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THE VERTICAL DISTRIBUTION AND DIURNAL MIGRATION OF CLADOCERA, *EVADNE NORDMANII* LOVEN AT DIFFERENT STATIONS IN THE IRISH SEA

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ABSTRACT

The vertical distribution and diurnal migration of *Evadne nordmanii* has been studied at different stations in the Irish Sea. There are many reports that the migrations of planktonic animals tend to be hampered by thermoclines and haloclines. Physical and chemical factors were compared with vertical distribution and diurnal migrations of the animal. *Evadne* must be essentially an epiplanktonic form with the ability to endure strong light intensity. The animals generally migrated to the very surface layer from their shallow day strata with the decrease of light intensity. During the night their distribution seems rather random or even throughout all the layers, with a tendency to concentrate at the bottom layers, when the water was homogeneous physically and chemically. *E. nordmanii* may penetrate minor thermocilines and haloclines, but they may avoid chemically distinct waters or possibly deep currents.

INTRODUCTION

The plankton of the Irish Sea has been extensively studied from the point of view of seasonal abundance (Herdman and his various co-workers, 1908-1921; Johnstone, Scott and Chadwick, 1924) and horizontal distribution (Williamson, 1952, 1956 a,b, 1963). Herdman and Scott(1909) also made occassional observations on the plankton at different depths, but this aspect of plankton research has never been the subject of any detailed study in these waters. Bainbridge(1958) reported on the vertical distribution of *Evadne* in Clyde Sea Area.

While Raymont(1963) regarded *Evadne* as a neritic species. Joregensen(1933) pointed out that it cannot be regarded as a neritic species and current play a very important role in its distribution in the Irish Sea. The comparative shallowness of the Irish Sea and the lack of barriers to the horizontal dispersion of planktonic species makes it unlikely that it will contain genetically distinct population of any species, but it contains a considerable range of depth, regions of strong and weak tides and a rather complex system of residual currents. It was therefore decided to make comparisons of the vertical distribution of the species at different stations with contrasting features within this sea area.

It is generally accepted that the diurnal change of light intensity is the most important single factor governing the diurnal migration of the animal(Russell, 1927; Bainbridge, 1961; Harris and Wolf, 1955). There are also many reports that the migrations of animals tend to be hampered by thermoclines and haloclines. Little consideration seems to have been given to the posibility that the animals may also respond to other chemical gradients and therefore investigations of the concentrations of nutrients at various depths were included in the present study.

MATERIALS AND METHODS

During 1969, samples were taken during daylight from four stations in the Irish Sea: two offshore stations A,B and two deep water stations C,D(Fig. 1). Plankton and hydrographical water samples were collected from various depths at each station.

Samples at station A were obtained from the motor boats, Cypris (8.8m) and Silver Spray (8.5m). All other samples were taken by R. V. Cuma (19.8m). Samples from stations A,B and C were taken about the middle of the day, those from station D at about 17.00 hrs. The times and dates of sampling are shown in Table 1. The aim was to occupy all stations within a fortnight and to repeat the sampling every two or three months. Comparable samples from stations A,B and C were not seperated by more than eight days except in November. Because of weather conditions, it was very difficult to match the times of collection at station D to those at other stations.

In 1970, samples were taken from stations B and E throughout 24 hours periods with R. V. Cuma. On October 11, 1969, samples were taken throughout 24 hours at station B as a preliminary study for the 1970 programme.

The samples were taken with a Clarke-Bumpus plankton sampler in a series of horizontal tows, each of about 10 to 15 minutes duration. The metering unit of the sampler was calibrated after towing a certain distance between two

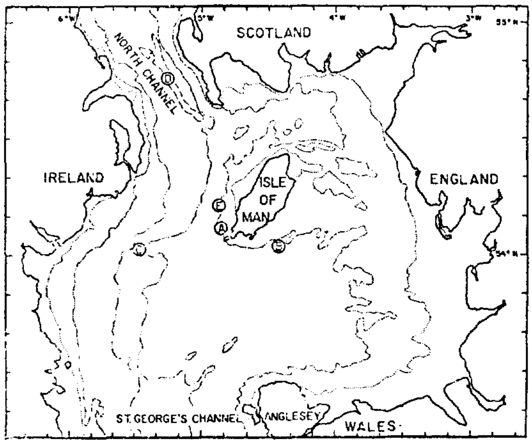

Fig. 1. Sampling stations in the Irish Sea and submarine contour.

Station A. 54°05′N, 4°50′W.	Submarine contour.	
Station B. 54°01′N, 4°25′W.	....	18 metres.
Station C. 54°00′N, 5°27′W.	....	37 metres.
Station D. 54°47′N, 5°16′W.	....	91 metres.
Station E. 54°12′N, 4°51′W.	....	182 metres.

buoys in Port Erin Bay.

The nets used in the sampler were made of No. 10N Nylon (0.24mm aperature size). The net was carefully washed after each sample and the washings added to the catches. The nets were changed each time as a precaution against contamination of samples by material from the previous hauls. The catches were preserved immediately the net came aboard by addition of concentrated formalin to bring the solution to a strength of 5%.

At station A, the sampler was towed at a speed of 2 to 3 knot with a multiplane kite ottor depressor (Colton, 1959). Furthermore towing depths were checked with "Selax"t ubes. At other stations, a heavy iron weight(250kg) was used with thicker trawl warp. At deep water stations C and D, no angle correction was needed, the because of the depth of weight was detected by echo-sounder below 60 m from the surface.

Water sampling was carried out just before or after plankton collections, at all stations and a Nansen-Paterson insulated water bottle

Station	Sampling			Weather condition		Remarks
	Date	Time	Mean time	Sky	Wind force*	
A	28- 1-1969	1300-1400	1330	Overcast	3	
	24- 3-1969	1320-1420	1350	Overcast	2	
	29- 5-1969	0940-1045	1010	Light cloud	2	
	25- 7-1969	0950-1050	1020	Light cloud	3	
	11-11-1969	1315-1410	1345	Overcast	2	
B	22- 1-1969	1250-1410	1330	Cloudy	2	
	26- 3-1969	1220-1340	1300	Light cloud	2	
	22- 5-1969	1155-1310	1230	Overcast	2	Very misty
	21- 7-1969	1120-1245	1200	Overcast	6	
	21-10-1969	1125-1240	1200	Cloudy	2	
C	29- 1-1969	1230-1500	1345	Overcast	6	
	27- 3-1969	1255-1520	1410	Cloud patches	2	
	23- 5-1969	1300-1530	1415	Cloudy	2	
	23- 7-1969	1235-1510	1350	Bright	0	
	12-11-1969	1300-1530	1420	Overcast	3	
D	3- 3-1969	1500-1800	1630	Overcast	2	Raining
	6- 5-1969	1530-1900	1710	Overcast	3	Raining
	30- 6-1969	1600-1910	1730	Overcast	2	Drizzling
	9-12-1969	1500-1815	1645	Overcast	5	Drizzling

Table 1. Date, time of sampling and weather condition during 1969. Wind force*=Beaufort wind scale.

was used for the collection of these samples. At station A, samples from May, July and November were collected four hours earlier than the plankton samples and, except in January, surface and bottom samples were taken. Long term hydrological studies at station A (Slinn, personal communication) have shown that there is usually no significant gradient between the surface and bottom, particularly during the summer.

In 1970 at all 24 hour stations, two samples, one in daytime and one at night, were taken. Samples were not collected on the west side at station B in February, because of gale force winds, and a night sampling at station E in June was also impossible for the same reason.

Oxygen was estimated by the Winkler method described by Jacobsen, Robinsen and Thompson (1950). The standard deviation of the method was found in ten estimations to be 0.018(38%). An Auto-lab salinometer was used for all salinity estimations.

Nutrients were all estimated colorimetrically: for nitrate, the method of Strickland and Parsons (1960) which was modified from Mullin and Riley's procedure(1955), was used, and for convenience nitrite measurements were done by the same method. Silicate was estimated by the method of Mullin and Riley (1955). Phosphate was measured using stannous chloride as a reducing agent, using a method based upon the procedure of Harvey (1948) and Armstrong (1949).

RESULTS

The results of seasonal abundance, physical and chemical factors at different stations in 1969 are summarized in Fig. 2. During 1969, *Evadne nordmanii* was found at some stations from March to December. When there was not any single specimen in the samples, it has not been described in Fig. 2. The maximum numbers occurred from May to July. In May, at stations A and C on the west side of the Isle of Man, the animals caught far exceeded those caught at other stations, while maximum occurrences at stations B and D occurred in June

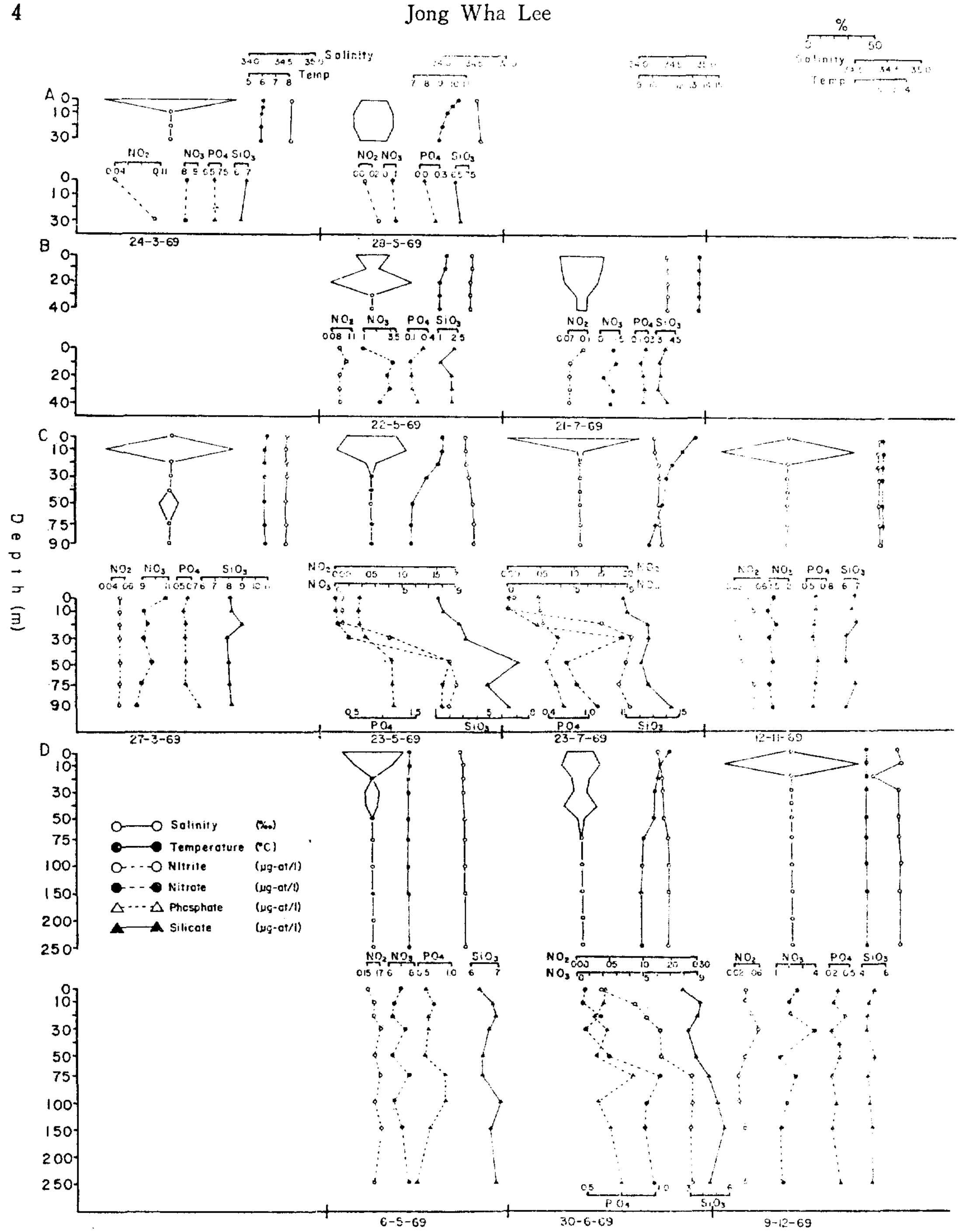

Fig. 2. Vertical distribution of *Evadne nordmanii* in 1969. The width of the kite diagram at a given depth represents the percentage of the total number of organisms caught at that depth per m^3. When organisms represented less than 1% of the total, these are shown as a dot, when no organisms were present, as a small circle. The time and date of each samples is given below the appropriate kite diagram. The results of physical and chemical factors are incorporated with each kite diagram.

and July respectively.

While Raymont (1963) regarded *Evadne* as a neritic species, Joregensen (1933) pointed out that it cannot be regarded as a neritic species and currents play a very important role in its distribution. She assumed that the species entered from St. George's Channel and must be rare in the western Irish Sea because of the main north-going currents through the eastern part of the Sea. Although there was a sampling gap of seven days between stations A and B in May this is probably insufficient to account for the low density at station B; the other west side station C, produced a very high concentration with a single day interval from station B. Samples taken in May by Williamson (1956a) also show a higher concentration on the west side than on the east side in 1952, but a sample in 1951 gave the opposite result. It seems that the great densities at stations A and C were affected by the mixing of inflowing water and water to the south-west of the Isle of Man (Williamson, 1956).

Abundances in the North Channel, recorded at station D in late June, seem to have some relationship with the stock of the eastern Irish Sea, considering densities at station B in July and north-going currents through the eastern Sea.

Kusmorskaya (1954) suggested that many dead Cladocera were found below the thermocline. Those animals found at 75 and 90 m at station C and 150 m at station D may have been dead animals, but this was not proved by staining.

In 1969, maximum abundances occurred above 20 m at all stations during the day. Samples in July from station B and C and in May from station D show maximum abundances at the surface layers, while a sample in May from station A shows the same concentrations at the surface and at the bottom (150 animals/m^3) with maximum abundance (250/m^3) between 10 and 20m. The virtual absence of *E. nordmanii* in samples from below 50 m suggests that it actively avoids the deeper layers. Its level of maximum day time abundance was always in the upper 20 m but not at any consistent level within this range.

The results at 24 hour stations B and E are summarized in Fig. 3 and 4. There was not a single organism in samples taken on October 21, 1969 at station B and on February 11, 1970 at station E, and these were not included in Fig. 3 and 4. Vertical distributions at the 24 hr. stations in 1970 show very contrasting results: a downward movement at night at station B and no conspicuous movement at station E. Results at station B were as follows:

June 3, 1970 - Maximum abundance shifted to the 5 m layer from 20 m at around 17.00 hrs. and arrived at the surface at sunset, and the maximum abundance was found at the bottom layer at midnight. Samples taken during the period of sunrise again showed a secondary maximum very clearly, at typical day depth of 10 m.

June 10, 1970 - Maximum abundance was at the 10 m layer at noon with considerable numbers at the surface; the maximum was at the 5 m layer at 17.00 hrs., with only five animals /m^3 at the surface compared with 60/m^3 at noon. There was a great reduction in the numbers of animals at 20 m between noon and 17.00 hrs., probably due to upward migration. Movement towards the bottom in darkness was later and less marked than on June 3. A tendency to upward movement with rather random distribution was shown by the samples taken during sunrise.

At station E, the animals showed no tendency to migrate to deep water at night as at station B. They were distributed mainly in the 5 and 10 m layers both during the day and at night, but a secondary maximum abundance in the 30 m layer at midnight was found in the samples taken on May 4, 1970.

DISCUSSION

The investigations made by Wiborg (1940, 1944, 1954, 1955) on the plankton in the Nor-

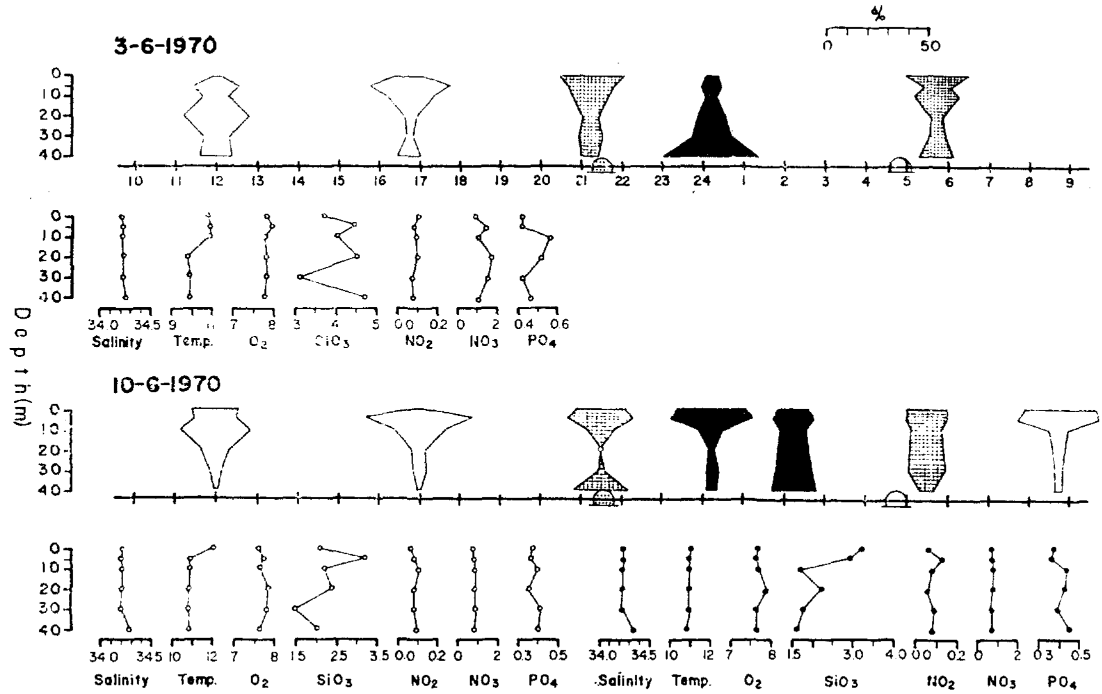

Fig. 3. Diurnal migration of *E. nordmanii* at station B in 1970. The horizontal scale represents the time of day (sunset indicated by dotted half circle and sunrise by half circle). Daytime samples are shown as white kite diagrams, dusk and dawn by cross hatches diagrams and night samples by black diagrams. N.S stands for no sampling because of mechanical failure. The results of physical and chemical factors one in day time (right half) and one at night (left half) are incoporated under kite diagram.

wegian coastal waters have shown that *Evadne* is mainly to be found living near the surface. Results from Bainbridge (1958) in the Clyde Sea area are similar to those of the present work; maximum abundance was always above 20 m layer. Bigelow (1926), Wiborg (1955), Motoda and Anraku (1952) also reported in other seas that they were always collected in the surface hauls. *Evadne spinifera* and *E. tergestins* occurred in the 0—20 m layer only (Vučetić, 1961). This shows that the optimum light intensity for the *E. nordmanii* is very high, if light is the main controlling factor of the depth at which the species normally lives, as claimed by Russell (1927).

Kusmorskaya (1954) says that "Cladocera, *Evadne* were found only above the zone of the thermocline. Below the thermocline, many dead Cladocera were found. Temperature apparently has a direct influence on the distribution of Cladocera". Ackefors (1969) pointed out that their distribution was above the discontinuity of temperature and salinity, and Hansen (1951) has noticed similar results. The distribution of the animals in May, June and July at stations C and D agrees with these observations.

All samples showed some upward and downward movement according to the decrease and increase of light intensity except the sample of August 11, 1970 at station E, when the maximum abundance retreated from the 5 m layer at 12.45 hrs. to the 20 m layer at 17.45 hrs.; photometer reading were reduced by one third at 17.00 hrs. from those of 12.45 hrs. While downward movement was conspicuous at around midnight in 3rd June, 1970 at station B, majority was in upper layer on 10th June, 1970. The comparative results can not be fully

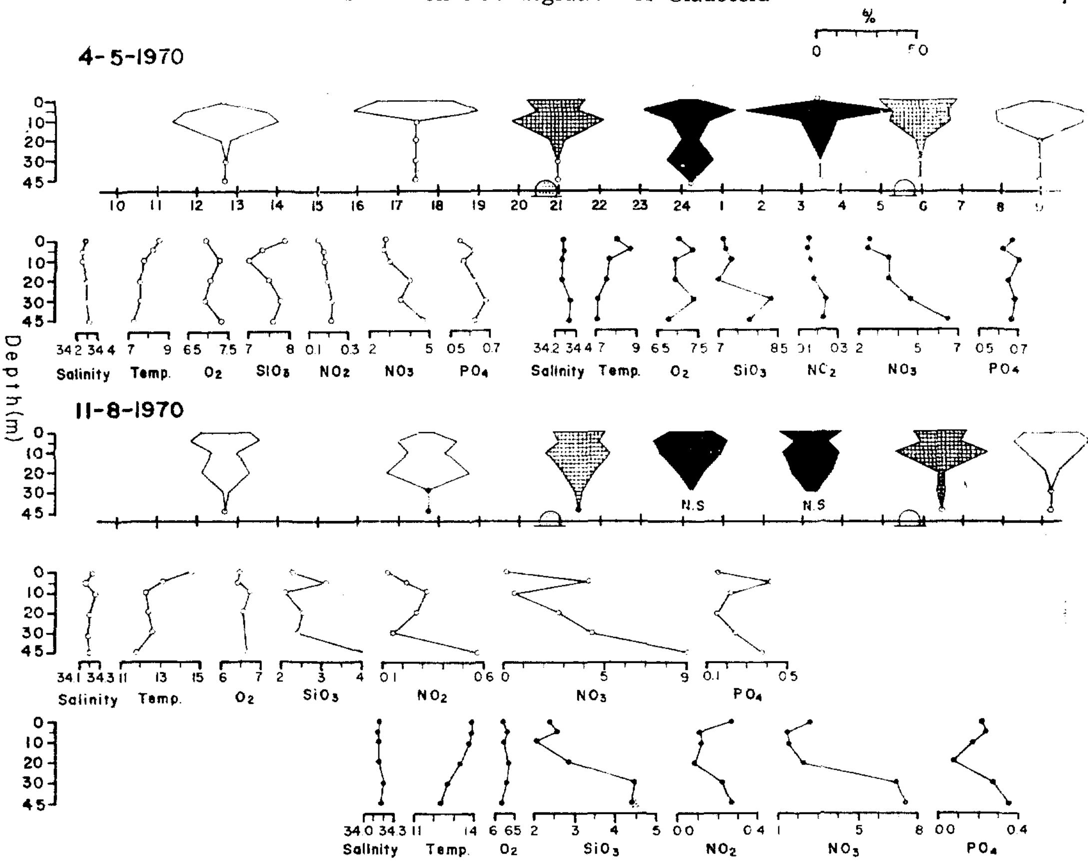

Fig. 4. Diurnal migration of *E. nordmanii* at station E in 1970 (sunset indicated by dotted half circle and sunrise indicated byhalf circle).

explained in terms of physical and chemical factors because valuable night water samples on 3rd June, was not available due to weather condition.

Savage (1926) described an upward migration from midwater to the surface, and a slight downward one from midwater to the bottom at night. The work of Kikuchi (1938) in the Hiruga lake produced similar results to those of station B in 1970; the animals were distributed from the surface to 10 m, but apparently descended at night. There were no noticeable temperature and salinity gradients at station B. Some temperature and salinity differences which can be regarded as significant at shallow water stations were noticeable at station E. On May 4, 1970, there was a temperature gradient between 5 and 10 m, but secondary maximum abundance was found in the 30 m layer below the thermocline and halocline layers at midnight. Two valuable bottom samples in the early morning were not available on August 11, 1970 due to the mechanical failure of the sampler but the animals might have avoided the very bottom layer.

Evadne must be essentially an epiplanktonic from with the ability to endure strong light intensity. The animals generally migrated to the very surface layer from their shallow day strata with the decrease of light intensity. During the night their distribution seems rather random or even throughout all the layers, with a tendency to concentrate at the bottom layers, when the water was homogeneous physically and chemically.

Apparent avoidance of the bottom layers at station E cannot be fully explained in terms of temperature and salinity, but these waters showed relatively high values of silicate and phosphate. The only conclusion that can be drawn is that *E. nordmanii* may penetrate minor thermoclines (about 1.0°C) and haloclines (about S. 0.05‰), but they may avoid chemically distinct waters or possibly deep currents.

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