of Ireland and off the western entrance to the English Channel. In 1936, at the instance of the Ministry of Agriculture and Fisheries, the Marine Biological Association of the United Kingdom started an investigation of the biology of this mackerel population of the Celtic Sea.

One of the aims of the investigation was to determine the duration and locality of spawning of the mackerel and the distribution of the pelagic young stages. To this end, a survey of the plankton and hydrology of the area was carried out during a series of cruises in the years 1937, 1938 and 1939. Joint co-operation in the programme of cruises by the Fisheries Departments of

Eire and France was agreed at a meeting of the Mackerel Sub-Committee of the International Council for the Exploration of the Sea held at the Plymouth Laboratory in December 1937 (Le Danois, 1939*a*, *b*). The following cruises were made:

	1937
12–20 April	S.S. *George Bligh* (United Kingdom)
27–30 May	Steam drifter *B.T.B.*, L.T. 1153 (U.K.)
20–22 July	Steam trawler *Elk*, M. 36 (U.K.)
	1938
23 March–5 April	S.S. *Quentin Roosevelt* (France)
6–9 April	S.S. *Quentin Roosevelt* (France)
7–12 April	S.S. *Muirchu* (Eire)
7–18 April	S.S. *George Bligh* (U.K.)
31 May–5 June	S.T. *Elk* (U.K.)
19–24 July	S.T. *Elk* (U.K.)
	1939
15–18 March	S.T. *Elk* (U.K.)
16–27 April	S.S. *George Bligh* (U.K.)
17–21 April	S.S. *Muirchu* (Eire)
2–7 June	S.T. *Elk* (U.K.)

Some of the results of this programme of research have already been published. Farran (1939) has described the distribution of mackerel eggs and young stages taken in April 1938 to the south of Ireland by the Irish Fishery Cruiser *Muirchu*. Extensive data resulting from the two cruises made in March and April 1938 by the French Research Ship *Quentin Roosevelt* have been fully reported by Furnestin (1939*a*), and an introductory account of the distribution of mackerel eggs and young stages in the area covered by the Plymouth cruises is included in preliminary reports of the work of the investigation at Plymouth (Steven & Corbin, 1939; Marine Biological Association, 1940*a*, *b*). The distribution of phosphates in the area in April 1938 has been described by Hickling (1938), and the phytoplankton distribution of the 1939 cruises has been examined in detail by Mare (1940).

In addition to the distribution of mackerel eggs and young stages in the Celtic Sea in 1937–9, the present paper gives an account of the spawning of the pilchard[1] and the distribution of certain zooplankton indicators—the *Sagitta* species of the area and *Muggiaea atlantica*. Temperature and salinity conditions are also described briefly; further detailed treatment of the hydrological data will be published at a later date.

The courses of the cruises and station numbers[2] are shown in Figs. 1 and 2. Details of station times and positions, and of numbers of organisms per haul are given in the Appendix (Table VI; pp. 124–32). For data of the French cruises, see Furnestin (1939*a*).

[1] Furnestin's paper (1945) on the biology of the Atlantic pilchard was received at the Plymouth Laboratory after completion of the present paper.

[2] In the text and figures, the station numbers of the *Muirchu* cruises are shortened by omitting the first two figures of the station number. Thus, Station SR 2872 reads SR 72. Full station numbers are given in Table VI with the last two figures printed in heavy type.

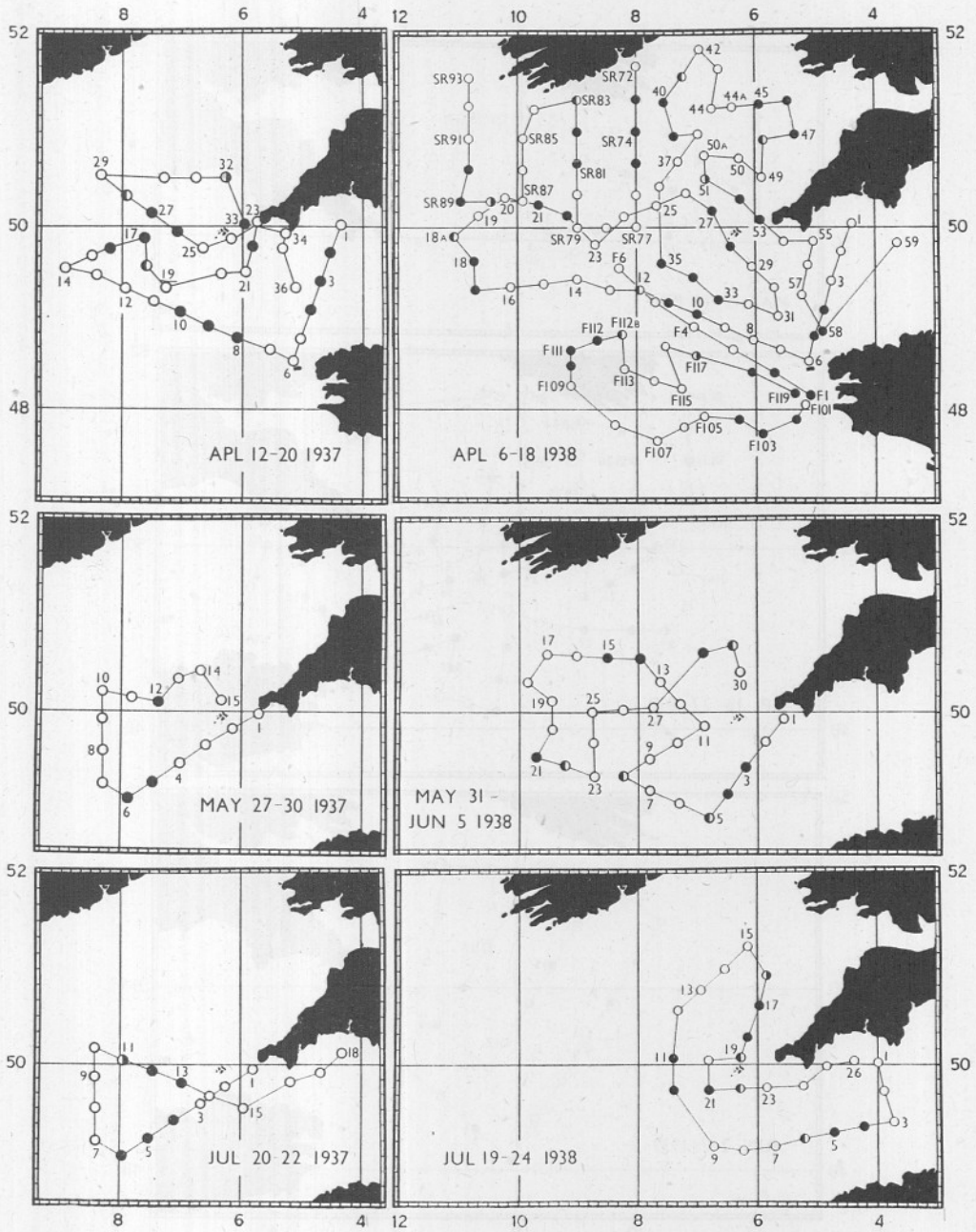

Fig. 1. 1937 and 1938 cruises; station positions. Stations worked by the *Muirchu* have the prefix SR; those worked by the *Quentin Roosevelt* have the prefix F. Only the first six stations (F 1–F 6) of the first cruise of the *Quentin Roosevelt* are shown; all stations (F 101–F 119) of the second cruise are shown. ◐ dawn; ○ day; ◑ dusk; ● night.

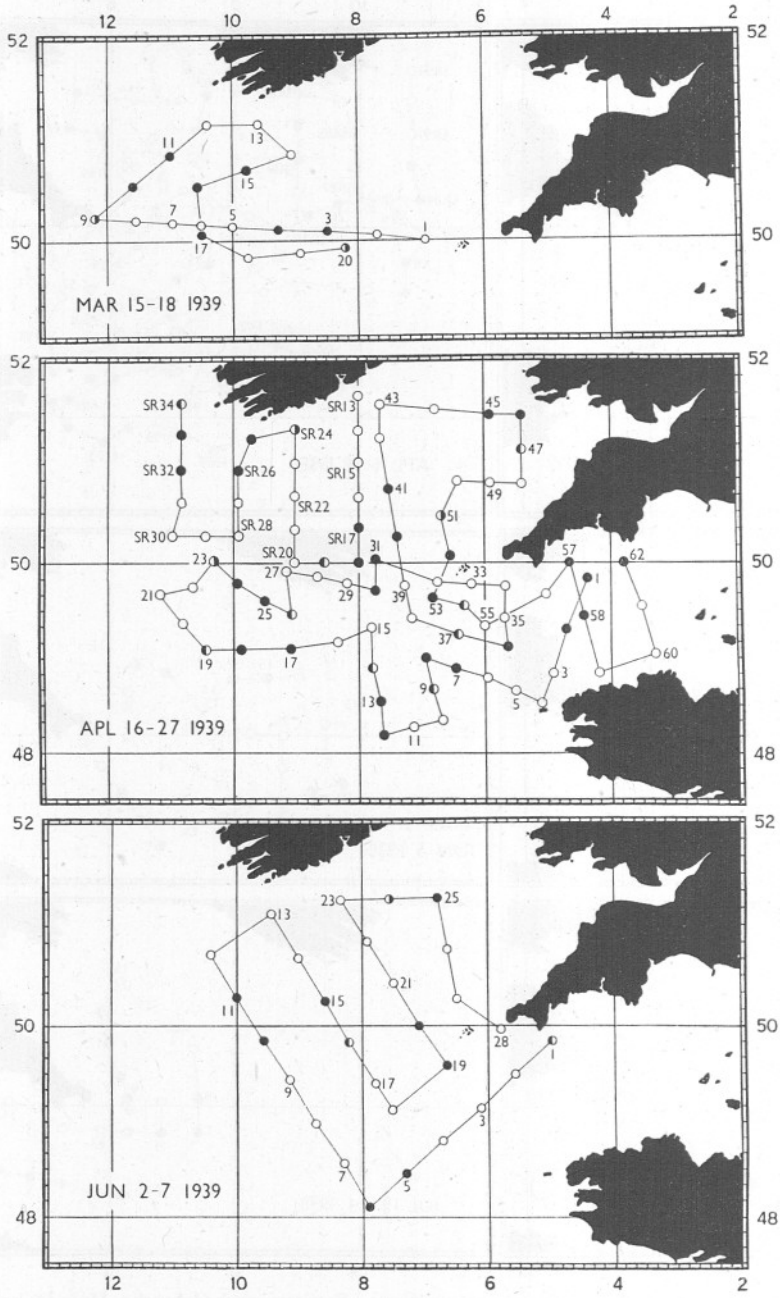

Fig. 2. 1939 cruises; station positions. Stations worked by the *Muirchu* have the prefix SR.
◐ dawn; ○ day; ◑ dusk; ● night.

Collection and Examination of Material

Throughout the cruises made from Plymouth and Eire, plankton was collected by half-hour oblique hauls of the 2 m. stramin ring-trawl. The method of fishing was the same as that described by Russell (1930, 1935*a*), but a slightly greater depth of water was sampled, the marks on the warp being at 10, 20, 35, 50 and 70 fm. (18, 36, 63, 91 and 126 m.) (Le Danois, 1939*a*). The use of a standard method of collection permits some degree of quantitative comparison of the results of different cruises and different years, but no more than broad comparisons can be made since stations were worked both in daylight and darkness during the cruises. On the *Quentin Roosevelt* cruises, hauls were made horizontally (15 min. at surface) or vertically (25–0 m. and 50–0 m.) with a 33 cm. 'petit filet type Boulogne' or a 1 m. 'grand filet Schmidt' (Furnestin, 1939*a*). The data are therefore not quantitatively comparable with those obtained by the oblique hauls of the 2 m. stramin ring-trawl, but are valuable as qualitative records. Water samples and temperature readings were taken with the Nansen-Petterson water-bottle.

All young fish caught in each haul were picked out for counting and identification. The fish-eggs in each haul were also picked out for counting and identification, or, in hauls where they were very numerous, the number was estimated by sampling.[1] The same methods were also used for the indicator species. The eggs were identified largely by inspection; the number dealt with was far too great to permit of identification of individual eggs by measurement of the diameter of the egg and of the oil globule. Inspection alone may perhaps be considered a somewhat uncertain means of identification, but it proves reliable after some experience in the recognition of different species of fish eggs has been acquired, and especially when used in combination with the certain identification characters provided by the chromatophore pattern of the embryo and the oil globule in the later development stages of the mackerel egg (Buchanan-Wollaston, 1911; Holt, 1893).

General Results

The Spawning of the Mackerel and the Distribution of the Pelagic Young Stages and the Spawning of the Pilchard

Before discussing the results of the present investigation, it will be of value to recall the existing records concerning the spawning of the mackerel in the seas around the south-west of the British Isles.

Matthias Dunn (1893) is remarkably accurate in his observations on the subject. He writes: '...the period of spawning...as a rule is in May and

[1] All totals obtained by sampling are indicated in Table VI by * after the number (e.g. 2450*); totals without this notation are exact counts.

June...and the spawning grounds...are in those waters covering the plateau of ground within the two hundred mile limit of our western and south-western shores.' Of the mackerel in the English Channel, he observes: 'They generally spawn late in June, but...I have known their spawning deferred so late as the 10th of August.' Allen (1897), summarizing the records of Cunningham (1890, 1892) for the Plymouth area, and of Holt (1892, 1893) and Green (1894) for the south-west coast of Ireland, gives the following as the chief spawning periods:

South-west of England (off Plymouth).	End of May to end of July.
South-west of Ireland.	May and June.

The records of mackerel young stages from Plymouth waters in the years 1906, 1908–9, 1913–14, 1917 and 1919 (Allen, 1917; Lebour, 1918; Clark, 1914, 1920) also led Clarke to observe that spawning in the area takes place from May to July, but he notes that, '...a later spawning period has been observed for some years, *vide* Lebour (1918) for the record of post-larvae in September 1917', and he concludes by giving the spawning period as May–August (Clark, 1920). Ehrenbaum (1923) quotes Allen, Cunningham, Holt and Green. Lissner (1939) gives the spawning period in the Channel and North Sea as (May), June and July, and for Ireland as (April), May, June and July. From records of the occurrence of mackerel young stages in the 2 m. ring-trawl plankton collections made throughout the year at Plymouth, Russell (1930, 1935*a*, 1936*b*, 1937, 1938*b*, 1939*a*, 1940) classifies the mackerel as a summer-spawner in Plymouth off-shore waters, noting however that 'the main spawning region is probably considerably further to the westward' (1926). Farran (1939) records very intense spawning to the south of Ireland in April 1938. Le Gall (1939) states: 'Dès Mars, aux accores du Plateau Continental Atlantique, on constate la présence d'œufs de maquereaux dans le plancton.... La ponte du maquereau débute donc vers mi-Mars à l'entrée occidentale de la Manche. Elle s'intensifie en Avril et en Mai (maximum), se poursuit en Juin, en Manche Occidentale. Nous avons pu l'observer jusqu'à la fin d'Août en Manche Orientale.' In a preliminary report of the present investigation, Steven & Corbin (1939) also state that spawning lasts from March until July or August, with a maximum from mid-April to mid-May, and occurs within the area of the Continental Shelf but mainly off-shore. This observation was based on a detailed examination of the 1937 material of the Plymouth investigation, together with a preliminary inspection of the plankton collections of 1938 and 1939. A full examination of all the material has now been completed and has revealed in considerable detail the locality and period of spawning of the mackerel population of the Celtic Sea in 1937–9. Probably the most outstanding feature of the survey is the similarity in each year of the numbers and locality of mackerel eggs and young stages, and of the sequence of changes with time in these two components of distribution.

Spawning begins in about the second week of March and continues until the end of July and into August. It increases very rapidly in intensity after the start and by mid-April reaches a peak which lasts until May. Thereafter it decreases more gradually, until by the end of July it is only very slight. This changing intensity of spawning is shown in Fig. 3 and Table I.

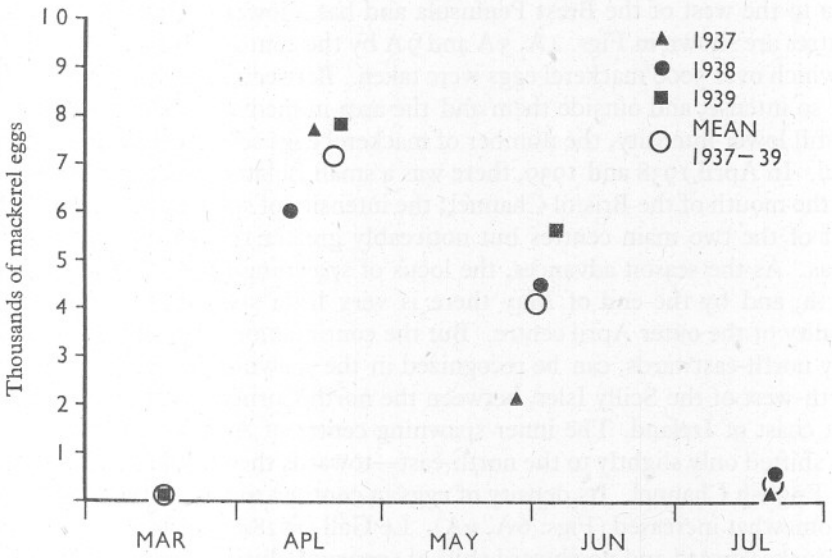

Fig. 3. Variation in intensity of spawning of the mackerel (data in Table I).

TABLE I. AVERAGE FOR EACH CRUISE OF THE TOTAL OF MACKEREL EGGS AT ALL STATIONS WHERE MORE THAN 100 WERE TAKEN

The number of stations from which the averages are obtained is shown in parentheses

	March	April	May–June	July
1937	No cruise	7659 (14)	2127 (10)	135 (1)
1938	No cruise	6003 (42)	4485 (23)	571 (7)
1939	118 (1)	7802 (38)	5660 (26)	No cruise
Mean 1937–9	118	7154	4090	353

Spawning takes place throughout the Celtic Sea during the period March to July. In the English Channel, and also in the Irish Sea, it is known to continue until August and probably in some years even until September, well after the main activity has finished in the Continental Shelf area. At the beginning of spawning in mid-March, the area is small and is situated well to the south-west of Ireland in the waters overlying the edge of the Continental Shelf (Fig. 8). By the mid-April peak, it has spread eastwards over the whole of the Celtic Sea, as far as the mouth of the English Channel and the entrances of the

St George's and Bristol Channels. There is little evidence that it extends into open oceanic waters beyond the 100 fm. line. The number of eggs, however, varies greatly in different parts of the area, and spawning is concentrated in two centres—to the west and south of the Celtic Sea. Of these, the outer western centre lying to the south of Ireland is the more extensive and contains the higher density of eggs. The inner southern centre covers a smaller area to the west of the Brest Peninsula and has a lower egg density. The two centres are shown in Figs. 4A, 5A and 9A by the contour enclosing all stations at which over 5000 mackerel eggs were taken. Between the centres spawning is not so intense, and outside them and the area immediately between them it is of still lower intensity, the number of mackerel eggs seldom exceeding 500 per haul. In April 1938 and 1939, there was a small isolated concentration of eggs off the mouth of the Bristol Channel; the intensity of spawning was lower than that of the two main centres but noticeably greater than in the surrounding areas. As the season advances, the locus of spawning moves farther east and north, and by the end of May there is very little spawning in the original locality of the outer April centre. But the continuation of it, shifted considerably north-eastwards, can be recognized in the spawning which occurs to the north-west of the Scilly Isles, between the north Cornish coast and the south-east coast of Ireland. The inner spawning centre of April is still present and has shifted only slightly to the north-east—towards the middle of the mouth of the English Channel. Its density of eggs in contrast to that of the outer centre is somewhat increased (Figs. 6A, 9A). Le Gall (1928*a*) draws attention to the gradual eastward and northward shift of spawning during April and May from the region south of Ireland, and he remarks on the presence at the end of May of two spawning areas towards the east—at the entrance to the St George's Channel (51° 18′ N., 7° 03′ W.) and some distance to the west of Ushant (48° 33′ N., 5° 50′ W.). The decrease in intensity of spawning and the eastward shift continue, and by mid-July no eggs are present to the west of Scilly. Their maximum numbers are little more than 1000 per haul in contrast to over 99,000 and 45,000 in April (1938, 1939). The occurrence of the larger hauls in the eastern part of the July spawning area indicates that the movement of spawning eastwards along the Channel and northwards into the Irish Sea still continues (Figs. 4C, 7A). In this connexion, Scott's records from the Irish Sea are especially valuable as they cover a considerable period of years. He found mackerel eggs only once in the northern area (south-west of the Isle of Man) during the years 1907–13. Farther south they were more numerous and he states that 'the eggs are not uncommon in the Cardigan Bay plankton at the beginning of July and it is possible that the majority of fish that arrive in the central area spawn on the way up from the south'. In support of this, he found that mackerel caught off Walney (north Lancashire) early in July (1901–12) were invariably in a spent condition (Scott, 1913, 1914*a*, *b*).

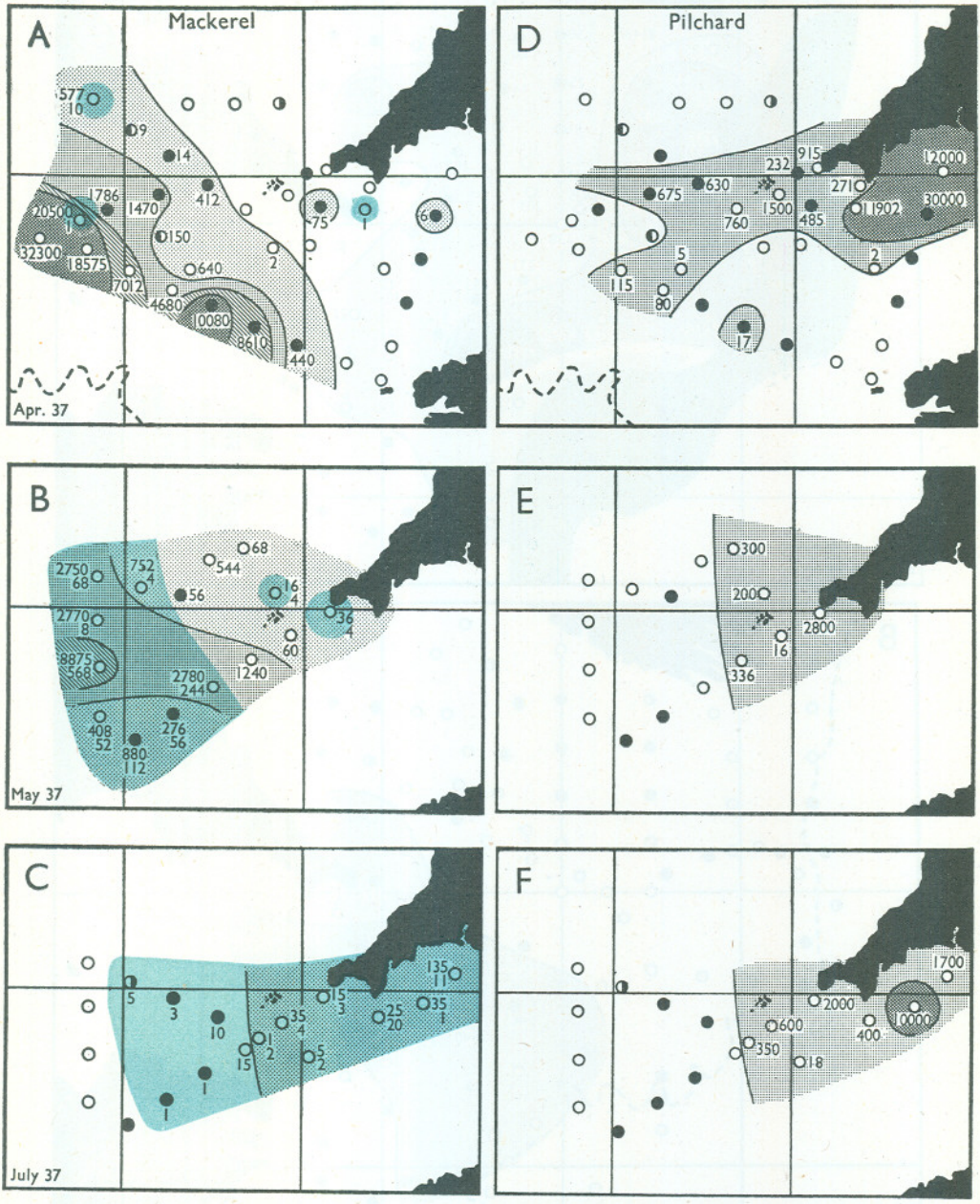

Fig. 4. Distribution of mackerel eggs (1–1000, 1001–5000, 5001–10,000, > 10,000) and young stages (blue areas) (A, B and C), and pilchard eggs (1–5000, > 5000) (D, E and F) in the Celtic Sea in April, May and July 1937. Figures refer to the numbers of eggs and young stages at each station. The broken line in this and succeeding figures indicates the 100 fm. contour.

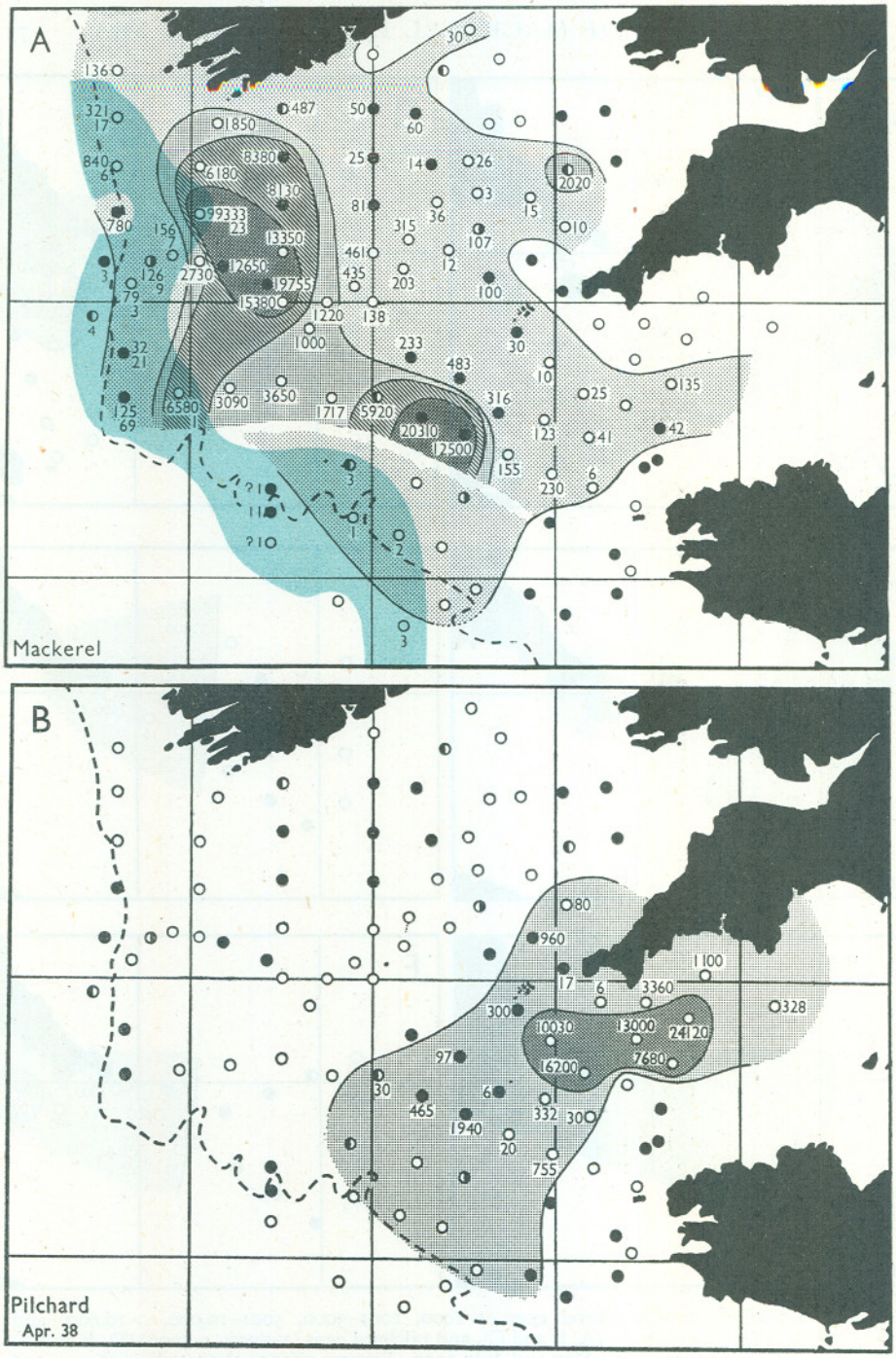

Fig. 5. Distribution of mackerel eggs (1–1000, 1001–5000, 5001–10,000, > 10,000) and young stages (blue area) (A), and pilchard eggs (1–5000, > 5000) (B) in the Celtic Sea in April 1938. Figures refer to the numbers of eggs and young stages at each station. Numbers of mackerel eggs and pilchard eggs at Sts. F 101–F 119 are not given (Furnestin, 1939*a*).

The changes in numbers and distribution of mackerel young stages[1] in the Celtic Sea are very similar to those of the eggs. None occurred in March

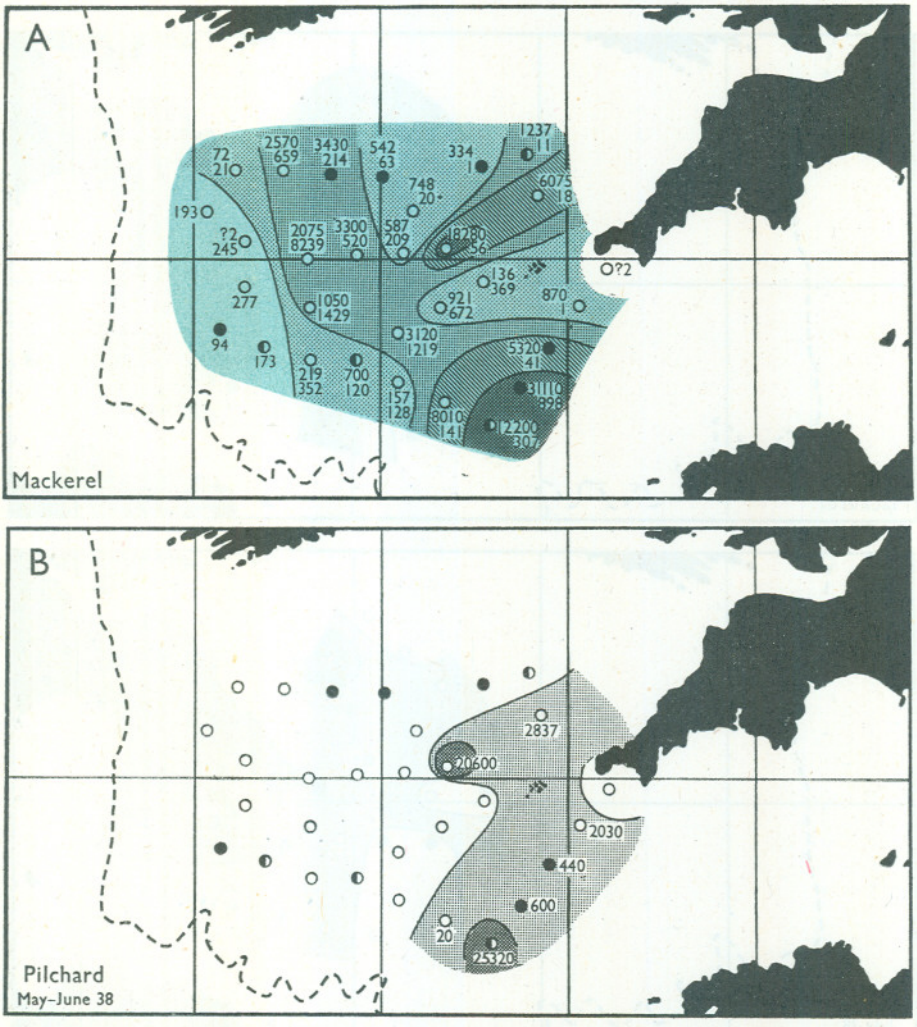

Fig. 6. Distribution of mackerel eggs (1–1000, 1001–5000, 5001–10,000, > 10,000) and young stages (blue area) (A), and pilchard eggs (1–5000, > 5000) (B) in the Celtic Sea in May–June 1938. Figures refer to the numbers of eggs and young stages at each station.

1939, and there appear to be no previous records of any being taken in the area as early as March. In the third week of April, small numbers of larvae and post-

[1] The material consists of 22,203 specimens; the largest measures 21 mm. (including tail) and may be regarded as past the post-larval stage since there is silvery pigment over most of the body and the finlets are developed on the caudal peduncle.

larvae are present in the plankton of the outer margin of the area—beyond the main spawning centres and towards the western and south-western edge of the Continental Shelf (Figs. 5A, 9A). The numbers caught in April 1938 and 1939

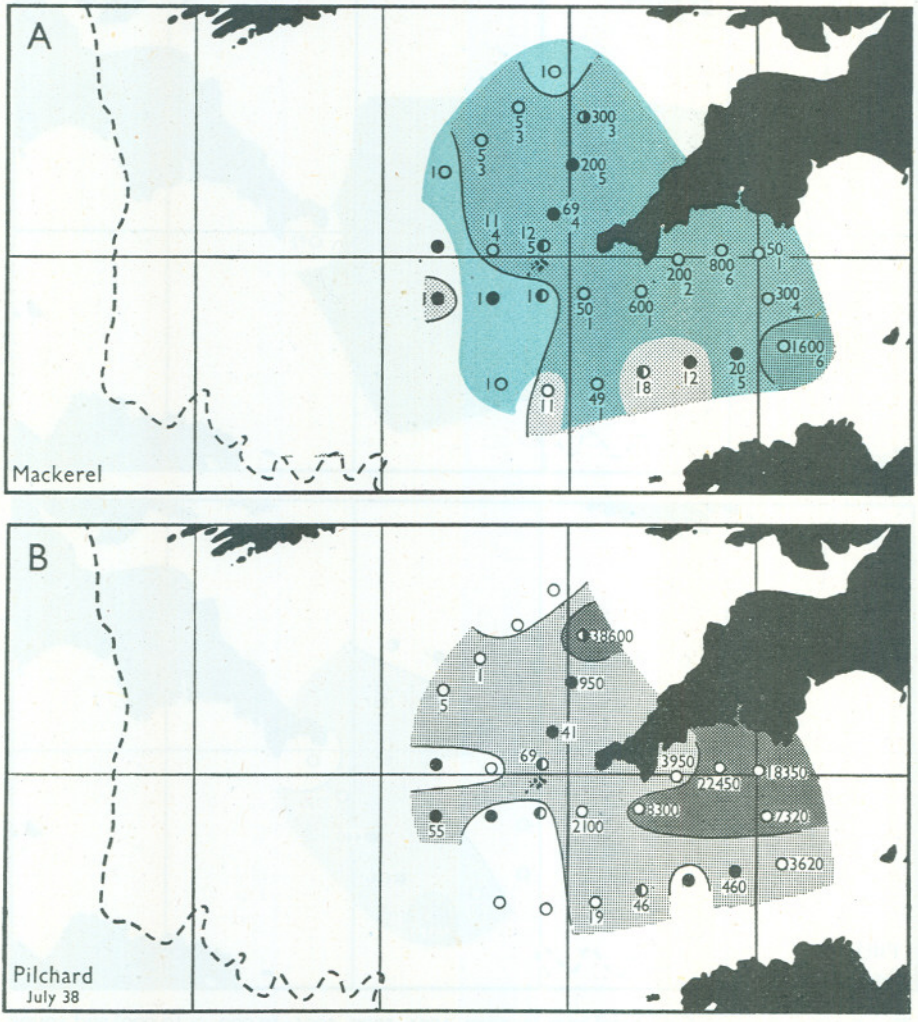

Fig. 7. Distribution of mackerel eggs (1–1000, 1001–5000) and young stages (blue areas) (A), and pilchard eggs (1–5000, > 5000) (B) in the Celtic Sea in July 1938. Figures refer to the numbers of eggs and young stages at each station.

in this region were almost all under 100 per haul. Le Gall (1928*a*) records young stages in April to the south of Ireland in the region of 50° 50′ N., 10° 00′ W., (18–26 April 1927). They do not occur, or are present in very small numbers only, on the landward side of the spawning centres—in the central,

northern and eastern areas of the Celtic Sea. In April 1939, three specimens were taken close to the small concentration of eggs off the mouth of the Bristol Channel. By the end of May and beginning of June, they are present throughout the Celtic Sea and are particularly abundant in the central area stretching from south-west Ireland to the Brest Peninsula (Figs. 4B, 6A, 10A). The largest haul contained 8239 specimens (St. 25, June 1938, day haul). They are less numerous towards the edge of the Continental Shelf, and also eastwards towards the English Channel and northwards towards the entrance to the Irish Sea. They are only occasionally taken at Plymouth in May but occur regularly there in small numbers in June (Allen, 1917; Lebour, 1918; Clark, 1914, 1920; Russell, 1930, 1935*a*, *et seq.*), and Clark (1914) observes that 'it is highly probable that the early stages occur in greater numbers much further out than the area investigated'. The area of abundance of young stages

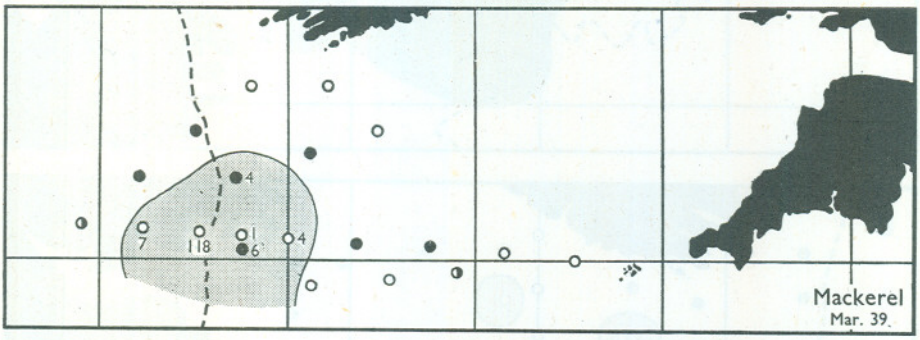

Fig. 8. Distribution of mackerel eggs in the Celtic Sea in March 1939. Figures refer to the number of eggs at each station. No young stages were taken.

bears the same relationship to the spawning centres at this time of year as did the area of occurrence of young stages in April. It is situated beyond them—towards the edge of the Continental Shelf. By July they are much less abundant, even fewer than in April. Their continued move to the north and east is still evident and they are no longer present in the central area of the Celtic Sea to the west of 8° W. where previously, at the beginning of June, they were so numerous (Figs. 4C, 6A). Table II shows the average total of mackerel young stages taken on each cruise. The maximum at the end of May and beginning of June stands out clearly. At Plymouth, Russell (1930, 1935*a*, *et seq.*) finds a maximal occurrence of young stages in July. They continue to be present in the plankton in August in the majority of years, and even until September (Lebour, 1918 and Russell, 1935*a*; records in September 1917 and 1930, 1931 and 1932). The figures in Table II show that the average for the July cruises (1937, 6; 1938, 2·8) is in close agreement with the July monthly average at Plymouth (period 1930–9; July average, 9).

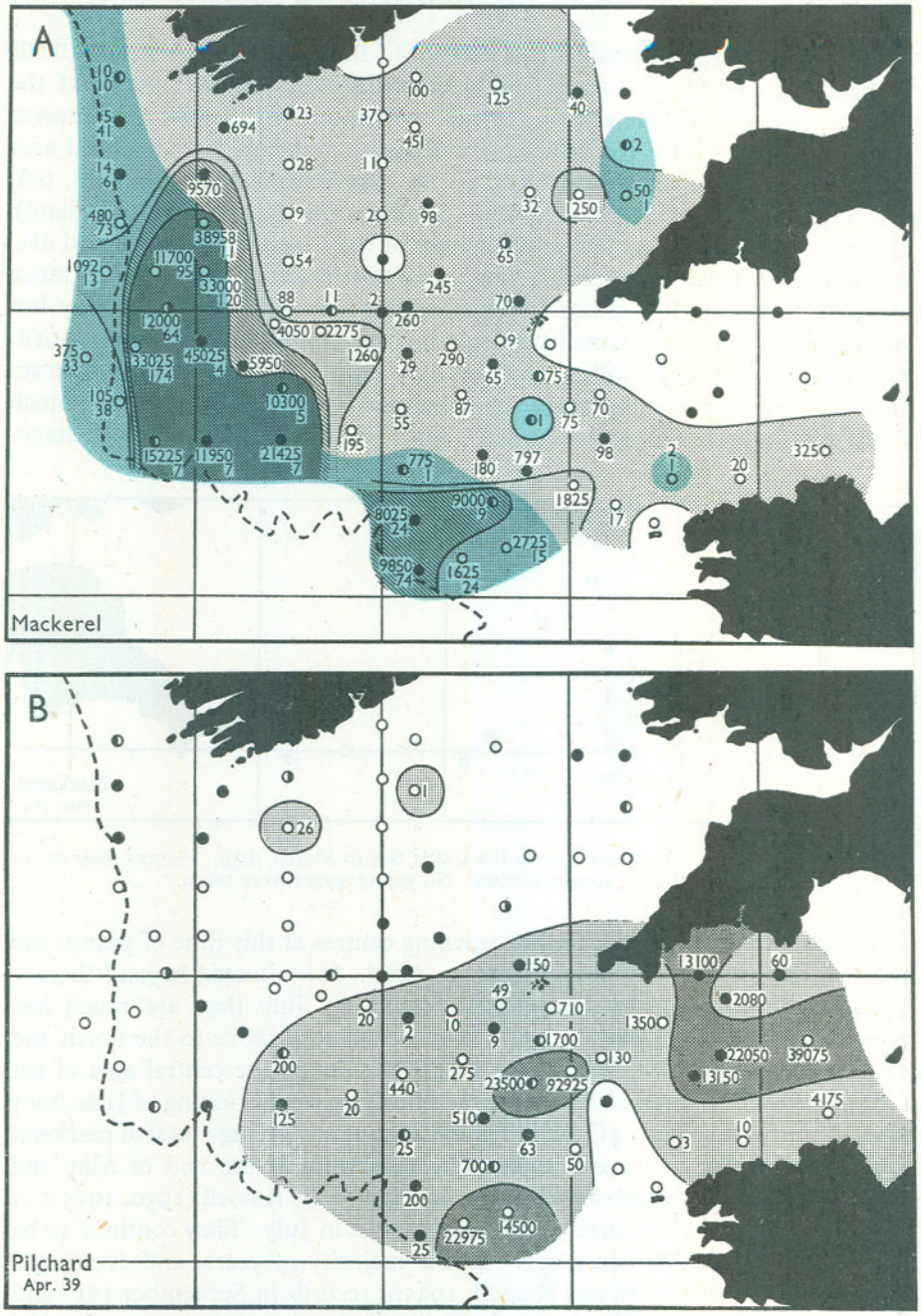

Fig. 9. Distribution of mackerel eggs (1–1000, 1001–5000, 5001–10,000, > 10,000) and young stages (blue areas) (A), and pilchard eggs (1–5000, > 5000) (B) in the Celtic Sea in April 1939. Figures refer to the numbers of eggs and young stages at each station.

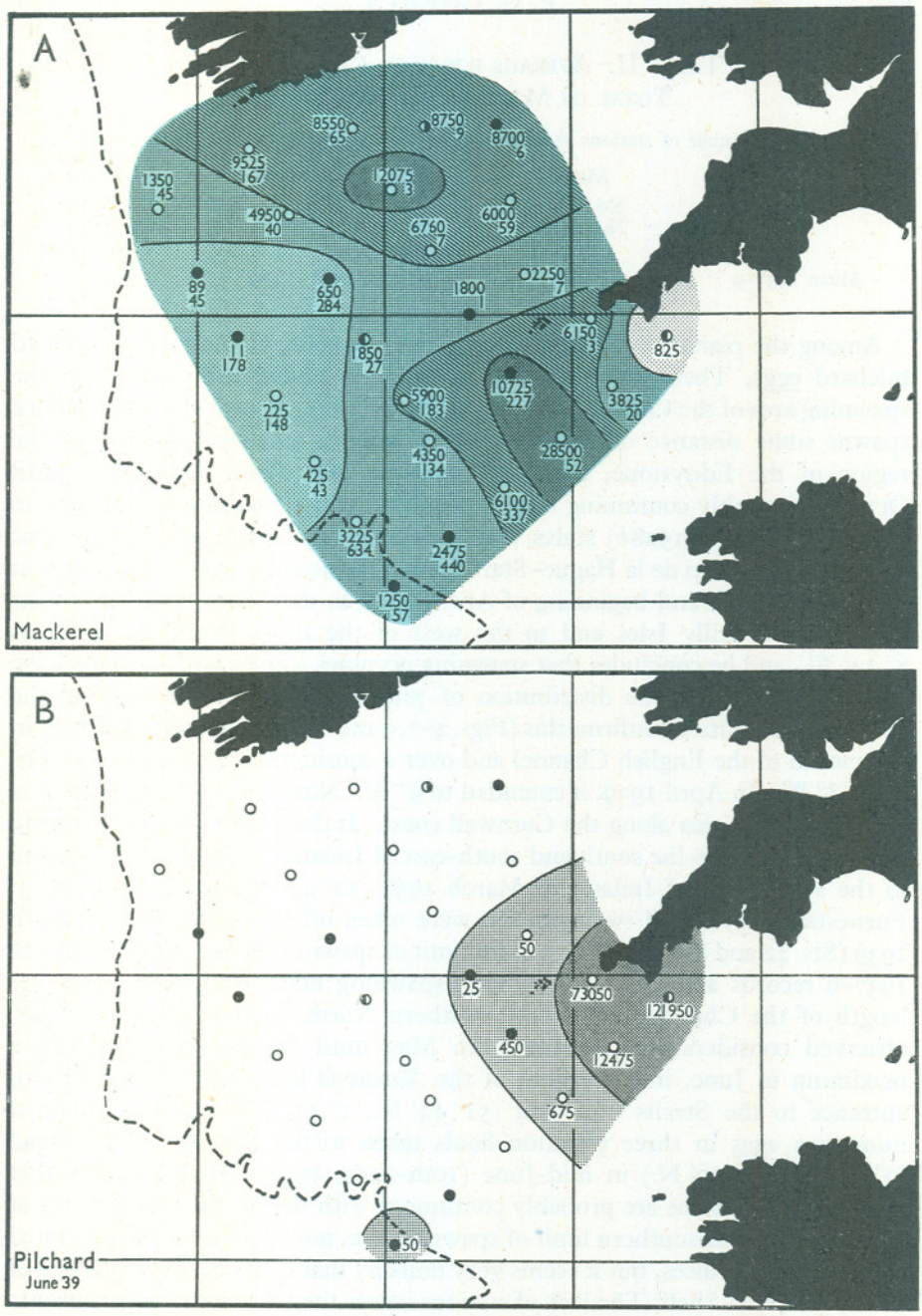

Fig. 10. Distribution of mackerel eggs (1–1000, 1001–5000, 5001–10,000, > 10,000) and young stages (blue area) (A), and pilchard eggs (1–5000, > 5000) (B) in the Celtic Sea in June 1939. Figures refer to the numbers of eggs and young stages at each station.

TABLE II. AVERAGE FOR EACH CRUISE OF THE TOTAL OF MACKEREL YOUNG STAGES

The number of stations at which they occurred is shown in parentheses

	March	April	May–June	July
1937	No cruise	3 (3)	112 (10)	6 (13)
1938	No cruise	14 (11)	575 (29)	2 (21)
1939	Nil	33 (26)	118 (27)	No cruise
Mean 1937–9	Nil	17	268	4

Among the plankton collected during 1937–9, some of the hauls contained pilchard eggs. These were counted in order to obtain information on the spawning area of the Cornish pilchard. Lebour (1921) records that the pilchard spawns some distance off shore in the Plymouth area—particularly in the region of the Eddystone, and that spawning lasts from mid-March until October, probably continuing into November, with a maximum from June to August. Le Gall (1928*b*) states that spawning takes place within the area: Scilly–Ushant–Cap de la Hague–Start Point. Furnestin (1939*a*) found eggs at the end of March and beginning of April, 1938, in the Channel mouth, to the south of the Scilly Isles and to the west of the Brest Peninsula as far as 8° 14′ W., and he concludes that spawning occupies a fairly wide area over the Continental Shelf. The distribution of pilchard eggs observed during the present investigation confirms this (Figs. 4–7, 9 and 10). Spawning takes place in the mouth of the English Channel and over a considerable area to the west as far as 8° W. In April 1939, it extended to 9° W. North of the Scilly Isles it is confined to the area along the Cornwall coast. It does not appear to occur to any great extent to the south and south-east of Ireland; a single egg was taken to the south-west of Ireland in March 1938 (50° 42′ N., 10° 00′ W.; St. 9; Furnestin, 1939*a*) and twenty-seven were taken off the south coast in April 1939 (Sts. 42 and SR. 23). The eastern limit of spawning is not indicated by the 1937–9 records and it is possible that spawning may occur throughout the length of the Channel and in the southern North Sea. Furnestin (1939*b*) observed considerable spawning from May until August (1931–4), with a maximum in June, in the region of the *Sandettié* lightship in the northern entrance to the Straits of Dover (51° 13′ N., 1° 53′ E.). He also obtained numerous eggs in three plankton hauls taken to the east of Beachy Head (0° 05′ W., 50° 40′ N.) in mid-June (10th–12th, 1938). He concludes that these spawning areas are probably continuous with that at the western end of the Channel. The southern limit of spawning was not conclusively determined on the 1937–9 cruises, but it seems very unlikely that it lies beyond the edge of the Continental Shelf. The lack of stations inside the Channel mouth prevents as comprehensive a survey of the distribution of pilchard eggs throughout each year as was possible with mackerel eggs. It is, however, evident that the main pilchard spawning area lies at the western entrance of the English

Channel, although intense spawning activity also takes place farther to the west, beyond the Channel mouth. In June 1938 and April 1939 two small concentrations, in which eggs were quite as numerous as in the main spawning area, occurred outside the mouth of the Channel (Figs. 6B, 9B). The distribution of pilchard eggs at the end of May and beginning of June, and in July, indicates that the spawning area does not extend in these months quite so far west as in April. Its western limit lies nearer to 7° W. than to 8° W. The average for each cruise of the total of pilchard eggs at all stations where more than 100 were taken is shown in Table III.

TABLE III. AVERAGE FOR EACH CRUISE OF THE TOTAL OF PILCHARD EGGS AT ALL STATIONS WHERE MORE THAN 100 WERE TAKEN

The number of stations from which the averages are obtained is shown in parentheses

	April	May–June	July
1937	4957 (12)	934 (4)	2508 (6)
1938	4474 (14)	8687 (6)	6895 (10)
1939	10,611 (22)	34,909 (5)	No cruise
Mean 1937–9	7542	21,798	6895

The 1937 averages show a maximum in April and a minimum at the end of May. In 1938 and 1939, however, the maximum occurred on the May–June cruise each year. It is possible that the irregularity of the 1937 averages may to some extent be due to the use of a smaller net on the May cruise and to the fact that only the fringe of the pilchard spawning area was worked. Pilchard eggs have been a constant and especially marked feature of the Plymouth plankton catches. They occur each year from April to November, with records in March in 1936 and in December in 1931, 1938 and 1939 (Russell, 1935*a*, 1936*b*, *et seq.*). These records have a maximum in June which Hickling (1945) has shown to be coincident with the maximum occurrence of spawning fish and with maxima in gonad weight, feeding activity and growth of the adult fish. Hickling's samples were obtained in the years 1936–8. This evidence strengthens the probability that the 1938 and 1939 averages are the truer reflexion of the changes in intensity of spawning and that the figures for 1937 are not representative.

The relationship of the mackerel and pilchard spawning areas is apparent in Figs. 4–7, 9 and 10. In April the main pilchard spawning in the Channel mouth takes place in an area containing few or no mackerel eggs (Figs. 4, 5, 9). As the season advances, the north-easterly shift of the mackerel spawning centres brings them nearer to those of the pilchard, and by the end of May and early June, there is considerable overlapping. This was particularly evident in May–June of 1938 when the spawning centres of the two species occupied the same areas (Fig. 6). The continued movement of the spawning of the mackerel eventually completes the overlapping of the total spawning areas

of the two species—not merely of the centres. This can be seen from the distribution of mackerel and pilchard eggs in July 1937 and 1938 (Figs. 4C, F, 7). The overall spawning areas were identical and it is noteworthy that the largest hauls of mackerel eggs were taken to the eastward in exactly those areas of maximal pilchard spawning activity.

Comparison of the distribution of phytoplankton in 1939 (Mare, 1940) and of mackerel and pilchard eggs gives no indication of any close relationship. In March, there was very little phytoplankton in the region where mackerel spawning was just starting. In April, both mackerel spawning centres were situated in areas of medium phytoplankton density. In May–June, the northern spawning centre was in an area of particularly sparse phytoplankton, while the southern centre lay in the region of greatest phytoplankton density. It must be noted, however, that in May–June phytoplankton production was very low throughout the area of the cruise and at its highest approached only the lower values of April. The main pilchard spawning areas in April were located largely in areas of dense phytoplankton, whereas in May-June, they were in an area of sparse phytoplankton. Far more data are required for further examination of the possibility of any correlation between the spawning of either the mackerel or pilchard and the distribution of phytoplankton.

The salinity and temperature observations of the 1937–9 cruises provide opportunity for examining the possibility of a relation between these factors and the distribution of the spawning centres of the mackerel and pilchard. Le Gall (1939) writes of the mackerel: 'Les déplacements des bancs à l'entrée occidentale de la Manche et à l'entrée sud de la Mer d'Irelande paraissent se faire principalement suivant les axes transgressifs caractérisés par une température et une salinité élevées (salinité supérieure a 35‰ et température variant de 10° a 15° suivant l'époque de l'année). La ponte se fait également dans les eaux transgressifes: les œufs et les larves de maquereaux étant nettement plus abondants dans les pêches planctoniques faites dans ces eaux.' Furnestin (1939*a*) also notes: 'la présence d'œufs et de larves de maquereaux semble être strictement limitée aux régions où se manifestent les trois grandes poussées transgressives'; and further, that it was only at stations of salinity near to or above 35·50‰ that mackerel eggs and young stages were taken on the *Quentin Roosevelt* cruises in 1938. Farran (1939) on the other hand observes that at the western stations of the *Muirchu* cruise of April 1938 where salinities exceeded 35·60‰, the numbers of mackerel eggs were low, in contrast to their particular abundance farther east in water of lower salinity. Of the spawning area of the pilchard Furnestin (1939*a*) remarks that it is 'en rapport étroit avec le mouvement général de la transgression atlantique sur le Plateau Continental. En effet, les différentes stations où nous avons trouvé des œufs de sardine sont situées sensiblement dans l'axe de la transgression. Ailleurs, dans les eaux continentales, nous n'en avons pas trouvé'. According to Fage (1920), the spawning and larval development of the pilchard in the

English Channel require a temperature of above 12° C.[1] and below 15° C. and he records a mean salinity of 35·27‰ during the spawning period, May–November. Le Gall (1928*b*) notes, however, that at one of the *Thor* stations[2] in the northern half of the Channel mouth, pilchard eggs were taken in a surface haul in water of 9·90° C., and he concludes that the pilchard in the Channel mouth area certainly spawns in temperatures below 12° C.

Table IV shows the mean temperature and salinity of the upper 25 m. of water in the mackerel and pilchard spawning centres in 1937–9 (means of all stations at which more than 5000 eggs were taken). Since there were indications of marked thermal stratification at 25 m. in May–June 1939 and July 1938, temperatures at surface and 5 m. only have been included; salinity means, however, include the values at 25 m. as vertically homohaline conditions extended to this depth. Mackerel spawning was much reduced (maximum, 1600 eggs) by July in 1938, although pilchard spawning was still very intense (maximum, 38,600 eggs); in order therefore to obtain as valid a comparison as

TABLE IV. MEAN TEMPERATURE AND SALINITY OF THE UPPER 25 M. OF WATER IN THE MACKEREL AND PILCHARD SPAWNING CENTRES

The number of stations from which the means have been calculated is shown in parentheses

	Salinity ‰		Temperature ° C.	
	Mackerel	Pilchard	Mackerel	Pilchard
April 1937	35·36 5, 25 m. (4)	35·18 5, 25 m. (2)	10·50 5, 25 m. (4)	9·51 5, 25 m. (2)
April 1938	35·35 0, 5, 25 m. (12)	35·36 0, 5, 25 m. (4)	10·27 0, 5, 25 m. (12)	10·07 0, 5, 25 m. (4)
April 1939	35·50 0, 5, 25 m. (14)	35·34 0, 5, 25 m. (5)	11·44 0, 5, 25 m. (14)	10·86 0, 5, 25 m. (5)
May–June 1939	35·15 5, 25 m. (7)	35·26 5, 25 m. (1)	14·63 5 m. (7)	11·42 5 m. (1)
July 1938	35·18 0, 5, 25 m. (3)	35·22 0, 5, 25 m. (5)	15·52 0, 5 m. (4)	15·70 0, 5 m. (6)

TABLE V. TEMPERATURE AND SALINITY RANGES IN THE MACKEREL AND PILCHARD SPAWNING CENTRES

Depths and number of stations as in Table IV above

	Salinity ‰		Temperature ° C.	
	Mackerel	Pilchard	Mackerel	Pilchard
April 1937	35·35–35·38	35·03–35·43	10·30–10·62	9·42– 9·71
April 1938	35·25–35·49	35·30–35·39	9·95–11·12	9·73–10·29
April 1939	35·33–35·58	35·10–35·52	10·49–12·30	10·27–11·80
May–June 1939	34·51–35·49	35·26–35·27	13·22–15·42	11·42
July 1938	35·06–35·36	35·06–35·36	14·16–16·30	14·16–16·30
Extreme range all cruises:	34·51–35·58	35·03–35·52	9·95–16·30	9·42–16·30

[1] Le Gall (1928*b*, p. 23) erroneously quotes this as 14° C.

[2] Fage (1920, p. 36); St. 31, 7 May 1906, 49° 45′ N., 4° 42′ W.; 20 pilchard eggs.

possible of the conditions in the spawning areas of the two species, the means of temperature and salinity for July 1938 have been calculated from the values at all stations where more than 100 mackerel eggs and more than 500 pilchard eggs were taken. Table V shows the ranges of temperature and salinity occurring in the spawning centres of the two species.

Considering first the means, it is apparent that as the season advances, conditions of reduced salinity and increased temperature are encountered in the mackerel spawning centres. In the pilchard spawning centres, salinities remain almost constant from April to July, with an indication of a slight diminution during this period, while temperatures rise from rather lower to slightly higher values than in the mackerel spawning centres. As a corollary to the above, the range of salinity throughout the period April–July, as well as the range in each month, is noticeably greater in the mackerel than in the pilchard spawning centres, while the greater temperature range occurs in the pilchard spawning centres. It has previously been noted that mackerel spawning in July is much diminished. In making any inference from the above figures, it would therefore be more correct to exclude from consideration the conditions pertaining in July in the mackerel spawning area. This was, however, exactly coincident with the pilchard spawning area, so that in fact, the July conditions were common to the spawning areas of both species. Moreover, the above remarks apply if the July conditions in the mackerel spawning area are discounted.

In April 1937, the mackerel spawning centres were entirely confined to water of salinity $>35{\cdot}3‰$, but it must be noted that this cruise was not as extensive as the April cruises of 1938 and 1939. In April 1938, an intrusion of saline water ($>35{\cdot}5‰$) lay between the outer and inner spawning centres, where the intensity of spawning was only moderate by comparison with that of the centres. In April 1939, the two mackerel spawning centres were largely situated in water of salinity $>35{\cdot}4‰$. In May–June 1939, the southern mackerel spawning centre occurred in salinities varying between $35{\cdot}26‰$ and $35{\cdot}49‰$, while the values in the northern centre were all lower than $35{\cdot}2‰$. These figures show the very considerable range of salinity in which intense mackerel spawning activity occurs and point to the somewhat doubtful value of ascribing salinity 'limits' to the spawning areas of the mackerel. It is evident that the shift of spawning during the season brings about the extent of this range to a greater degree than actual changes in salinity itself at one place.

The Distribution of the Sagitta *species and of* Muggiaea atlantica *in Relation to Hydrological Conditions*

Before discussing the distribution of some of the zooplankton indicator species observed during the present investigation, it will be convenient to examine briefly the hydrological data obtained on the cruises of April 1937,

1938 and 1939, June 1939 and July 1938. Further details are given on pp. 109–117. In April 1937, 1938 and 1939 salinities were vertically homohaline generally. The disposition of the isohalines in April and July 1938 and in April and June (upper 25 m.) 1939 is in general agreement with the conception of an anti-clockwise or cyclonic circulation of the waters in the eastern part of the Celtic Sea, as described by Matthews (1914), Harvey (1925, 1929, 1930), Lumby (1925) and others. Medium salinity water (35·3–35·4 ‰), probably derived from the salt water (> 35·5 ‰) lying on the edge of the Continental Shelf to the west of the Brest Peninsula, extended northwards across the mouth of the English Channel and continued through the Land's End–Scilly Channel. Travelling along the north Cornish coast, it was turned west by the course of the circulation in the region of the Bristol Channel, then south-west and finally south, having now become considerably diluted and indistinguishable in salinity from the low salinity tongue (< 35·2 ‰) forming the outer western south-flowing component of the circulation. In April 1937 conditions were rather different from the above. Very low salinity water (< 35·1 ‰) extended from Ushant to the southern tip of the Cornish Peninsula, blocking the Channel mouth and separating medium salinity water (> 35·3 ‰) in the neighbourhood of Plymouth from water of similar salt content to the west of the Channel mouth.

Attention has been drawn to the bearing of this circulation on the biology of the south-western area and its importance as a distributing agent of plankton organisms by the work of Gough (1905), Russell (1935*b*, 1936*a*, *c*, 1939*b*), Mare (1940), Corbin & Panikkar (1942).

The distribution on the 1937–9 cruises of *Sagitta elegans*, *S. setosa*, *S. serratodentata* and *S. lyra*, and of the siphonophore *Muggiaea atlantica* is described on pp. 97–109. Russell (1935*b*, 1936*a*, *c*, 1939*b*) has shown the value of plankton organisms, particularly *Sagitta elegans*, *S. setosa* and *S. serratodentata*, as indicators of water movements in the Celtic Sea. He found that *S. setosa* is associated with Channel water, *S. elegans* with mixed oceanic and coastal water in the area of the cyclonic swirl, and that *S. serratodentata*, a purely oceanic species, occurs in typical *elegans* water in years of strong Atlantic in-flow into the Channel. Water also enters the Channel mouth from the south-west. It may be warm and of purely oceanic origin with a characteristic macroplankton indicator community, which does not, however, carry any *Sagitta* species (Russell, 1935*b*, 1939*b*), or it may be low salinity water entering close round Ushant (Poole & Atkins, 1929). The 1937–9 records clearly show the predominance of *S. elegans* in the central area of the Celtic Sea. Equally evident is the predominance of *S. serratodentata* in the outer area along the edge of the Continental Shelf, and of *S. setosa* in a small area off the mouth of the Bristol Channel and in parts of the English Channel mouth. *S. lyra* was nowhere the dominant species but its occurrence was noticeably limited to the edge of the Continental Shelf (Figs. 11, 12). These distributions

are in agreement with Russell's findings. Of the distribution of *S. elegans* in the Celtic Sea, he remarks: 'We do not know how much further this area extends to the south. It may perhaps stretch right across the mouth of the Channel, or it may be reasonably expected that the area changes and lies in fact in the region of the cyclonic circulation known to exist at the mouth of the Channel south of Ireland.' He notes that only *S. serratodentata* occurred in the small area of the Bay of Biscay (centred on 47° 00′ N., 7° 40′ W.) which the *Research* Expedition investigated in 1904 (Russell, 1935*b*). No *S. elegans* were taken beyond the 100 fm. line at the southernmost stations of the *Quentin Roosevelt* cruise of April 1938; *S. serratodentata* only were present (Furnestin, 1939*a*). The distribution of *S. elegans* to the westward in April 1938 and March and April 1939 also indicates that the species does not extend far beyond the western edge of the Continental Shelf. These records show that the distribution of *S. elegans* to the south-west of the British Isles is confined to the Continental Shelf area of mixed oceanic and coastal water (see Russell, 1939*b*, fig. 5, p. 182). It is of interest to compare the above records with the findings of Redfield & Beale (1940) and Clarke, Pierce & Bumpus (1943) in the western Atlantic area of the Gulf of Maine and Georges Bank. In the shallow water (under 100 m.) over Georges Bank there is an anticyclonic eddy carrying a permanent population of *S. elegans* in which no other *Sagitta* species are endemic, although *S. serratodentata*, *S. lyra*, *S. enflata*, *S. maxima* and *Eukrohnia hamata* have been recorded in the area as immigrants from the deeper waters of the Gulf of Maine to the north and the Atlantic to the east. Clarke *et al.* (1943) state: 'The area of relatively homogeneous water overlying the central portion of Georges Bank was found to change in extent from cruise to cruise, but to be sharply delineated from the surrounding stratified water masses, and has been designated as the "Mixed Area".' They also observe that '*S. serratodentata* and *S. enflata*, which were taken chiefly in the September cruise, occurred entirely outside the margin of the Mixed Area.' In the detailed account of the distribution of the *Sagitta* species observed during the present investigation, it is noted that *S. elegans* was most numerous in the southern half of the English Channel mouth and to the west of the Brest Peninsula, particularly in April of each year and to a less marked degree in May–June of 1938 and 1939. In July 1937 and 1938, it was scarce generally. Indications of another area of abundance to the south of Ireland in April 1938 and 1939 rest almost entirely on the evidence from night hauls and cannot therefore be regarded as conclusive, more especially in view of the fact that a small area immediately to the south was devoid of *Sagitta* of any species. The water in the area of the Channel mouth was particularly rich in phosphates in April 1938 (Hickling, 1938) and had a high density of phytoplankton in April 1939 (Mare, 1940). Without further data, it would, however, be premature to correlate the abundance of *S. elegans* with these conditions since the species was not outstandingly numerous at the westernmost stations and in the region

off the Bristol Channel mouth where rich phosphate values (April 1938) and dense phytoplankton (April 1939) also occurred.

Gough (1905) gives a comprehensive account of the distribution of *Muggiaea atlantica* over the south-western area in 1904. From the region of Ushant, it spread progressively into the English Channel, the Bristol Channel area, the southern part of the Irish Sea and along the south coast of Ireland. He emphasizes the need for care in drawing conclusions as to water movements from the distribution of an epiplanktonic organism which may be subject to the effects of wind drift in the surface waters and which is capable of rapid asexual reproduction. The hydrological data, however, led Matthews (1909) to agree with his statement that the migrations of *M. atlantica* afforded 'evidence as to the direction of currents during that year'. Russell (1935*b*) also stresses the requirement of caution before including *M. atlantica* in his list of indicators of 'south-western' water. In discussing the occurrence of indicator species at Plymouth in the years 1930–4, he writes: '. . .it is noticeable that the "south-western" water indicators seem usually to follow the disappearance of "western" water. It appears almost as though we might have here a seasonal phenomenon rather than an indication of water movement, the warm water species increasing when the water is sufficiently warmed.' Evidence from the occurrence of other plankton animals and from hydrological observations is, however, contrary to this interpretation, and he continues: 'There is thus an indication from the plankton observations of a pulse of "western" water entering the Channel, with its maximum about May. This pulse retracts as the pulse of Atlantic water entering the North Sea from the north increases; and this is followed by a pulse of "south-western" water into the Channel.'

In April 1937, *Muggiaea atlantica* was plentiful in the vicinity of Ushant and its distribution extended northwards to the Scilly Isles and westwards from Ushant. It was absent from stations closest to the south coast of Devon and Cornwall (Fig. 13A). Its numbers decreased progessively northwards and westwards from Ushant, pointing to a centre of distribution in that region. It has previously been remarked that a tongue of low salinity water occupied the Channel mouth in April 1937. Comparison of the spread of this fresh water and the distribution of *M. atlantica* leaves little doubt that it carried the *M. atlantica* with it. A single specimen of *M. kochi*[1] was found about 20 miles north of Ushant (St. 5). In this connexion, it should be noted that Russell (1938*b*) records the occurrence in the first half of 1937 of several planktonic species unusual to the Plymouth area. In May and July 1937, no stations were worked in the Ushant area, but *M. atlantica* was present in the northern half of the Channel mouth (including stations nearest the coast), and in the Land's End–Scilly area (Figs. 13B, C). It was considerably more numerous than in April. But this fact and the abundance of the species at Plymouth in the late

[1] I am indebted to Mr F. S. Russell for confirming the identification of this specimen.

summer and autumn (Russell, 1938*b*) cannot, in view of Russell's and Gough's cautionary remarks, be taken as evidence of continued transport from the Ushant area. The April invasion of the Channel mouth, however, appears to have been definitely associated with the low salinity inflow from Ushant.

In April 1938, *M. atlantica* was absent from the southern half of the Channel mouth and the region of Ushant. It only occurred in the coastal waters around the Cornish Peninsula (Fig. 13D). Low salinity water was present in the Ushant area close to the west coast of the Brest Peninsula and round the north-west coast. It was narrowly confined to the coastal region by a warm salt tongue lying farther off the coast. This penetrated from the south-west towards the southern half of the Channel mouth and, judging from the indications of water mixing in the mouth of the Channel, contributed considerably to the higher salinities there. In May–June 1938, all stations were well to the west of Ushant (about 100 miles) and the Channel mouth. *M. atlantica* was present from north of Scilly to the southermost station—some 110 miles west by north of Ushant (Fig. 13E). In July 1938, the distribution of *M. atlantica* was similar to that of April. It was confined to the coastal waters close to the Cornish Peninsula (Fig. 13F). It is probable that this distribution continued for the greater part of the year since it occurred at Plymouth in every month of the year although in rather low numbers (Russell, 1939*a*).

In April 1939, *M. atlantica* occurred in the southern half of the mouth of the Channel. It extended northwards from Ushant to about half-way across the Channel towards Scilly, and eastwards for some little distance along the north coast of the Brest Peninsula (Fig. 13G). The numbers taken were small, but their disposition with a maximum at the Ushant station, indicated both the origin and direction of spread of the species. Salinity conditions in the area were similar to those of April 1937. Low salinity water which was fairly warm in the deeper layers, flowed northwards close to the French coast past Ushant. It spread about half-way across the mouth of the Channel and also along the north coast of the Brest Peninsula. To the west and closely hemming it in to the Ushant coast, was a tongue of slightly more saline water. This extended northwards across the Channel mouth to Scilly and was evidently derived from the salt water beyond the edge of the Continental Shelf. As in April 1937 there seems to be a close correlation between the distribution of *M. atlantica* and the low salinity inflow round the Brest Peninsula. In May–June 1939, *M. atlantica* occurred well out to the south-west in more saline water than in April. It was not found in the northern half of the mouth of the Channel. No stations were worked near the Brest Peninsula. The invasion foreshadowed in April did not take place and it was 'remarkably scarce' at Plymouth that year (Russell, 1940).

The distribution of *M. atlantica* in 1937–9 throws some light on its value as

an indicator species and also on the problem of the origins of the water in the western Channel mouth. In particular, the April records together with the hydrological conditions and the yearly observations at Plymouth on other planktonic species appear to relate to the incursion of 'south-western' water, which itself may be derived from water masses from more than one source (Russell, 1939*b*).

In April 1937, an invasion of *M. atlantica* into the Channel mouth was associated with a strong inflow of low salinity water from Ushant. The oceanic *Sagitta serratodentata* was also more extensively distributed in the area than in April of the other two years, although no strongly saline conditions with which it is usually associated were found in the region of the Channel mouth or to the westward. In the first half of the year at Plymouth, several infrequently recorded planktonic organisms were taken (*Discomedusa lobata*, *Pelagia noctiluca*) and also one species new to the area (*Rhincalanus nasutus*) (Russell, 1938*b*).

In April 1938, *Muggiaea atlantica* occurred in the northern half of the Channel mouth only where apparently it had remained 'resident' since the previous autumn when it was numerous (Russell, 1939*a*). Low salinity water lay to the south of Ushant but did not enter the Channel. It was closely confined to the west coast of the Brest Peninsula by an inflow of saline water from the south-west. This spread eastwards into the Channel mouth restraining any northward flow of the fresh water.

In the region of the saline incursion, there was a break in the distribution of *Sagitta serratodentata*, separating a small community of the species round the north-west coast of the Brest Peninsula from the main population farther to the west along the edge of the Continental Shelf. No unusual planktonic species occurred at Plymouth in the first half of the year (Russell, 1939*a*).

In April 1939, fresh water from the Ushant area spread half-way across the Channel mouth carrying with it small numbers of *Muggiaea atlantica*. To the west of this was a more saline intrusion northwards across the mouth of the Channel, similar to that of April 1938. It did not, however, spread so far eastwards into the Channel and was less saline. In the region of its entry from the south it again appeared to split the distribution of *Sagitta serratodentata*. No unusual planktonic species were recorded at Plymouth and *Muggiaea atlantica* was remarkably scarce throughout the year (Russell, 1940).

These records present something of a paradox. There is little doubt that the low salinity inflow of April 1937 carried with it both the *M. atlantica* and certain plankton species not usually taken at Plymouth. These, including *M. atlantica*, are generally considered to be 'oceanic' (Russell, 1938*a*) and would be expected to occur in saline conditions, and not in the low salinities recorded. But in 1938 and 1939, when the April incursion of saline water into the Channel mouth from the south-west was considerable, there was a

lack of 'oceanic' species. Their appearance in early 1937, when the area was filled with water of particularly low salinity, suggests that the fresh water on its way to the Channel mouth, had flowed alongside a body of 'oceanic' water containing the *M. atlantica* and the unusual species, and had gathered them into itself in sufficient quantity to transport them across the Channel.

M. atlantica thus transported, was able successfully to maintain a breeding population in an alien locality for a period of at least twelve months (April 1937–8), probably longer, without recruitment or re-seeding from its original stock, and in a considerable salinity range. Without previous records therefore, its presence is unlikely to be of great value in determining the history or origin of the water in which it occurs.

The lack of 'oceanic' species in the saline incursions of April 1938 and 1939, when hydrological conditions would seem to have favoured their occurrence, may be compared with the general lack of plankton in the 'Biscay water' observed off Ushant by Russell in July 1935 (Russell, 1936*a*).

Attempt at more detailed identification of the above records of planktonic species with specific water masses would be little more than groundless speculation. The need, however, for a further extensive series of data in the Channel mouth and to the south—over the edge of the Continental Shelf—is only too apparent. Until this can be achieved, the present records continue to emphasize the acknowledged complexity of the water movements in the Channel mouth and the varied origins of the water masses entering the area.

Results of the Cruises

The Distribution of Mackerel Eggs

1937

12–20 *April* (Fig. 4A).

Spawning was intense in the west and south-west of the area of the cruise. With the exception of Sts. 2 and 22 where less than 100 mackerel eggs per haul were taken, none occurred in the eastern half—in the region of the Channel mouth and to the north of Scilly. The greatest density of eggs was present along the southern line of stations (Sts. 9–15), and their numbers decreased from south-west to north-east of the area. The maximum haul of 32,300 eggs was taken at the westernmost station (St. 14). In the south-west, where spawning was generally intense, there was a concentration (over 18,000 eggs per haul) in the neighbourhood of 49° 30′ N., 8° 40′ W. (Sts. 13–15) and an indication of a second lesser concentration (over 8000 eggs per haul) at 48° 50′ N., 6° 30′ W., some 60 miles east south-east of this and about 60 miles south south-west of Scilly (Sts. 9 and 10).

27–30 *May*[1] (Fig. 4B).

Mackerel eggs were taken at all stations on the cruise, indicating that spawning activity had extended farther to the north-east towards Land's End since April. But a decrease in the intensity of spawning was evident from the fact that the largest haul contained only 8875 eggs (St. 8) compared with 32,300 in April.[2] It was also shown by the smaller numbers of eggs farthest to the south-west (Sts. 5, 6 and 7). The gradation from large numbers of eggs at the westerly stations to few eggs at the easterly stations was again noticeable.

20–26 *July* (Fig. 4C).

The numbers and distribution of mackerel eggs in July revealed that the main spawning to the westward of the Channel mouth had completely finished. No eggs were taken to the west of the Scilly Islands (Sts. 3–13) and only very diminished spawning activity continued inside the Channel mouth. The maximum haul, containing only 135 eggs, was made at the easternmost station off Plymouth (St. 18), and catches at other stations were very considerably less than this.

1938

6–18 *April*[3] (Fig. 5A).

Mackerel eggs were present over nearly the whole area of the Celtic Sea. They were absent from the extreme marginal regions of the area: from the two westernmost Stations (Sts. 18A and SR 89), from the north-eastern area off the Bristol Channel and the St George's Channel (Sts. SR 72, 41 and 43–47), from the northern half of the mouth of the English Channel (Sts. 1, 2, 52–56 and 62), from the area of Ushant and the west coast of the Brest Peninsula (Sts. 5, 6, 58, F 101–F 104, F 118 and F 119), and from the southernmost region (Sts. F 107–F 111). Two centres of very intense spawning activity were evident. The larger outer centre was situated to the south of Ireland between 9 and 10° W. and covered a considerable area from 49° 20′ N. to 50° 10′ N. (Sts. 16, 21, 22, SR 82, SR 85 and SR 86). The smaller inner one was centred on 49° 05′ N., 7° 15′ W., some 60 miles south-south-west of the Scilly Isles (Sts. 10–12). In the outer centre, the maximum haul contained the very large number of 99,333 mackerel eggs (St. SR 86) and catches at other stations in the area ranged from over 6000 to over 19,000. In the inner centre hauls contained between 5000 and 20,000 eggs. The two centres of spawning

[1] On this cruise, plankton was collected by oblique hauls (usual method of working) with a 1 m. stramin net. It has been estimated that the fishing capacity of the 1 m. stramin net is $\frac{1}{4}\times$ that of the 2 m. stramin ring-trawl. Actual numbers of fish eggs, etc. taken on this cruise have therefore been multiplied by four so that comparisons with the results of other cruises may be of the same order.

[2] Station 8 (May 1937) was about 10 miles east of Stations 13 and 15 (April 1937) where 18,570 and 20,500 mackerel eggs were taken.

[3] See also Farran (1939) and Furnestin (1939*a*). A single mackerel egg was taken on 29 March 1938, to the south of Ireland (Furnestin, 1939*a*; St. 12; 50° 22′ N., 9° 55′ W.).

activity were noticeably localized and the density of mackerel eggs outside them was seldom greater than 400 per haul, except at stations immediately between them (Sts. 13–15, 23 and SR 78) where larger hauls of 1000–3090 eggs occurred. At Station 48, off the mouth of the Bristol Channel, 2020 mackerel eggs were taken.

31 *May*–5 *June* (Fig. 6A).

Mackerel eggs were absent from the westernmost area (Sts. 18–22), but were taken at all other stations on the cruise. Two dense concentrations of eggs were present. The smaller of these lay to the west and north of the Scilly Isles (Sts. 12 and 30; 18,280 and 6075 eggs). The larger was situated to the south of Scilly, outside the mouth of the English Channel (Sts. 3–6; 5320–31,110 eggs). To the west of the two concentrations and between them, mackerel eggs were considerably less numerous. The southern spawning centre of this cruise can be identified with the inner centre of April. The density of eggs was of the same order although slightly larger catches showed an increase of spawning activity since April. Moreover it was situated in the same latitude, having shifted only slightly eastwards from the April position, so that the western station overlapped the position of the eastern station of the April concentration. Mackerel eggs were few or did not occur at all in the area occupied by the large outer spawning centre of April.

19–24 *July* (Fig. 7A).

Spawning was very diminished in intensity compared with that of April and May–June, and no longer occurred in the Celtic Sea to the westward of Scilly. Eggs were present inside the mouth of the Channel as far west as Scilly, and slightly beyond this—to 7° W.—in the area to the north of Scilly. They were absent from the westernmost stations (Sts. 9–12, 21 and 22) and the northernmost station off the Bristol Channel mouth (St. 15). The spawning area had shifted nearly 200 miles eastwards since May–June; the western limit which was then between 9 and 10° W., now lay between 6 and 7° W. The maximum haul of 1600 eggs was taken at the easternmost station (St. 3) and catches were smallest at the westerly stations.

1939

15–18 *March* (Fig. 8).

Small numbers of mackerel eggs occurred in a restricted area at the western edge of the Continental Shelf, about 70 miles south-south-west of Ireland (Sts. 5–8, 16 and 17). The maximum haul contained 118 eggs (St. 8). The area of distribution lay between 10 and 12° W. and did not extend farther north than 51° N. The southern limit was not determined.

16–27 *April* (Fig. 9A).

Spawning had greatly increased both in intensity and extent since the third week in March. Mackerel eggs were distributed throughout the area of the

cruises, except in the northern half of the mouth of the English Channel (Sts. 1, 2, 33, 37, 56–58, 61 and 62), at the mouth of the Bristol Channel (Sts. 46 and 47), and at single stations close to Ushant (St. 4), off the southern Irish coast (St. SR 13) and in the central area (St. SR 17). As in April 1938, there were two centres of intense spawning activity to the west and south. The outer centre was situated to the south of Ireland between 9 and 11° W. and extended southwards from 51° 00′ N. to the edge of the Continental Shelf (Sts. 17–19, 22–26 and SR 26–SR 29). The largest hauls, containing between 5950 and 45,025 mackerel eggs, were taken in this centre. In the smaller inner centre, lying some 90–100 miles west of the Brest Peninsula and centred at about 48° 30′ N., 8° 00′ W. (Sts. 9, 11 and 12), spawning was less intense and catches did not exceed 10,000 eggs per haul. The southern boundaries of the two centres were not determined, but it seems probable that they were continuous as one area along the southern edge of the Continental Shelf. Outside the centres, hauls usually contained fewer than 500 eggs. At Station 49, off the mouth of the Bristol Channel, 1250 eggs were taken. It has already been mentioned that a similarly isolated large haul of mackerel eggs (2020) occurred in this area in April 1938.[1]

2–7 *June* (Fig. 10A).

Mackerel eggs were taken at all stations on the cruise and were concentrated in two centres. The northern centre in which the lesser intensity of spawning occurred (maximum haul, 12,075 eggs; St. 22) lay between the south-east coast of Ireland and the north coast of Cornwall (Sts. 13 and 21–26). The southern centre in which spawning was more intense (maximum haul, 28,500 eggs; St. 3) was situated immediately outside the Channel mouth (Sts. 3, 4, 17, 19 and 28). To the westward of the centres, in the region of the outer April centre, few eggs were present. Comparison of the positions of the two centres with those of April shows the extent of the north-eastward movement of spawning. In the northern centre which was almost certainly a continuation of the outer centre of April, a considerable diminution in spawning intensity had taken place. While the southern centre, which from its position was clearly identifiable with the inner April centre, showed, as in 1938, an increase in intensity of spawning since April.

The Distribution of Mackerel Young Stages

1937

12–30 *April* (Fig. 4A).

It was originally stated that no mackerel young stages were taken in April 1937 (Steven & Corbin, 1939). This record requires correction since the identification of eleven young fish, which in the earlier examination could not be determined with certainty, has now been established. A careful comparison

[1] St. 48, April 1938, 50° 55′ N., 5° 50′ W.; St. 49, April 1939, 50° 48′ N., 5° 53′ W.

of the specimens with the abundant material of later cruises leaves no doubt that they are young mackerel. Ten specimens were taken to the westward of the area of the cruise (Sts. 15 and 29) and a single specimen was taken to the south of the Lizard (St. 35). Elsewhere on the cruise no mackerel young stages were taken.

27–30 *May*[1] (Fig. 4B).

Considerable numbers of young stages were caught on this cruise and the main area of their distribution lay to the south-west (Sts. 4–11) where mackerel eggs were generally most numerous. Small numbers were also taken between Land's End and Scilly (Sts. 1 and 15). The largest haul, containing 568 specimens, was recorded to the westward (St. 8, day haul) where the greatest number of eggs was taken.

20–22 *July* (Fig. 4C).

Young stages were very much less numerous than in May and were absent from the westernmost area (Sts. 6–10) where previously they had been numerous. They occurred at the easterly stations where spawning still continued, as well as at a number of stations farther west where no mackerel eggs were recorded. The largest catch (20 specimens, St. 16, day haul) was taken to the south of the Lizard, in the eastern part of the area of distribution of the young stages.

1938

6–18 *April*[2] (Fig. 5A).

The distribution of mackerel young stages was confined to the extreme western and south-western margins of the area, towards the edge of the Continental Shelf and beyond the two main spawning centres (Sts. 16–20, SR 86, SR 88, SR 89, SR 91, SR 92, F 107 and F 109–F 114). They were absent from the central, northern and eastern areas, on the landward side of the spawning centres. The majority of hauls contained fewer than 20 specimens, although 69 were taken in one night haul (St. 17).

31 May–5 *June* (Fig. 6A).

In comparison with the numbers taken in April, mackerel young stages were exceedingly numerous. They were present throughout the area of the cruise except off Land's End (St. 1). Their distribution had shifted very considerably north-east since April and they now occurred in the central area of the Celtic Sea where previously they were not recorded. They reached maximal abundance (over 500 per haul) in a broad belt extending across the area of the cruise from north-west to south-east (Sts. 4, 9, 10, 16 and 24–26), in the centre of which the very large number of 8239 specimens was recorded in a daylight haul (St. 25). Station 4 was the only night haul in the area of maximal

[1] See note 1, p. 91.

[2] See also Farran (1939) and Furnestin (1939*a*).

abundance. To the west and south, and more markedly to the north-east of this area, their numbers progressively decreased. It has been noted that in April the young stages occurred beyond the centres of spawning. This was also evident in May–June.

19–24 *July* (Fig. 7A).

Young stages were present in very small numbers (maximum, 6). They occurred at all stations except the two westernmost (Sts. 10 and 11) and three stations in the middle of the Channel mouth (Sts. 5, 6 and 8). As in July 1937, their distribution extended farther west than that of the eggs and it had shifted very considerably eastwards and slightly northwards since May–June. The western boundary on this cruise lay along about 7° 20′ W., while on the May–June cruise it was to the west of 10° W.

1939

15–18 *March.*

No mackerel young stages were taken on this cruise.

16–27 *April* (Fig. 9A).

The distribution of mackerel young stages was similar to that of April 1938. They were taken at the westerly and southerly stations, mainly beyond the spawning centres, although this tendency was not so marked as in April 1938. They were also slightly more numerous than in April 1938 (maximum 174, St. 22, day haul). The 1939 cruise was about a week later than in 1938, and in consequence the records probably represent a later stage in the distribution of the young mackerel, when more had hatched into the plankton and their spread north-eastwards from the edge of the Continental Shelf was more extended. Single specimens were taken off Ushant (St. 3) and off the mouth of the English Channel (St. 31), and three occurred near the mouth of the Bristol Channel (Sts. 47 and 48), close to the isolated concentration of eggs (St. 49).

2–7 *June* (Fig. 10A).

Young stages were present throughout the area except near the Lizard (St. 1). They were more numerous than in April and were most abundant (maximum 634, St. 7, day haul) in an area lying to the westward of the spawning centres and extending from the south-west of Ireland towards the Brest Peninsula (cf. May–June 1938). Their numbers progressively decreased to the north and east of the area of maximal abundance, and small catches at some of the westernmost stations (Sts. 6, 8, 11 and 12), showed that beyond it they were also becoming fewer. Off the mouth of the Bristol Channel (St. 26, day haul) 59 specimens were taken, close to the position of the small concentration of eggs which occurred there in April.

The Distribution of Pilchard Eggs

1937

12–20 *April* (Fig. 4D).

Spawning occurred in the northern half of the Channel mouth and extended to the west and south-west of Scilly as far as 8° W. The centre of spawning was situated inside the mouth of the Channel, off the south coast of Devon and Cornwall (Sts. 1, 2 and 35; over 10,000 eggs per haul). No eggs were taken in the southern half of the mouth of the Channel (Sts. 3–8, 10, 21 and 22), at the westernmost stations (Sts. 13–16 and 18) and to the north-west of Scilly (Sts. 27–32).

27–30 *May*[1] (Fig. 4E).

Pilchard eggs were taken in the Land's End–Scilly region (Sts. 1–3, 14 and 15); they were absent from the western area (Sts. 4–13). Catches were small (maximum 2800, St. 1) but of the same order of size as those of April from this area. No stations were worked inside the mouth of the Channel where the April concentration was situated.

2–22 *July* (Fig. 4F).

No pilchard eggs were found to the west of Scilly (cf. May 1937) and the spawning area was identical with that of the mackerel (Sts. 1, 2 and 14–18). The largest hauls were taken to the eastward, in the region of the April spawning centre (maximum 10,000 eggs, St. 17).

1938

6–18 *April*[2] (Fig. 5B).

Pilchard eggs were present in a broad area extending from the north coast of Cornwall south-westwards across the entrance to the Channel. The centre of spawning was situated, as in April 1937, in the northern half of the Channel mouth (Sts. 2, 3, 29 and 30), where hauls containing from 7680 to 24,120 were taken. No eggs were present in the western and northern parts of the Celtic Sea nor in the southern half of the mouth of the Channel and off the Brest Peninsula.

31 *May*–5 *June* (Fig. 6B).

The distribution of pilchard eggs on this cruise was similar to that of April, extending from north of the Scilly Isles southwards across the mouth of the Channel (Sts. 2–6, 12 and 30). Only the western limit of distribution was determined, since no stations were worked inside the mouth of the English Channel. They were absent off Land's End (St. 1) and from the western area

[1] See note 1, p. 91.

[2] See also Furnestin (1939*a*). A single pilchard egg was taken on 24 March 1938, to the south of Ireland (Furnestin, 1939*a*; St. 9; 50° 42′ N., 10° 00′ W.).

beyond about 7° 30′ W. The largest hauls were made to the west of Scilly (St. 12; 20,600 eggs) and about 70 miles farther south outside the Channel mouth (St. 5; 25,320 eggs).

19–24 *July* (Fig. 7B).

Pilchard eggs were numerous at the easterly stations. They were absent or scarce to the west of Scilly and towards the southern half of the mouth of the Channel. The main concentrations were situated similarly to those of May–June, off the north coast of Cornwall (Sts. 16 and 17; 950 and 38,600 eggs) and inside the Channel mouth in the northern half (Sts. 1, 2 and 23–26; 2100–22,450 eggs).

15–18 *March.* **1939**

No pilchard eggs were taken on this cruise.

16–27 *April* (Fig. 9B).

Pilchard eggs occurred at all stations in the Channel mouth and to the westward as far as 9° W. This was considerably farther west than on previous cruises. They were absent from a small area immediately to the north of Ushant, from the westernmost stations and also the area to the north of the Scilly Isles, except for the occurrence of 27 eggs off the south-east coast of Ireland (St. 42, 1 egg; St. SR 23, 26 eggs). Three spawning centres were present. The largest of these occurred inside the middle of the Channel mouth (Sts. 2, 57, 58 and 61; 13,100–39,075 eggs). The two smaller centres lay farther to the west. One was situated immediately outside the middle of the Channel mouth (Sts. 37 and 55; 23,500 and 92,925 eggs); the other occurred farther to the south, about 90–100 miles west of Ushant (Sts. 10 and 11; 14,500 and 22,975 eggs) in an area immediately adjoining the smaller inner concentration of mackerel eggs.

2–7 *June* (Fig. 10B).

Pilchard eggs were found in the easternmost area of the cruise, near Scilly and the tip of the Cornish Peninsula (Sts. 1–3, 19, 20, 27 and 28); elsewhere to the west and north none was taken. No stations were worked inside the mouth of the Channel. They were very numerous to the south of Land's End and the Lizard, and the exceptionally large haul of 121,950 eggs was taken in this area (St. 1).

The Distribution of Sagitta elegans *Verrill*

12–20 *April* (Fig. 11A). **1937**

No *Sagitta* spp. were taken at Stations 1, 25 and 30. *S. elegans* was taken at all other stations and was the dominant species over the whole area with the exception of the two westernmost stations (Sts. 13 and 14) where *S. serrato-dentata* was more numerous. The numbers per haul show very considerable variation due to diurnal vertical migration, but a general tendency for the

species to be less abundant towards the west is noticeable. The largest haul was taken about 20 miles west of Ushant (4610 specimens, St. 7, day haul).

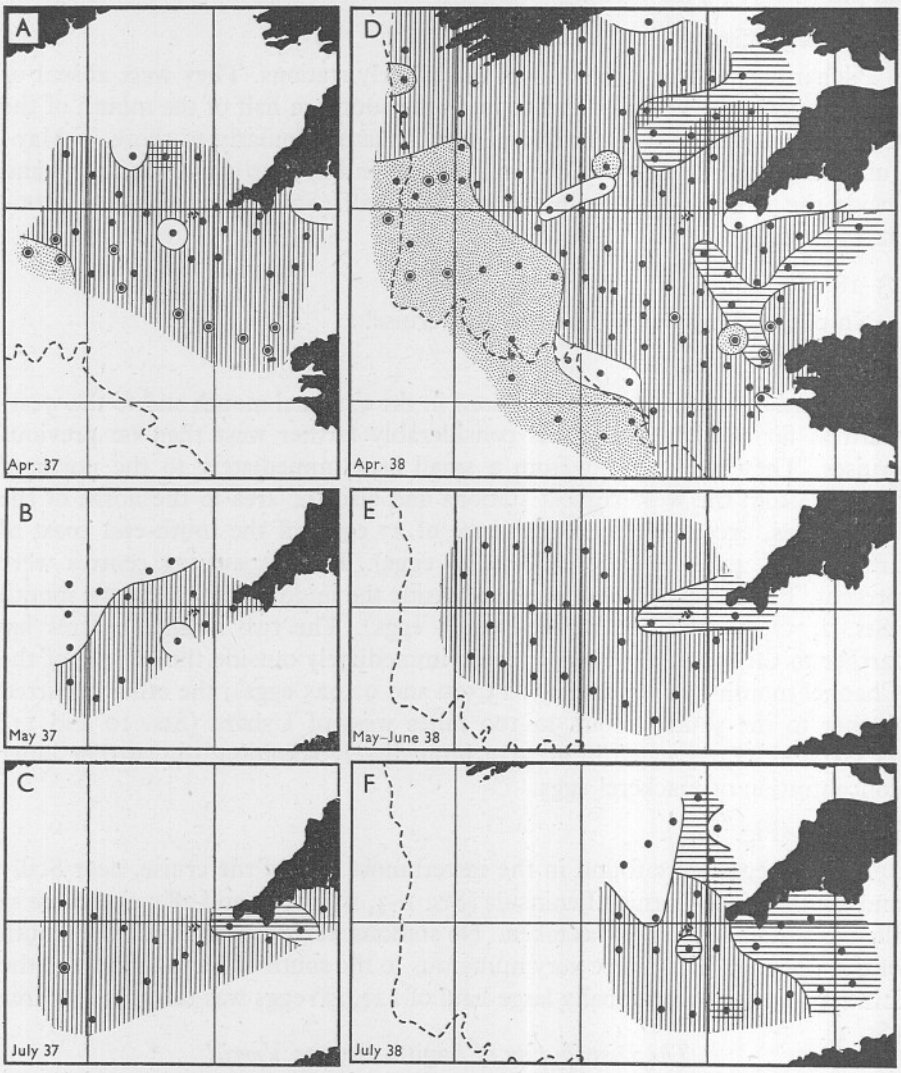

Fig. 11. Areas of dominance of *Sagitta elegans* ||||, *S. setosa* ≡ and *S. serratodentata* ▦ in the Celtic Sea in 1937 (A, B and C) and 1938 (D, E and F). ⊙ *S. lyra* present.

27–30 *May*[1] (Fig. 11B).

No *Sagitta* spp. were taken at Stations 3, 8–11, 13 and 14. *S. elegans* was recorded at all other stations and was the dominant species throughout the

[1] See note 1, p. 91.

area, although very much less numerous than in April (maximum 300, St. 5, night haul).

20–22 *July* (Fig. 11C).

The species was taken at all stations on the cruise and was dominant in the whole area with the exception of two separate stations, off Land's End and east of the Lizard, where *S. setosa* predominated (Sts. 1 and 17). Numbers had increased very considerably since May, but were not so great as in April (maxima, 1560 (day) and 2800 (night); Sts. 8 and 13).

7–18 *April*[1] (Fig. 11D). **1938**

No *Sagitta* spp. were taken at Stations 1, 24, 25, 42, 54, SR 78, F 101, F 113–F 115. *S. elegans* was distributed over almost the whole area of the Celtic Sea; it was absent from certain marginal areas (St. 42 in the north; Sts. 18A, 19 and SR 89 in the west; Sts. 16, F 106–F 110 and F 113–F 115 in the south; Sts. 1, 29, 54 and 59 in the northern half of the Channel mouth) and from one station (St. 36) adjoining the central patch in which no *Sagitta* spp. occurred (Sts. 24, 25 and SR 78). The majority of the large catches of *S. elegans* were taken at night stations (see Table VI), and for this reason the greatest reserve is required in pointing out any particular concentration within the distribution of the species. It seems probable, however, that an area of abundance was present in the vicinity of Ushant (Sts. 4 and 5 (night), 2950 and 3270 specimens; Sts. 6 and 7 (day), 287 and 900 specimens) where both day and night hauls were noticeably larger than those of the surrounding stations. Several large catches were made to the south of Ireland (Sts. 21, 22, 39, SR 73–SR 75 and SR 81–SR 83; 600–5200 specimens) but all occurred at night stations and cannot therefore be considered as representing a true concentration of the species. A large daylight haul was also taken about 30 miles south-west of Valencia (St. SR 93; 1405 specimens). *S. elegans* was the dominant species in the central area of the Celtic Sea from southern Ireland to the approach to Ushant. At the western and south-western stations it was outnumbered by *S. serratodentata*, and in the areas off the entrance to the Bristol and English Channels *S. setosa* was the predominant species.

31 *May*–5 *June* (Fig. 11E).

S. elegans was taken at all stations. It was the dominant species throughout the area of the cruise except in the region off Land's End past Scilly in which *S. setosa* predominated (Sts. 1 and 11). In the area west of the Channel mouth, very large catches were taken in day and night hauls (Sts. 2, 7, 8, 10, 11, 24 and 25 (day), 600–5820 specimens; Sts. 3 and 4 (night), 7040 and 29,340 specimens). At the westernmost and northernmost stations numbers were generally lower.

[1] See also Furnestin (1939*a*).

19–24 *July* (Fig. 11 F).

No *Sagitta* spp. were taken at Stations 12, 14 and 16. The area of distribution of *S. elegans* lay to the west of the Channel mouth and extended slightly to the north of the Scilly Isles. A single specimen was taken at the northernmost station (St. 15) and four occurred off Plymouth (Sts. 1 and 26). The species was very much less numerous than in April and in May–June (maxima: St. 9 (day), 500 specimens; St. 21 (night), 1000 specimens).

1939

15–18 *March* (Fig. 12 A).

The species occurred at all stations except the two westernmost (Sts. 8 and 9) and was present in considerable numbers (maxima: St. 1 (day) 700 specimens; St. 20 (dusk) 2850 specimens). It was the dominant species from the area of Scilly westwards to about 10° W. Farther west, *S. serratodentata* was the most numerous species.

16–27 *April* (Fig. 12 B).

No *Sagitta* spp. were taken at Stations 26, 28, 37, 39, 43, 48, 49, SR 13, SR 20, and SR 28. With the exception of the above stations and also Stations 22, SR 21, SR 23 and SR 30, *S. elegans* was distributed over the whole of the Celtic Sea and was taken in particular abundance at the southern half of the mouth of the English Channel in both day and night hauls (Sts. 2–8 and 36; maxima, 6240 (day) and 11,440 (night)). Large catches were also taken in the area to the south of Ireland and west-north-west of Scilly and, although the majority occurred at night stations, two daylight hauls in the area contained considerably greater numbers than at surrounding stations (Sts. 31, 40, 41, 52 and SR 15–SR 19; maxima, 905 (day) and 10,875 (night)). A central patch in which no *Sagitta* spp. occurred (Sts. 26, 28, SR 20 and SR 28) was situated a little to the west of the barren patch of April 1938. *S. elegans* was the dominant species throughout the greater part of the Celtic Sea, including the mouth of the Bristol Channel and the southern half of the mouth of the English Channel. In the northern half of the Channel mouth it was replaced as the dominant species by *S. setosa*, and by *S. serratodentata* in the western area and at some of the southern stations.

2–7 *June* (Fig. 12 C).

No *Sagitta* spp. were taken at Stations 14 and 17. With the exception of these and a single station close to Land's End (St. 28), *S. elegans* occurred throughout the area of the cruise. It was dominant over almost the whole area except at the westernmost station and the southernmost station where *S. serrato-*

dentata was more numerous (Sts. 6 and 12), and in the Land's End–Lizard area where *S. setosa* predominated (Sts. 1 and 28). It was most abundant in

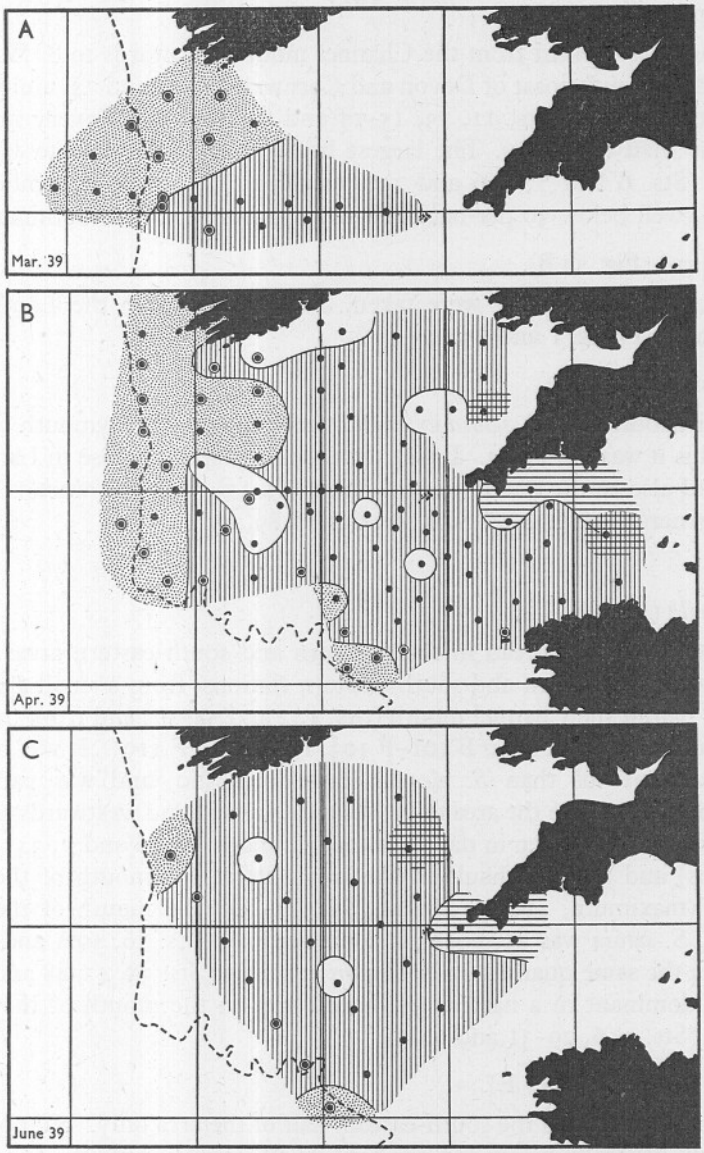

Fig. 12. Areas of dominance of *Sagitta elegans* ||||, *S. setosa* ≡ and *S. serratodentata* ▒ in the Celtic Sea in 1939. ⊙ *S. lyra* present.

the area to the west of the Channel mouth (Sts. 3, 4, 5 and 19; 2100, 950 (day), 1125, 2175 (night)).

The distribution of Sagitta setosa *J. Müller*

1937

12–20 *April* (Fig. 11 A).

S. setosa was present from the Channel mouth westwards to 8° W. It was absent off the south coast of Devon and Cornwall (Sts. 1 and 34) and from the area north of Scilly (Sts. 11, 13, 15–17 and 23–25). It was very much less numerous than *S. elegans*. The largest hauls were taken close to Ushant in daylight (Sts. 6 and 7; 166 and 130 specimens); elsewhere numbers were almost all well below 30 per haul. Nowhere was the species dominant.

27–31 *May*[1] (Fig. 11 B).

Twenty specimens only were taken, at two stations in the Land's End–Scilly Channel (Sts. 1 and 15).

20–22 *July* (Fig. 11 C).

The distribution of *S. setosa* extended westwards from Plymouth to Scilly; west of this it was not taken. It was the dominant species close to Land's End (St. 1) and also to the east of Lizard Head (St. 17). Catches were very much smaller generally than *S. elegans* (maximum 89, St. 1).

1938

6–18 *April*[2] (Fig. 11 D).

S. setosa was widespread in the northern and south-eastern areas. It was absent from the western and south-western stations, from a small area in the northern half of the Channel mouth (Sts. 1, 2 and 54–57) and from the region to the south of Ushant (Sts. F 101–F 103, F 118 and F 119). It was considerably less numerous than *S. elegans* (maximum 520) and was particularly scarce (maximum 8) in the area to the south of Ireland and westwards to 10° W. Large catches were taken in day hauls near Ushant (Sts. 6 and 7; 345 and 520 specimens) and in night hauls in the area outside the mouth of the Bristol Channel (maximum, 400 specimens, St. 47). Off the mouth of the Bristol Channel, *S. setosa* was dominant at some stations (Sts. 46, 50A and 51) and present in the same quantity as *S. elegans* at others (Sts. 38, 47, 48 and 50). It was also dominant in a narrow ⊢ shaped area in the mouth of the English Channel (Sts. 3, 6, 29–31 and 62).

31 *May*–5 *June* (Fig. 11 E).

S. setosa occurred in the south-eastern half of the area only. Numbers were very small, generally below 100 per haul, at all stations, with the exception of a large haul of 2300 specimens taken to the west of Scilly in daylight (St. 11). It was the dominant species at this station and off Land's End (St. 1).

[1] See note 1, p. 91.

[2] See also Farran (1939) and Furnestin (1939*a*).

19–24 *July* (Fig. 11F).

The species was taken in small numbers (maxima: 46 (day), St. 20; 49 (night), St. 18) at the easterly stations, both north of the Cornish Peninsula and in the Channel mouth. It did not occur to the west of Scilly (Sts. 6–14 and 16). It was dominant off the mouth of the Bristol Channel (Sts. 15 and 17) and inside the mouth of the English Channel to the east (Sts. 1–4 and 24–26).

1939

15–18 *March* (Fig. 12A).

One specimen of *S. setosa* was taken about 25 miles south-east of the Fastnet Lighthouse (St. 14).

16–27 *April* (Fig. 12B).

The area of distribution was restricted to the Bristol Channel mouth and the mouth of the English Channel and did not extend westwards of 6° W., with the exception of three specimens taken immediately west of Scilly (Sts. 32 and 52) and a single specimen off the Channel mouth (St. 8). It was also absent from a small area inside the Channel mouth (Sts. 2, 58 and 59). It did not occur as far west as in April 1938 either outside the Channel mouth or to the south of Ireland. In comparison with the large catches of *S. elegans*, it was scarce (maxima: 38 (day), St. 3; 185 (night), St. 62). It was the dominant species in the northern part of the Channel mouth (Sts. 56, 57 and 62). It was not, however, dominant at the entrance to the Bristol Channel as in April 1938, although at one station in this region it occurred in numbers equal to those of *S. elegans* (St. 48; both species, five specimens). At one station immediately south-west of Scilly (St. 32) it also appeared to be dominant; this is, however, probably not significant as the total of *Sagitta* spp. taken was only three specimens—two *setosa* and one *elegans*.

2–7 *June* (Fig. 12C).

The species was taken in small numbers (maximum, 300 (day), St. 3) in the eastern half of the cruise—to the west of the Bristol Channel mouth and the English Channel mouth as far as 8° W. Beyond this it did not occur. It was the dominant species close to Land's End and the Lizard although very few specimens occurred here (Sts. 1 and 28; 8 and 2 specimens).

The Distribution of Sagitta serratodentata *Krohn*

1937

12–20 *April* (Fig. 11A).

The area of distribution of the species was continuous from the southern half of the mouth of the English Channel, along the southern line of stations to the western stations both north and south of Scilly. It was absent from the northern half of the Channel mouth (Sts. 1, 2 and 34–36) and from an area

extending south-westwards from Land's End to some 50–60 miles south-west of Scilly (Sts. 17, 19, 23–25, 32 and 33). These two areas were nearly cut off from one another in the vicinity of Land's End by a tongue of *S. serratodentata* (Sts. 20–22) which extended northwards between them across the Channel mouth to within 15 miles of Land's End. The species was dominant at the two westernmost stations (Sts. 13 and 14) and was slightly more numerous generally than *S. setosa* (maxima: 262 (day), St. 8; 285 (night), St. 26). Large catches were made at three day stations in the region of Ushant (Sts. 6–8; 233, 225 and 262 specimens).

27–30 *May*[1] (Fig. 11B).

Very small numbers (maximum 8, St. 6 (night)) were taken in the south-western area only (Sts. 4–7).

20–22 *July* (Fig. 11C).

Catches were also small on this cruise (maximum 58, St. 8 (day)) and the species occurred only to the west of the Scilly Isles (Sts. 3, 6–9 and 11–13).

1938

6–18 *April*[2] (Fig. 11D).

S. serratodentata was widely distributed over the western area of the Celtic Sea from the edge of the Continental Shelf eastwards to about 7° W. It also occurred in the southern half of the mouth of the English Channel and off the Brest Peninsula. It was not taken outside the Bristol Channel (excepting three specimens at St. 47) and the entrance to the St George's Channel, nor in the northern half of the mouth of the English Channel and outside to the south of the Scilly Isles. In the south-eastern area it was absent from several stations (Sts. 8, 9, F 1, F 3, F 101, F 103, F 105 and F 112*b*–F 119) disposed roughly in the shape of a cross (+), the arms of which separated four quarters in which *S. serratodentata* occurred. From a comparison of the distribution in April 1939, it seems probable that the north-south break in distribution was a true discontinuity while the east-west break was not. The numbers per haul of *S. serratodentata* were about equal to those of *S. setosa* except off Ushant (St. 7) where the large catch of 2270 specimens was taken in a day haul. It was the dominant species at this station, over the whole of the south-western marginal area, and at one station in the central area (St. 36), although here only three specimens were taken and no other *Sagitta* spp. were present.

31 *May*–5 *June* (Fig. 11E).

The species was irregularly distributed over the western half of the cruise and did not occur to the east of 7° W. Very small numbers were taken (maximum 30 (night), St. 7) and it did not predominate in any part of the area.

[1] See note 1, p. 91.

[2] See also Furnestin (1939*a*).

19–24 *July* (Fig. 11 F).

One specimen only of *S. serratodentata* was taken outside the Channel mouth (St. 8, day haul).

1939

15–18 *March* (Fig. 12 A).

S. serratodentata was present at all except the two easternmost stations (Sts. 8 and 9). The eastern limit of its distribution lay along 8° W. and it was the dominant species to the west of 10° W. Numbers per haul were about equal to those of *S. elegans* (maxima: 850 (day), St. 8; 2310 (night), St. 11).

16–27 *April* (Fig. 12 B).

S. serratodentata was present in the western half of the Celtic Sea and along the southern margin. In the western area, its distribution did not extend eastwards of 9° 30′ W.; it was absent from the area south of the entrance to the St George's Channel and off the Bristol Channel. In the east it was absent from the northern half of the mouth of the English Channel and to the west and south of Scilly. Along the southern margin its distribution was discontinuous. There was a break in the neighbourhood of Ushant (6° W.) which separated a small body of *S. serratodentata* in the southern half of the Channel mouth (Sts. 2–5, 36 and 59) from the western population. This distribution shows a close resemblance to that of April 1938 but, owing to the lack of stations, it was unfortunately not possible to determine the southward extent of the break. The species was most numerous towards the edge of the Continental Shelf. It was dominant in the area west of 10° W., and to the south of Ireland, where an eastward extension of its area of dominance reached as far as 9° 30′ W. It was also dominant at the southernmost stations (Sts. 11, 12 and 14). It occurred in greater numbers than *S. setosa* but was not so numerous as *S. elegans* (maxima: 1510 (day), St. 21; 1305 (night), St. SR 33).

2–7 *June* (Fig. 12 C).

The area of distribution extended over the western part of the cruise (Sts. 4–12, 15 and 18), from south-west of the Fastnet Light to the region well to the west of the Brest Peninsula. It was entirely absent from the area south of Ireland and outside the Channel mouth. Catches were not so large as in April (maxima: 75 (day), St. 8; 600 (night), St. 5) and it was dominant at the westernmost station (St. 12) and the southernmost station (St. 6) only. It was considerably more numerous than *S. setosa*.

The Distribution of Sagitta lyra *Krohn*

S. lyra occurred in very much smaller numbers than any of the foregoing three species of *Sagitta*. It was not dominant in any of the areas in which it occurred.

12–20 *April* (Fig. 11A). **1937**

The species was taken along the southern line of stations from Ushant westwards (Sts. 5–9, 11, 13–15 and 18; maximum 16, St. 7, day haul).

27–30 *May*.

None was taken on this cruise.

20–22 *July* (Fig. 11C).

A single specimen occurred at Station 8 (day haul).

6–18 *April* (Fig. 11D). **1938**

The species was present in the neighbourhood of Ushant (Sts. 5–7 and 33) and at some of the westernmost stations (Sts. 16, 17, 18A (maximum 20, dawn haul), 20 and SR 88).

31 *May*–5 *June, and* 19–24 *July*.

No *S. lyra* were taken on these two cruises.

15–18 *March* (Fig. 12A). **1939**

S. lyra occurred in the neighbourhood of 10° W. (Sts. 6, 11–13 and 15–18). It was absent from the westernmost stations (Sts. 7–10) and did not occur very far east of 10° W. It was noticeably more numerous in night hauls (maximum 50, St. 15) than in day hauls (maximum 14, St. 12).

16–27 *April* (Fig. 12B).

The species occurred at a considerable number of stations along the edge of the Continental Shelf from the south-west of Ireland to Ushant. With the exception of a large catch (115 specimens) taken in daylight at the westernmost station (St. 21), no hauls contained more than 18 specimens.

2–7 *June* (Fig. 12C).

The species was present at the southernmost (Sts. 6–8) and westernmost stations (Sts. 11 and 12). The largest haul contained 28 specimens (St. 6, night haul).

The Distribution of Muggiaea atlantica *Cunningham*

12–20 *April* (Fig. 13A). **1937**

M. atlantica occurred in the eastern part of the area of the cruise. It was most numerous in the neighbourhood of Ushant where 75, 127 and 107 specimens were taken (Sts. 5–7, day hauls) and its distribution extended thence across the mouth of the Channel in lessening numbers as far as the

Land's End–Scilly Channel and westwards to 7° W. It was absent off the south coast of Cornwall (Sts. 1, 33 and 34) and from the western and north-western region outside the Channel mouth (Sts. 10–18 and 25–32). A single specimen of *M. kochi* was taken about 20 miles to the north of Ushant (St. 5).

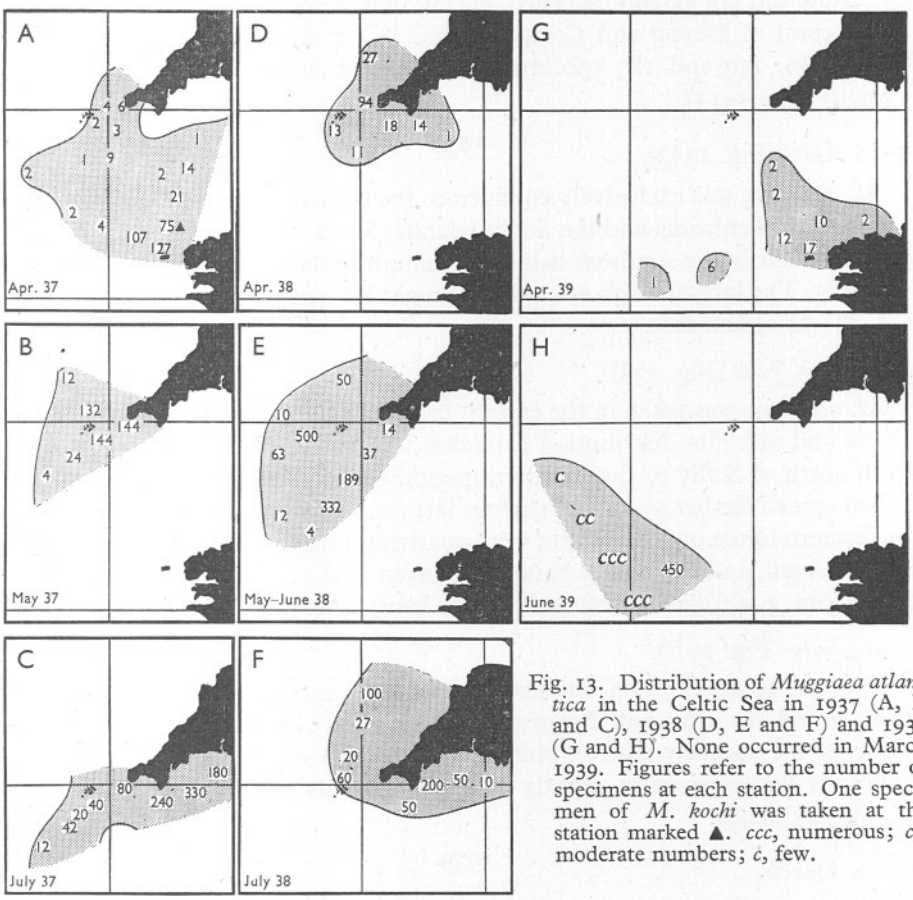

Fig. 13. Distribution of *Muggiaea atlantica* in the Celtic Sea in 1937 (A, B and C), 1938 (D, E and F) and 1939 (G and H). None occurred in March 1939. Figures refer to the number of specimens at each station. One specimen of *M. kochi* was taken at the station marked ▲. *ccc*, numerous; *cc*, moderate numbers; *c*, few.

27–30 *May*[1] (Fig. 13B).

The species was taken in the eastern half of the area of the cruise. The western limit of distribution occurred to the west of Scilly at 7° W. No stations were worked to the east of Land's End, inside the mouth of the Channel. It was most numerous in the region of the Land's End–Scilly Channel (Sts. 1 and 2; 144 and 144 specimens; day hauls) and catches here were rather larger than the maximum of April. It was absent from the western stations (Sts. 5–13).

[1] See note 1, p. 91.

20–22 *July* (Fig. 13 C).

The species was taken in the northern half of the Channel mouth and to the west as far as 7° W. No stations were worked in the southern half of the Channel mouth, and the eastern limit of distribution was not determined as the cruise did not extend eastward of 4° W. The largest hauls occurred off the south coast of Devon and Cornwall (Sts. 16, 17 (day hauls) and 18 (dawn haul); 240, 330 and 180 specimens). It was absent from the westernmost stations (Sts. 5–13).

1938

7–18 *April* (Fig. 13 D).

M. atlantica was exclusively confined to the coastal waters around the tip of the Cornish Peninsula and the Scilly Islands (Sts. 2, 28, 29, 49 and 53–55). It did not occur in the southern half of the mouth of the Channel nor to the west of Scilly. The largest catch was taken at night between Land's End and Scilly (St. 53; 94 specimens).

31 *May*–5 *June* (Fig. 13 E).

M. atlantica was taken in the eastern half of the area of the cruise (Sts. 1–6, 10–12 and 30). Its distribution extended westwards to about 7° 30′ W. and from north of Scilly to the southern margin of the cruise (48° 50′ N.; St. 5). It had spread farther south and slightly farther west since April. The southern and eastern limits of distribution were not determined. It was more numerous than in April, and three large hauls were taken in the area to the south-west of Scilly (Sts. 3, 4 (night hauls) and 11 (day haul); 189, 332 and 500 specimens).

19–24 *July* (Fig. 13 F).

The area of distribution was similar to that of April; it was confined to the area around the Cornwall Peninsula (Sts. 1, 16–19 and 24–26) and did not occur in the southern half of the Channel mouth or to the west of Scilly. Numbers were generally slightly less than in May–June (maximum 200, St. 25, day haul).

1939

15–18 *March*.

No *M. atlantica* were taken on this cruise.

16–27 *April* (Fig. 13 G).

Very small numbers (maximum 17, St. 4, day haul) were taken in the south-eastern area only—in the southern half of the mouth of the English Channel (Sts. 3–5, 30, 35 and 59) and at two stations some distance to the west of the Brest Peninsula (Sts. 10 and 12).

2–7 *June* (Fig. 13 H).

The species was present in the south-western area between 7° W. and 8° 30′ W. (Sts. 5–9). This was considerably farther to the west than on previous

cruises. It was absent from the northern and north-western areas and also from the eastern area off the Channel mouth. No stations were worked in the southern half of the Channel mouth, where it occurred in April. Considerably greater numbers were taken than in April (450, St. 5, night haul).

Hydrological Conditions, Temperature and Salinity

No hydrological data were obtained on the cruises of May and July 1937, May–June 1938, and March and June 1939.

12–20 *April.* **1937**

Water samples were taken at 5, 25 and 50 m.[1]

Salinity (Fig. 14A). Salinities were vertically homohaline. Water of fairly high salinity (35·31–35·48 ‰) lay to the westward of the Channel mouth. It was separated from water of similar salinity inside the Channel—off Plymouth—

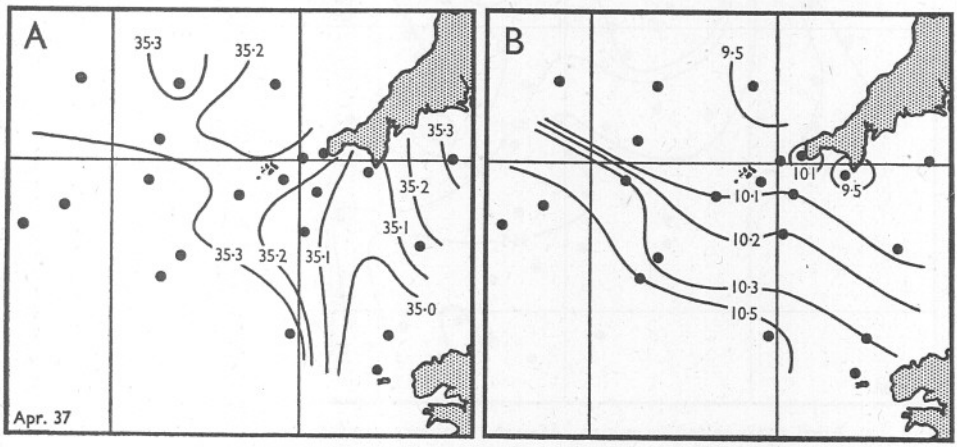

Fig. 14. April 1937; salinities (A) and temperatures (B) at 5 m.

by a broad tongue of low salinity (<35·10 ‰) which extended northwards from Ushant across the Channel mouth as far as the Lizard. North of the Scilly Isles, salinities were also low (35·09–35·21 ‰, total range, all depths; Sts. 32 and 33), but were probably not continuous with the Ushant tongue which appeared to be retained by an eastward extension of slightly more saline water past Scilly to Land's End (35·22–35·30 ‰, total range, all depths; Sts. 23 and 24).

Temperature (Fig. 14B). Temperatures were homothermal at all depths. At Station 23, noticeably high values were recorded, which are however, almost certainly attributable to inshore conditions. The station was less than two miles from the coast of Land's End, in a depth of 20½ fms. (37·5 m.).

[1] Salinity and temperature data of the April 1937 cruise have been published in the *Bulletin Hydrographique* for the year 1937 (1939).

6–18 *April.* 1938

Water samples were taken at 0, 5, 25, 50 m. and bottom on the *George Bligh* cruise,[1] at 0, 10, 20, 40, 60, 100, 140, 200 m. and bottom on the *Muirchu* cruise,[2] and at 5, 50, 100 m. and bottom on the *Quentin Roosevelt* cruise.[3]

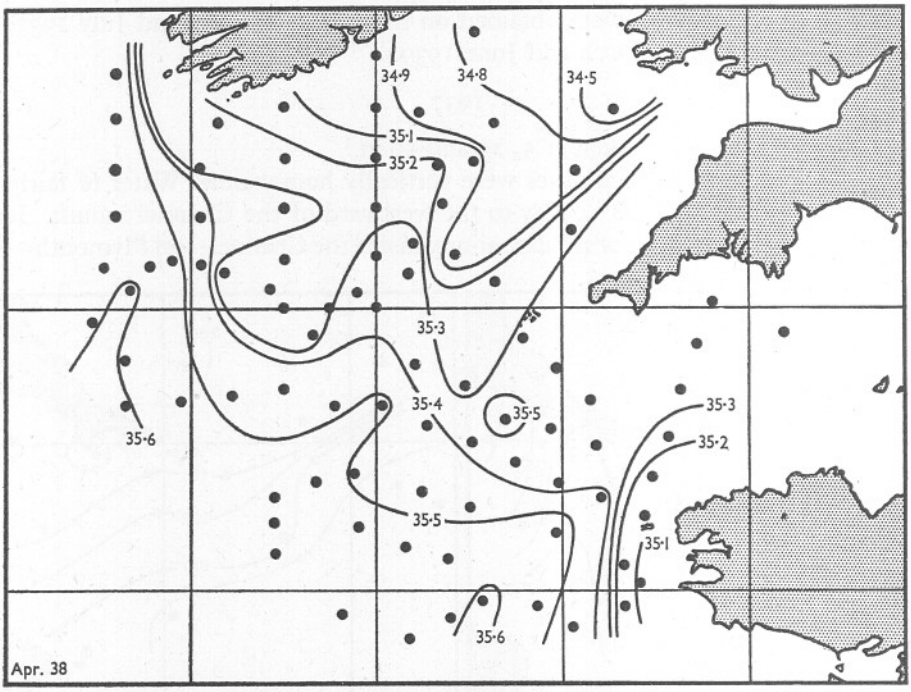

Fig. 15. April 1938; salinities at 5 m. *Muirchu* stations were sampled at 10 m.; there was very little difference between salinities at this depth and at surface.

Salinity (Fig. 15). Conditions were homohaline at all depths. Low salinity water ($<35{\cdot}20\,^{0}/_{00}$) was present in the south-eastern area—close to the Brest Peninsula, and also in the northern area—from the south coast of Ireland to the mouth of the Bristol Channel. Fairly high salinity water ($35{\cdot}30$–$35{\cdot}40\,^{0}/_{00}$) occupied the northern half of the mouth of the Channel and the region to the

[1] Salinity and temperature data of the *George Bligh* cruise of April 1938 are to be published in the *Bulletin Hydrographique*.

[2] Salinity and temperature data of the *Muirchu* cruise of April 1938 have been published in the *Bulletin Hydrographique* for the years 1938 and 1939 (1944).

[3] For salinity and temperature data, see Furnestin (1939*a*). Data of the first part of the *Quentin Roosevelt* cruise (23 March–5 April 1938) are not included in the above account owing to their slightly earlier date than the *George Bligh* and *Muirchu* observations; data of the second part of the cruise (6–9 April 1938; Sts. F 101–F 119, this paper; 101–119, Furnestin (1939*a*)) are included.

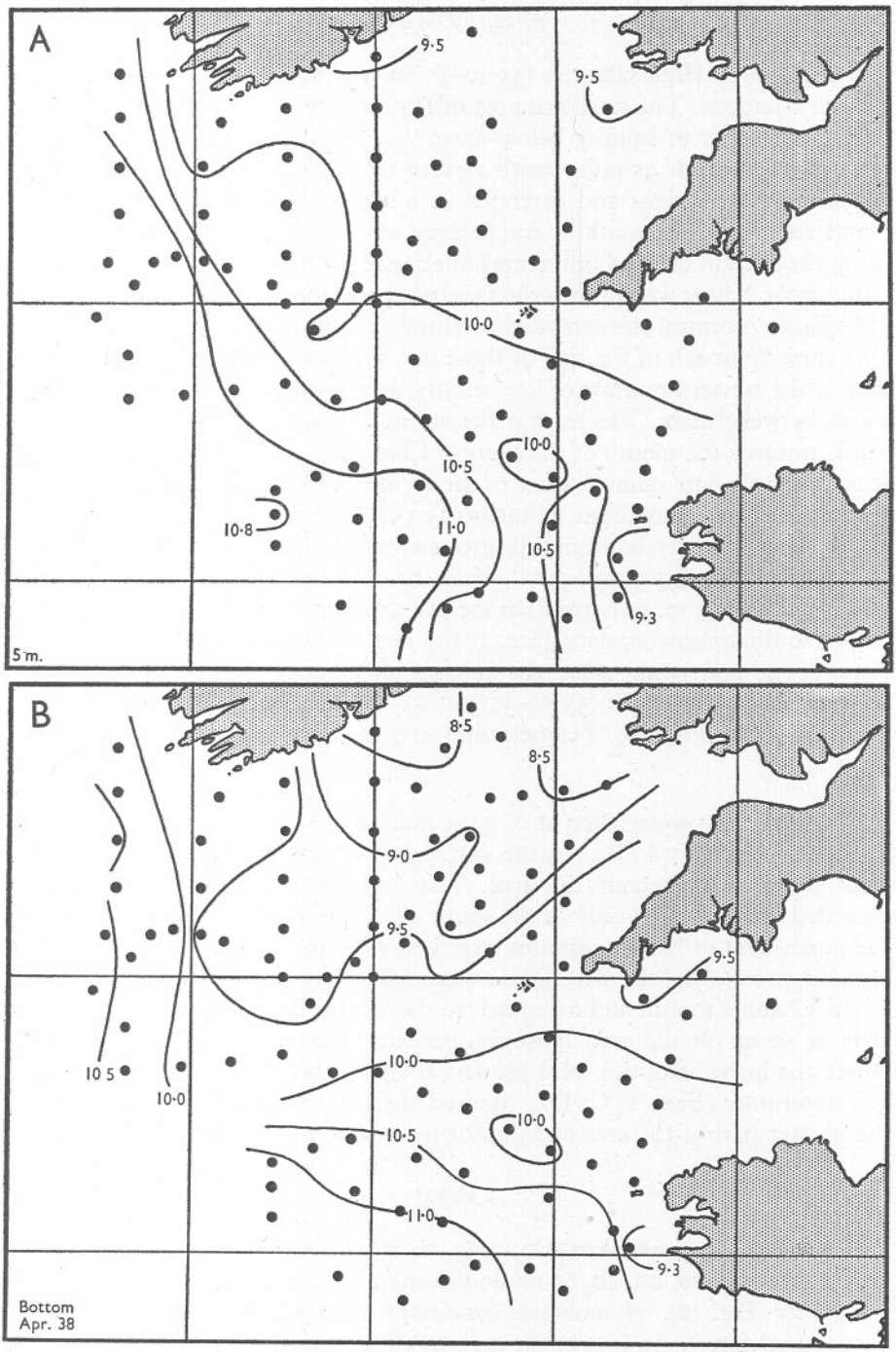

Fig. 16. April 1938; temperatures at 5 m. (A) and bottom (B). *Muirchu* stations were sampled at 10 m.; there was very little difference between values at this depth and at surface.

south of Scilly. High salinities (35·40–35·60‰) prevailed at the western and southern stations. The northern area of low salinity gave rise to two separate tongues of water of salinity below 35·30‰. The first extended southwards along 7° W. to some 35 miles south-west of Scilly (St. 34). The second tongue lay farther to the west and extended in a south-westerly direction between 8 and 10° W., as far south as the latitude of Scilly. The high salinity water along the margin of the Continental Shelf made three incursions into the less saline areas. There was an easterly directed penetration in the area to the south of Ireland. A central one extended northwards along 8° W. to about 50° 30′ N. The close approach of the tips of these two tongues narrowly constricted the root of the western outflow of low salinity water which extended south-westwards between them. The third penetration of saline water, extending northwards towards the mouth of the English Channel, lay off the Brest Peninsula. It confined the low salinity water in the vicinity of Ushant very closely to the French coast. The medium salinities (35·35‰) in the Channel mouth were probably in part derived from this last penetration since small isolated lacunae of higher salinity (35·39–35·51‰) than the surrounding water were found at varying depths (5 m. to bottom) as far east as Station 1 off Plymouth. At two of the southernmost stations (Sts. F 108 and F 109), salinities were slightly lower (35·48 and 35·44‰) at 200 m. than in the upper layers and at stations immediately to the north (35·52–35·59‰).

Temperature (Fig. 16). Temperatures at 5 m. and bottom are shown.

19–24 *July*.

Water samples were taken at 0, 5, 25 and 50 m.[1]

Salinity (Figs. 17A, B). In the surface waters (0 and 5 m.), low salinities were present throughout the area. The maximum value of 35·34‰ was recorded at one station only to the south of Land's End (St. 23, 5 m.), and to the north-west of Scilly, salinities were below 35·10‰. In the deeper layers (25 and 50 m.), slightly more saline water (35·30–35·46‰) occupied the area of the Channel mouth and extended, to the west and north of Scilly, particularly at 50 m. It did not, however, penetrate eastwards into the Channel, where the lower salinities were present at all depths.

Temperature (Figs. 17C, D). Marked thermal stratification occurred over the greater part of the area at 25 m. or just above this depth.

1939

6–18 *April*.

Water samples were taken at 0, 5, 25, 50 m. and bottom on the *George Bligh* cruise and at 0, 10, 20, 40, 60 m. and bottom on the *Muirchu* cruise.[1]

Salinity (Fig. 18). Homohaline conditions prevailed at all depths. Water of very low salinity (< 34·80‰) was present off the mouth of the Bristol Channel

[1] Data to be published in the *Bulletin Hydrographique*.

and along the south coast of Ireland. With slightly increased salinity (to 35·10 ‰), it extended south-westwards from the mouth of the Bristol Channel as far as the latitude of the Scilly Isles and to the west of them (St. 31). With a further slight rise of salinity (to 35·30 ‰), its influence was traceable as a tongue of considerable breadth lying to the west of Scilly and reaching as far south as

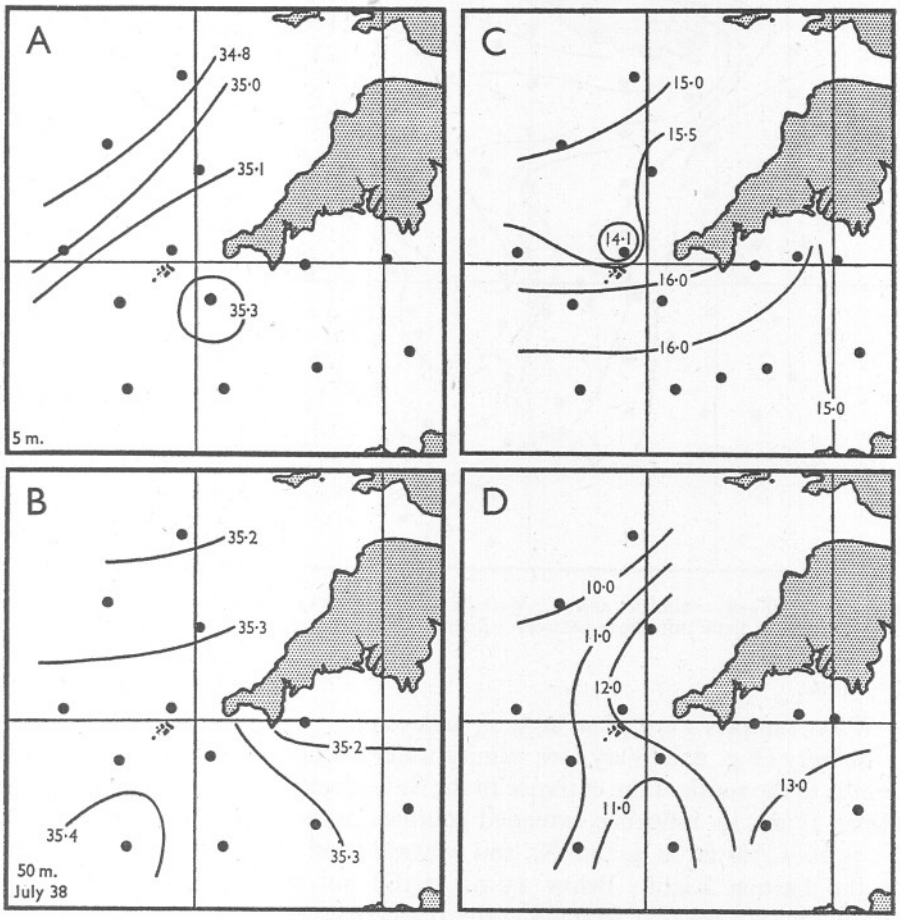

Fig. 17. July 1938; salinities (A and B) and temperatures (C and D) at 5 and 50 m.

49° N. Low salinities (< 35·20 ‰) were also present in the vicinity of Ushant and occupied the southern half of the mouth of the English Channel. Between these two regions of low salinity, a slightly more saline tongue (35·30–35·38 ‰) extended northwards along 6° W.—across the mouth of the Channel as far as Scilly. It was evidently derived from the higher salinity water (> 35·50 ‰) which was present farther to the south at the edge of the Continental Shelf. This saline water occurred in the western and southern areas, and in addition

to the extension of its influence across the mouth of the English Channel referred to above, there was an easterly directed penetration to the south of Ireland.

Temperature (Fig. 19). Temperatures at 5 m. and bottom are shown.

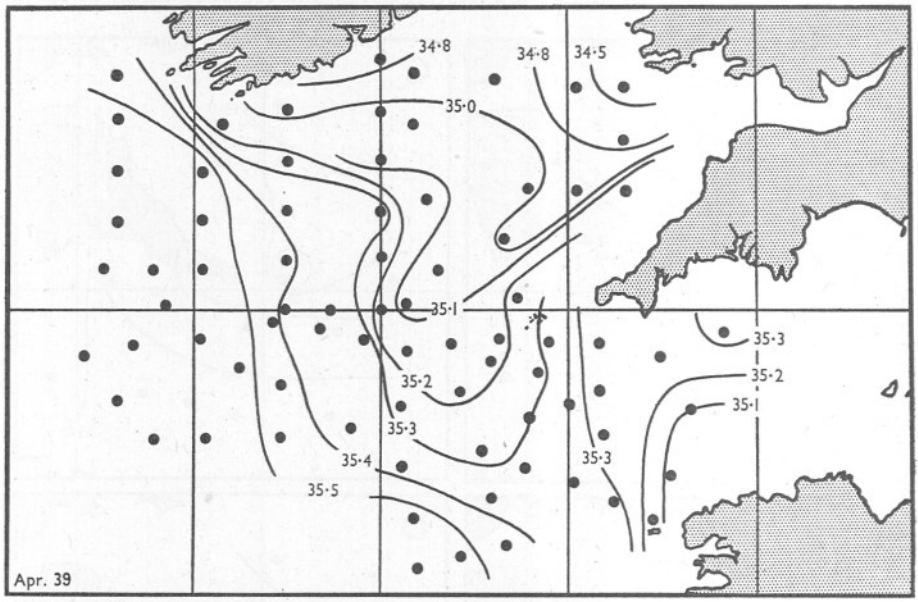

Fig. 18. April 1939; salinities at 5 m. *Muirchu* stations were sampled at 10 m.; there was very little difference between values at this depth and at surface.

2–7 *June.*

Water samples were taken at 5, 25 and 50 m.[1]

Salinity (Fig. 20). Very low salinity water (<34·77‰) was present at all depths to the south of the entrance to the St George's Channel (St. 25). In the upper 25 m., its influence extended southwards as a tongue of low salinity (<35·20‰) as far as 49° 20′ N., and westwards off the coast of Ireland as far as the Fastnet Light. Below 25 m., it did not reach farther south than 50° 20′ N., nor very far west along the Irish coast. At the western and south-western stations saline water (>35·40‰) occurred at all depths, and in the upper 25 m. it extended northwards across the Channel mouth to Scilly (35·59‰, 5 m., St. 27, 20 miles north of Scilly) .At 50 m., this northerly flow was checked by slightly fresher water (35·2–35·3‰), which extended westwards from the mouth of the Channel, also blocking at this deeper level the southward flow of low salinity water from the St George's Channel region.

Temperature (Fig. 21). Temperatures at 5 and 50 m. are shown.

[1] Data to be published in the *Bulletin Hydrographique*.

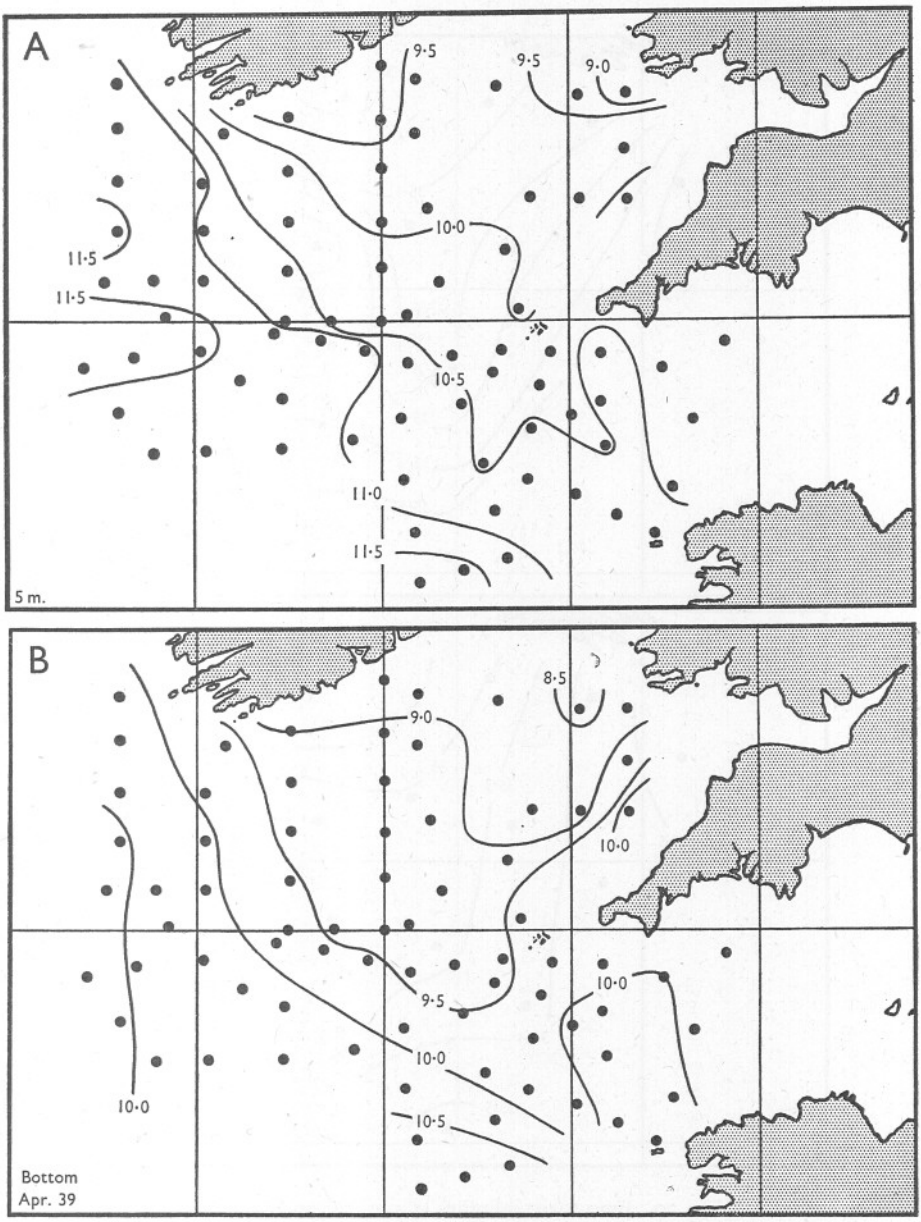

Fig. 19. April 1939; temperatures at 5 m. (A) and bottom (B). *Muirchu* stations were sampled at 10 m.; there was very little difference between values at this depth and at surface.

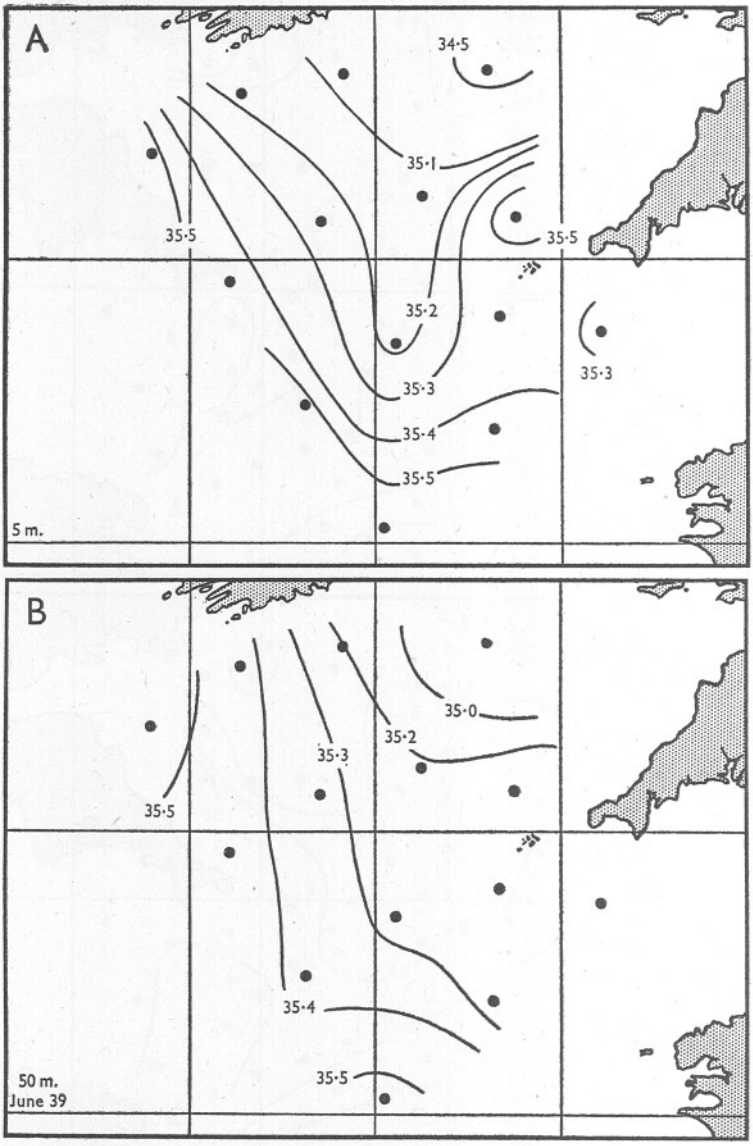

Fig. 20. June 1939; salinities at 5 m. (A) and 50 m. (B).

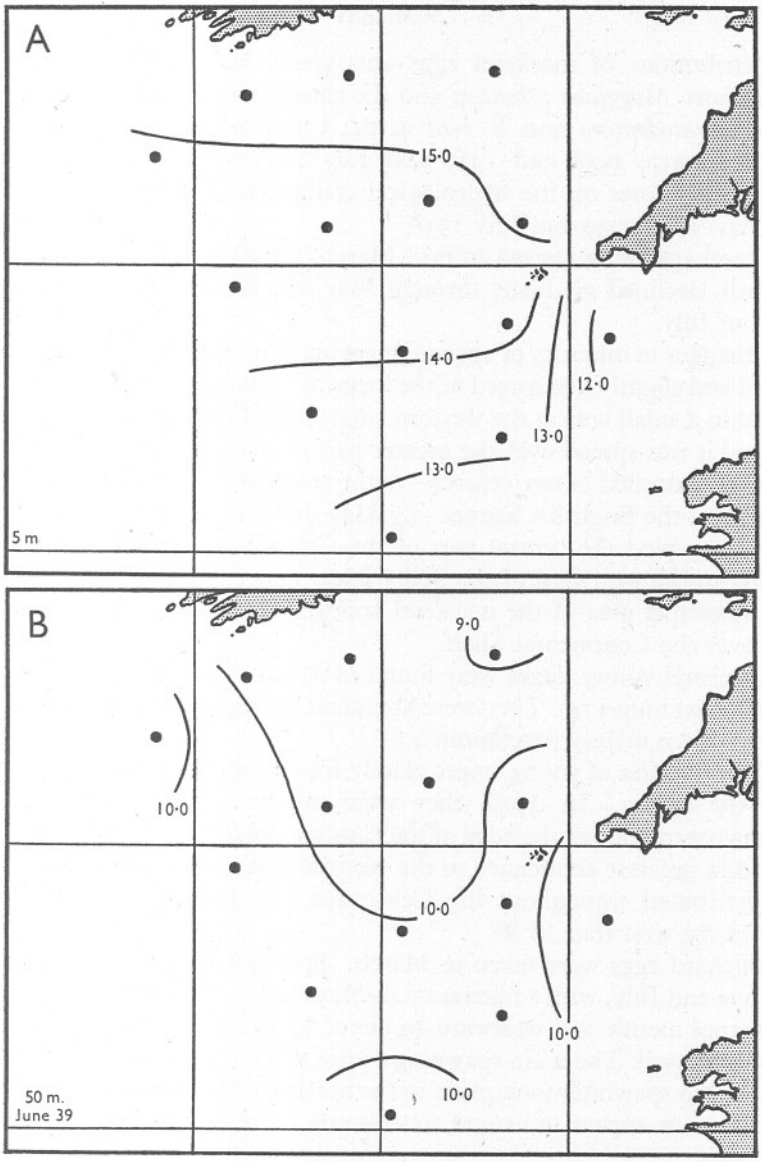

Fig. 21. June 1939; temperatures at 5 m. (A) and 50 m. (B).

Summary

The distributions of mackerel eggs and young stages, pilchard eggs, the siphonophore *Muggiaea atlantica* and the chaetognaths *Sagitta elegans*, *S. setosa*, *S. serratodentata* and *S. lyra* in the Celtic Sea in March 1939, April, May–June 1937, 1938 and 1939 and July 1937 and 1938 are described, together with notes on the hydrological conditions in April 1937, 1938 and 1939, May–June 1939 and July 1938.

Mackerel spawning started in mid-March, rapidly reached a maximum in mid-April, declined gradually through May and June and was very slight at the end of July.

The changes in intensity of spawning are accompanied by a continuous shift eastward and slightly northward of the locus of spawning. In March spawning occurred in a small area at the western edge of the Continental Shelf only. In mid-April it was spread over the greater part of the Celtic Sea, with the main activity concentrated in two centres—to the south of Ireland and to the west of the mouth of the English Channel. By May–June it had shifted farther to the east and occupied the central area of the Celtic Sea. In July there was no spawning to the westward of the Scilly Isles.

The spawning area of the mackerel appears to be confined to the shallow waters over the Continental Shelf.

No mackerel young stages were found in March. Small numbers occurred in April (maximum 174). They were abundant in May–June (maximum 8239), and very scarce in July (maximum 20).

The distribution of young stages closely follows the movement of spawning during the season. In April, they were present to the westward of the spawning centres, along the edge of the Continental Shelf. In May–June, they occurred in greatest abundance to the westward of the spawning centres, but were distributed throughout the Celtic Sea. In July, they did not occur farther to the west than 8° W.

No pilchard eggs were taken in March. Spawning was observed in April, May–June and July, with a maximum in May–June. It occurred in the area of the Channel mouth and westward to about 8° W., and also along the north coast of Cornwall. The main spawning centre was situated in the mouth of the Channel. No spawning took place in the north-western area of the Celtic Sea and it does not appear to extend southwards beyond the edge of the Continental Shelf.

At the western end of the English Channel, spawning lasts from March until December (Russell). It probably occurs throughout the length of the English Channel (Furnestin).

Muggiaea atlantica was not taken in March. It occurred mainly in the mouth of the Channel from April to July. There is evidence that in April 1937

and 1939 it was carried into this area with an inflow of low salinity water from the Ushant area.

Sagitta elegans was the dominant *Sagitta* species throughout the central area of the Celtic Sea on all cruises. Its area of distribution did not appear to extend beyond the Continental Shelf. There was evidence of a centre of abundance in April and May–June to the north-west of Ushant immediately outside the Channel mouth.

Sagitta setosa occurred mainly in the eastern part of the Celtic Sea. It was dominant in parts of the English Channel mouth and off the entrance to the Bristol Channel.

Sagitta serratodentata was distributed over the western and southern areas. It was the dominant species along the edge of the Continental Shelf.

Sagitta lyra occurred along the edge of the Continental Shelf. It was more restricted to this area than *S. serratodentata*.

I am greatly indebted to the late Dr E. J. Allen, C.B.E., F.R.S., who was Director of the Plymouth Laboratory when the mackerel investigation began in 1936, for his advice and warm encouragement to a new worker; and to his successor, the late Dr S. W. Kemp, F.R.S., for generous encouragement and help during the work. My sincere thanks are due to the present Director and staff of the Plymouth Laboratory for their interest, encouragement and practical help throughout the work, particularly to Mr G. A. Steven who was in charge of the investigation. I am much indebted to Mr G. P. Farran of the Fisheries Branch of the Department of Agriculture and Fisheries, Eire, for his kindness in allowing me to examine the complete collections made by the Fishery Cruiser *Muirchu* in April 1938 and 1939 and for his generous permission to use these extensive data. I am indebted to Mr P. H. T. Hartley and to the late Mr P. R. Crimp, for valuable help in the work of some of the cruises. My thanks are also due to Captain W. H. Stewart, lately of the Research Ship *George Bligh* (Ministry of Agriculture and Fisheries), to Mr B. Moore, lately Master of the Lowestoft Steam Drifter *B.T.B.*, to Mr W. H. E. Nichols of Plymouth, lately Master of the Steam Trawler *Elk*, and to the members of the crews of these ships for the great care and interest they showed in the work of the cruises. Part of the preparation of this report was done during tenure of a Leverhulme Research Grant, for which I owe acknowledgement to the Trustees of the Leverhulme Research Fellowships.

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APPENDIX

TABLE VI. NUMBERS OF MACKEREL EGGS, MACKEREL YOUNG STAGES, PILCHARD EGGS AND INDICATOR SPECIES PER ½ HR. OBLIQUE HAUL OF THE 2 M. STRAMIN RING-TRAWL.

* denotes figure obtained by sampling. Nt, night haul. Dn, dawn haul. Dk, dusk haul.

Station number (date in parenthesis)	Station position	Time of haul (G.M.T.)	Mackerel eggs	Mackerel young stages	Pilchard eggs	*Muggiaea atlantica*	*Sagitta elegans*	*Sagitta setosa*	*Sagitta serrato-dentata*	*Sagitta lyra*
				1937						
12–20 April. S.S. *George Bligh*										
1 (12)	50° 01′ N., 4° 21′ W.	17.25–17.55	..	..	12,000*	..	..	..	..	..
2 (12)	49° 42′ N., 4° 32′ W.	20.53–21.27 Nt	6	..	30,000*	1	25	1	..	..
3 (13)	49° 23′ N., 4° 41′ W.	00.13–00.45 Nt	..	..	..	14	2,680*	3	1	..
4 (13)	49° 05′ N., 4° 51′ W.	03.41–04.06 Nt	..	..	..	21	975*	20	29	..
5 (13)	48° 46′ N., 5° 01′ W.	06.54–07.27	..	..	..	75 (1 *M. kochi*)	225*	21	48	4
6 (13)	48° 31′ N., 5° 09′ W.	10.25–10.55	..	..	..	127	800*	166*	233*	4
7 (13)	48° 38′ N., 5° 32′ W.	13.08–13.38	..	..	..	107	4,615*	130*	225*	16
8 (13)	48° 46′ N., 6° 05′ W.	17.03–17.32	440*	..	..	4	471	31	262	1
9 (13)	48° 54′ N., 6° 34′ W.	21.05–21.36 Nt	8,610*	..	17*	2	645*	10*	20*	1
10 (14)	49° 03′ N., 7° 01′ W.	00.25–00.55 Nt	10,080*	..	..	..	1,575*	2	60	..
11 (14)	49° 10′ N., 7° 28′ W.	04.03–04.35 Nt	4,680*	..	80*	..	480*	..	2	3
12 (14)	49° 18′ N., 7° 58′ W.	07.53–08.22	7,012*	..	115*	..	12	1	3	..
13 (14)	49° 27′ N., 8° 26′ W.	11.27–11.56	18,575*	..	..	..	5	..	6	1
14 (14)	49° 32′ N., 8° 58′ W.	15.53–16.23	32,300*	..	..	..	12	1	93	13
15 (14)	49° 40′ N., 8° 30′ W.	19.34–20.04	20,500*	1	..	..	341	..	9	2
16 (14)	49° 44′ N., 8° 11′ W.	22.59–23.29 Nt	1,786*	..	..	..	350*	..	30	..
17 (15)	49° 51′ N., 7° 37′ W.	02.24–02.54 Nt	1,470*	..	675*	..	270*	..	..	..
18 (15)	49° 33′ N., 7° 35′ W.	05.43–06.12 Dn	150*	..	..	..	350*	6	14	3
19 (15)	49° 19′ N., 7° 15′ W.	09.09–09.38	640*	..	5*	2	25	5	..	..
20 (15)	49° 28′ N., 6° 20′ W.	15.52–16.20	2	..	..	1	2,550*	14	11	..
21 (15)	49° 28′ N., 5° 56′ W.	18.09–18.38	..	..	..	9	1,775*	34	127	..
22 (15)	49° 46′ N., 5° 48′ W.	21.17–21.46 Nt	75*	..	485*	3	22	2	1	..
23 (18)	50° 02′ N., 5° 44′ W.	11.54–12.21	..	..	915*	6	275*	1	..	..
24 (18)	49° 51′ N., 6° 10′ W.	15.14–15.42	..	..	1,500*	2	32	1	..	..
25 (18)	49° 45′ N., 6° 38′ W.	18.07–18.36	..	..	760*	..	..	..	..	..
26 (18)	49° 56′ N., 7° 03′ W.	21.18–21.48 Nt	412*	..	630*	..	1,062*	..	285*	..
27 (19)	50° 08′ N., 7° 29′ W.	00.42–01.13 Nt	14	..	..	..	1,127*	..	22	..
28 (19)	50° 19′ N., 7° 55′ W.	03.58–04.27 Dn	9	..	..	..	2,425*	..	4	..
29 (19)	50° 31′ N., 8° 20′ W.	07.04–07.33	577*	10	..	..	15	..	2	..
30 (19)	50° 30′ N., 7° 16′ W.	12.57–13.25	..	..	..	..	..	..	..	..
31 (19)	50° 30′ N., 6° 45′ W.	15.50–16.20	..	..	..	..	3	..	2	..
32 (19)	50° 30′ N., 6° 15′ W.	19.05–19.34 Dk	..	..	..	..	1,870*	..	..	..
33 (20)	50° 01′ N., 5° 58′ W.	01.49–02.19 Nt	..	..	232*	4	138	..	..	..
34 (20)	49° 55′ N., 5° 16′ W.	06.12–06.39	..	..	271	..	57	..	..	..
35 (20)	49° 45′ N., 5° 18′ W.	08.19–08.49	..	1	11,902*	..	48	2	..	..
36 (20)	49° 19′ N., 5° 07′ W.	12.30–13.00	..	..	2	2	342	3	..	..

27–30 May.† Steam drifter *B.T.B.*

1 (27)	49° 59′ N., 5° 42′ W.	07.48–08.23	36	4	2,800*	144	76	8	..	..
2 (27)	49° 48′ N., 6° 08′ W.	11.20–11.51	60	..	16	144	244	..	..	..
3 (27)	49° 37′ N., 6° 35′ W.	14.20–14.52	1,240	..	336	24	..	..	..	..
4 (27)	49° 25′ N., 7° 00′ W.	18.13–18.44	2,780*	244	..	4	36	..	4	..
5 (27)	49° 13′ N., 7° 27′ W.	19.24–19.56 Nt	276	56	..	..	300*	..	4	..
6 (28)	49° 02′ N., 7° 52′ W.	00.47–01.19 Nt	880	112	..	..	264	..	8	..
7 (28)	49° 12′ N., 8° 17′ W.	03.53–04.23	408	52	..	..	76	..	4	..
8 (28)	49° 33′ N., 8° 17′ W.	07.20–07.52	8,875*	568	..	..	..	..	..	..
9 (28)	49° 54′ N., 8° 18′ W.	10.33–11.12	2,770*	8	..	..	..	..	..	..
10 (28)	50° 12′ N., 8° 18′ W.	13.45–14.17	2,750*	68	..	..	..	..	..	..
11 (28)	50° 08′ N., 7° 48′ W.	16.43–17.15	752	4	..	..	..	..	..	..
12 (28/29)	50° 05′ N., 7° 21′ W.	19.30–04.30 Nt‡	56	..	..	..	88	..	..	..
13 (29)	50° 20′ N., 7° 02′ W.	12.10–12.41	544	..	..	..	..	..	..	..
14 (30)	50° 25′ N., 6° 40′ W.	08.29–09.00	68	..	300*	12	..	..	..	..
15 (30)	50° 06′ N., 6° 19′ W.	11.31–12.02	16	4	200*	132	28	12	..	..

20–22 July. Steam trawler *Elk*

1 (20)	49° 57′ N., 5° 44′ W.	12.20–12.45	15*	3	2,000*	80*	24	86	..	..
2 (20)	49° 45′ N., 6° 12′ W.	15.15–15.45	35*	4	600*	40*	17	6	..	..
3 (20)	49° 33′ N., 6° 37′ W.	18.10–18.40	..	15	..	42	280*	1	9	..
4 (20)	49° 22′ N., 7° 03′ W.	21.20–21.50 Nt	..	1	..	12	40*	..	..	..
5 (21)	49° 10′ N., 7° 29′ W.	00.22–00.52 Nt	..	1	..	§	§	§	§	§
6 (21)	48° 59′ N., 7° 56′ W.	03.45–04.15 Nt	..	..	..	..	1,700*	..	18	..
7 (21)	49° 09′ N., 8° 22′ W.	06.45–07.15	..	..	..	..	31	..	3	..
8 (21)	49° 30′ N., 8° 22′ W.	10.02–10.32	..	..	..	..	1,566*	..	58	1
9 (21)	49° 51′ N., 8° 23′ W.	13.11–13.41	..	..	..	..	7	..	2	..
10 (21)	50° 10′ N., 8° 23′ W.	16.34–17.04	..	..	..	..	2	..	..	..
11 (21)	50° 02′ N., 7° 54′ W.	19.30–20.00 Dk	..	5	..	..	92	..	2	..
12 (21/22)	49° 55′ N., 7° 25′ W.	22.35–23.05 Nt	..	3	..	..	240*	..	1	..
13 (22)	49° 47′ N., 6° 56′ W.	01.35–02.05 Nt	..	10	..	..	2,800*	..	1	..
14 (22)	49° 38′ N., 6° 28′ W.	06.02–06.32	1	2	350*	20	10	1	..	..
15 (22)	49° 30′ N., 5° 54′ W.	10.00–10.30	5	2	18	..	73	27	..	..
16 (22)	49° 48′ N., 5° 07′ W.	13.08–13.38	25*	20	400*	240*	180*	20*	..	..
17 (22)	49° 54′ N., 4° 37′ W.	16.02–16.32	35*	1	10,000*	330*	6	38	..	..
18 (22)	50° 07′ N., 4° 15′ W.	19.10–19.35	135*	11	1,700*	180*	18	4	..	..

† See note 1, p. 91.
‡ Metre-net attached to foot rope of mackerel drift-nets which were fishing during the night.
§ Haul lost owing to enemy action before these organisms were counted.

TABLE VI (*cont.*)

Station number (date in parenthesis)	Station position	Time of haul (G.M.T.)	Mackerel eggs	Mackerel young stages	Pilchard eggs	*Muggiaea atlantica*	*Sagitta elegans*	*Sagitta setosa*	*Sagitta serrato-dentata*	*Sagitta lyra*
				1938						
7–18 April. S.S. *George Bligh*										
1 (7)	50° 02′ N., 4° 22′ W.	13.16–13.53	..	..	1,100*	..	..	..	..	..
2 (7)	49° 43′ N., 4° 32′ W.	17.18–17.48	..	..	24,120*	1	1	3	..	..
3 (7)	49° 24′ N., 4° 42′ W.	20.10–20.40	135*	..	7,680*	..	31	36	..	..
4 (7/8)	49° 05′ N., 4° 50′ W.	23.52–00.22 Nt	42	..	..	..	2,950*	350*	33	..
5 (8)	48° 48′ N., 5° 00′ W.	04.19–04.50 Nt	..	..	..	..	3,275*	72	62	3
6 (8)	48° 31′ N., 5° 06′ W.	09.20–09.50	..	..	..	..	287	345	67	2
7 (8)	48° 39′ N., 5° 34′ W.	12.39–13.09	6	..	..	..	900*	525*	2,270*	3
8 (8)	48° 45′ N., 6° 02′ W.	16.00–16.30	230*	..	755*	..	8	6	..	..
9 (8)	48° 53′ N., 6° 30′ W.	19.09–19.39	155*	..	20*	..	230*	..	..	..
10 (8)	49° 02′ N., 6° 58′ W.	22.27–23.00 Nt	12,500*	..	1,940*	..	480*	5	14	..
11 (9)	49° 10′ N., 7° 27′ W.	01.54–02.24 Nt	20,310*	..	465*	..	105*	..	7	..
12 (9)	49° 18′ N., 7° 57′ W.	05.11–05.41 Dn	5,920*	..	30*	..	4	..	2	..
13 (9)	49° 18′ N., 8° 27′ W.	08.38–09.08	1,717*	..	..	..	27	..	46	..
14 (9)	49° 25′ N., 9° 00′ W.	12.02–12.33	3,650*	..	..	..	2	1	20	..
15 (9)	49° 22′ N., 9° 34′ W.	15.22–15.52	3,090*	..	..	..	1	..	21	..
16 (9)	49° 20′ N., 10° 07′ W.	18.40–19.10	6,580*	1	..	..	..	..	6	2
17 (9)	49° 18′ N., 10° 42′ W.	22.06–22.36 Nt	125	69	..	..	325*	..	500*	1
18 (10)	49° 37′ N., 10° 43′ W.	01.35–02.06 Nt	32	21	..	..	27	..	51	..
18*a* (10)	49° 53′ N., 11° 03′ W.	05.21–06.16 Dn	..	4	..	..	..	..	63	20
19 (10)	50° 07′ N., 10° 39′ W.	13.27–13.57	79	3	..	..	..	..	9	..
20 (10)	50° 18′ N., 10° 11′ W.	18.11–18.41	156	7	..	..	13	..	74	2
21 (10)	50° 14′ N., 9° 39′ W.	22.56–23.26 Nt	12,650*	..	..	..	925*	..	26	..
22 (11)	50° 07′ N., 9° 10′ W.	03.30–04.00 Nt	19,755*	..	..	..	3,150*	..	125*	..
23 (11)	49° 48′ N., 8° 41′ W.	07.33–08.03	1,000*	..	..	..	9	2	1	..
24 (11)	50° 06′ N., 8° 11′ W.	11.21–11.51	435	..	..	..	..	..	..	..
25 (11)	50° 13′ N., 7° 38′ W.	14.51–15.21	203	..	..	..	..	..	..	..
26 (11)	50° 21′ N., 7° 08′ W.	18.18–18.52	12	..	..	..	420*	100*	1	..
27 (11)	50° 10′ N., 6° 42′ W.	22.27–22.58 Nt	100*	..	..	..	62	1	..	..
28 (12)	49° 46′ N., 6° 24′ W.	04.09–04.39 Nt	30*	..	300*	13	24	10	..	..
29 (12)	49° 33′ N., 6° 03′ W.	07.31–08.02	10*	..	10,030*	11	..	2	..	..
30 (12)	49° 20′ N., 5° 40′ W.	11.02–11.32	25*	..	16,200*	..	5	40	..	..
31 (12)	49° 01′ N., 5° 36′ W.	14.23–14.53	41	..	30	..	7	31	..	..
32 (12)	49° 09′ N., 6° 06′ W.	17.42–18.12	123	..	332	..	4	1	..	..
33 (12)	49° 11′ N., 6° 37′ W.	21.01–21.31 Nt	316	..	6	..	1,675*	150*	..	1
34 (13)	49° 26′ N., 7° 01′ W.	00.26–00.56 Nt	483	..	97	..	240*	..	..	..
35 (13)	49° 35′ N., 7° 33′ W.	03.48–04.18 Nt	233	..	..	..	70*	..	2	..
36 (13)	50° 25′ N., 7° 35′ W.	10.52–11.22	315	..	..	..	..	..	3	..
37 (13)	50° 41′ N., 7° 16′ W.	14.58–15.36	36	..	..	..	80	52	7	..
38 (13)	50° 58′ N., 6° 57′ W.	18.36–19.06	26	..	..	..	92	93	2	..
39 (13)	50° 57′ N., 7° 20′ W.	21.50–22.20 Nt	14	..	..	..	2,360*	154	8	..

40 (14)	50° 18′ N., 7° 30′ W.	01.16–01.46 Nt	60*	..	..	..	161	35	9	..
41 (14)	51° 33′ N., 7° 11′ W.	04.39–05.09 Dn	..	..	..	..	62	14	1	..
42 (14)	51° 50′ N., 6° 55′ W.	08.07–08.37	30*	..	..	..	..	..	..	..
43 (14)	51° 38′ N., 6° 36′ W.	11.22–11.54	..	..	..	..	52	10	..	..
44 (14)	51° 14′ N., 6° 24′ W.	14.56–15.26	..	..	..	..	71	22	..	..
44*a* (14)	51° 15′ N., 6° 18′ W.	17.42–17.55	..	..	..	..	88	24	..	..
45 (14)	51° 17′ N., 5° 55′ W.	20.12–20.42 Nt	..	..	..	..	360*	300*	..	..
46 (14)	51° 19′ N., 5° 25′ W.	23.29–00.00 Nt	..	..	..	..	31	36	..	..
47 (15)	50° 58′ N., 5° 19′ W.	02.40–03.10 Nt	..	..	..	..	400*	400*	3	..
48 (15)	50° 55′ N., 5° 50′ W.	06.04–06.34 Dn	2,020*	..	..	..	118	112	..	..
49 (15)	50° 31′ N., 5° 52′ W.	10.00–10.30	10*	..	80*	27	76	62	..	..
50 (15)	50° 43′ N., 6° 15′ W.	13.18–13.48	15	..	..	..	1	1	..	..
50*a* (15)	50° 45′ N., 6° 50′ W.	16.33–17.03	3	..	..	..	72	92	..	..
51 (15)	50° 30′ N., 6° 49′ W.	19.56–20.26 Dk	107	..	..	..	34	55	..	..
52 (16)	50° 17′ N., 6° 14′ W.	00.33–01.03 Nt	..	..	960*	..	200*	150*	1	..
53 (16)	50° 04′ N., 5° 54′ W.	03.54–04.24 Nt	..	..	17	94	38	7	..	..
54 (16)	49° 50′ N., 5° 30′ W.	07.31–08.02	..	..	6	18	..	..	..	..
55 (16)	49° 50′ N., 5° 00′ W.	11.58–12.28	..	..	3,360*	14	31	..	..	..
56 (16)	49° 34′ N., 5° 06′ W.	15.43–16.14	..	..	13,000*	..	13	..	..	..
57 (16)†	49° 15′ N., 5° 12′ W.	18.25–18.55	..	..	..	..	68	..	..	..
58 (17)†	48° 51′ N., 4° 51′ W.	01.27–01.57 Nt	..	..	..	..	248	..	..	..
59 (18)†	49° 49′ N., 3° 37′ W.	12.22–12.52	..	..	328*	..	12	..	..	..
7–12 April. Fishery cruiser *Muirchu*										
SR 2872 (7)	51° 40′ N., 8° 00′ W.	18.07–18.40	..	..	..	..	164	6	4	..
SR 2873 (7)	51° 20′ N., 8° 00′ W.	21.20–21.55 Nt	50*	..	..	..	650*	9*	11*	..
SR 2874 (8)	51° 00′ N., 8° 00′ W.	00.25–01.00 Nt	25	..	..	..	1,285*	40	24	..
SR 2875 (8)	50° 40′ N., 8° 00′ W.	03.39–04.15 Nt	81	..	..	..	5,200*	8*	136*	..
SR 2876 (8)	50° 20′ N., 8° 00′ W.	06.40–07.15	461	..	..	..	22	4	1	..
SR 2877 (8)	50° 00′ N., 8° 00′ W.	09.30–10.05	138	..	..	..	8	2	5	..
SR 2878 (8)	50° 00′ N., 8° 30′ W.	12.22–12.55	1,220*	..	..	..	..	..	..	..
SR 2879 (8)	50° 00′ N., 9° 00′ W.	15.10–16.00	15,380*	..	..	..	1	..	..	..
SR 2880 (8)	50° 20′ N., 9° 00′ W.	18.35–19.09	13,350*	..	..	..	4	..	1	..
SR 2881 (8)	50° 40′ N., 9° 00′ W.	21.54–22.28 Nt	8,130*	..	..	..	2,174*	6*	69*	..
SR 2882 (9)	51° 00′ N., 9° 00′ W.	01.05–01.39 Nt	8,380*	..	..	..	1,037*	4	53	..
SR 2883 (9)	51° 20′ N., 9° 00′ W.	04.42–05.16 Dn	487*	..	..	..	1,670*	8	12	..
SR 2884 (9)	51° 14′ N., 9° 43′ W.	10.58–11.31	1,850*	..	..	..	24	1	3	2
SR 2885 (11)	50° 56′ N., 9° 55′ W.	11.00–11.34	6,180*	..	..	..	285	1	35	..
SR 2886 (11)	50° 36′ N., 9° 55′ W.	14.07–14.40	99,333*	23	..	..	21	1	114	..
SR 2887 (11)	50° 16′ N., 9° 55′ W.	17.18–17.51	2,730*	..	..	..	3	..	4	..
SR 2888 (11)	50° 16′ N., 10° 26′ W.	20.26–20.49 Dk	126	9	..	..	17	..	40	1
SR 2889 (11/12)	50° 16′ N., 10° 57′ W.	23.48–00.22 Nt	..	3	..	..	..	..	59	..
SR 2890 (12)	50° 36′ N., 10° 48′ W.	03.11–03.45 Nt	780*	..	..	..	33	..	23	..
SR 2891 (12)	50° 56′ N., 10° 48′ W.	06.39–07.12	840*	6	..	..	5	..	1	..
SR 2892 (12)	51° 16′ N., 10° 48′ W.	09.46–10.20	321	17	..	..	4*	..	28*	..
SR 2893 (12)	51° 33′ N., 10° 48′ W.	12.53–13.27	136	..	..	..	1,405*	..	181	..

† Owing to bad weather, a 1 m. stramin net was used; it was fished over the side while the ship drifted. Counts have therefore been multiplied by 4.

TABLE VI (*cont.*)

Station number (date in parenthesis)	Station position	Time of haul (G.M.T.)	Mackerel eggs	Mackerel young stages	Pilchard eggs	*Muggiaea atlantica*	*Sagitta elegans*	*Sagitta setosa*	*Sagitta serrato-dentata*	*Sagitta lyra*
				1938						
31 May–5 June.	Steam trawler *Elk*									
1 (31)	49° 56′ N., 5° 33′ W.	15.55–16.25	2(?)	..	..	14	7	85	..	..
2 (31)	49° 40′ N., 5° 51′ W.	19.44–20.14	870*	1	2,030*	37	1,000*	90*	..	..
3 (31)	49° 23′ N., 6° 11′ W.	23.03–23.33 Nt	5,320*	41	440*	189	7,040*	170*	..	..
4 (1)	49° 06′ N., 6° 30′ W.	02.40–03.10 Nt	31,110*	898	600*	332	29,340*	30*	..	..
5 (1)	48° 50′ N., 6° 49′ W.	04.48–05.18 Dn	12,200*	307	25,320*	4	55	5	..	..
6 (1)	49° 00′ N., 7° 18′ W.	09.08–09.38	8,010*	141	20*	12	4	..	..	..
7 (1)	49° 08′ N., 7° 48′ W.	16.28–16.58	157	128	..	..	5,820*	30*	30*	..
8 (2)	49° 17′ N., 8° 15′ W.	04.06–04.36 Dn	700*	120	..	..	1,140*	10*	..	..
9 (2)	49° 28′ N., 7° 48′ W.	07.37–08.07	3,120*	1,219	..	..	390*	..	..	..
10 (2)	49° 39′ N., 7° 20′ W.	10.46–11.16	921	672	..	63	1,200*	3	1	..
11 (2)	49° 50′ N., 6° 53′ W.	13.31–14.01	136	369	..	500*	600*	2,300*	..	..
12 (2)	50° 04′ N., 7° 16′ W.	16.55–17.25	18,280*	56	20,600*	10	9	4	1	..
13 (2)	50° 19′ N., 7° 37′ W.	19.54–20.24	748	20	..	..	70	..	2	..
14 (2)	50° 33′ N., 7° 59′ W.	23.09–23.39 Nt	542	63	..	..	120	..	8	..
15 (3)	50° 34′ N., 8° 31′ W.	02.40–03.20 Nt	3,430*	214	..	..	260*	..	..	..
16 (3)	50° 35′ N., 9° 03′ W.	06.00–06.30	2,570*	659	..	..	10	..	..	..
17 (3)	50° 36′ N., 9° 33′ W.	09.16–09.46	72	21	..	..	81	..	..	..
18 (3)	50° 19′ N., 9° 52′ W.	12.17–12.47	..	193	..	..	196	..	1	..
19 (3)	50° 07′ N., 9° 28′ W.	15.30–16.00	2(?)	245	..	..	290*	..	2	..
20 (3)	49° 48′ N., 9° 28′ W.	18.50–19.20	..	277	..	..	78	..	..	..
21 (4)	49° 30′ N., 9° 44′ W.	00.00–00.30 Nt	..	94	..	..	33	..	10	..
22 (4)	49° 24′ N., 9° 15′ W.	04.12–04.42 Dn	..	173	..	..	28	..	..	..
23 (4)	49° 17′ N., 8° 45′ W.	07.21–07.51	219	352	..	..	..	..	4	..
24 (4)	49° 39′ N., 8° 46′ W.	10.30–11.00	1,050*	1,429	..	..	1,050*	1	2	..
25 (4)	50° 00′ N., 8° 47′ W.	13.35–14.05	2,075*	8,239	..	..	1,525*	..	25*	..
26 (4)	50° 01′ N., 8° 15′ W.	16.43–17.13	3,300*	520	..	..	3	1	..	..
27 (4)	50° 02′ N., 7° 44′ W.	19.53–20.23	587*	209	..	..	150*	1	4	..
28 (5)	50° 37′ N., 6° 54′ W.	01.35–02.05 Nt	334	1	..	..	270*	..	..	..
29 (5)	50° 42′ N., 6° 24′ W.	04.43–05.13 Dn	1,237*	11	..	..	18	3	..	..
30 (5)	50° 25′ N., 6° 17′ W.	08.35–09.05	6,075*	18	2,837*	50*	11	..	..	..
19–24 July.	Steam trawler *Elk*									
1 (19)	50° 01′ N., 4° 00′ W.	13.34–14.04	50*	1	18,350*	10	3	10	..	..
2 (19)	49° 42′ N., 3° 52′ W.	16.40–17.10	300*	4	7,320*	..	..	9	..	..
3 (19)	49° 22′ N., 3° 42′ W.	19.34–20.04	1,600*	6	3,620*	..	..	26	..	..
4 (19)	49° 19′ N., 4° 12′ W.	22.39–23.12 Nt	20*	5	460*	..	..	5	..	..

5 (20)	49° 15′ N., 4° 42′ W.	01.53–02.23 Nt	12	..	..	..	15	2	..	..
6 (20)	49° 11′ N., 5° 12′ W.	05.25–05.55 Dn	18	..	46	..	1	..	..	..
7 (20)	49° 06′ N., 5° 41′ W.	08.27–08.57	49	1	19	..	1	1	..	..
8 (20)	49° 03′ N., 6° 13′ W.	11.29–12.00	11	..	..	..	1	..	..	..
9 (20)	49° 06′ N., 6° 43′ W.	18.03–18.34	..	1	..	..	500*	..	1	..
10 (21)	49° 42′ N., 7° 23′ W.	00.42–01·12 Nt	1	..	55	..	180*	..	..	..
11 (21)	50° 03′ N., 7° 23′ W.	03.48–04.20 Nt	..	..	..	..	160*	..	..	..
12 (21)	50° 33′ N., 7° 09′ W.	07.32–08.02	..	1	5	..	..	..	..	..
13 (21)	50° 47′ N., 6° 56′ W.	10.44–11.15	5	3	1	..	..	..	..	..
14 (21)	51° 00′ N., 6° 32′ W.	13.54–14.24	5	3	..	..	..	..	..	..
15 (21)	51° 13′ N., 6° 08′ W.	17.06–17.36	..	1	..	..	1	19	..	..
16 (21)	50° 56′ N., 5° 50′ W.	20.39–21.11 Dk	300*	3	38,600*	100*	..	..	..	..
17 (21/22)	50° 37′ N., 5° 58′ W.	23.44–00.16 Nt	200*	5	950*	27	..	32	..	..
18 (22)	50° 17′ N., 6° 09′ W.	02.03–02.33 Nt	69	4	41	20*	29	49	..	..
19 (22)	50° 03′ N., 6° 16′ W.	05.10–05.40 Dn	12	5	69	60*	1	7	..	..
20 (22)	50° 02′ N., 6° 48′ W.	08.33–09.04	11	4	..	..	..	..	..	..
21 (24)	49° 42′ N., 6° 48′ W.	01.06–01.36 Nt	..	1	..	..	1,000*	46	..	..
22 (24)	49° 43′ N., 6° 17′ W.	05.00–05.32 Dn	..	1	..	..	..	7	..	..
23 (24)	49° 44′ N., 5° 45′ W.	08.35–09.05	50*	1	2,100*	..	2	1	..	..
24 (24)	49° 45′ N., 5° 13′ W.	11.50–12.20	600*	1	8,300*	50*	..	6	..	..
25 (24)	49° 59′ N., 4° 50′ W.	15.23–15.55	200*	2	3,950*	200*	..	10	..	..
26 (24)	50° 02′ N., 4° 22′ W.	17.49–18.19	800*	6	22,450*	50*	1	29	..	..

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15–18 March. Steam trawler *Elk*

1 (15)	50° 00′ N., 6° 55′ W.	11.44–12.18	..	..	..	..	700*	..	..	..
2 (15)	50° 03′ N., 7° 40′ W.	17.09–17.40	..	..	..	..	600*	..	..	..
3 (15)	50° 05′ N., 8° 29′ W.	21.45–22.15 Nt	..	..	..	..	1,950*	..	67	..
4 (16)	50° 07′ N., 9° 17′ W.	02.16–02.46 Nt	..	..	..	..	2,725*	..	95	..
5 (16)	50° 09′ N., 10° 00′ W.	06.42–07.12	4	..	..	..	175*	..	44	..
6 (16)	50° 10′ N., 10° 29′ W.	09.48–10.18	1	..	..	..	13	..	225*	1
7 (16)	50° 12′ N., 10° 57′ W.	12.48–13.18	118*	..	..	..	1	..	350*	..
8 (16)	50° 13′ N., 11° 31′ W.	16.01–16.32	7	..	..	..	1	..	850*	..
9 (16)	50° 14′ N., 12° 12′ W.	19.20–19.50 Dk	..	..	..	..	..	..	50*	..
10 (16)	50° 34′ N., 11° 34′ W.	23.18–23.48 Nt	..	..	..	..	..	..	300*	..
11 (17)	50° 52′ N., 9° 03′ W.	04.14–04.44 Nt	..	..	..	..	39	..	2,310*	42
12 (17)	51° 10′ N., 10° 23′ W.	08.40–09.10	..	..	..	..	4	..	185*	14
13 (17)	51° 10′ N., 9° 35′ W.	13.05–13.35	..	..	..	..	1	..	150*	4
14 (17)	50° 52′ N., 9° 03′ W.	16.23–16.53	..	..	..	..	78	1	435*	..
15 (17)	50° 43′ N., 9° 47′ W.	20.40–21.10 Nt	..	..	..	..	700*	..	750*	50
16 (18)	50° 33′ N., 10° 33′ W.	00.34–01.04 Nt	4	..	..	..	109	..	700*	43
17 (18)	50° 03′ N., 10° 29′ W.	04.45–05.15 Nt	6	..	..	..	354	..	690*	42
18 (18)	49° 49′ N., 9° 46′ W.	10.05–10.35	..	..	..	..	80	..	52	1
19 (18)	49° 52′ N., 8° 58′ W.	14.32–15.02	..	..	..	..	31	..	14	..
20 (18)	49° 55′ N., 8° 12′ W.	18.45–19.22 Dk	..	..	..	..	2,850*	..	1	..

TABLE VI (*cont.*)

Station number (date in parenthesis)	Station position	Time of haul (G.M.T.)	Mackerel eggs	Mackerel young stages	Pilchard eggs	*Muggiaea atlantica*	*Sagitta elegans*	*Sagitta setosa*	*Sagitta serrato-dentata*	*Sagitta lyra*
				1939						
16–27 April. S.S. *George Bligh*										
1 (16)	49° 50′ N., 4° 21′ W.	20.12–20.45 Nt	..	..	2,080*	..	420*	24	..	..
2 (17)	49° 18′ N., 4° 41′ W.	01.41–02.11 Nt	..	..	13,150*	..	11,440*	..	2	..
3 (17)	48° 50′ N., 4° 54′ W.	06.45–07.14	2	1	3	10	6,240*	38	111	..
4 (17)	48° 31′ N., 5° 05′ W.	10.15–10.45	..	..	..	17	2,480*	20*	45	1
5 (17)	48° 39′ N., 5° 30′ W.	13.49–14.19	17	..	..	12	2,700*	..	49	..
6 (17)	48° 47′ N., 5° 58′ W.	18.07–18.37	1,825*	..	50*	..	925*	..	..	..
7 (17)	48° 53′ N., 6° 27′ W.	22.24–22.52 Nt	797*	..	63*	..	1,203*	..	..	..
8 (18)	49° 00′ N., 6° 55′ W.	02.21–02.51 Nt	180*	..	510*	..	6,480*	1	1	..
9 (18)	48° 40′ N., 6° 48′ W.	06.04–06.35 Dn	9,000*	9	700*	..	32	..	1	..
10 (18)	48° 20′ N., 6° 40′ W.	09.40–10.10	2,725*	15	14,500*	6	63	..	20	1
11 (18)	48° 16′ N., 7° 07′ W.	15.16–15.46	1,625*	24	22,975*	..	15	..	46	4
12 (18)	48° 10′ N., 7° 35′ W.	22.14–22.44 Nt	9,850*	74	25*	1	400*	..	575*	4
13 (19)	48° 32′ N., 7° 38′ W.	02.06–02.37 Nt	8,025*	24	200*	..	525*	..	85	18
14 (19)	48° 53′ N., 7° 45′ W.	05.49–06.19 Dn	775*	1	25*	..	4	..	14	..
15 (19)	49° 19′ N., 7° 47′ W.	09.24–10.01	55*	..	440*	..	18	..	1	..
16 (19)	49° 10′ N., 8° 20′ W.	13.46–14.17	195*	..	20*	..	14	..	4	1
17 (19)	49° 06′ N., 9° 05′ W.	20.20–20.50 Nt	21,425*	7	125*	..	850*	..	150*	..
18 (20)	49° 05′ N., 9° 53′ W.	00.47–01.17 Nt	11,950*	7	..	..	42	..	20	1
19 (20)	49° 05′ N., 10° 26′ W.	04.24–04.55 Dn	15,225*	7	..	..	18	..	21	1
20 (20)	49° 21′ N., 10° 48′ W.	07.59–08.29	105	38	..	..	3	..	184	15
21 (20)	49° 40′ N., 11° 10′ W.	11.05–11.35	375*	33	..	..	1	..	1,510*	115
22 (20)	49° 44′ N., 10° 39′ W.	16.27–16.57	33,025*	174	..	..	..	..	30	5
23 (20)	50° 01′ N., 10° 18′ W.	19.58–20.28 Dk	12,000*	64	..	..	35	..	46	..
24 (20)	49° 47′ N., 9° 57′ W.	23.25–23.55 Nt	45,025*	4	..	..	175*	..	125*	..
25 (21)	49° 36′ N., 9° 30′ W.	02.45–03.15 Nt	5,950*	..	..	..	175*	..	11	1
26 (21)	49° 28′ N., 9° 04′ W.	06.04–06.34 Dn	10,300*	5	200*	..	..	..	..	..
27 (21)	49° 55′ N., 9° 10′ W.	11.25–11.57	4,050*	..	..	..	..	..	1	1
28 (21)	49° 51′ N., 8° 40′ W.	14.49–15.27	2,275*	..	..	..	..	..	..	..
29 (21)	49° 47′ N., 8° 10′ W.	18.29–18.59	1,260*	..	20*	..	2	..	..	..
30 (21)	49° 42′ N., 7° 42′ W.	22.10–22.40 Nt	29	..	2	..	1,250*	..	..	..
31 (22)	50° 02′ N., 7° 42′ W.	02.12–02.42 Nt	260	..	..	..	5,525*	..	..	..
32 (22)	49° 48′ N., 6° 43′ W.	07.04–07.34	9	..	49	..	1	2	..	..
33 (22)	49° 46′ N., 6° 11′ W.	10.42–11.12	..	..	710*	..	27	..	..	..
34 (22)	49° 45′ N., 5° 40′ W.	No haul								
35 (22)	49° 25′ N., 5° 40′ W.	18.49–19.19	70*	..	130*	2	3	..	..	..
36 (22)	49° 07′ N., 5° 37′ W.	22.47–23.17 Nt	98	..	..	2	2,500*	5	43	..
37 (23)	49° 15′ N., 6° 24′ W.	05.54–06.24 Dn	..	1	23,500*	..	..	..	..	..
38 (23)	49° 25′ N., 7° 08′ W.	12.06–12.36	87*	..	275*	..	67	..	..	..
39 (23)	49° 45′ N., 7° 14′ W.	16.17–16.47	290*	..	10*	..	..	..	..	..
40 (23)	50° 15′ N., 7° 22′ W.	21.35–22.05 Nt	245	..	..	..	1,850*	..	..	..

41 (24)	50° 44′ N., 7° 30′ W.	02.48–03.18 Nt	98	..	..	..	10,875*	..	..	..
42 (24)	51° 14′ N., 7° 38′ W.	08.10–08.40	451	..	1	..	11	..	..	..
43 (24)	51° 34′ N., 7° 37′ W.	12.08–12.38	100*	..	..	..	..	..	..	..
44 (24)	51° 31′ N., 6° 46′ W.	17.05–17.35	125*	..	..	..	9	..	..	..
45 (24)	51° 28′ N., 5° 54′ W.	21.52–22.22 Nt	40*	..	..	..	162	1	..	..
46 (25)	51° 28′ N., 5° 22′ W.	01.33–02.03 Nt	..	..	..	..	1,100*	5	..	..
47 (25)	51° 08′ N., 5° 22′ W.	05.05–05.35 Dn	..	2	..	..	20	6	..	..
48 (25)	50° 48′ N., 5° 22′ W.	08.30–09.00	50*	1	..	..	5	5	..	..
49 (25)	50° 48′ N., 5° 53′ W.	12.15–12.45	1,250*	..	..	..	..	..	..	..
50 (25)	50° 49′ N., 6° 24′ W.	16.16–16.46	32	..	..	..	..	..	..	..
51 (25)†	50° 28′ N., 6° 40′ W.	19.47–20.17 Dk	65*	..	..	..	76	..	..	..
52 (25)†	50° 04′ N., 6° 31′ W.	22.36–23.06 Nt	70*	..	150*	..	1,575*	1	..	..
53 (26)†	49° 38′ N., 6° 48′ W.	01.53–02.24 Nt	65	..	9	..	800*	..	..	..
54 (26)	49° 33′ N., 6° 19′ W.	05.48–06.18 Dn	75*	..	1,700*	..	3	..	..	..
55 (26)	49° 20′ N., 6° 00′ W.	13.55–14.25	75*	..	92,925*	..	2	..	..	..
56 (26)	49° 40′ N., 5° 00′ W.	17.50–18.20	..	..	1,350*	..	2	3	..	..
57 (26)	50° 00′ N., 4° 38′ W.	21.35–22.05 Nt	..	..	13,100*	..	1	3	..	..
58 (27)	49° 26′ N., 4° 24′ W.	02.50–03.20 Nt	..	..	22,050*	..	168	..	..	..
59 (27)	48° 50′ N., 4° 10′ W.	07.45–08.15	20*	..	10*	2	350*	..	2	..
60 (27)	49° 02′ N., 3° 16′ W.	13.53–14.23	325*	..	4,175*	..	90	50	..	..
61 (27)	49° 32′ N., 3° 29′ W.	18.52–19.22	..	..	39,075*	..	8	8	..	..
62 (27)	50° 00′ N., 3° 45′ W.	22.20–22.50 Nt	..	..	60*	..	58*	183*	..	..
17–21 April. Fishery cruiser *Muirchu*										
SR 2913 (17)	51° 40′ N., 8° 00′ W.	12.00–12.30	..	..	..	..	..	..	..	..
SR 2914 (18)	51° 20′ N., 8° 00′ W.	12.30–13.00	37*	..	..	..	37	..	1	..
SR 2915 (18)	51° 00′ N., 8° 00′ W.	15.35–16.05	11	..	..	..	386	..	2	..
SR 2916 (18)	50° 40′ N., 8° 00′ W.	18.30–19.00	2	..	..	..	905*	..	6	..
SR 2917 (18)	50° 20′ N., 8° 00′ W.	21.45–22.15 Nt	..	..	..	..	2,626*	..	12	..
SR 2918 (19)	50° 00′ N., 8° 00′ W.	01.10–01.35 Nt	2	..	..	..	6,660*	..	2*	..
SR 2919 (19)	50° 00′ N., 8° 32′ W.	04.25–04.50 Dn	11	..	..	..	493*	..	14	..
SR 2920 (19)	50° 00′ N., 9° 00′ W.	07.35–08.00	88	..	..	..	..	..	..	..
SR 2921 (19)	50° 20′ N., 9° 00′ W.	10.40–11.10	54	..	..	..	..	..	2	..
SR 2922 (19)	50° 40′ N., 9° 00′ W.	13.50–14.20	9	..	..	..	21	..	35	..
SR 2923 (19)	51° 00′ N., 9° 00′ W.	16.50–17.20	28	..	26	..	..	..	1	1
SR 2924 (19)	51° 20′ N., 9° 00′ W.	19.42–20.12 Dk	23	..	..	..	..	..	..	1
SR 2925 (19)	51° 14′ N., 9° 42′ W.	23.25–23.55 Nt	694	..	..	..	135	..	2	1
SR 2926 (20)	50° 56′ N., 9° 55′ W.	02.45–03.15 Nt	9,570*	..	..	..	700*	..	1,024*	9*
SR 2927 (20)	50° 36′ N., 9° 55′ W.	06.10–06.40	38,958*	11	..	..	1	..	7	..
SR 2928 (20)	50° 16′ N., 9° 55′ W.	09.20–09.50	33,000*	120	..	..	..	..	..	..
SR 2929 (20)	50° 16′ N., 10° 26′ W.	12.40–13.10	11,700*	95	..	..	1	..	1	5
SR 2930 (20)	50° 16′ N., 10° 57′ W.	16.10–16.40	1,092*	13	..	..	..	..	29	..
SR 2931 (20)	50° 36′ N., 10° 48′ W.	19.24–19.54	480	73	..	..	6*	..	194*	20*
SR 2932 (20)	50° 56′ N., 10° 48′ W.	22.24–22.54 Nt	14	6	..	..	60*	..	467*	12*
SR 2933 (21)	51° 16′ N., 10° 48′ W.	02.00–02.30 Nt	5	41	..	..	91	..	1,305*	1
SR 2934 (21)	51° 33′ N., 10° 48′ W.	04.55–05.25 Dn	10	10*	..	..	84*	..	384*	..

† Owing to bad weather, the net was fished over the side while the ship drifted.

TABLE VI (*cont.*)

Station number (date in parenthesis)	Station position	Time of haul (G.M.T.)	Mackerel eggs	Mackerel young stages	Pilchard eggs	*Muggiaea atlantica*	*Sagitta elegans*	*Sagitta setosa*	*Sagitta serrato-dentata*	*Sagitta lyra*
				1939						
2–7 June. Steam trawler *Elk*										
1 (2)	49° 50′ N., 4° 57′ W.	04.12–04.42 Dn	825*	..	121,950*	..	1	8	..	..
2 (2)	49° 29′ N., 5° 33′ W.	08.34–09.04	3,825*	20	12,475*	..	75*	Few	..	..
3 (2)	49° 08′ N., 6° 07′ W.	13.02–13.32	28,500*	52	675*	..	2,100*	300*	..	..
4 (2)	48° 47′ N., 6° 43′ W.	17.22–17.52	6,100*	337	..	..	950*	..	103	..
5 (2)	48° 26′ N., 7° 18′ W.	22.00–22.30 Nt	2,475*	440	..	450*	1,125*	..	600*	..
6 (3)	40° 05′ N., 7° 53′ W.	02.30–03.00 Nt	1,250*	57	50*	Numerous	..	..	350*	28
7 (3)	48° 32′ N., 8° 18′ W.	07.23–07.53	3,225*	634	..	Numerous	112*	..	50*	17
8 (3)	48° 58′ N., 8° 45′ W.	12.15–12.45	425*	43	..	Moderate	150*	..	75*	1
9 (3)	49° 25′ N., 9° 10′ W.	17.05–17.35	225*	148	..	Few	325*	..	62*	..
10 (3)	49° 50′ N., 9° 35′ W.	21.30–22.00 Nt	11	178	..	..	150*	..	Few	..
11 (4)	50° 17′ N., 10° 00′ W.	02.20–02.50 Nt	89	45	..	..	425*	..	287*	1
12 (4)	50° 42′ N., 10° 25′ W.	07.43–08.13	1,350*	45	..	..	2	..	31	7
13 (4)	51° 06′ N., 9° 27′ W.	13.55–14.25	9,525*	167	..	..	17	..	..	..
14 (4)	50° 40′ N., 9° 02′ W.	18.50–19.20	4,950*	40	..	..	..	..	..	..
15 (4)	50° 14′ N., 8° 36′ W.	23.20–23.50 Nt	650*	284	..	..	100*	..	2	..
16 (5)	49° 49′ N., 8° 12′ W.	04.15–04.45 Dn	1,850*	27	..	..	325*	..	..	..
17 (5)	49° 23′ N., 7° 46′ W.	08.55–09.25	5,900*	183	..	..	..	..	..	..
18 (5)	49° 07′ N., 7° 30′ W.	16.15–16.45	4,350*	134	..	..	250*	1	4	..
19 (5)	49° 35′ N., 6° 39′ W.	22.24–22.54 Nt	10,725*	227	450*	..	2,175*	1	..	..
20 (6)	50° 00′ N., 7° 04′ W.	03.15–03.45 Nt	1,800*	1	25*	..	81	..	..	..
21 (6)	50° 25′ N., 7° 29′ W.	07.43–08.13	6,760*	7	..	..	7	..	..	..
22 (6)	50° 50′ N., 7° 55′ W.	12.15–12.45	12,075*	3	..	..	116	..	..	..
23 (6)	51° 14′ N., 8° 20′ W.	16.15–16.45	8,550*	65	..	..	9	..	..	..
24 (6)	51° 14′ N., 7° 32′ W.	21.00–21.30 Dk	8,750*	9	..	..	25	1	..	..
25 (7)	51° 15′ N., 6° 47′ W.	01.20–01.50 Nt	8,700*	6	..	..	825*	1	..	..
26 (7)	50° 45′ N., 6° 38′ W.	05.50–06.20	6,000*	59	..	..	2	2	..	..
27 (7)	50° 16′ N., 6° 29′ W.	11.08–11.38	2,250*	7	50*	..	10	..	..	..
28 (7)	49° 58′ N., 5° 47′ W.	14.32–15.02	6,150*	3	73,050*	..	..	2	..	..