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GROWTH PATTERN AMONG THE POST-NAUPLIAR STAGES OF THREE SPECIES OF EUPHAUSIACEA (CRUSTACEA)

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ABSTRACT

Experimental data regarding the larval development in Euphausiacea are very much limited and hence the pattern of larval development and the growth rate are estimated by making use of the material obtained from the open sea. Several methods of estimating the growth have been in use. The author attempts here to demonstrate the growth pattern among the post-naupliar developmental stages of three species namely *Euphausia diomedeae* Ortmann, *E. sibogae* Hansen and *Stylocheiron armatum* Colosi, based on material obtained from the southeastern Arabian Sea. A comparative study has also been made of the pattern of growth among these species.

The percentage of increase in body length in the three species mentioned above generally showed considerable decrease as development progressed from first calyptopis onwards. However, considerable variation was observed in the rate of increment in length in between species. It was also found that the larval length and the length in adults are not proportional in the three species. The accuracy of the identity of larval stages and of the larval sequence were verified using the 'Brooks Law' of larval growth. Attention is also drawn to the modern technique of calculating growth rates by the application of log/linear regression equations relating the duration of the intermoult period to successive moult numbers or body lengths.

INTRODUCTION

In Euphausiacea, although development is a continuous process, the greater part of the growth occurs at ecdyses and therefore is a step-like process. Well defined larval stages have been identified in euphausiids at naupliar as well as post-naupliar levels. The rate of growth of larvae and adults of several species of euphausiids occurring in the Pacific, Atlantic, Arctic and Antarctic Oceans have been estimated by several authors, through statistical analysis of samples of natural populations and in some cases through observing the growth and moulting in the laboratories and these have been reviewed by Mauchline and Fisher (1969) and Mauchline (1980). But there is practically no information on growth aspects of euphausiids from the Indian Ocean.

The egg size in different species of euphausiid vary considerably. However, there is no direct relationship between the size of the egg and the size of the adults. The size of the eggs greatly influences the naupliar and calyptopis stages, these stages being comparatively larger in species where the egg size is relatively larger. With this fact in view a study was taken up for understanding the growth pattern among the post-naupliar stages of three species of euphausiids abundantly occurring in the Arabian Sea, of which two belong to the genus *Euphausia* (in which case the eggs are relatively smaller and are shed freely into the water) and the third one belongs to the genus *Stylocheiron* (in which case the eggs are relatively larger and are carried by the females). It is to be mentioned that no attempt is made here to relate the larval lengths with time or to make any conclusions on the time required for the development and differentiation of a species through the different stages. The detailed morphological descriptions of the larvel stages of species considered have been given by Mathew (1971 and 1973).

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Material and Methods

The euphausiid larval material used in the present study was obtained from the zooplankton samples collected with the Indian Ocean Standard Net (Curie, 1963) during the cruises of R. V. *VARUNA* from the continental shelf areas between Calicut and Karwar (latitudes 11° 32′ N and 14° 54′ E) along the southwest coast of India. The zooplankton was collected as open vertical hauls from almost bottom to the surface. The samples were preserved in 3% commercial formalin buffered with hexamine. In the laboratory the larval material of the concerned species was sorted out, separated into stages, identified, counted and measured.

Euphausia diomedeae

Three calyptopis and six furcilia stages were identified in this species. Altogether 40 larvae belonging to the calyptopis and 220 larvae belonging to the furcilia stages were measured. The length range and the mean in each of the larval stages are presented in Fig. 1. In this species the post-naupliar developmental stages are well demarcated without any overlapping in lengths in between stages. A slight overlapping in length was noticed in between furcilia stages 2 and 3. In this species the percentage of increase in length showed considerable decrease as development progressed from the first calyptopis onwards, but a slight irregularity was observed between furcilia 4 and 5. In the fourth furcilia the percentage of growth rate was slightly higher than in the previous stages. The observed increase in the percentage at the sixth furcilia could be due to the

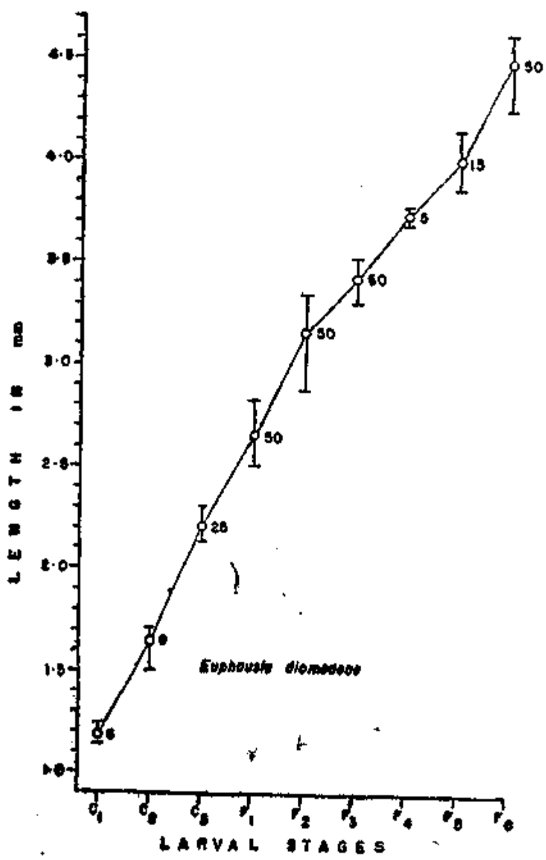

FIG. 1. The growth pattern among the post-naupliar stages of *Euphausia diomedeae*.

measurement of some of the immediate post-larvae (difficult to distinguish) along with the sixth furcilia larvae. In *E. diomedeae* the first furcilia stage is a critical stage from where onwards there is a drastic increase at each stage in the percentage of increase in the growth rate. For example when an increase by 1.02 mm took place at the calyptopis stages (3 instars), the length increment effected at the furcilia stages (6 instars) was 1.83 mm.

Euphausia sibogae

In this species overlapping of length occurred from the second furcilia onwards. It was slight in between F-2 and F-3 but quite pronounced from F-3 to F-6 (Fig. 2). Some larvae of common lengths occurred at three consecutive stages namely F-3, F-4 and F-5. The high percentage in the rate of increment in length was nullified with the second calyptopis in *E. sibogae*. From the third calyptopis onwards the rate of increase in length gradually reduced from 27.92 per cent in calyptopis-3

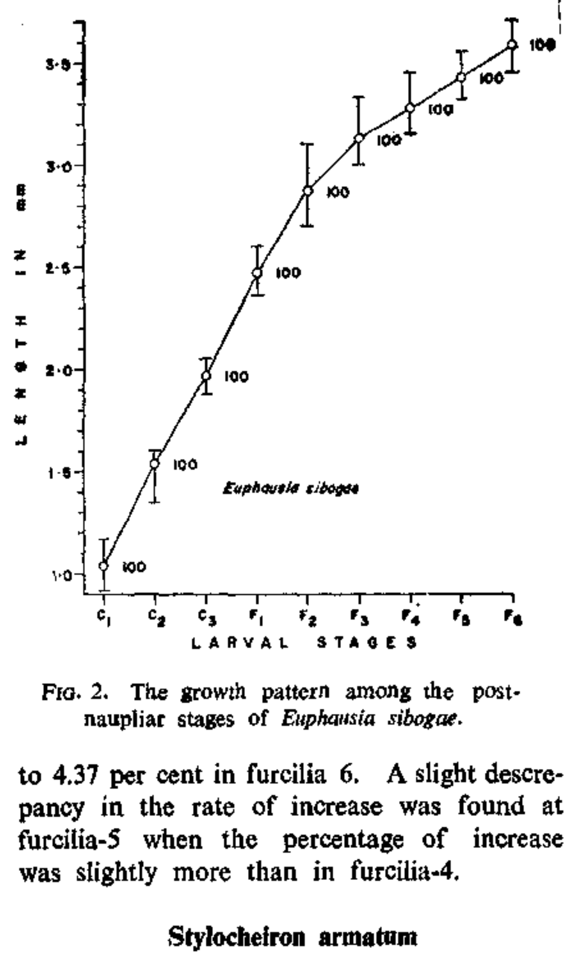

FIG. 2. The growth pattern among the post-naupliar stages of *Euphausia sibogae*.

to 4.37 per cent in furcilia 6. A slight descrepancy in the rate of increase was found at furcilia-5 when the percentage of increase was slightly more than in furcilia-4.

Stylocheiron armatum

In this species 53 larvae were measured for the calyptopis stages while the furciliae were represented by 490 larvae in six stages. The species exhibited a somewhat steady growth rate in the post-naupliar stages. Considerable overlapping of length occurred in between furcilia stages F-3 and F-4 (Fig. 3). The actual increments in length and the growth factor are given in Table 3. From Fig. 3 it is seen that the percentage of increase from the

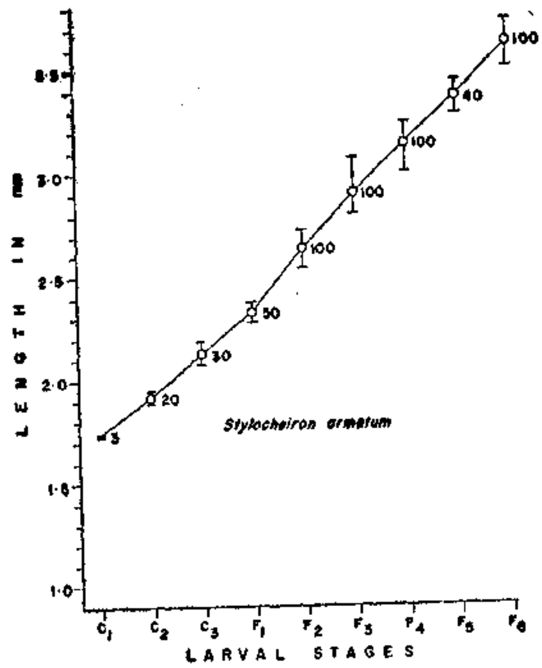

FIG. 3. The growth pattern among the post-naupliar stages of *Stylocheiron armatum*.

first calyptopis to the last furcilia is somewhat uniform unlike in the case of the first two species. The simple reason for this is that even at the calyptopis level, the larvae of *S. armatum* were longer than in the other two species, so that a substantial increase in length in the early stages was not required in this species as it was necessitated in the case of *E. diomedeae* and *E. sibogae*. However, a slightly accelerated growth rate was noticed in between calyptopis-3 and furcilia-1 and between furcilia-2 and furcilia-3. The highest growth rate and the percentage in increment in the post-naupliar stages were noticed when the larvae moulted from the third calyptopis to the first furcilia (Table 3).

Discussion

As could be expected for any other organisms, in the three species considered here also the percentage of increase in length at the early stages (calyptopes) was found to be greater than in the later stages (furciliae). However, the rate of increase varied considerably among the three species. In *E. diomedeae* and *E. sibogae* the rate of increment in length was more than that in *S. armatum* at the calyptopis levels.

From the published accounts it is seen that until the larval forms get their nourishment from the yolk of the eggs (metanauplius stage) not much size difference occur among the larvae of different species, eventhough their adult measurements varied very much. Mauchline and Fisher (1969) in their review of the works done on the larval development brought together in a Table the length ranges of nauplius, metanauplius and calyptopis of several species measured by various authors and there it was observed that the size of metanauplius of 11 species ranged between 0.40 and 0.80 mm only (except in the case of *Euphausia superba* and *Thysanoessa gregaria* in which it was more) and at the end of the calyptopis stages when the larvae started feeding actively the length ranged from 1.6 to 4.8 mm. However, in the case of species of *Stylocheiron* the length range of early stages themselves was more than that for the corresponding stage in others.

A comparative study of the size among the post-naupliar instars of *E. diomedeae*, *E. sibogae* and *S. armatum* revealed that the calyptopis of the last species, measured longer than the former two species. It becomes a matter of interest when it is considered that the total length of adult specimens of *S. armatum* measured much less than the adults of the other two species. The maximum lengths (mm) recorded for males and females are :

		Male	Female
E. diomedeae	..	16.00	17.50
E. sibogae	..	11.50	12.50
S. armatum	..	6.75	9.00

The increased lengths at the early stages of the larvae of *S. armatum* when compared to the other two species could be due to the reason that the eggs which are carried by the females of *S. armatum* are considerably larger on account of the large quantities of yolk and such a condition perhaps helps to hatch larger larvae. But after hatching the growth rate of the larvae of *S. armatum* slows down whereas in the other two species in which the size of the early larvae are smaller growth increase takes place at a faster rate to be proportionate to the adult lengths.

The early larvae of *S. carinatum*, an allied species of *S. armatum* has been measured by Lebour (1950) and it was found that the length ranged between 0.90 and 0.96 mm which is far more than for the similar stages in other genera of euphausiids. However, from the first calyptopis onwards the growth rate suddenly decreased.

Baker (1959) has studied the growth rate among the calyptopes and furciliae of *Euphausia triacantha*, a cold water species. The adults of this species measured more than about three times the adult length of *E. sibogae* and two times that of *E. diomedeae*. However, the first calyptopis larva had a mean length of 1.00 mm which is comparable to the length of the corresponding stage of the present two species of this genus. But from this stage

TABLE 1. *Rate of increase in length (in %) and the growth factors at different levels of development of post-naupliar stages of* E. diomedeae

Larval Stages		Mean length (mm)	Length increment (mm)	Percentage of increase	Growth factor	No. of larvae measured
C-1	..	1.18	..	..	..	6
C-2	..	1.64	0.46	38.98	1.39	9
C-3	..	2.20	0.56	34.15	1.34	25
F-1	..	2.65	0.45	20.45	1.20	50
F-2	..	3.15	0.50	18.87	1.19	50
F-3	..	3.42	0.27	8.57	1.09	50
F-4	..	3.73	0.31	9.06	1.09	5
F-5	..	4.00	0.27	7.24	1.07	15
F-6	..	4.48*	0.48*	12.00*	1.12*	50

C-1 to C-3 : Calyptopis stages 1 to 3.
F-1 to F-6 : Furcilia stages 1 to 3.
* biass due to difficulty in separating F-6 from immediate post-larvae.

TABLE 2. *Rate of increase in length (in %) and the growth factors at different levels of development of post-naupliar stages of* E. sibogae

Larval stages		Mean length (mm)	Length increment (mm)	Percentage of increase	Growth factor	No. of larvae measured
C-1	..	1.04	..	..	..	100
C-2	..	1.54	0.50	48.08	1.48	100
C-3	..	1.97	0.43	27.92	1.28	100
F-1	..	2.47	0.50	25.38	1.25	100
F-2	..	2.87	0.40	16.19	1.16	100
F-3	..	3.13	0.26	9.06	1.09	100
F-4	..	3.27	0.14	4.47	1.05	100
F-5	..	3.43	0.16	4.89	1.05	100
F-6	..	3.58	0.15	4.37	1.04	100

TABLE 3. *Rate of increase in length (in %) and the growth factors at different levels of development of post-naupliar stages of* S. armatum

Larval stages		Mean length (mm)	Length increment (mm)	Percentage of increase	Growth factor	No. of larvae measured
C-1	..	1.74	..	..	..	3
C-2	..	1.92	0.18	10.34	1.10	20
C-3	..	2.13	0.21	10.94	1.11	30
F-1	..	2.43	0.30	14.08	1.14	50
F-2	..	2.64	0.21	8.64	1.09	100
F-3	..	2.90	0.26	9.85	1.10	100
F-4	..	3.14	0.24	8.28	1.08	100
F-5	..	3.37	0.23	7.32	1.07	40
F-6	..	3.62	0.25	7.42	1.07	100

onwards the increments in larval length were about three times more in between each instar of *E. triacantha* than what was found in *E. diomedeae* and *E. sibogae* during the present investigation. This trend is observed to be maintained till the end of the last furciliae. For the sake of comparison the percentage of increase in length and the growth factors at the calyptopis and furcilia of *E. triacantha* have been worked out from the measurements given by Baker (1959) and the same is presented in Table 4.

Brooks (1886) observed that in the stomatopod larvae the increase in length from moult to moult was so constant that 'comparative measurements gave proof of identity which could hardly be made more conclusive by rearing the larvae'. In stomatopods he found the rate of growth to be an increase from stage to stage by a factor of 1.25. Fowler (1909) termed this numerical relationship between stages as 'Brooks Law' and stated that 'During early growth each stage increases at each moult by a fixed percentage of its length, which is approximately constant for the species and sex'. In copepoda and decapod larvae there is a marked tendency for the growth factor to be around 1.26 and the factor tends to decrease with age. Gurney (1942) worked out the growth factor among the larval stages of *Euphausia superba* based on measurements made by Fraser (1963) and found that the values fell around 1.31 with a range from 1.03 to 1.82. According to Gurney (1942) the 'Brooks Law' is not sufficiently exact to be relied upon; but may be a useful instrument when attempting to connect up into a series of larvae taken in plankton. He further states that if the growth factor between any two stages assumed to belong to the same species exceeds 1.5 for example, there is at least a possibility that there has been an error in identification.

An attempt has been made to work out the growth factor at the different post-naupliar stages of the three species considered here with the hope that it would give added proofs to the identity of the larvae as well as the sequence of larval stages (Tables 1-3). Thus it was found that in *E. diomedeae* the growth factors fell around 1.19 with a range between

TABLE 4. *Rate of increase in length (in %) and the growth factors at different levels of development of post-naupliar stages of* E. triacantha

Larval stages	Mean length (mm)	Length increments (mm)	Percentage of increase	Growth factor	No. of larvae measured
C-1 ..	1.0	..	..	..	24
C-2 ..	1.9	0.9	90.00	1.90	27
C-3 ..	2.9	1.0	52.63	1.53	82
F-1 ..	4.4	1.5	51.72	1.52	110
F-2 ..	5.7	1.3	29.55	1.30	152
F-3 ..	6.9	1.2	21.05	1.21	171
F-4 ..	8.1	1.2	17.39	1.17	130
F-5 ..	9.6	1.5	18.52	1.19	73
F-6 ..	9.6	0.0	0.0	1.00	71
F-7 ..	10.0	0.4	4.17	1.04	59

1.07 and 1.39 among the different post naupliar stages. It was also noticed that as the growth progressed from C-1 to F-5 there was a gradual reduction in the growth factor. However, a drastic drop in it was noticed between C-3 and F-1. In *E. sibogae* the growth factors among the post-naupliar stages clustered around 1.18 with a range from 1.04 to 1.48. The reduction in growth factor was regular and gradual but with an abrupt change in between C-2 and C-3. The growth factors among the larval stages of *S. armatum* was found distributed around 1.10 with a range from 1.07 to 1.14. Thus in all the three species considered here it was found that the growth factors in between the successive stages was below 1.5 and therefore it may be safely concluded that there was no ambiguity regarding the larval identification and the sequence of stages.

Recently an emperical approach to analysing growth rate of crustaceans has been developed by Mauchline (1980). He found that the duration of the intermoult period increased logarithmically while the growth factors decreased logarithmically when plotted against body lengths or successive moult numbers. In the absence of experimental data relating to growth factors to body length in Euphausiacea, Machuline (1980) found this decay of growth factors against increasing body length to be a good tool in the determination of larval stages especially when they are collected from different geographical areas in different seasons. When log/linear regression equations relating the duration of the intermoult period to successive moult numbers or body lengths were calculated by him for some species it was found that the correlation coefficients were significant at 1—5% level in majority of cases. The regression analyses of growth factors on successive moult numbers of the three species dealt with here have been done by Mauchline (1980) based on data published by the author.

References

Baker, A. De C. 1959. Distribution and life history of *Euphausia triacantha* Holt and Tattersall. '*Discovery*' *Rep.*, **29** : 309-340.

Brooks, W. K. 1886. Report on the stomatopoda collected by H.M.S. 'Challenger' during the years 1873-1876. *Voy. H.M.S. 'Challenger', Zoology*, **16** : 1-116.

Curie, R. I. 1963. The Indian Ocean Standard Net. *Deep Sea Res.*, **10** : 27-32.

Fowler, G. H. 1909. Biscayan plankton collected during a cruise of H.M.S. 'Research', 1900, Part XII. The Ostracoda. *Trans. Linn. Soc. London* (2) Zool., **10** : 219-236.

Fraser, F. C. 1936. On the development and distribution of the young stages of krill (*Euphasia superba*). '*Discovery*' *Rep.*, **14** : 3-192.

Gurney, R. 1942. Larvae of decapod crustacea. *Ray Soc., London, Monogr.*, **129** : 306 pp.

Lebour, M. V. 1950. Some euphausiids from Bermuda. *Proc. zool. Soc., London.*, **119** : 823-837.

Mathew, K. J. 1971. Studies on the larval stages of Euphausiacea from the Indian seas. 1. Diagonstic characters of post-nupliar stages of *Euphausia diomedeae* Ortmann and *E. distinguenda* Hansen. *J. mar. biol. Ass. India*, **13** (1) : 52-60.

——— 1973. Studies on the larval stages of Euphausiacea from the Indian seas. 2. Description of post-naupliar stages of *Stylocheiron carinatum* G.O. Sars. *J. mar. biol. Ass. India*, **17**(1) : 1-16.

Mauchline, J. 1980. The Biology of Mysids and Euphausiids. J. H. S. Blaxter, F. S. Russel and M. Yonge (Ed.) *Advances in Marine Biology*, Academic Press, London and New York, **18** : 373-681.

——— and L. R. Fisher 1969. The Biology of Euphausiids. F. S. Russel and M. Yonge (Ed). *Advances in Marine Biology*. Academic Press, London and New York, **7** : 1-454.