The Vertical Distribution of Marine Macroplankton. X. Notes on the Behaviour of Sagitta in the Plymouth Area.

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With 8 Figures in the Text.

The researches on the vertical distribution of plankton in the sea in the Plymouth area are tending to indicate that light is a controlling factor of great importance in the behaviour of the larger plankton animals (**13** and **16**). It appears probable that for some species there are certain conditions of light that members of that species tend to collect in during the daytime, and owing to the absorption of light penetrating from above the animals move vertically upwards or downwards towards their light optimum. But in the sea we do not find that *all* the members of the species are concentrated at the level at which apparently the optimum conditions occur ; rather is it that only the greatest number are found at that level, the remainder being at varying distances above and below and decreasing in number with distance apparently as modified by the rate of light absorption. In other words, the animals appear to be distributed around the optimum on a probability curve.

Now in speaking of the members of a species above, it is assumed that we are referring to a population of animals all of the same sex and age. It is well known that animals of different ages seem to prefer different depths (**16**, p. 239) ; therefore in attempting to unravel the leading principles in the behaviour of plankton animals by means of field collections it is essential that we should be careful to base our conclusions on populations of a species all as nearly as possible of the same age. From this standpoint the Crustacea are probably the best group to work on, as the successive stages are well marked and easily recognisable on account of the habit of moulting. It is probably for this reason that of all the animals studied in our previous researches on vertical distribution the copepod *Calanus finmarchicus* has given us the picture of a typical daytime distribution most nearly corresponding to that we should expect if the animals are distributed round an optimum light condition with upper and lower limits within which the population lives, as in the theory previously outlined (**13**,

p. 419) ; for we have known that we were dealing with animals of the same sex and of as nearly as possible the same age.

With the majority of other animals, however, the vertical distributions given in the previous publications have been, for each species, those of populations of a heterogeneous mixture of ages and perhaps of sex. It is not legitimate therefore to attempt to draw fundamental conclusions from such results ; they have merely provided us with a knowledge of the depths at which the majority of any one species live and the range within which a mixed population of that species remains. This important point is well brought out in the following pages in which the behaviour of a Sagitta population is dealt with.

General Results.

The details given here represent the results of collections made with the 2-metre stramin ring-trawl during 24 hours on two different occasions, the first on July 15–16th, 1924, and the second on June 3–4th, 1926.

A careful examination of the Sagitta occurring on these occasions has shown that there are in the Plymouth area two common species, *Sagitta elegans* Verrill, and what is probably *Sagitta setosa* J. Müller. These two species have in previous records been included under one name, *Sagitta bipunctata* Quoy and Gaimard, a name now used for a warm-water species apparently not occurring in this area (**17**, pp. 7–16, and **18**, p. 19). The results for the Sagitta population as a whole on June 15–16th, 1924, have already been published (**11**, p. 792)—under the name of *Sagitta bipunctata ;* the original material has since been re-examined and studied in more detail and the results are given in the following pages. Fortunately it was found that on that date almost the entire catches were made up of *S. elegans*, and that *S. setosa* was either absent or only present in such small numbers as not to affect the general picture given in **11**, page 792 and Figure 3, which must now be regarded as referring to *S. elegans*.

On June 3–4th, 1926, *S. setosa* was much more common, and it is probable that its abundance varies from year to year. An examination of the Sagitta populations throughout the year 1930 has shown that *S. setosa* was almost absent in June and July. Meek (**8**, p. 743) has found in the North Sea off the Northumberland coast that the two species, *S. elegans* and *S. setosa,* vary much in their relative abundance, the years in which one species was common apparently showing a rarity of the other species and vice versa.

The collections described in this paper were both made with the 2-metre stramin ring-trawl and the full conditions at the time of collecting have already been published (**11** and **15**). On each date five series of collections were made at definite times during the 24 hours, the net being towed horizontally for periods of ten minutes each at different depths in each

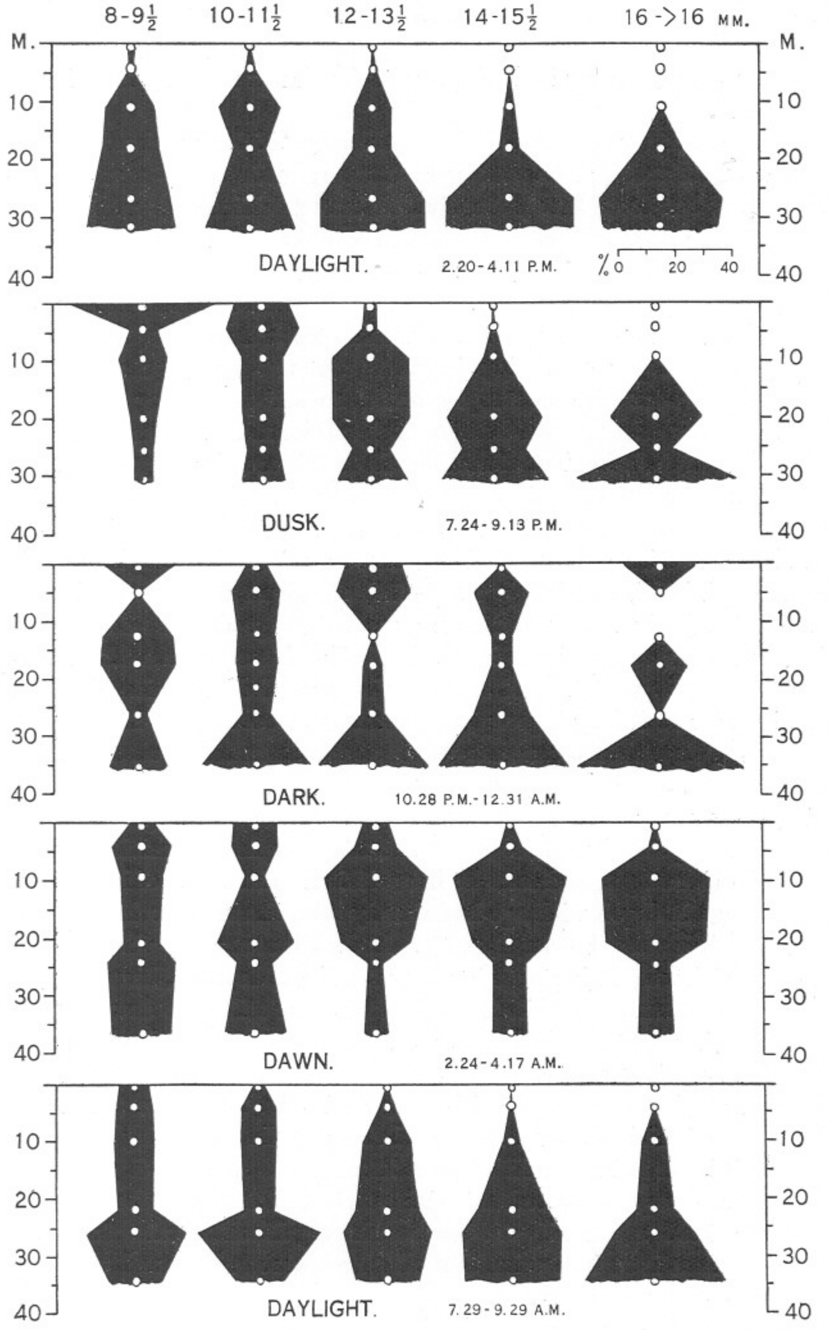

FIG. 1.—The percentage vertical distribution of *Sagitta elegans* at the times shown on June 3rd–4th, 1926. For each period—" daylight," " dusk," " dark," " dawn," and " daylight "—the Sagitta are divided into 8–9½, 10–11½, 12–13½, 14–15½, and 16–>16 millimetre groups. The white spots and black circles indicate the average depths at which hauls were taken. Bottom was at 54 metres.

series, the depths being indicated by the depth-recorder (**11**, Fig. 1, and **15**, Fig. 1).

Measurements were made of the total lengths of Sagitta from samples from each collection ; the measurements were made to the nearest half-millimetre, but have here been divided into 2-millimetre groups. The numbers in each 2-millimetre group of those measured have been given in Tables IV, V, and VI on pages 409–411 ; unfortunately in the June, 1926, collections the numbers measured are on some occasions rather low. The collections had been previously worked up and samples only of the whole catches kept ; on finding that there were two species present it was necessary to re-examine the samples, and as a result of dividing the Sagitta into the two species the numbers for each species measured are low. The indications of the behaviour of the animals on this occasion appear however to be quite definite and are confirmed by the July, 1924, collections for which larger numbers of animals were available for measurement.

Tables IV–VI show the numbers measured in each sample, and in Tables VII, VIII, and IX (pp. 412–414) are given the calculated total numbers of Sagitta in each 2-millimetre length group for each collection. These results, given in Tables VII–IX, are expressed diagramatically in Figures 1, 2, and 3, where the vertical distribution diagrams are given for each length group, the numbers at each depth in each diagram being expressed as percentages of the total number at all depths for that diagram.

These diagrams show that in the daylight the younger stages of *Sagitta elegans* are apparently able to withstand much higher intensities of light than the older stages, and can also live within a wider range of intensities. This change in depth with age has already been shown for other species, e.g. *Krohnia hamata* (Fowler, **4**, p. 76). At dusk it seems that the youngest stages, which were living high in the water in the daytime, have reached the surface in numbers while the older stages are still deep down. This behaviour is most clearly brought out in Figure 1, which shows the behaviour of *S. elegans* on June 3–4th, 1926. A very similar type of behaviour was shown on July 15–16th, 1924 (Fig. 2), but in this figure there are no individuals over $13\frac{1}{2}$ mm. in length. In comparing Figures 1 and 2 this latter point should be borne in mind and only the diagrams for similar size groups compared one with another. After dark the numbers caught in 1926 were really too low to give significant results ; in 1924, however, there is an indication that all stages were to be found unevenly mixed from top to bottom.

In the dawn a process of resorting is taking place, and on both occasions it is very evident that the older stages started to leave the surface first ; this is clearly shown in both Figures 1 and 2, while in Figure 1 the stages from 12 mm. and upwards in length appear already to be massing in an

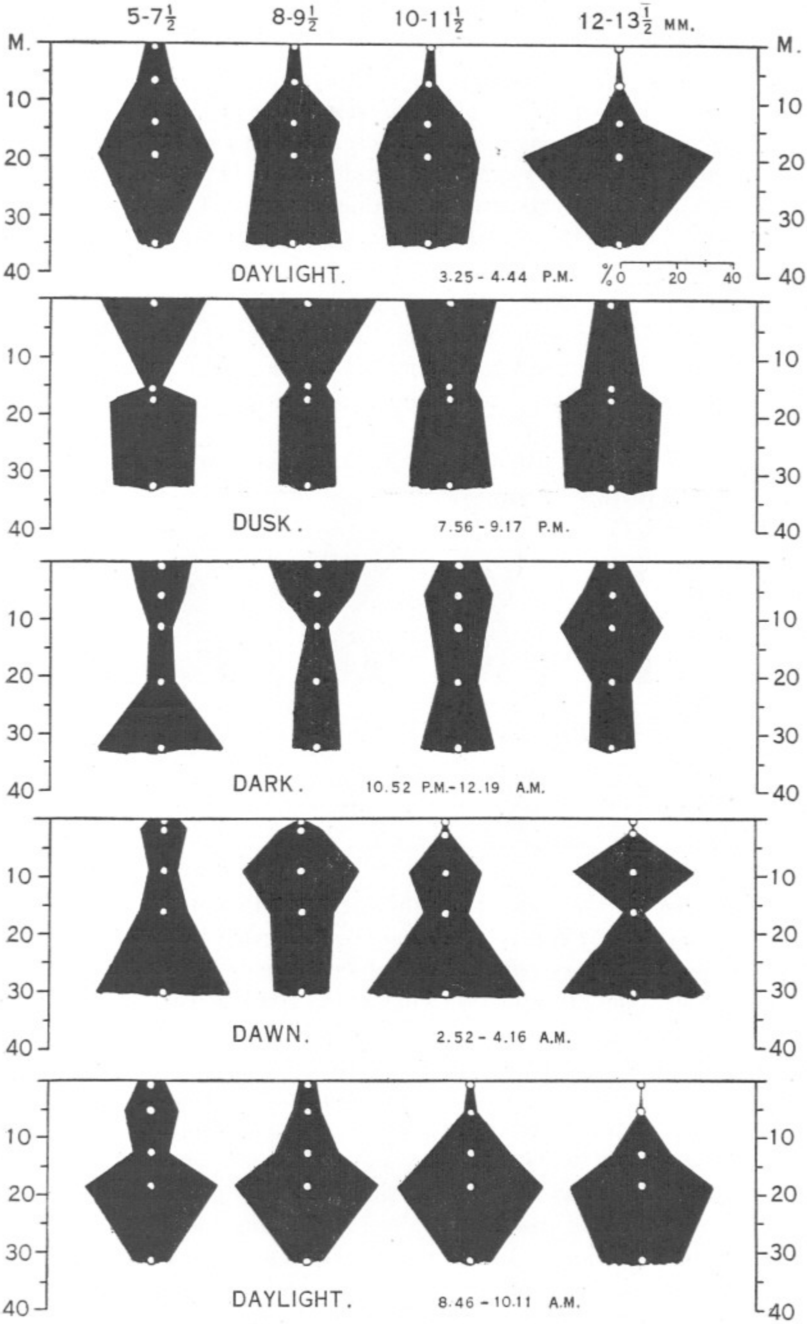

FIG. 2.—The percentage vertical distribution of *Sagitta elegans* at the times shown on July 15th–16th, 1924. For each period—" daylight," " dusk," " dark," " dawn," and " daylight "—the Sagitta are divided in 5–7½, 8–9½, 10–11½, and 12–13½ millimetre groups. The white spots and black circles indicate the average depths at which hauls were taken. Bottom was at 54 metres.

optimum region. The following day the vertical distribution has assumed a picture very similar to that of the previous afternoon, except that there is a tendency for the Sagitta to stretch more into the upper layers—a phenomenon exhibited by other plankton animals on that day and probably due to clouding of the water by a thick swarm of Calanus.

On June 3–4th, 1926, *Sagitta setosa* were on the whole not sufficiently abundant to give a picture of their behaviour ; at dusk, however, when they were most abundant in the catches, their behaviour appears to have been very similar to that of *S. elegans*. The younger stages have migrated to the surface before the larger forms, as shown in Figure 3. It is to be noticed also that on the whole there is a tendency for all stages to be

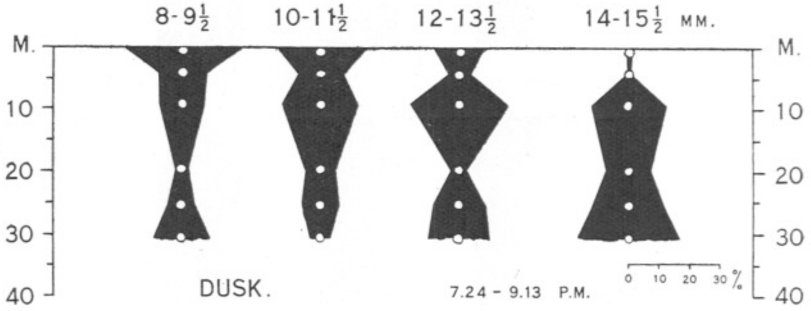

FIG. 3.—The percentage vertical distribution of *Sagitta setosa* at " dusk " on June 3rd, 1926. The Sagitta have been divided into 8–9½, 10–11½, 12–13½, and 14–15½ millimetre groups. The white spots and black circles indicate the average depths at which hauls were taken. Bottom was at 54 metres.

slightly higher in the water than the corresponding stages of *S. elegans* at the same time (cf. Fig. 1) : whether this difference is shown also in the daytime we cannot say until further observations have been made.

Huntsman in the Atlantic waters of Canada gives indications of a similar type of behaviour with *Sagitta elegans*. For instance (**5**, p. 465), he divided the Sagitta into two groups, those under and those over 20 mm. in length. Of the larger group specimens were only obtained at the surface at 6 p.m., 9 p.m., and 12 midnight ; while those under 20 mm. were present at the surface at all hours of the day and night, and there is an indication that the smallest sizes stay nearer the surface longest in the daytime, e.g. 9 a.m., occasional specimens up to 10 mm. long ; 12 noon, occasional specimens up to 9 mm. ; 3 p.m., many specimens up to 13 mm. ; 6 p.m., very many specimens up to 16 mm. ; 12 midnight, many specimens up to 20 mm. ; 3 a.m., several specimens up to 18 mm. ; and 6 a.m., occasional specimens up to 11 mm. He says further, " inside the Gulf in June larger individuals came to the surface than came above 30 metres in August, for 9 a.m., 12 m., 9 p.m., 12 midnight and 6 a.m. This decrease in the daily vertical migration is doubtless due to the warming of the surface water."

He sums up, "The facts point to the following conclusions: *Sagitta elegans* is confined to water of comparatively low salinity, being stopped in its migration into the depths by water of high salinity. It is affected by light, coming nearer the surface at night. It is affected by temperature, keeping to the colder water. The young behave differently from the adults, living in the lighter, warmer surface water. With increasing age it becomes gradually restricted to the darker, colder water, which is deeper." These results are confirmed by Bigelow (**2**, p. 316) in his survey of the plankton of the Gulf of Maine, and Huntsman and Reid (**6**) give further data on increase of size with depth.

A Comparison of the Behaviour of Sagitta with the Light Intensity Conditions.

In a previous publication I illustrated in outline the theory of the vertical movements of plankton animals on the basis that they were distributed in a chance distribution around an optimum condition of light in the daytime. It was suggested that they followed this optimum condition towards the surface at dusk, and that at night the light stimulus was removed and they became free to move anywhere.* The following day those near the surface pick up their optimum condition again and follow it downwards as the light increases in strength, picking up recruits from deeper layers as they come into the influence of the stimulus of the increasing light. "It seems most probable that the types of distribution shown by the different species are due to a combination of the speed of upward movement of which they are capable and the time at their disposal for such upward migration" (**16**, p. 236).

This theory appears essentially to be borne out by the results here given for *Sagitta elegans ;* we see very clearly how at dusk the younger stages only have had time to reach the surface *en masse* before the light fades away, but the older stages coming from deeper layers never have time to reach the surface in quantity until after dark when they are free to roam anywhere.

An attempt has been made to compare these results with the actual variations of the light intensity beneath the surface of the sea. Throughout the year 1930 continuous records of light intensity have been made from a photometer on the parapet of the flat roof of the Laboratory. The photometer contained a Burt vacuum sodium photo-electric cell sensitive mainly to blue light, and the intensities were recorded on a thread recorder

* It must be understood that this behaviour would be modified under extreme conditions of other factors, such as temperature, as would the vertical movements (Russell **13**, p. 435, and Nikitine **9**).

in the Laboratory (**1**). It so happened that on June 4th, 1930, the weather was cloudless and clear, and the light conditions must have approximated very closely to those on June 3rd and 4th, 1926, when the collections of Sagitta were made (for weather conditions see **15**, p. 830). The actual light intensities throughout June 4th, 1930, have been recorded on the above instrument, and I am able here to publish the curve (Fig. 4) through the kind permission of Dr. W. R. G. Atkins by whom the researches on light intensity are being carried out. In Figure 4 the actual intensities are given as thousands of metre candles, based upon a standardization of a vacuum potassium cell against a carbon arc ; the sodium cell was then standardized in daylight against the potassium cell.

Unfortunately, however, we do not know the transparency of the water

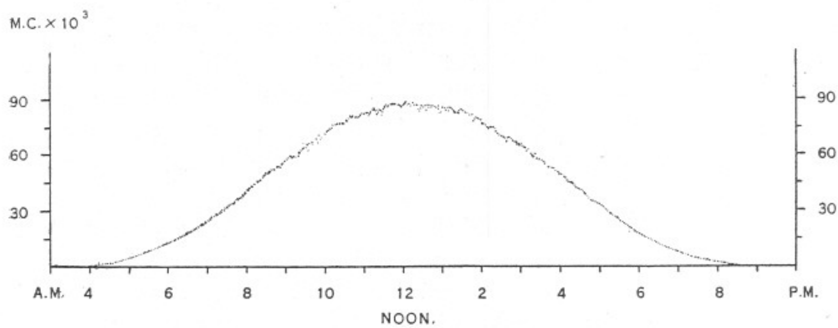

FIG. 4.—Curve of light intensity obtained on roof of Plymouth Laboratory with vacuum photo-electric cell and thread-recorder (**1**) on June 4th, 1930 : a clear cloudless day. (By courtesy of Dr. W. R. G. Atkins.) The intensities are given as thousands of metre-candles.

on June 3rd, 1926, except that the Secchi disc disappeared at a depth of 10 metres, and we are therefore unable to estimate for certain the intensities at different depths beneath the surface. Animal plankton on that day was very abundant, and it is possible that the coefficient of absorption may have been in the region of 0·200 ; it seems almost certain to have been considerably more than 0·100. Poole and Atkins (**10**, p. 308) give as a mean coefficient of absorption for Station E1 for a number of readings throughout the year 0·150 for the upper 20 metres, 0·120 for 20 to 40 metres, and 0·111 for 40 to 60 metres. Moreover, their work has shown that there is considerable variation to be found in the opacity of the water at different depths on any one day, due possibly to the aggregation of plankton animals into definite zones. One cannot therefore hope to estimate with any accuracy the light conditions beneath the surface unless actual light measurements have been made, at any rate at a few depths.

Taking a coefficient of absorption of 0·200 for all depths with a surface loss of illumination of 15% by reflection (**10**, p. 309) and using the air

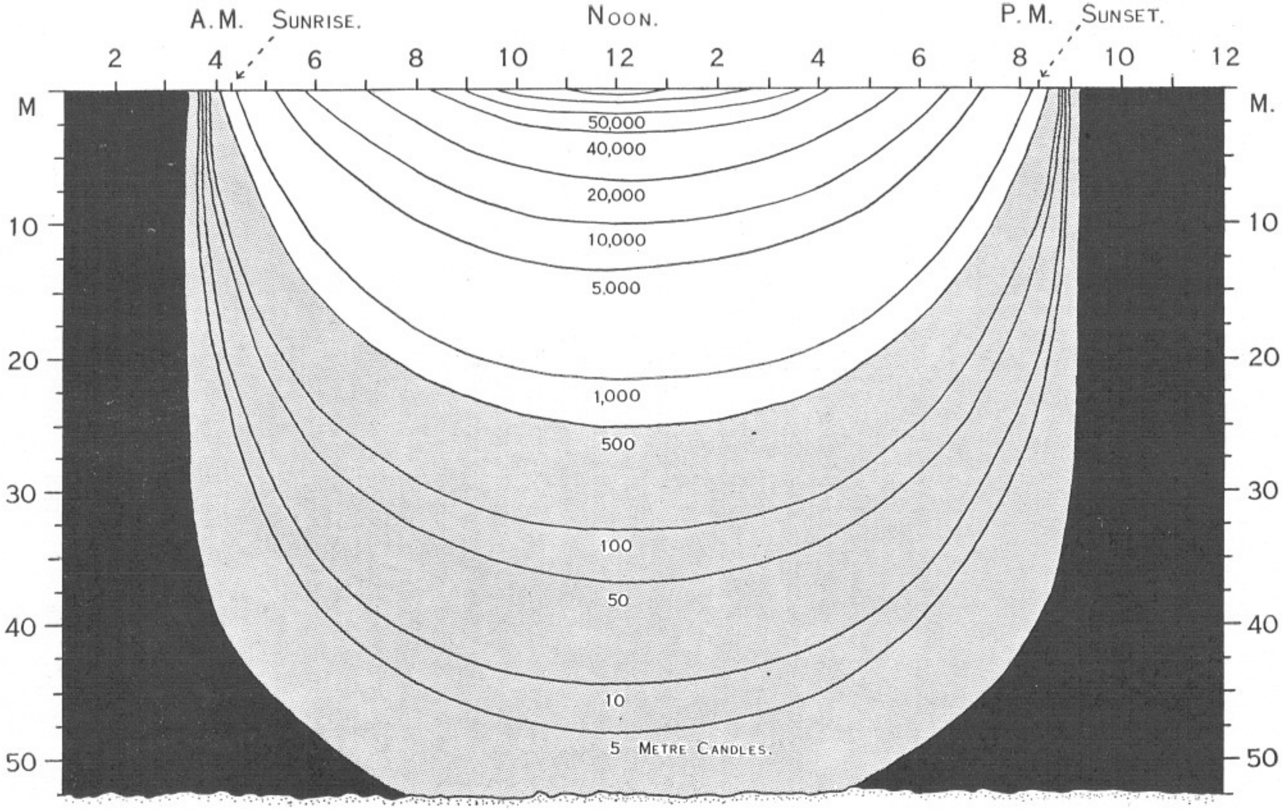

FIG. 5.—Curves of equal light intensities beneath the sea surface throughout the 24 hours, calculated from the air intensities obtained on June 5th, 1930, taking the coefficient of absorption of the water as being 0·200 at all depths and allowing for a reflection loss of 15%. The blackened area corresponds to the zone of "darkness" (see text) and the stippled area to the region in which "twilight" intensities would be experienced. The intensities are given in metre-candles and the depths in metres.

illumination figures obtained for June 4th, 1930 (Fig. 4), I have calculated the intensities beneath the sea surface at all times of the day.* By means of these results I have drawn in Figure 5 the lines of equal light intensities beneath the sea surface throughout the day. As I have already said, this picture can have no real significance and must be hypothetical only, but it is instructive as giving an idea of the conditions beneath the sea surface and as we shall see later it will serve a purpose. In Figure 7, p. 403, I have also given the lines of equal intensities for the same conditions, save that in this case the coefficient of absorption has been taken as being 0·100 at all depths. It is probably somewhere between the conditions figured in Figures 5 and 7 that the conditions beneath the surface on June 3rd and 4th, 1926, lay. In both these figures I have marked in black the area in which the conditions are those of "darkness" in the accepted meaning of the word, that is where the light intensity is such as we experience well after sunset when the stars are shining brightly, or less. The shaded area represents intensities of light lying between darkness and the illumination almost immediately after sunset on a clear evening, conditions which would be covered by the term "twilight." We thus can see at a glance at what times and depths darkness or twilight conditions would be experienced.

Let us study first Figure 5. It shows that between the hours of 7 a.m. and 5 p.m. the lines of equal intensities do not vary greatly in depth, but that before and after these times their slopes become very steep until eventually the light fades out almost abruptly. From this figure we could easily understand how animals living around an optimum of, say, 5000 m.c. at midday will have time to mass at the surface in the evening if they follow their optimum upwards; but animals which live at 50 m.c. at midday will be unable to keep pace with the suddenly disappearing light at evening and will never reach the surface in great numbers as the light stimulus is removed too soon.

But if we compare this figure with the behaviour of Sagitta given in Figures 1 and 2 an interesting point arises. In Figure 6 I have plotted the depths at which *Sagitta elegans*, 12 to 13½ mm. in length, first appear beneath the surface in abundance equivalent to 30% on the scale given in Figures 1 and 2, in the morning and afternoon of the two days in question.

* I am indebted to Dr. W. R. G. Atkins for the light intensities after sunset. It is probable that actually at sunset the usual illumination is in the neighbourhood of 1000 metre candles: the figures given me by Dr. Atkins were measured on October 3rd, 1927, and were as follows: sun just down, 620 m.c.; 15 minutes after, 530 m.c.; 20 minutes after, 178 m.c.; 26 minutes after, 73 m.c.; 30 minutes after, 35 m.c. (small print readable); 34 minutes after, 19 m.c. (small print readable with difficulty); 39 minutes after, 9·5 m.c.; 41 minutes after, 2·5 m.c. (Jupiter and first magnitude stars visible). The lag between sunset and 15 minutes after was probably due to cloud reflection; it has been smoothed out in Figures 5 and 7. The intensities before sunrise are taken as being the same as those after sunset.

It will be seen that on June 3rd–4th, 1926, the two points lie very close to 25 metres, and on July 15th–16th, 1924, they again appear very nearly at the same depth, namely, in this case 15 metres. From the curves of equal intensities given in Figure 5 it appears that in 1924 the Sagitta were therefore becoming abundant at somewhere between 2000 and 3000 metre-candles in both the morning and the afternoon, and similarly that in 1926 these points lay somewhere between 300 and 400 m.c. If now we plot the similar points for the dawn distribution we find that in 1924 it lies not on the 2000–3000 m.c. curve, but only at 50–100 m.c., at about

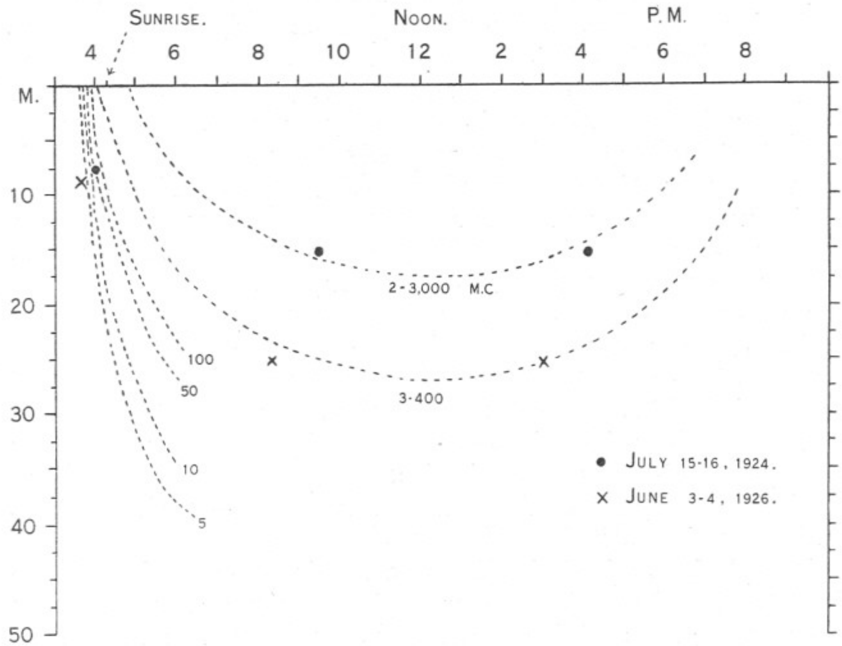

FIG. 6.—Depths at which *Sagitta elegans* of 12 to 13½ mm. in length first appear beneath the surface in an abundance equalling 30% on the scale in Figures 1 and 2 on June 3rd–4th, 1926, and July 15th–16th, 1924, in the morning, afternoon, and at "dawn." The dotted curves are the lines of equal light intensities taken from Figure 5.

7·5 metres. A similar state of affairs is shown for 1926, where the 30% point lies at about 8·5 metres at an intensity of below 5 m.c. Now the close agreement in the intensities at which the Sagitta are living in the morning and afternoon may be mere coincidence and have no significance, since we cannot say for certain what the intensities were on the days in question. But the difference between the intensities to which the Sagitta were reacting at dawn and those which they experienced in the daytime must be significant. Examination of Figures 1 and 2 shows clearly that the Sagitta of 12 mm. and over had started to leave the surface even before sunrise, For instance, on June 4th, 1926, Sagitta 12–13½ mm. long were already showing signs of leaving the surface, and those of 14–15½ mm. in length and longer had already left the surface layers down to 4 metres when the haul at that depth was made at 3.49–3.59 a.m. : this is well before sunrise, which occurred at 4.17 a.m.,* and the air illumination must probably have been less than 300 m.c. at any rate. Similarly, on July 16th, 1924, Sagitta 12–13½ mm. long had already left the surface layers by 3.51–4.1 a.m., when sunrise should be at 4.24 a.m. (sunrise not recorded in log).

It seems from these data that the Sagitta must have started to leave the surface before the illumination reached that at which many are found to be living in the daytime. This would appear to indicate that the Sagitta are more sensitive to light immediately after the darkness of the night than they are later in the daytime. Thus is would seem that they can become adapted to light conditions of higher intensity as the morning goes on.

Indications that this may be so with some fresh-water plankton animals is given by Worthington, who says (**19**, p. 2) as a result of observations made during 26 hours in Lake Lucerne, " Most species start their descent at dawn and reach their lowest level before the sun attains its zenith. Then a slow upward movement starts, accelerates at dusk, and continues for two or three hours after complete darkness."

Clarke, experimenting with the fresh-water Daphnia, has recently produced evidence that this crustacean can become adapted to light of various intensities. He suggests that (**3**, p. 120) " There is, then, no ' absolute optimum ' light intensity for these *Daphnia.* They do not seek any particular intensity of illumination. The animals become adapted to the light intensity which exists at that time and place—this is for them a ' relative optimum.' "

That plankton animals should show a certain power of adaptation to light conditions is probably to be expected, and it would seem that possibly they live around a shifting optimum during the course of the day. It should be borne in mind, however, that probably they are only capable of adaptation within limits, and that outside these limits definite avoiding reactions set in. Until observations in the field are made synchronously with accurate light-intensity measurements at all depths it is premature to discuss the matter further.

Figure 7 has been inserted to draw attention to the very great effect that the transparency of the water has upon the intensity of the illumination beneath the surface. In this figure the coefficient of absorption of the water has been taken as 0·100 at all depths, and it can be seen that each iso-intensity line has been pushed down exactly twice as deep as in Figure 5,

* This is the sunrise time recorded in the log : theoretically it should have been 4.11 a.m. : the discrepancy is probably due to " sunrise " being the appearance of the sun above the hills of Dartmoor.

where the coefficient of absorption was taken as being 0·200 at all depths. This will mean that animals living in the " twilight " zone with an upper limit of about 500 m.c. will be abundant nearly up to 25 metres at midday under the conditions of Figure 5, while under the conditions of Figure 7 they will be forced right to the bottom.

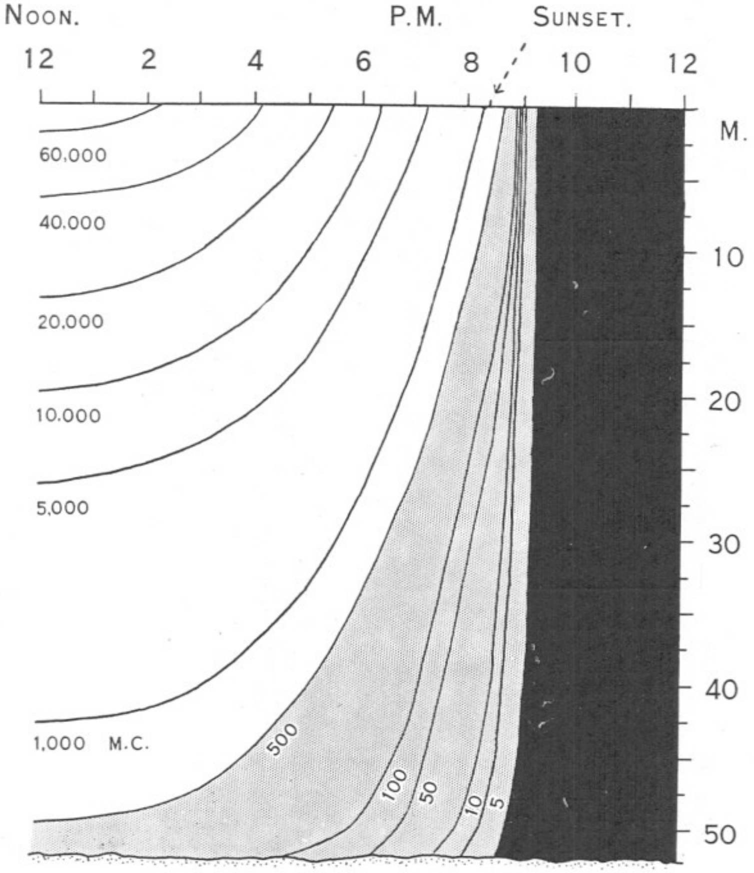

FIG. 7.—Curves of equal light intensities beneath the sea surface from noon to midnight, calculated from the air intensities obtained on June 5th, 1930, taking the coefficient of absorption of the water as being 0·100 at all depths and allowing for a reflection loss of 15%. The blackened area corresponds to the zone of " darkness," and the stippled area to the region in which " twilight " intensities would be experienced. The intensities are given in metre-candles and the depths in metres.

In view of the above I have reproduced here Figure 8 which gives the behaviour of Sagitta on two successive days, June 16th, 17th, and 18th, 1925. This figure has already been published as for *S. bipunctata* (**13**, p. 88) ; unfortunately the material is no longer available, so that it is not possible to say whether *S. elegans* or *S. setosa* predominated. It can be seen that the behaviour here shown differs very markedly from that on the other two dates given in Figures 1 and 2 in this present publication. On June 16th–18th, 1925, the Sagittas became very abundant at night, but in the daytime they were very scarce, and the impression gained is that they must have retreated to very near the bottom (54 m.) in the daytime. It may well have been that on these two days in June, 1925, the water was far more transparent than on the two occasions in 1924 and 1926 ; certainly the animal plankton was very much less abundant, on the two days in 1925, than it was on either of the days in 1924 or 1926, and this alone would probably have an appreciable effect on the transparency of the water. But why the Sagitta should have left the surface so suddenly

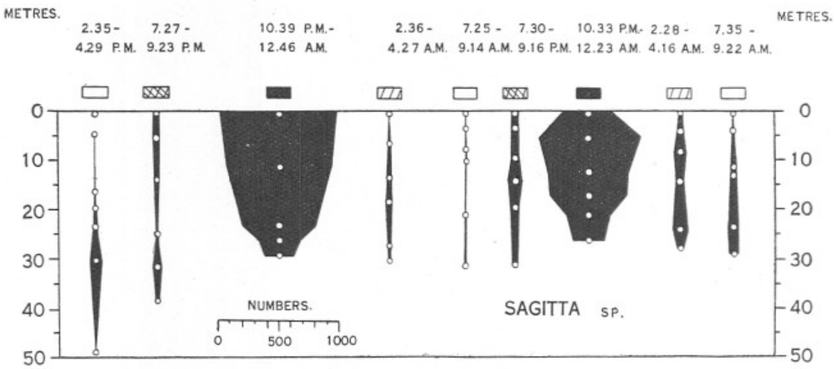

FIG. 8.—The vertical distribution of Sagitta sp. at the times shown, on June 17–18–19th, 1925. The plain, cross-hatched, black, and shaded rectangles represent " daylight," " dusk," " dark," and " dawn " respectively. The white spots and black circles indicate the average depths at which hauls were taken.

in the early mornings of June 18th and 19th, 1925, is hard to explain. Inspection of Figure 8 shows that apparently the majority of the Sagitta had already left the upper 30 metres by 2.36 a.m. and 2.28 a.m., about an hour and a half before sunrise. At this time the light intensity must have been almost negligible and some other factor was perhaps operating.

It should be realised that on days of intermittent sunshine the light intensity beneath the sea surface is changing to an enormous degree. Under such conditions it is natural to suppose that the animals take up an average position in the water, being constantly stimulated to move upwards or downwards. On clear bright days, however, the position in the water appears to be very constant, but presumably it must take a little time for a population of animals to settle around their optimum conditions.

This leads one to wonder whether in nature there are not perhaps two separable types of behaviour, namely the picking up of optimum conditions by means of random movements under fairly constant intensities, and the stimulation of active responses by sudden changes in intensity. This latter would operate at dusk and dawn; that such a behaviour is possible is perhaps indicated by the work of Kikuchi (**7**) who has shown an apparent double migration to the surface in the evening, first on the sun striking behind a mountain and secondly at the time of true sunset. This might possibly account for the sudden disappearance of Sagitta so early before sunrise.

SUMMARY.

1. The diurnal behaviour of Sagitta of different sizes is shown as a result of collections made with the 2-metre stramin ring-trawl throughout 24 hours on July 15th–16th, 1924, and on June 3rd–4th, 1926.

2. The younger stages of *Sagitta elegans* appear to withstand higher intensities of light in the daytime than do the older stages, and they migrate first to the surface at dusk, as do those of *Sagitta setosa*. The older stages leave the surface first at dawn.

3. Diagrams are given showing the curves of equal intensities of light beneath the sea surface throughout 24 hours as calculated from air intensities obtained in June, with a reflection loss of 15%; (*a*) assuming a coefficient of absorption of 0·200 at all depths, and (*b*) assuming a coefficient of absorption of 0·100 at all depths.

4. It appears, from a comparison of the behaviour of *Sagitta elegans* with the calculated light conditions beneath the surface, that the older Sagitta at any rate are more sensitive to light in the early morning after the darkness of the night and can become adapted to light of higher intensities later in the day.

5. Previously published observations on the behaviour of Sagitta sp. on June 17th–18th–19th, 1925, show quite a different type of behaviour from the above, possibly due to more transparent water, the Sagitta only appearing abundantly above 30 metres in the dark. They had again migrated to below 30 m. before there was any appreciable light.

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TABLE I.

Total numbers of Sagitta elegans caught in 10-minute hauls of the 2-metre Ring-trawl at each depth on June 3rd–4th, 1926.

	Daylight. 2.20– 4.11 p.m.	Dusk. 7.24– 9.13 p.m.	Dark. 10.28 p.m.– 12.31 a.m.	Dawn. 2.24– 4.17 a.m.	Daylight. 7.29– 9.29 a.m.
S.	40	513	143	257	117
II.	92	392	188	454	347
III.	1028	755	108	1152	852
IV.	1117	1318	156	993	1426
V.	3784	766	124	388	2428
VI.	4090	1530	456	507	2112

TABLE II.

Total numbers of Sagitta setosa caught in 10-minute hauls of the 2-meter Ring-trawl at each depth on June 3rd–4th, 1926.

	Daylight. 2.20– 4.11 p.m.	Dusk. 7.24– 9.13 p.m.	Dark. 10.28 p.m.– 12.31 a.m.	Dawn. 2.24– 4.17 a.m.	Daylight. 7.29– 9.29 a.m.
S.	13	677	287	93	13
II.	49	288	452	116	244
III.	92	745	412	338	107
IV.	83	252	264	207	194
V.	167	464	317	172	272
VI.	120	550	604	72	808

TABLE III.

Total numbers of Sagitta elegans caught in 10-minute hauls of the 2-metre Ring-trawl at each depth on July 15–16th, 1924.

	Daylight. 3.25– 4.45 p.m.	Dusk. 7.55– 9.17 p.m.	Dark. 10.50 p.m.– 12.20 a.m.	Dawn. 2.50– 4.16 a.m.	Daylight. 8.45– 10.11 a.m.
S.	98	2060	1040	66	355
II.	196	1230	1600	203	760
III.	1195	1460	1760	1010	3400
IV.	2925	2290	990	490	7130
V.	1190	2400	1573	1510	2710

TABLE IV.

ACTUAL NUMBERS OF SAGITTA ELEGANS MEASURED FROM CATCHES ON JUNE 3RD–4TH, 1926.

Depth in metres.	Length in millimetres. <7½	8–9½	10–11½	12–13½	14–15½	>16	Total.
			DAYLIGHT. 2.20–4.11 p.m.				
S.	1	11	10	14	2	–	38
4·3	–	2	15	10	2	1	30
10·8	1	7	33	45	14	–	100
18	3	7	15	42	24	9	100
26·6	–	3	10	35	44	8	100
31·5	1	3	16	32	41	7	100
			DUSK. 7.24–9.13 p.m.				
S.	4	16	15	5	–	–	40
4·4	1	4	25	7	2	–	39
9·3	2	6	12	35	9	–	64
19·7	–	3	11	33	36	17	100
25·3	1	3	10	19	28	7	68
30·3	–	2	10	26	36	26	100
			DARK. 10.28 p.m.–12.31 a.m.				
S.	1	4	2	5	–	1	13
4·6	–	–	3	4	3	–	10
12·3	–	4	4	–	2	–	10
17·2	1	5	5	2	2	1	16
25·9	–	1	3	2	5	–	11
35	2	3	10	9	10	2	36
			DAWN. 2.24–4.17 a.m.				
S.	–	1	6	5	1	–	13
4	–	4	10	13	8	2	37
9·5	1	3	6	36	48	20	114
20·5	1	3	20	24	30	17	95
24·4	–	5	8	5	11	4	33
36·3	–	4	14	7	12	5	42
			DAYLIGHT. 7.29–9.29 a.m.				
S.	–	5	6	2	3	–	16
4	–	4	11	12	3	1	31
10	1	2	5	15	7	4	34
21·8	–	2	5	22	28	6	63
25·7	1	5	19	30	38	14	107
34·3	1	3	8	23	40	26	101

TABLE V.

ACTUAL NUMBERS OF SAGITTA SETOSA MEASURED FROM CATCHES ON JUNE 3RD–4TH, 1926.

Depth in metres.	<7½	8–9½	10–11½	12–13½	14–15½	>16	Total.
			DAYLIGHT. 2.20–4.11 p.m.				
S.	–	2	3	2	3	2	12
4·3	–	5	6	1	4	–	16
10·8	2	2	3	1	1	–	9
18	1	1	3	3	–	–	8
26·6	1	2	5	6	1	1	16
31·5	–	1	5	1	1	1	9
			DUSK. 7.24–9.13 p.m.				
S.	1	22	26	15	1	1	66
4·4	1	8	13	6	1	–	29
9·3	1	8	20	24	11	1	65
19·7	–	2	7	4	6	1	20
25·3	–	5	10	13	11	3	42
30·3	–	10	6	16	16	3	51
			DARK. 10.28 p.m.–12.31 a.m.				
S.	–	2	7	7	5	5	26
4·6	1	1	2	4	16	–	24
12·3	–	5	8	4	14	7	38
17·2	–	4	3	4	12	3	26
25·9	–	2	4	8	9	5	28
35	2	3	3	12	21	7	48
			DAWN. 2.24–4.17 a.m.				
S.	–	1	3	4	–	–	8
4	–	3	1	6	1	–	11
9·5	1	4	5	10	9	4	33
20·5	2	2	4	4	5	3	20
24·4	1	4	5	2	3	1	16
36·3	–	1	–	1	3	–	5
			DAYLIGHT. 7.29–9.29 a.m.				
S.	1	–	–	–	1	–	2
4	2	14	5	1	1	–	23
10	–	1	–	2	3	–	6
21·8	–	1	3	2	3	–	9
25·7	–	2	–	5	6	–	13
34·3	–	3	8	8	12	8	39

TABLE VI.

ACTUAL NUMBERS OF SAGITTA ELEGANS MEASURED FROM CATCHES ON JULY 16–17TH, 1924.

Depth in metres.	<7½	8–9½	10–11½	12–13½	>14	Total.
			DAYLIGHT. 3.25–4.45 p.m.			
S.	4	7	16	6	–	33
6·6	12	17	43	29	–	101
13·6	10	34	94	79	7	224
19·5	5	10	44	127	14	200
34·5	2	18	49	43	3	115
			DUSK. 7.55–9.17 p.m.			
S.	12	67	123	55	1	258
7	–	–	–	–	–	–*
15·1	1	9	32	47	3	92
17·1	6	16	50	93	8	173
32·3	6	18	73	89	6	192
			DARK. 10.50 p.m.–12.20 a.m.			
S.	5	17	23	19	–	64
5·8	4	12	37	39	1	93
11·2	2	4	31	63	2	102
20·7	3	10	31	36	2	82
32·2	11	9	44	34	2	100
			DAWN. 2.50–4.16 a.m.			
S.	23	9	7	–	–	39
1·9	37	51	28	5	–	121
9	3	15	26	22	1	67
16	5	9	18	4	–	36
30·1	13	8	62	30	–	113
			DAYLIGHT. 8.45–10.11 a.m.			
S.	38	62	34	1	–	135
5·3	12	15	15	3	–	45
12·5	6	23	69	42	1	141
18·3	16	38	90	78	–	222
31·1	7	16	49	81	2	155

* The tube containing these specimens had dried up.

TABLE VII.

TOTAL NUMBERS OF SAGITTA ELEGANS AT 2-MILLIMETRE INTERVALS OCCURRING AT EACH DEPTH ; ON JUNE 3RD–4TH, 1926, IN 10-MINUTE HAULS WITH THE 2-METRE RING-TRAWL.

Depth in metres.	Time.	Length in millimetres. <8	8–9½	10–11½	12–13½	14–15½	>15½	Total.
			DAYLIGHT.					
S.	4.1 p.m.	1	12	10	15	2	–	40
4·3	3.44 ,,	–	6	46	31	6	3	92
10·8	3.25 ,,	10	71	340	463	144	–	1028
18	3.3 ,,	33	78	168	469	268	101	1117
26·6	2.42 ,,	–	113	378	1325	1665	303	3784
31·5	2.20 ,,	41	123	655	1308	1677	286	4090
			DUSK.					
S.	9.3 p.m.	51	205	195	62	–	–	513
4·4	8.46 ,,	12	39	251	71	19	–	392
9·3	8.26 ,,	23	68	143	415	106	–	755
19·7	8.9 ,,	–	39	145	435	475	224	1318
25·3	7.48 ,,	15	31	115	215	314	76	766
30·3	7.24 ,,	–	31	153	397	552	398	1530
			DARK.					
S.	12.21 a.m.	11	45	22	54	–	11	143
4·6	12.1 ,,	–	–	56	76	56	–	188
12·3	11.36 p.m.	–	43	43	–	22	–	108
17·2	11.13 ,,	9	48	48	21	21	9	156
25·9	10.51 ,,	–	11	33	23	57	–	124
35	10.28 ,,	27	37	128	109	128	27	456
			DAWN.					
S.	4.7 a.m.	–	21	117	98	21	–	257
4	3.49 ,,	–	50	123	159	99	23	454
9·5	3.29 ,,	12	35	57	369	484	196	1152
20·5	3.8 ,,	10	30	209	247	318	179	993
24·4	2.47 ,,	–	58	93	58	128	51	388
36·3	2.24 ,,	–	50	167	86	143	61	507
			DAYLIGHT.					
S.	9.19 a.m.	–	36	45	15	21	–	117
4	8.59 ,,	–	45	121	135	35	11	347
10	8.38 ,,	26	51	128	375	170	102	852
21·8	8.17 ,,	–	43	114	499	627	143	1426
25·7	7.52 ,,	24	121	437	680	850	316	2428
34·3	7.29 ,,	21	63	169	486	824	549	2112

TABLE VIII.

TOTAL NUMBERS OF SAGITTA SETOSA AT 2-MILLIMETRE INTERVALS OCCURRING AT EACH DEPTH ON JUNE 3RD–4TH, 1926, IN 10-MINUTE HAULS WITH THE 2-METRE RING-TRAWL.

Depth in metres.	Time.	Length in millimetres. <8	8–9½	10–11½	12–13½	14–15½	>15½	Total.
			DAYLIGHT.					
S.	4.1 p.m.	–	2	3	2	4	2	13
4·3	3.44 ,,	–	15	19	3	12	–	49
10·8	3.25 ,,	21	21	30	10	10	–	92
18	3.2 ,,	11	11	30	31	–	–	83
26·6	2.41 ,,	10	22	52	63	10	10	167
31·5	2.20 ,,	–	13	68	13	13	13	120
			DUSK.					
S.	9.3 p.m.	14	224	264	149	13	13	677
4·4	8.46 ,,	8	81	130	61	8	–	288
9·3	8.28 ,,	15	89	224	275	127	15	745
19·7	8.9 ,,	–	25	88	50	76	13	252
25·3	7.48 ,,	–	56	111	144	121	32	464
30·3	7.24 ,,	–	110	66	171	171	33	550
			DARK.					
S.	12.21 a.m.	–	23	78	78	54	54	287
4·6	12.1 ,,	18	18	36	77	303	–	452
12·3	11.36 p.m.	–	54	87	45	152	74	412
17·2	11.13 ,,	–	40	32	40	120	32	264
25·9	10.51 ,	–	22	44	92	102	57	317
35	10.28		36	36	151	266	91	604
			DAWN.					
S.	4.7 a.m.	–	11	35	47	–	–	93
4	3.49 ,,	–	32	10	64	10	–	116
9·5	3.29 ,,	10	41	51	105	90	41	338
20·5	3.8 ,,	21	21	41	41	52	31	207
24·4	2.47 ,,	10	43	53	23	33	10	172
36·3	2.24 ,,	–	14	–	14	44	–	72
			DAYLIGHT.					
S.	9.19 a.m.	7	–	–	–	6	–	13
4	8.59 ,,	22	148	54	10	10	–	244
10	8.38 ,,	–	18	–	35	54	–	107
21·8	8.17 ,,	–	21	64	45	64	–	194
25·7	7.52 ,,	–	41	–	106	125	–	272
34·3	7.29 ,,	–	65	161	170	251	161	808

TABLE IX.

TOTAL NUMBERS OF SAGITTA ELEGANS AT 2-MILLIMETRE INTERVALS OCCURRING AT EACH DEPTH ON JULY 16–17TH, 1924, IN 10-MINUTE HAULS WITH THE 2-METRE RING-TRAWL.

Depth in metres.	Time.	Length in millimetres. <8	8–9½	10–11½	12–13½	>13½	Total.
			DAYLIGHT.				
S.	4.34 p.m.	12	21	47	18	–	98
6·6	4.18 ,,	23	33	84	56	–	196
13·6	4.1 ,,	54	180	502	422	37	1195
19·5	3.44 ,,	73	146	644	1857	205	2925
34·5	3.25 ,,	20	187	507	445	31	1190
			DUSK.				
S.	9.7 p.m.	97	534	983	438	8	2060
7	8.49 ,,	–	–	–	–	–*	1230
15·1	8.32 ,,	16	143	508	745	48	1460
17·1	8.15 ,,	80	211	662	1232	105	2290
32·3	7.56 ,,	74	225	913	1114	74	2400
			DARK.				
S.	12.9 a.m.	83	281	364	312	–	1040
5·8	11.52 p.m.	64	208	640	672	16	1600
11·2	11.34 ,,	35	70	528	1092	35	1760
20·7	11.16 ,,	40	118	376	436	20	990
32·2	10.52 ,,	173	142	692	535	31	1573
			DAWN.				
S.	4.6 a.m.	39	15	12	–	–	66
1·9	3·51 ,,	63	85	47	8	–	203
9	3.34 ,,	40	222	394	334	20	1010
16	3.14 ,,	69	122	245	54	–	490
30·1	2.52 ,,	181	105	831	393	–	1510
			DAYLIGHT.				
S.	10 a.m.	99	163	89	4	–	355
5·3	9.43 ,,	205	251	251	53	–	760
12·5	9.26 ,,	136	543	1667	1020	34	3400
18·3	9.8 ,,	500	1211	2924	2495	–	7130
31·1	8.46 ,,	136	271	866	1410	27	2710

* The tube containing these specimens had dried up.