Variations in the Amount of Macroplankton by Day and Night.

By

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With 3 Figures in the Text.

THE investigations of the International Passamaquoddy Fisheries Commission were concerned, *inter alia*, with the principal food fishes of the region, one of which was the Herring. Demarcation of the spawning areas necessitated a study of the geographical distribution of the larvæ, for which purpose a modified Petersen's Young Fish Trawl was employed. My thanks are due to Mr. Michael Graham, to whom I am greatly indebted for the opportunity of examining the interesting collections of macroplankton on which this account is based.

My thanks are also due to Doctor C. J. Fish for his assistance, to Professor W. M. Tattersall for his help in the identification of the Euphausiids and to Professor Alexander Meek for confirmation of the Sagitta present in the material.

The collections covered a period of 48 consecutive hours, during the course of which 20 oblique hauls, from bottom to surface, were made with a stramin ring-trawl 5 feet in diameter. The net was fitted with two bridles only, a sinker being attached to the lower edge of the ring by means of a strop 6 feet long. The method of fishing was the same as that employed in an earlier experiment (Gardiner and Graham, 1925, p. 3), but with the additional precaution that the angle of the towing warp was kept at 35° to 45°. As before, each haul was of 30 minutes duration.

The times at which the hauls were made are given in Table I, and the approximate course of the boat, drifting under the influence of wind and tide, is shown in Figure 1. The twenty Stations were centred on the position 43° 50′ N. by 64° 30′ W., roughly 17 miles off Liverpool, Nova Scotia. Observations were continued from 8.42 p.m. on May 9th to 6 p.m. on May 11th, 1932. The wind was variable and light, and the sea, save at the first Station, comparatively smooth (0–3 Beaufort). With one exception, Station N. 234, when there was a haze, the sky was clear. Surface temperature ranged from 4·4° to 6·8° C.

The common species in the collections were :—

Thysanoëssa raschii M. Sars.
,, *inermis* Kröyer.
,, *longicaudata* Kröyer.
Sagitta elegans Verrill.
Calanus finmarchicus (Gunnerus).
Calanus hyperboreus Kröyer.

Specimens of *Themisto compressa* Goës, f. *compressa* Goës (Stephensen), *Metridia longa* (Lubbock) and *Pareuchæta norvegica* (Boëck) occurred in many of the collections in addition to occasional small hauls of Decapod larvæ and Cœlenterates. In the first haul, N. 217, the net touched bottom and this collection contained some 250 specimens of *Erythrops erythrophthalma* (Goës).

The numbers of the more abundant species taken in each of the 20 oblique hauls are given in Table I.

TABLE I.

NUMBERS OF SELECTED ORGANISMS IN EACH OF THE TWENTY COLLECTIONS, MAY 9–11TH, 1932.

Station.	Soundings in Fathoms	Time (A.S.T.).	*Th. raschii.*	*Th. inermis.*	*Th. longicaudata.*	*S. elegans.*	*C. finmarchicus.*	*C. hyperboreus.*	Herring Larvæ.	Fish Ova.
N. 217	56	2024	3,018	49	0	5,750	3,250	1,550	22	147
218	50	2206	3,210	350	0	6,100	1,100	275	29	260
219	51	0004	5,232	80	0	12,880	3,120	1,200	25	432
220	55	0151	2,886	240	0	10,800	4,800	1,440	12	438
221	65	0347	1,281	427	28	4,500	6,450	2,950	0	130
222	72	0628	59	59	2	2,475	6,050	1,400	1	244
223	56	0916	3	0	0	1,020	3,480	760	0	297
224	42	1214	0	0	0	1,180	1,380	520	1	305
225	45	1531	1	0	0	1,550	4,000	1,750	2	190
226	50	1819	6	0	0	2,375	3,750	1,250	5	365
227	50	2010	1,276	36	17	2,750	3,575	850	2	201
228	56	2214	2,427	218	0	3,300	10,200	3,400	0	137
229	65	0008	3,310	814	55	3,720	13,200	1,680	3	180
230	65	0144	3,147	725	0	7,350	11,600	5,500	2	164
231	64	0342	2,278	362	0	9,675	5,650	6,450	1	176
232	58	0623	33	12	1	2,550	6,300	5,800	0	64
233	58	0855	27	2	0	2,975	4,200	1,100	8	85
234	55	1148	7	13	0	1,175	3,250	1,450	5	121
235	60	1529	5	0	0	3,550	4,600	1,750	0	397
236	48	1809	10	2	0	2,925	2,525	675	2	445

The data are expressed graphically in Figures 2 and 3. The curve for Euphausiids is based on the totals of the three species.

As far as the Euphausiids are concerned, virtually none was taken in the daytime, and no statistical treatment need be invoked to demonstrate a significant difference. Sagitta, too, showed a marked discrepancy between day and night hauls, the latter comprising 75% of the total

catch. In the cases of *Calanus finmarchicus* and *C. hyperboreus* 61% of the total numbers of each of these species were taken in the night collections. These differences can be shown to be significant, and are not to be ascribed to the operation of chance in irregularly distributed populations.

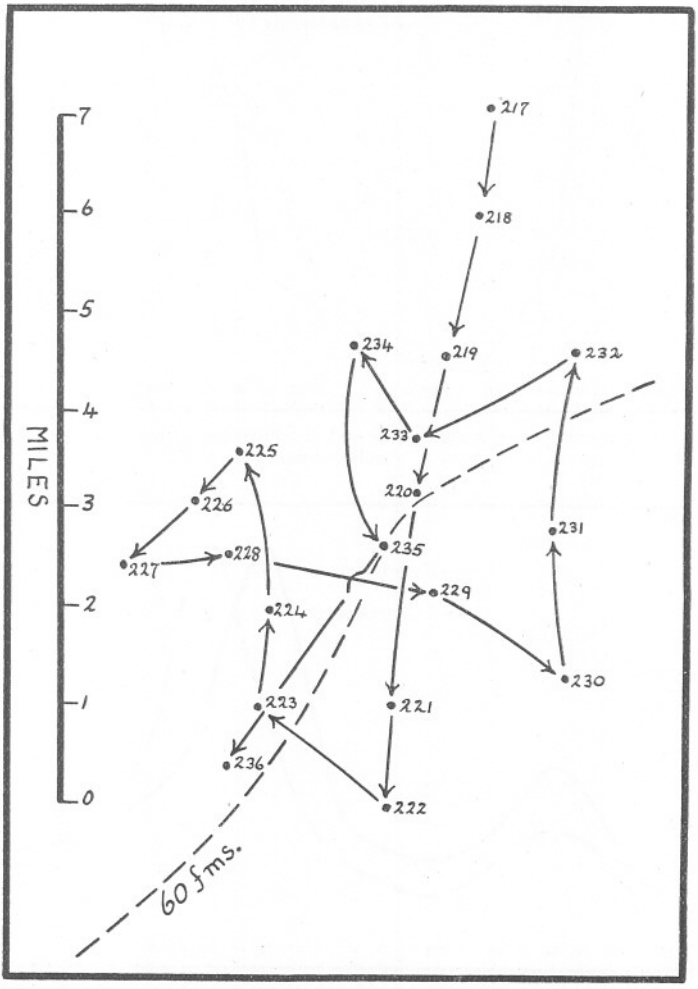

FIG. 1.—Approximate positions of Stations, and course of vessel drifting under influence of wind and tide.

No such difference exists in the case of the Fish Ova. The catches of Herring larvæ on the first night (Stations N. 217 to N. 220) were undoubtedly in excess of those made during the ensuing daylight period. At first sight this would seem to be in accordance with Russell's findings

for Clupeid larvæ (Russell, 1930, p. 649), but the results of the second night's observations coupled with a study of the positions at which the

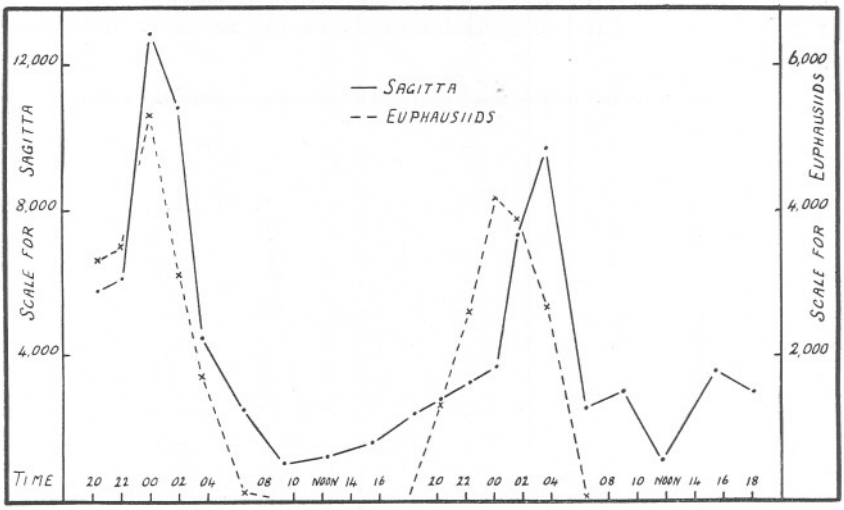

FIG. 2.—Actual numbers of Euphausiids and of Sagitta occurring in each of the twenty collections.

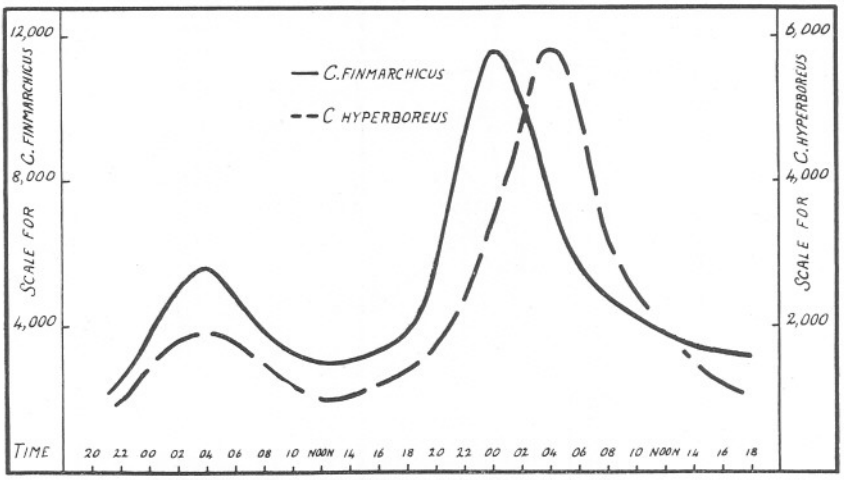

FIG. 3.—Abundance of *Calanus finmarchicus* and of *C. hyperboreus* throughout the period of 48 hours covered by the observations.

bigger catches occur would suggest that the larvæ were restricted to a definite area (see Fig. 1, p. 561).

It has been shown in an earlier paper (Gardiner and Graham, 1925, p. 6) that consecutive hauls of a Petersen's Young Fish Trawl will not

catch each time the same number of organisms, and it appeared that fluctuations in the region of ±40% were to be expected. The conclusion arrived at was that the greater part of such differences was due to irregularity in the horizontal distribution of the organisms themselves, a view which has been confirmed by more recent work (see Gardiner, 1931, p. 453). In these circumstances, then, one is clearly entitled to smooth the curves, especially since the purpose of the diagrams is to represent differences which, as already stated, are significant. Smoothing has been carried out in the cases of *C. finmarchicus* and *C. hyperboreus* only, the greater degree of uniformity in horizontal distribution rendering this unnecessary for the Euphausiids and for Sagitta.

Larger catches by night than in the adjacent hours of daylight have been recorded by a number of workers for many planktonic animals ; the reverse has also been observed. So far as can be ascertained it is usually held that in the former case such differences result from a proportion of the animals moving to depths greater than have been (or can be) fished by the net. In the case of some species, especially larger and more active ones, it has also been suggested that discrepancies may result from the animals' ability to dodge the net. In the present instance we have three classes of animals, differing in size and swimming power, all of which have been caught in greater numbers in the darkness, thus enabling these two suggested explanations to be examined.

Euphausiids

There is abundant evidence from the literature that Thysanoëssa and allied forms live close to the bottom by day (Otterström, 1910, p. 10 ; Lebour, 1924, p. 404 ; Hickling, 1925, p. 741 ; Russell, 1927, p. 588 ; Southern and Gardiner, 1932, p. 155 and Macdonald, 1927, p. 756).

On the other hand, there is also no lack of evidence that Euphausiids may occasionally be found right at the surface in broad daylight (Hickling, *loc. cit.*, p. 742 ; Bigelow, 1926, p. 145 ; Macdonald, *loc. cit.*, p. 776).

In the present experiment a note was made in the Log : " At 12.30 p.m. *Shrimp* were visible in the water." On this occasion (Station N. 234, 11.5.32) Euphausiids were seen in fair abundance, and a single specimen taken in a bucket of surface water was found to be *Th. inermis*. Herring larvæ and Eel (Anguilla) were present, but in smaller numbers. By 4 p.m. (Station N. 235) the Log records that the plankton was no longer to be seen. In the tow-netting made when *Shrimp* were known to be in the surface water only 20 specimens occurred, 13 *Th. raschii* and 7 *Th. inermis*.

The possibility that Euphausiids may avoid a net has been recognised

by most observers (e.g. Holt and Tattersall, 1905, p. 137 ; Ruud, 1932, p. 14 ; Frost, 1932, p. 203, etc.), and although I would hold this responsible for a small part of the paucity of Euphausiids at Station N. 234, to ascribe to this cause the whole of the enormous discrepancies between day and night collections would surely be to endow these animals with powers of swimming altogether too great. Moreover, such an hypothesis would entail the bulk of the population remaining by day in the upper illuminated levels, where, in point of fact, Hickling (*loc. cit.*, p. 739) shows that they are almost certainly not to be found.

Sagitta.

Whatever explanation we may accept for this phenomenon with regard to the Euphausiids, it is impossible to believe that in the case of Sagitta it is due to the animals avoiding the net. They are by no means active creatures and, moreover, are known on occasions to migrate downwards by day (Russell, 1931 and 1933). It is thus tolerably certain that the discrepancies between day and night catches are due to a proportion of the population moving downwards to levels below those fished by the net.

It is well established that Sagittas of different size do not respond in the same way to changes in light intensity, and the present material was examined to see whether there was any indication that one size group more than another had sunk to those levels which the net could not sample. In all, over two thousand specimens of *S. elegans* were measured and the mean length in each of the twenty collections determined. This was found to vary between 22 and 25 mm., but no correlation with the hour at which the sample was taken could be detected.

Calanus finmarchicus and *Calanus hyperboreus*.

The differences between the daylight and dark collections, whilst significant, were not so marked in the case of these two species as in those considered above.

The large mesh employed with the ring-trawl retains no more than a small proportion of *C. finmarchicus* in Stage IV and on this account only specimens in Stages V and VI were enumerated. In the case of the larger *C. hyperboreus*, individuals in Stage IV were more abundant and were included in the counts.

It is known that the older and larger individuals tend to live below the younger (see Gardiner, 1933, p. 464 ; Marshall, 1933, p. 128) and thus might be expected to disappear from the daylight catches to a greater extent than the younger stages. In order to test this, the percentage of adult specimens (♂ and ♀) of *C. finmarchicus* occurring in the 20 collections,

together with the mean figure for each of the periods of daylight and darkness was determined. These are set out in Table II. It will be seen that during the daylight, adults disappear from the population to a small, but definite extent. According to the test provided by Fisher (1930, p. 114) the difference between the mean percentages in darkness and daylight is a significant one.

TABLE II.

PERCENTAGE OF ADULT SPECIMENS OF C. FINMARCHICUS OCCURRING IN EACH OF THE TWENTY COLLECTIONS.

	Station.	Time.	Percentage of Adults (Stage VI).		Station.	Time.	Percentage of Adults (Stage VI).
	N. 217	2024	62%		N. 227	2010	54%
DARKNESS.	218	2206	77	DARKNESS.	228	2214	65
	219	0004	77		229	0008	64
	220	0151	57		230	0144	48
	221	0347	59		231	0342	43
			Mean 66%				Mean 55%
DAYLIGHT.	222	0628	51%	DAYLIGHT.	232	0623	35%
	223	0916	54		233	0855	57
	224	1214	54		234	1148	54
	225	1531	46		235	1529	38
	226	1819	37		236	1809	49
			Mean 48%				Mean 47%

SUMMARY AND CONCLUSIONS.

1. Twenty oblique hauls of a stramin ring-trawl, diameter of mouth 5 feet, were made during a period of 48 hours off Liverpool, Nova Scotia, in May, 1932.

2. The common species were *Thysanoëssa raschii*, *Th. inermis*, *Sagitta elegans*, *Calanus finmarchicus* and *C. hyperboreus*.

3. All of the above occurred in the collections made during the night in larger numbers than in those in the daytime. No such discrepancy appeared in the case of the Fish Ova.

4. The discrepancy is held to be due in each case to a proportion of the population sinking to depths greater than could be sampled by the net.

5. Adult *Calanus finmarchicus* tended to disappear to a relatively

greater extent than individuals in Stage V. No such phenomenon could be detected in the larger specimens of *Sagitta elegans*.

6. Discrepancies of this kind would have to be taken into account when lines of Stations are worked by day and night. The probability of error will be greatest where the mesh employed is large, and particularly so in those cases where the lowest levels are left unsampled.

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