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NET AVOIDANCE BEHAVIOUR AMONG LARVAL, JUVENILE AND ADULT EUPHAUSIIDS

K. J. MATHEW
Central Marine Fisheries Research Institute, Cochin-682 031

ABSTRACT

During the present investigations an attempt was made to assess the degree of net avoidance capability of euphausiids at the larval, juvenile and adult levels. The study was faciliated by a series of zooplankton samples collected during both day and night from 5 m above bottom to the surface. In spite of sampling from 'almost' bottom, striking difference in the avilability was observed especially for the adults of several species being, in most of the cases, more in the night samples. The results obtained have led to derive some conclusions on the behaviour of euphausiids.

The present studies indicated that as far as the larvae were concerned, the degree of variation in abundance was least between day and night and this speaks for their inability to avoid an approaching net in the day light. However, marked increase in number was osbserved with the juveniles in the night samples. A night time increase by 57 times was observed with the juveniles of *Euphausia diomedeae*, a surface shoaling species, whereas *Stylocheiron affine*, a mesopelagic species showed an increase by 0.21 times only in the night samples. The adults also showed marked difference of occurrence between day and night. An increase in number by 65.7 times was noticed in the night abundance of *Euphausia sibogae*, again a surface swarming species, over the day time occurrence. However, in the case of *S. affine* the night time increase was of the magnitude of 2.3 times only.

INTRODUCTION

THE EUPHAUSIIDS being provided with well developed locomotory appendages are relatively fast moving and are known for their diurnal vertical migration. The difference in size among species and within species (larvae, juveniles and adults) makes each one of them perform locomotory movements in varying intensities. Usually more euphausiids are caught in samples collected during the night and this is attributed to their entry into the sampling area from the deeper areas during the night by vertical migration. Eventhough vertical migration is one of the factors influencing the night time abundance of euphausiids there can be several other factors controlling this phenomenon. Studies conducted by some of the earlier workers show that the euphausiids dodge or sink at the approaching of nets during the day time (Tattersall, 1924 ; Mackinthosh, 1934 ; Hardy, 1936 ; Moore, 1950 ; Barham, 1957 ; Marr, 1962 ; Brinton, 1967 ; Jerde, 1967). The avoidance capability may be evinced more by the adults than by larvae or juveniles, especially by those living in the surface waters. Moore (1950) estimated an escapement factor of atleast 10 by comparing catch data and *in-situ* visual estimates of bioluminescence. Therefore it becomes apparent that the numerical abundance of planktonic organisms, especially the adult euphausiids, in the night samples cannot be attributed to vertical migration alone. This is more proved when sampling is done from bottom to the surface during both day and night and still differences in abundance occur, being more in the night samples.

Eventhough some information ere available on the net avoidance behaviour of euphausiids, studies have not been made on the reaction of different stages of euphausiids (larvae, juveniles and adults) to an approaching net. Also there has not been any quantification of net avoidance behaviour among the different stages. The present study is aimed at resolving the above two aspects.

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Material and Methods

The material used for the present investigations was collected during the cruises of R. V. *VARUNA* from the continental shelf area of the southwest coast of India over a period of one year on a bimonthly basis. A total of 182 samples collected with the IOS Net were examined of which 80 were taken during night. Sampling for zooplankton was carried out from 5 m above bottom to the surface as open vertical hauls. The larvae, juveniles and adults of the species considered were sorted out separately and enumerated. Six abundantly occurring euphausiid species namely *Pseudeuphausia latifrons*, *Euphausia diomedeae*, *E. sibogae*, *Nematoscelis gracilis*, *Stylocheiron armatum* and *S. affine* were selected for the present study. For each the samples of all the months were grouped under day and night category as the case may be. Since the day samples were more in number than the night samples, for the sake of comparison, first the night samples were made proportionate to the day samples. Similarly, the proportionate occurrence of specimens in the night samples in relation to their number in the day samples was also estimated in the same way. Finally the actual number of samples/specimens in samples was compared with the estimated values for the night samples to get the rate of increase/decrease of/in the night samples by using the formula $R = \frac{AN}{EN} - 1$, where R is rate of increase/decrease of/in night samples over day samples, AN is actual number of/in night samples and EN is estimated number of/in night samples.

Net avoidance among larval euphausiids

The results of the study are given in Tables 1 and 2. From Table 1 it is seen that larval forms of species except *S. affine* occurred in more number of night samples than in the day samples. Further the night samples were comparatively more in the case of *E. diomedeae* and *N. gracilis* and the increase was by 1.55 and 1.07 times respectively than the day samples. The least increase with regard to the night samples was noticed in the case of *P. latifrons*. However, with regard to *S. affine* the day samples showed a slight edge over the night samples.

The proportionate occurrence of larval specimens in the night samples in relation to the day samples as given in Table 2 indicates that in the case of all the species the occurrence of larval specimens was more in the night samples, the degree of increase ranging from 0.3 to 10.6 times. The maximum abundance was observed in the case of *E. diomedeae*.

Net avoidance among juvenile euphausiids

The results of the study are given in Tables 2 and 3. The juveniles of all the species considered occurred in more number of night samples. The rate of increase of night samples in which the juveniles occurred was more than the samples in which the larvae were present except in the case of *N. gracilis*. The greatest variation in the number of day and night samples was found with *E. diomedeae* in which

TABLE 1. *Estimated number of night samples and the rate of increase/decrease of the same in relation to positive day samples in which the larvae occurred*

Species	Actual No. of samples in which larvae occurred		Estimated No. of night samples to make them proportionate to day samples	Rate of increase (+)/decrease (—) of night samples over day samples
	Day	Night		
P. latifrons ..	32	29	25.10	+ 0.16
E. diomedeae ..	6	12	4.71	+ 1.55
E. sibogae ..	22	22	17.25	+ 0.28
N. gracilis ..	8	13	6.27	+ 1.07
S. armatum ..	18	19	14.12	+ 0.35
S. affine ..	18	13	14.12	— 0.08

Total No. of day samples examined : 102, night samples examined : 80.

TABLE 2. *Estimated number of larvae in night samples and the rate of increase of the same in relation to that in the positive day samples*

Species	Occurrence of larvae (No./1000 m³ of water)		Estimated No. of larvae in night samples to make them proportionate to day samples	Rate of increase (+) of specimens in night samples
	Day	Night		
P. latifrons ..	125	165	98	+ 0.7
E. diomedeae ..	6	58	5	+ 10.6
E. sibogae ..	544	1968	427	+ 3.6
N. gracilis ..	17	17	13	+ 0.3
S. armatum ..	44	113	35	+ 2.2
S. affine ..	35	40	28	+ 0.4

TABLE 3. *Estimated number of night samples and the rate of increase of the same in relation to posttive day samples in which juveniles occurred*

Species	Actual No. of samples in which juveniles occurred		Estimated No. of night samples to make them proportionate to day samples	Rate of increase (+) of night samples over day samples
	Day	Night		
P. latifrons ..	21	26	16.47	+ 0.58
E. diomedeae ..	3	8	2.35	+ 2.40
E. sibogae ..	18	21	14.12	+ 0.49
N. gracilis ..	9	14	7.06	+ 0.98
S. armatum ..	12	17	9.41	+ 0.81
S. affine ..	15	13	11.76	+ 0.11

case the rate of increase of night samples was of the order of 2.40 times than the day samples. This was followed by *N. gracilis* and *S. armatum*. The least difference was observed in the case of *S. affine*. The findings on juveniles were further verified by a study on the numerical abundance of juvenile specimens in the day and night samples. The results of the study are given in Table 4.

With regard to the number of samples in which the adults occurred, a remarkable increase was noticed with the night samples and the rate of increase was far more than that was found with the larvae or juveniles (Table 5). The maximum difference was observed for *N. gracilis* which occurred in 13.10 times more night samples than day samples. The least difference between the day and night samples was found again with regard to *S. affine* (0.11).

TABLE 4. *Estimated number of juveniles in night samlpes and the rate of increase of the same in relation to that in the positive day samples*

Species	Occurrence of juveniles (No./1000 m³ of water)		Estimated No. of juveniles in night samples to make them proportionate to day samples	Rate of increase (+) of specimens in night samples
	Day	Night		
P. latifrons ..	44	78	35	+ 1.2
E. diomedeae ..	1	58	1	+ 57.0
E. sibogae ..	51	124	40	+ 2.1
N. gracilis ..	4	21	3	+ 6.0
S. armatum ..	3	45	2	+ 22.0
S. affine ..	18	17	14	+ 0.2

From Table 4 it is seen that the juveniles or *E. diomedeae* were especially more in the night samples and the difference was of the order of 57.0 times than in the day samples. The same was the trend with the larvae of this species (Table 1 and 2). *S. armatum* came next in whose case the increase in the night samples was of the magnitude of 22.0 times. In the other species the difference in number between the day and night samples ranged from 0.2 time in *S. affine* to 6.0 times in *N. gracilis*.

Net avoidance among adult euphausiids

The adult specimens obtained during the present investigations were separately treated to get some information of their behaviour. The method as it was applied to the larvae and juveniles was used for the adults also. *E. diomedeae* was not considered for this study because the adults of this species were very scarse in the samples.

When the number of adult specimens in the day and night samples was considered it was found that in the case of all the species considered the night samples contained comparatively more number of them than in the day samples (Table 6). The greatest abundance in the night samples was observed with *S. armatum* (86.0 times) and *S. sibogae* (65.7 times). With regard to the other species also the rate of increase in the night samples was far more than in the day samples.

DISCUSSION

The night time abundance of euphausiids could have been attributed to their vertical migration had the samples been collected from intermediate levels of the water column to the surface. In the present case since all the samples, collected during day as well as night were from bottom to the surface the

influence of vertical migration could be ruled out.

The net avoidance as a behaviour has been studied in other planktonic organisms also. Mysids have been found to avoid nets used in littoral region. Flemminger and Clutter (1965) found that sampling for *Metamysidopsis elongata* was more efficient in darkness. The euphausiids escaping nets have been studied more than 30 mm tended to escape capture by nets moving through the water at speeds less than almost 1 m per second. However, there was no difference between number of smaller animals caught in slow and fast hauls. Jerde (1967) obtained evidence of avoidance of 1 m net by euphausiids in the size range of 22-28 mm. Brinton (1967) studied the net avoidance behaviour among a number of species and found that *Nyctiphanes simplex*, *Thysanoessa gregaria*,

TABLE 5. *Estimated number of night samples and the rate of increase of the same in relation to positive day samples in which adults occurred*

Species	Actual No. of samples in which adults occurred		Estimated No. of night samples to make them proportionate to day samples	Rate of increase (+) of night samples over day samples
	Day	Night		
P. latifrons ..	14	20	10.98	+ 0.82
E. sibogae ..	5	16	2.92	+ 4.48
N. gracilis ..	1	11	0.78	+ 13.10
S. armatum ..	3	18	2.35	+ 6.66
S. affine ..	15	13	11.76	+ 0.11

to some extent in the past. Marr (1962) after studying the swarming nature of krill (*Euphausia superba*) and the samples collected both day and night concluded that both avoidance and vertical migration could be contributing, equally perhaps, to the day time minimum in the surface catch. Mauchline (unpublished) towed 1 m stramin net at different speeds and found that *Meganyctiphanes norvegica* of body length *Stylocheiron suhmi*, and *S. affine* effectively avoided nets in the surface layers while *Euphausia recurva*, *E. mutica*, *Nematoscelis difficilis*, *Nematobrachion flexipes*, *Stylocheiron elongatum*, *S. abbreviatum* and *S. maximum* effectively avoided nets in the deeper layers.

The present study not only gave an insight into the capacity of different species of euphau-

TABLE 6. *Estimated number of adults in night samples and the rate of increase of the same in relation to that in the positive day samples*

Species	Occurrence of adults (No./1000 m³ of water)		Estimated No. of adults in night samples to make them proportionate to day samples	Rate of increase (+) of specimens in night samples
	Day	Night		
P. latifrons ..	6	60	5	+ 11.0
E. sibogae ..	4	200	3	+ 65.7
N. gracilis ..	1	8	1	+ 7.0
S. armatum ..	3	174	2	+ 86.0
S. affine ..	19	50	15	+ 2.3

siids to avoid net, but also gave specific evidence to the same exhibited by their larvae, juveniles and adults. The three life stages of almost all species considered showed night time abundance eventhough in varying degrees indicating that all are capable of dodging the net when it is visible to the eyes, that is during the day. While the larval forms could avoid the net to the least extent, in view of their limited mobility, the juveniles with their better locomotory powers could escape from being captured in a better way and the adults especially of those surface living species which could very well see an approaching net could perform it still more efficiently.

It is worthwhile to discuss here the degree at which the different species and their life history stages reacted to the net in the day light (Table 2, 4 and 6). All three life stages of *S. affine* which is one of the smaller species of euphausiid showed the least tendency to move away from the net. This was evidenced by their almost equal occurrence in the day and night samples. *P. latifrons* which is also a smaller species, and living in the neritic waters exhibited net avoidance to a moderate extent. The larvae and juveniles of *E. diomedeae* were more in the night samples. The larvae and juveniles of *E. sibogae* did not show any pronounced night time abundance but their adults were exception to this. This again is a surface living species. *N. gracilis*, a mesopelagic medium sized species did not show great difference in occurrence between day and night at their early stages suggesting that their capacity to move away from the net was negligible. Almost same was the experience with *S. armatum* also.

The less number of day samples itself in which larvae, juveniles and adults were caught as noticed during the present investigations (Table 1, 3 and 5) may be reckoned as an indirect evidence to the differential behaviour of these life history stages during day and night which finally tell upon the net avoidance reaction of fast moving planktonic organisms. In conclusion it may be stated that while the tendency to avoid a sampling net is almost universal among epi and mesopelagic species of euphausiids (being more among relatively larger species living in epipelagic zone), it is least among larvae, comparatively pronounced among juveniles and maximum among adults and this tendency is manifested by visual as well as locomotory capabilities.

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