The Seasonal Abundance of the Pelagic Young of Teleostean Fishes in the Plymouth Area. Part III. The Year 1935, with a Note on the Conditions as Shown by the Occurrence of Plankton Indicators.

By

F. S. Russell,

Naturalist at the Plymouth Laboratory.

With 4 Figures in the Text.

Observations on the seasonal abundance of the pelagic young of teleostean fishes as shown by half-hour oblique hauls with the 2-metre stramin ring-trawl for the period 1924 to 1934 have already been published (Russell, 1930, b, and 1935, a). The data were given in two reports covering six- and five-year periods respectively. Now that a foundation for the comparison of future years has been laid it is thought advisable to publish the results of each new year separately. If publication of these results is delayed for a period of years it is likely that they will lose considerably in value, since in the science of fishery research it is necessary to keep abreast of the times so that data obtained may be available as soon as possible for workers in other areas.

The present report gives the results for the year 1935. Collections have been made in exactly the same way as given in the last report (1935, a). The dates on which collections were made are given in Table I, and the monthly average catches for all young fish, all young fish less clupeids, and each species of fish, are given in Table II. In Figure 1 is shown the curve for the fortnightly average catches of all young fish less clupeids. Superimposed on this curve in Figure 1 is that for the fortnightly average catches averaged over the years 1930 to 1934 inclusive. This curve had been given in Figure 1, page 150, of the last report (1935, a) to act as a basis for comparison of future years. It is obvious from Figure 1 that the total yield of young fish in 1935 was far below the average. In the last report the decline in the numbers of the young of summer spawning fish in recent years was commented upon. It is evident that in 1935 not only was there a further decline in the young of summer spawning fish, but a decline also in the young of spring spawning fish. The sum of the monthly average catches for all young fish less clupeids (last column on Table II) was 427 ; this is less than half of that for 1934 which was 1144.

The sum of the monthly average catches for the post-larvæ of those species which show maximal abundance in the months June to October inclusive, excluding clupeids, was only 37 in 1935, compared with 79 in 1934 (see last report, 1935, a, page 170). In the last report, pages 170–171, attention was drawn to the parallel between the abundance of these summer young fish and the quantity of phosphate present in the water in the previous winter. It was suggested that the available phosphate was likely to determine to some extent the production of young fish. In the winter 1934–35 the maximum phosphate content of the water at E1 (kindly supplied me by Dr. L. H. N. Cooper), given as the mean content

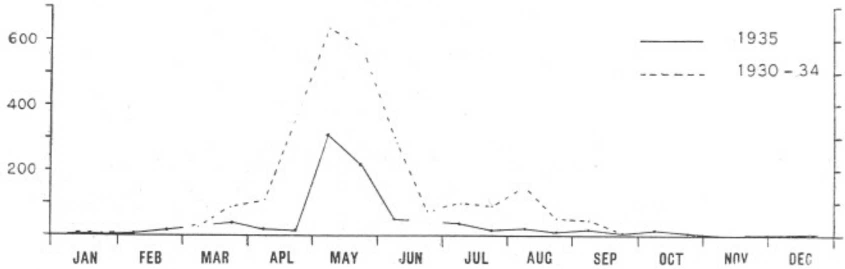

FIG. 1.—Curves showing the average catches in half-hour oblique hauls with the 2-metre ring-trawl for each fortnight for all young fish, excluding Clupeids, in 1935 (————) and the same averaged over the whole period 1930 to 1934 inclusive (– – – –).

of the water column as mg.P per cubic metre corrected for salt error, was 12·5 mg. on January 15th, 1935. This is a deviation of −27% from the mean of the years 1923–33, and is the lowest value yet recorded as a winter maximum.* The correlation between the abundance of young fish

* Dr. Cooper has informed me of two slight mathematical errors in the figures previously published (Russell, 1935, a). The maximum for the year 1927–28 should read 20 instead of 19 ; and that for 1928–29, 20 on January 7 instead of 17 on January 2. Dr. Cooper has included the winter 1934–35 and recalculated the percentage deviation from the new mean. I give these results below together with the young fish results for summer spawning fish (excluding Clupeids).

Phosphate.		*Young fish.*	
Winter.		*Year.*	
1923–24	+20	1924	696
1924–25	+ 2	1925	140
1925–26	+29	1926	909
1926–27	− 3	1927	170
1927–28	+17	1928	(no records)
1928–29	+17	1929	321
1929–30	(no records)	1930	403
1930–31	− 6	1931	230
1931–32	−21	1932	197
1932–33	− 9	1933	117
1933–34	−18	1934	79
1934–35	−26	1935	37

The only discrepancy in this series of observations occurs in 1932 when for a perfect fit the young fish figures might have been expected to have been lower. There was, however, a marked influx of *elegans* water in July-August, 1932, which may have brought with it a larger number of young fish.

and the phosphate available at the beginning of the year is thus further confirmed. The effect of low phosphate content in 1935 appears moreover to have shown itself not only on the young of summer spawning fish but also on those of spring spawners.

This correlation is worthy of further consideration. If in an enclosed body of water there is a given content of manurial salts at the beginning of the year a certain proportion of this will be passed on during the year through the plankton to the fish and bottom-living fauna. The phosphorus accumulated in plankton organisms not eaten during the year will be returned to the water on their death ; and similarly that contained in the bodies of bottom-living animals whose life-histories do not exceed one year will find its way back into the water on their death and decay. But those fish or bottom animals living for a greater period than one year will have added a certain quantity of phosphorus to their tissues during the first year that will not be immediately returned to the water. The phosphorus content of the water will thus be diminished by that amount by the end of the year. It is thus likely that an enclosed body of water should show a gradual decrease in its phosphorus content until after a number of years a balance is set up according to the length of life of the different inhabitants.* If added to this a certain weight of fish is caught and removed each year there will be a further drain on the phosphorus content of the water.

There are indications that we have a possible analogy to this in the waters of the English Channel. On the whole there exists a body of Channel water kept distinct from that of the Atlantic. Apart from replenishment from Atlantic sources the only addition of phosphate to Channel water comes from the rivers flowing into it. Observations made on the plankton content (Russell, 1935, b, and 1936) have shown that the Atlantic water off the mouth of the Channel appears to be richer than Channel water, and as such might be supposed to have a higher phosphate content. A large incursion of Atlantic water far into the Channel may thus lead to a replenishment of phosphate in the Channel in areas where the two waters can become well mixed, and possibly also by its potentiality for increasing the bottom fauna by better survival of larval stages in the plankton rich water and the introduction of new stock.† Similar

* It should not be overlooked that there are other factors which may control the winter phosphate maximum. It is probable, for instance, that in sunny autumns a proportion of the phosphate will be removed from the water by a diatom outburst which may not return until the following spring and much of which will be passed on to animals whose winter survival may consequently be high. In such years the winter maximum may then be lower than in years when conditions are unfavourable for an autumn outburst of phytoplankton.

† In this connexion it is interesting to record that in 1930 there were many Luidia larvæ (which are indicators of *elegans* water, Russell, 1935, b, p. 325) ; in July, 1932, Mr. D. P. Wilson informed me that Luidia were unusually abundant in the trawl catches off Plymouth.

causes may operate in the southern bight of the North Sea, either from Atlantic water entering from the north or by exceptional passage of this water from the Channel through the Dover Straits.

Examination of the Sagitta populations off Plymouth over a number of years has shown that since 1932 Channel water has predominated (see below). In certain years there have been major incursions of Atlantic water from the mouth of the Channel, and it is noteworthy that in those years the production of young fish was high. In its bearing on fishery problems there are two possibilities to be considered. Firstly the bulk of the spawning population of fish may live in the Atlantic water and move with it. In this case a large production of young fish will be due to a large spawning stock. Secondly, the spawning population may be spread over the whole Channel area and the presence of plankton-rich Atlantic water in that area may lead to a high survival of young. As far as our knowledge goes at present the latter possibility seems the more likely, and if such be true the bearings of water movements and the phosphate content of the water on the fluctuations of fish populations in the Channel and southern North Sea are obvious.

An account of the possible origin and movements of water masses in the neighbourhood of Plymouth as shown by plankton indicators for the years 1930 to 1934 inclusive has already been published (Russell, 1935, b). In that report the occurrence of "western" and of "south-western" water was mentioned. It has now been shown in a paper in the present number of this Journal (Russell, 1936) that probably the "western" water is that water in cyclonic circulation to the south of Ireland, while the "south-western" water is that passing up past Ushant. The "western" water is characterised by the presence of *S. elegans* and referred to as *elegans* water. There is also another body of water, Channel water, characterised by the presence of *S. setosa* in places, and everywhere by the absence of the planktonic indicators of *elegans* water.

In the belief that the changes in abundance of young fish off Plymouth from year to year may eventually be associated with the distribution of these water masses I have included in this report the conditions existing off Plymouth during 1935 as indicated by plankton animals. The curves for the numbers of *S. elegans* and *S. setosa* in the half-hour ring-trawl collections are given in Figure 2, together with the percentage composition of the Sagitta population by these two species. The dates of these catches are the same as those for the young fish (Table I). A diagram is given in Figure 3 showing the presence or absence of certain plankton animal indicators during 1935 in the same collections. Both these figures are direct continuations of the diagrams given in my previous paper (Russell, 1935, b, Figs. 1 and 2, pp. 312 and 313, and Fig. 4, p. 318; the months January and February are repeated in the present Fig. 2). These diagrams

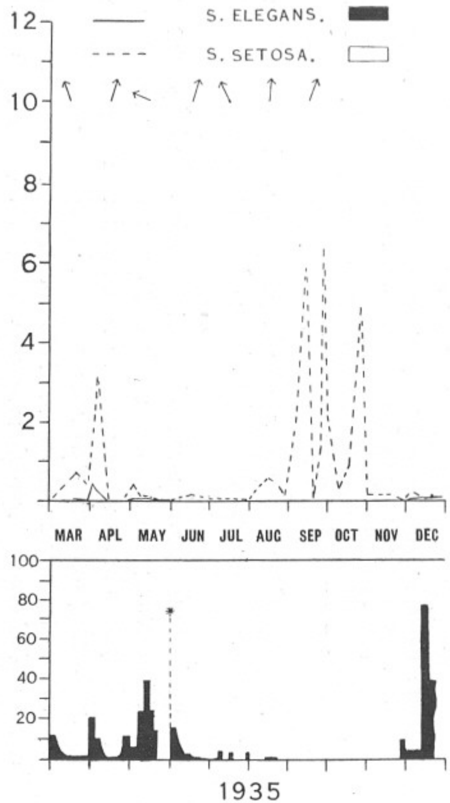

FIG. 2.

FIG. 2.—Above, curves showing the actual abundance of *S. elegans* (————) and *S. setosa* (– – – – –) in half-hour oblique hauls with the 2-metre ring-trawl made usually at weekly intervals during the period March to December, 1935. (The numbers are in thousands.) Below, the percentage composition of the Sagitta populations during the same period; *S. elegans*, black; *S. setosa*, white.

At the top of the diagram the arrows indicate the mean direction (true) of flow of water through the Straits of Dover for each month as indicated by the Carruthers Current Meter working from the Varne Lightship. The current data for October and November were received too late for inclusion in the diagram. They were October, N. 24° E.; and November, N. 29° E.; in comparison with September, N. 20° E. (Continued from Russell, 1935, b, Fig. 2, p. 313.)* = *S. setosa*, 1; *S. elegans*, 2.

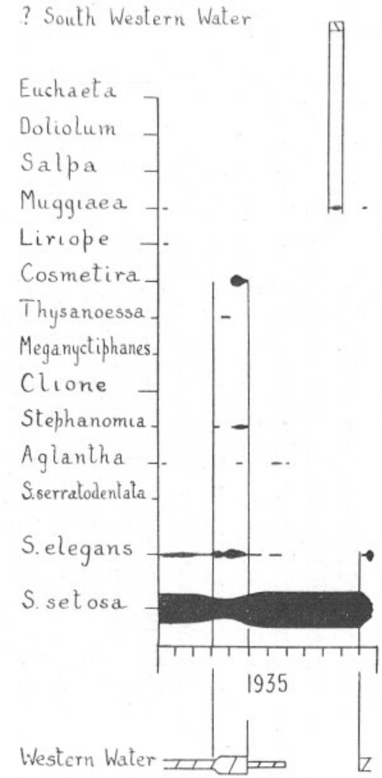

FIG. 3.

FIG. 3.—Diagram showing the occurrence of the various planktonic indicators in collections off Plymouth during the year 1935. (Continued from Russell, 1935, b, Fig. 4, p. 318.)

show that the year 1935 was characterised by the predominance of *setosa* or Channel water off Plymouth. At the beginning of the year there was a slight admixture of *elegans* water which, as in previous years, increased somewhat in April and May. This may possibly have been an indication of a tongue of *elegans* water extending up the centre of the Channel well offshore. An increase in the proportion of *S. elegans* is shown in December, backed by the presence of euphausian larvæ (Russell, 1936); a collection taken at E2, midway between Plymouth and Ushant, on November 21st, 1935, showed the presence of pure *elegans* water in that locality. In 1935 the occurrence of "south-western" water was almost negligible off Plymouth. At the top of the diagram in Figure 2 showing the occurrence of the two Sagitta species have been inserted arrows showing the directions (true) of the average daily flow for each month of the residual current through the Straits of Dover. These data have been kindly sent me by Dr. J. N. Carruthers. This shows that the flow through the Dover Straits has not yet resumed its predominant easterly direction as was shown in 1930 and 1931 when *elegans* water was so conspicuous off Plymouth.

The above indications of the conditions off Plymouth are in agreement with the hypothesis that the paucity of young fish in 1935 may be related

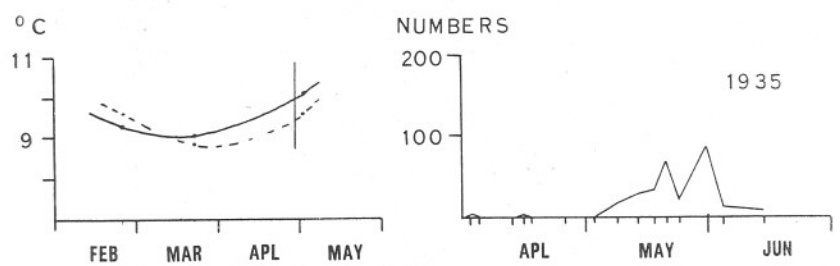

FIG. 4.—*Right:* Curves showing the actual catches of young whiting, *G. merlangus*, in half-hour oblique hauls with the 2-metre ring-trawl on each day of collection in the months April, May, and June for the year 1935.
Left: Temperatures in February, March, April and May for the year 1935. ——— surface at L5; – – – – – bottom at E1.

with the presence of Channel water poor in phosphates. The plankton off Plymouth in the autumn and early winter of 1935 was exceptionally scarce.

For comparison with previous years it will be helpful to make a further analysis of the young fish results in 1935. It was shown in the last report (1935, a) that in some years the time of maximum abundance of the young of spring spawners occurred early and in others late. In this respect 1935 was a late year, the peak of maximum abundance occurring in the first half of May. In previous years a possible connexion between late or early years and the temperature of the water was shown, using

G. merlangus as an example (Russell, 1935, a, Fig. 4, p. 159). Similar curves have been given here in Figure 4 for *G. merlangus* in 1935. The right-hand curve shows the actual catches of this species on each day of collecting in April, May and June. The peak of this curve occurred on May 20th (that on May 30th has been discounted because the majority of whiting caught on that day were of a large size and in association with the jelly-fish Cyanea). The left-hand curves show the temperatures of the water during the months February to May at the surface at L5 near the Eddystone and at the bottom at E1, ten miles beyond. The upright line cutting the curves in this figure indicates a point 3 weeks earlier than the date of maximum abundance of young whiting. As in the previous years this point occurs somewhere about 9·5° C.

Since the year 1935 has been the worst year recorded in this series of observations it is worth comparing it with other years to find the extent of fluctuation. Below are given figures for the sum of average monthly catches for the more important species in 1935 (last column in Table II, p. 604) divided by the sum of the average monthly catches for the period 1930 to 1934 (last column but one in Table I, pp. 152–3 of the last report, 1935, a). In the second column are shown the results of dividing the best years in the period 1930 to 1934 by the year 1935. A similar table was given in the previous report on page 165.

	1935 / Av. 1930–34.	Best/1935.
G. merlangus	0·25	6·3 (1932)
G. minutus	0·07	40·3 (1931)
Onos spp.	0·17	13·0 (1930)
Arnoglossus spp.	0·21	9·9 (1931)
S. norvegicus	0·27	5·4 (1932)
P. limanda	0·11	14·0 (1931)
P. microcephalus	0·09	20·5 (1932)
S. variegata	0·39	4·1 (1932)
Callionymus spp.	0·20	3·1 (1930)
S. scombrus	0·23	11·2 (1930)
Gobiid spp.	0·07	39·7 (1930)

The first column shows that 1935 was a much worse year even than 1929, in which year the spring peak of abundance appeared to have been wiped out possibly by depredations of Ctenophores (see Russell, 1935, a, pp. 165–166).

In the previous report the largest fluctuations as shown by dividing the best year by the worst year were 11·9 for Gobiid spp. and 11·5 for *S. scombrus*; apart from these the fluctuations for most species lay below 5 times. The figures given here for 1935 show very large fluctuations for

G. minutus, Gobiid spp., Onos spp., *P. limanda* and *P. microcephalus*. Although the fluctuations for the first two named may be exaggerated owing to the habit of the young fish living possibly deeper than the net has sampled (Russell, 1930, a, p. 648), it is evident that we are reaching magnitudes comparable with the major fluctuations known to occur in the populations of certain food fishes.

From the above figures it can be seen that the best years (in brackets in the second column) for each fish have not fallen together. They have however only occurred in the years 1930, 1931 and 1932. While 1930 and the first half of 1931 were periods during which *elegans* water was predominant off Plymouth, 1932 was the first year of the *setosa* predominance which has continued to the present day. The success of any one species of fish cannot therefore as yet be linked with water movements as shown by the Sagitta population. It is however notable that, except for *Cottus bubalis* which is only caught in very small numbers, no fish has had its best year during the period 1933 to 1935, and the worst year so far recorded has fallen after a prolonged continuation of *setosa* predominance. Full agreement cannot yet be expected as so many other factors not dealt with here may enter into the picture. It is, for instance, especially necessary to know more about the spawning regions of the different species of fish.

In continuation of data given in the previous report (1935, a, pp. 168–169) it should be recorded that the landings of whiting by British sailing trawlers in area VII, d–e, in the English Channel fell in 1934 to 2·3 cwt.* per 100 hours' fishing. The curve of landings of whiting has thus continued to follow the curve of abundance of young whiting in the ring-trawl collections.

As regards the scarcity of young fish in 1935 it should be noted that the numbers of young clupeids were also far below those for other years. There was however a great abundance of the eggs of the pilchard. These ocucrred in the catches on the following dates: April 12, June 15, July 3 (many), July 14 (many), July 17 (many), September 18, September 24, October 9 (many), October 16, October 31 (many) and November 19.

SUMMARY.

Records are given on the abundance of the pelagic young of teleostean fishes off Plymouth as shown by half-hour oblique hauls with the 2-metre stramin ring-trawl.

In comparison with similar observations made since 1924 the year 1935 has been the poorest yet recorded.

A parallel between the quantity of phosphate in the water at the

* In the previous report (1935, a) in Figure 8 " cwt " should read " 1/10 cwt."

beginning of the year and the abundance of young fish is further confirmed. In January, 1935, the winter maximum phosphate value was the lowest yet recorded.

Observations are given on the conditions off Plymouth as shown by plankton animal indicators during 1935. The year was marked by a predominance of *Sagitta setosa* or Channel water. The possible correlation between the scarcity of young fish and the presence of Channel water is indicated.

The difference between the numbers in 1935 and those in the best years since 1930 show that for certain species of fish the changes in abundance may be regarded as nearing the dimensions of the major fluctuations known for certain food fish.

REFERENCES.

RUSSELL, F. S. 1930, a. The Vertical Distribution of Marine Macroplankton. IX. The Pelagic Young of Teleostean Fishes in the Plymouth Area. Journ. Mar. Biol. Assoc., N.S., Vol. XVI, No. 2, pp. 639–676.

—— 1930, b. The Seasonal Abundance and Distribution of the Pelagic Young of Teleostean Fishes Caught in the Ring-Trawl in Offshore Waters in the Plymouth Area. *Ibid.*, Vol. XVI, No. 3, pp. 707–722.

—— 1935, a. The Seasonal Abundance and Distribution of the Pelagic Young of Teleostean Fishes Caught in the Ring-trawl in Offshore Waters in the Plymouth Area. Part II. *Ibid.*, Vol. XX, No. 2, pp. 147–179.

—— 1935, b. On the Value of Certain Plankton Animals as Indicators of Water Movements in the English Channel and North Sea. *Ibid.*, Vol. XX, No. 2, pp. 309–331.

—— 1936. Observations on the Distribution of Plankton Animal Indicators made on Col. E. T. Peel's yacht *St. George* in the Mouth of the English Channel, July, 1935. *Ibid.*, Vol. XX, No. 3, pp. 507–522.

TABLE I.

DATES ON WHICH COLLECTIONS WERE MADE, 1935.

All 2 miles east of Eddystone unless otherwise stated.

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
2*	5	20	2§	2	4	3	6	5	1	19	4
2	13	28	4	8	15	10	14	12	9	28	10
10	19		12	13		17	21	18‖	16		17
16			15	16		23	28	24	25		
21			17	20		23‡		25	31		
29†			25	23		30					
				30							

* Haul taken in the dark. † Haul taken at L4–L5. ‡ Haul taken at E1.
§ Haul taken 4 miles S.S.E. of Mewstone. ‖ Haul taken at L3.

TABLE II.

AVERAGE MONTHLY CATCHES OF POST-LARVÆ PER HALF-HOUR.
Oblique haul with 2-metre ring-trawl, 1935.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Σ
Total Young Fish	50	15	206	80	273	55	36	18	11	88	15	14	861
Ditto, less Clupeids	2	7	40	17	250	50	24	15	11	9	2	3	430
All Clupeid spp.	48	8	166	63	23	5	12	2	1	78	13	11	430
Clupea harengus	39	1	–	+	–	–	–	–	–	–	–	–	40
Gadus pollachius	–	–	–	+	4	–	–	–	–	–	–	–	4
Gadus merlangus	–	–	–	1	36	10	2	–	–	–	–	–	49
Gadus minutus	–	–	1	1	5	–	–	–	–	–	–	–	7
Gadus luscus	+	+	–	1	1	–	–	1	+	2	1	2	8
Gadus callarius	–	–	–	+	–	–	–	–	–	–	–	–	+
Onos spp.	–	–	–	1	4	3	–	–	+	–	1	–	9
Molva molva	–	–	–	–	+	–	–	–	–	–	–	–	+
Merluccius merluccius	–	–	–	–	–	–	–	+	–	+	–	–	+
Raniceps raninus	–	–	–	–	–	–	+	–	–	+	–	–	+
Capros aper	–	–	–	–	–	–	–	–	–	–	–	–	–
Zeus faber	–	–	–	–	–	–	–	–	–	+	–	–	+
Arnoglossus sp.	–	–	–	–	–	1	1	2	2	1	–	–	7
Rhombus lævis	–	–	–	–	+	–	–	+	–	–	–	–	+
Rhombus maximus	–	–	–	–	–	–	–	1	–	–	–	–	1
Scopthalmus norvegicus	–	–	–	–	8	8	+	–	–	–	–	–	16
Zeugopterus punctatus	–	–	–	–	2	1	–	–	–	–	–	–	3
Zeugopterus unimaculatus	–	–	–	–	–	–	+	+	–	–	–	–	+
Pleuronectes limanda	–	–	–	+	6	–	–	–	–	–	–	–	6
Pleuronectes flesus	–	–	–	2	–	–	–	–	–	–	–	–	2
Pleuronectes microcephalus	–	–	–	–	2	–	–	–	–	–	–	–	2
Solea vulgaris	–	–	–	+	1	–	–	–	–	–	–	–	1
Solea variegata	–	–	–	–	27	4	+	–	–	1	–	–	32
Solea lascaris	–	–	–	–	–	–	–	–	+	–	–	–	+
Solea lutea	–	–	–	–	–	–	–	–	–	–	–	–	–
Serranus cabrilla	–	–	–	–	–	–	–	–	–	–	–	–	–
Caranx trachurus	–	–	–	–	–	–	–	1	2	–	–	–	3
Mullus surmuletus	–	–	–	–	–	–	–	–	–	–	–	–	–
Morone labrax	–	–	–	–	–	1	–	–	–	–	–	–	1
Ammodytes sp.	2	6	36	2	–	–	–	–	2	1	–	–	49
Ammodytes lanceolatus	–	–	–	2	2	1	1	1	+	–	–	–	7
Cepola rubescens	–	–	–	–	–	–	–	–	+	–	–	–	+
Callionymus sp.	–	–	1	2	150	19	9	4	1	2	1	+	189
Labrus bergylta	–	–	–	–	+	1	+	–	-	–	–	–	1
Labrus mixtus	–	–	–	–	–	1	–	–	–	–	–	–	1
Ctenolabrus rupestris	–	–	–	–	–	–	2	–	+	–	–	–	2
Crenilabrus melops	–	–	–	–	–	–	2	+	–	–	–	–	2
Centrolabrus exoletus	–	–	–	–	–	–	–	–	–	–	–	–	–
Trachinus vipera	–	–	–	–	–	1	+	2	2	–	–	–	5
Scomber scombrus	–	–	–	–	+	1	2	2	–	–	–	–	5
Gobius spp.	–	+	–	1	+	–	1	–	–	–	1	+	3
Lebetus scorpioides	–	–	–	–	+	–	–	–	+	+	–	–	+
Blennius ocellaris	–	–	–	–	–	–	–	+	+	+	–	–	+
Blennius pholis	–	–	–	–	–	–	+	–	–	–	–	–	+
Blennius gattorugine	–	–	–	–	–	2	3	1	+	+	–	–	6
Chirolophis galerita	–	–	3	–	–	–	–	–	–	–	–	–	3
Agonus cataphractus	–	–	–	+	–	–	–	–	–	–	–	–	+
Trigla spp.	–	–	–	–	1	1	–	–	+	+	–	–	2
Cottus bubalis	–	–	–	3	1	–	–	–	–	–	–	–	4
Liparis montagui	–	–	–	+	–	–	–	–	–	–	–	–	+
Lepadogaster bimaculatus	–	–	–	–	–	–	–	–	–	–	–	–	–
Lophius piscatorius	–	–	–	–	–	–	+	–	–	–	–	–	+