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Distribution and abundance of cladocerans in the eastern Arabian Sea

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ABSTRACT

Of the two species, *Penilia avirostris* Dana and *Evadne tergestina* Claus encountered, 86% of the population of the former occurred within the 50 m depth zone and 75% of the total population of the latter in the 50 m-100 m depth zone. Striking day-night variations in the population densities of *Penilia* and *Evadne* were observed. The samples collected at night contained 99.7% and 88% of the populations of the former and latter species respectively. Swarming of *Evadne* and *Penilia* is a regular phenomenon during the southwest monsoon season.The highest concentration of the former species was observed in August and that of the latter in September. High concentrations of *Penilia* and *Evadne* were observed in the 30 m depth zone off Cochin and in the 40 m depth zone off Karwar. The abundance of *Penilia* observed in the 30 m depth zone of Wadge Bank off Cape Comorin coincided with its maximum recorded in August off Cochin. The length frequency studies on *Penilia* and *Evadne* showed that different size classes dominated in the different regions from 07°N to 19°N and that an increase in size of the individuals was evident from south to north in both *Penilia* and *Evadne*. Fecundity of *Penilia* was the highest in the southernmost region between 07°00'N and 09°00'N while that of *Evadne* was in the northern region, 15°N- 19°N. Gamogenetic females of both *Penilia* and *Evadne* were very few in number. Occurrence of large numbers of parthenogenetic females of *Penilia* and *Evadne* with well developed advanced embroys in their brood pouches in the night samples probably suggest nocturnal brood maturation.

INTRODUCTION

Marine cladocerans are a group of unique planktonic crustaceans that exhibit parthenogenesis and swarming during certain seasons of the year. They are an ideal prey of the planktivorous fishes and play an important role in the marine food web and as feed in piscicultural practices.

Preliminary observations in the distribution,abundance and seasonal variations of cladocera as a group from the shelf and oceanic waters of the seas around India were

reported earlier (Naomi *et al.* 1989). The specieswise abundance, length frequency distribution, fecundity,seasonal and diurnal variations of the cladocerans occurring in the samples collected by *FORV Sagar Sampada* during 1985-1987 from the shelf and oceanic waters of the eastern Arabian Sea are presented in this report.

MATERIALS AND METHODS

Out of the 592 samples collected by oblique hauls from an average depth of 150 m to the surface using a twin Bongo 60 net of mesh aperture 0.33 mm fitted with a calibrated flowmeter, 62 samples contained cladocera. Of which 32 were collected during nighttime and the rest during daytime.

The average number of *Penilia avirostris* and *Evadne tergestina* present in half a degree square area was estimated per 1000 m^3. Since the depth at the stations sampled varied from 27 m to 4060 m the area of the Arabian Sea between 07°N — 23°N lat. and 68° 25'E — 77°30'E long. was divided into five depth zones for comparing the specieswise abundance. And also into 8 regions from south to north for the purpose of regionwise abundance. Day- night variations and fluctuations in the premonsoon (February- May), monsoon (June-September) and postmonsoon (October-January) seasons were also noted.

The number of individuals examined was 789 of which 587 were *Evadne* and the rest 202 were *Penilia*. The number measured for determining the gross and standard length was 50 when the sample contained large numbers, otherwise all the specimens were measured. The gross length (GL) of *Evadne* was taken as the total length of the carapace including head (Mullin & Onbe,1992) and the standard length (SL) as the distance from the cervical part to the tip of the caudal furcae. The GL of *Penilia* was taken as the distance from the anterior tip of the head to the base of the caudal setae (Della Croce, 1965). The GL of each embryo per parthenogenetic female was measured and the fecundity, i.e. the number of eggs or embryos per batch was counted. Variations in the mean fecundity and length frequency distributions in different latitudes and seasons were studied. Correlation between hydrography and the abundance of cladocerans is attempted for a few stations sampled where the concentration of *Penilia* and *Evadne* were high.

RESULTS AND DISCUSSION

Studies on the distribution of cladocerans in the eastern Arabian Sea during 1985-1987 revealed that the abundance of *Evadne tergestina* and *Penilia avirostris* in the coastal waters of Cochin (10°N-76°E) and Karwar (14°51'N-73°37'E) was quite high. The trends in seasonal upwelling and the high overall biological productivity of the region off Cochin and Karwar have been well documented as both are well-known for the production of major pelagic fishes along the west coast of India (Johannessen *et al.* 1981; Naomi 1986; Rao, *et al.* 1992). The hydrophysical conditions defined by the temperature of 24.55°C, salinity of 26.20×10^{-3} and the dissolved

oxygen content of 2.47-1.25 ml/l during August (Table 1) appeared to have favoured the proliferation of these planktonic crustaceans in the coastal waters off Cochin in the 30 m depth zone, where the abundance of *Penilia* far exceeded that of *Evadne*. The other regions of high abundance of *Penilia* are in the Wadge Bank (Table 1) off Cape Comorin (07°10'N-77°10'E) as well as in the northeastern part (23°N- 67°E) of the Arabian Sea known for the high productivity as reported by Warren *et al.* (1966) and Rao *et al.* (1979). During August *Penilia* alone constituted the high concentration of cladocera in the 30 m depth zone around the Wadge Bank when the temperature was as low as 23.5°C but the salinity 34.58×10^{-3} and oxygen values 4.5 ml/l recorded were higher. On the other hand, in the region off Karwar in the 40 m depth zone the density of *Penilia* (25989) and *Evadne* (47813) was higher in September. While in the northeastern part of the Arabian Sea in the 50 m depth zone the concentration of *Penilia* (2244) observed during October was moderate. These observations concur with the views of Pillai & Pillai (1975) and Mukundan (1971) that the abundance and disappearance of cladocera are abrupt and there is a south to north movement in their occurrence along the west coast of India between July and December.

The distribution of *Evadne* was such that 75% occurred in the 50- 100 m depth zone though the sampling depth varied from 27 m to 4060 m while 86% of *Penilia* was present in the region up to a depth of 50 m and beyond that it occurred in isolated pockets (Fig.1). More than 85% of *Penilia* occurred in the second region between 09°01'N and 11°00'N lat. (Fig.2) while dense populations of *Evadne* were observed between 13°01'N-15°00'N lat. near the coast where upwelling was reported by Panikkar & Jayaraman (1966) during the southwest and early postmonsoon seasons. The increase in the population of cladocera following upwelling has been reported by others (Naomi *et al.* 1989; Longhurst and Bainbridge, 1964). It was observed that the concentration of *Penilia* was higher in the monsoon season contributing to 99.7% of the total. The abundance of *Evadne* constituting 83% also occurred in the monsoon

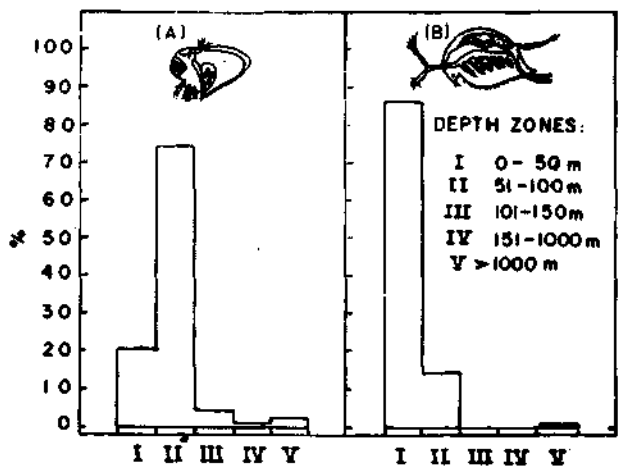

Fig.1 — Variation in the abundance of *Evadne* (A) and *Penilia* (B) in different depth zones

Table 1 — Hydrographic parameters of some selected stations along with the cladoceran abundance in the eastern Arabian Sea

Date	Time (hrs)	Position		Depth (m)	No./1000 m^3		Temp. (°C)	Salinity ($\times 10^{-3}$)	Diss. oxygen (ml/l)	Depth of haul (m)
		Lat. °N	Long. °E		*Penilia*	*Evadne*				
26.6.86	1745	07°20'	77°26'	126	0	2,676	26.2	33.2	4.41	0
							-	33.2	4.28	10
							-	33.2	3.79	20
							-	32.5	3.57	30
27.6.86	0036	07°49'	77°06'	59	0	773	25.0	32.5	4.41	0
							-	32.2	4.28	10
							-	32.2	2.05	20
							-	31.8	1.07	30
27.6.86	1110	08°14'	77°08'	38	63	159	23.8	32.5	4.19	0
							-	32.2	1.96	10
							23.0	33.2	1.43	20
							-	32.5	1.33	30
2.7.86	0518	10°28'	75°55'	27	547	894	25.5	34.3	2.45	0
							23.8	34.6	0.86	10
							23.5	35.0	0.49	20

Contd.

Table 1 — *Contd....*

Date	Time (hrs)	Position		Depth (m)	No./1000 m^3		Temp. (°C)	Salinity ($\times 10^{-3}$)	Diss. oxygen (ml/l)	Depth of haul (m)
		Lat. °N	Long. °E		*Penilia*	*Evadne*				
2.7.86	0846	10°00'	76°04'	28	0	318	27.0	35.0	3.66	0
							24.0	33.2	1.02	10
19.8.86	1822	10°00'	76°00'	34	7,24,545	8,182	24.6	26.1	2.47	0
							-	26.2	1.72	10
							-	26.3	1.00	20
							-	26.2	1.25	30,
25.8.86	2124	07°55'	77°10'	55	89,460	0	23.5	34.6	4.5	0
							-	35.1	5.2	10
							-	34.7	4.7	20
							-	34.3	4.7	30
21.9.86	1930	16°52'	72°26'	90	0	282	27.0	34.3	4.0	0
							26.8	34.8	4.0	10
							26.6	35.1	3.8	20
							26.7	35.4	3.5	30

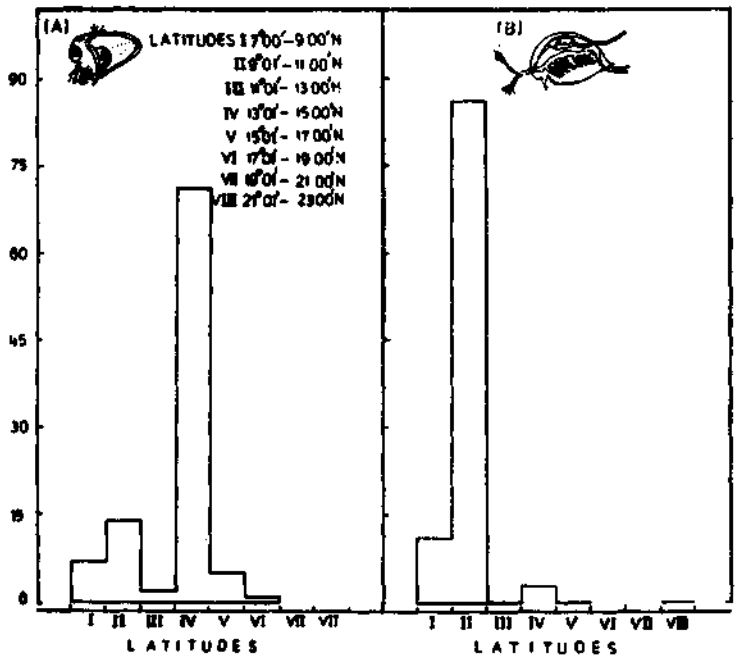

Fig.2 — Variation in the abundance of *Evadne* (A) and *Penilia* (B) in different latitudes

and the concentration observed per month was found to be highest in September followed by August. The density of one species was more than the other in the coastal waters off Cochin during August and Karwar during September as reported earlier by Naomi (1986) and Rajagopalan *et al.* (1992).

The study of seasonal variations in the density of cladocerans in the day and night time collections revealed the occurrence of *Penilia* limited to the collections made during nighttime in the monsoon season (99.7%) with only a few specimens occurring in the day time samples. However, they were present comparatively in large numbers during the postmonsoon season in the day collections. Figure 3 shows greater concentration of *Evadne* in the night collections made during the premonsoon and monsoon seasons when compared to those of day collections. However, *Evadne* was more or less equal during day and night in the postmonsoon season. The depth of the stations except in one (1402 m) from where the cladocerans obtained varied from 27 to 92 m indicating that these organisms remained in the column during night. Onbe (1977) suggests that cladocerans are known to perform reverse diurnal migrations and according to Mullin & Onbe (1992) diurnal vertical migrations are not undertaken by *Penilia* but *Evadne* migrates to deeper waters at night in the Inland sea of Japan.

The length frequency studies (Fig.4) revealed that the gross length (GL) of the parthenogenetic females of *Evadne* ranged from 375 to 1175 μm and the standard

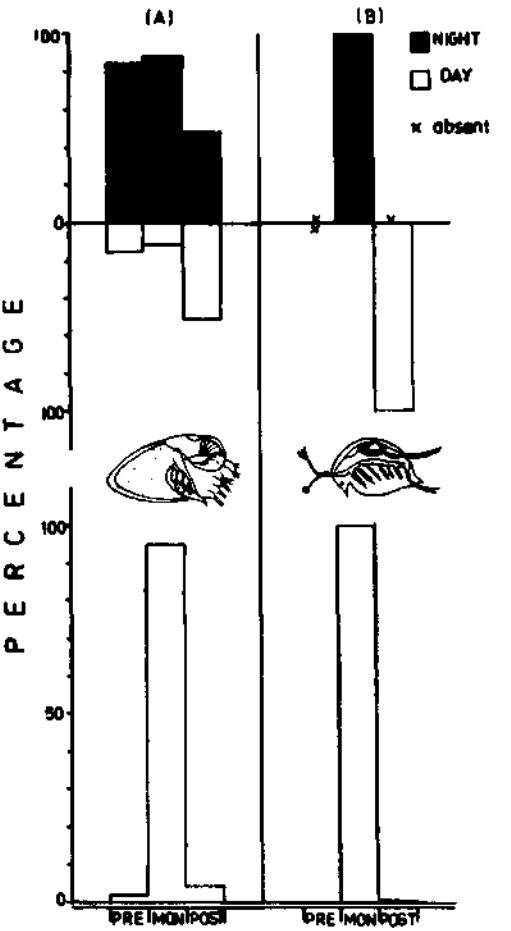

Fig.3 — Seasonal variation of *Evadne* (A) and *Penilia* (B) during day and night

length (SL) from 275 to 700 µm. Females of *Evadne* of size class 375-400 µm were without embryos except in one specimen carrying four embryos and the SL of this particular individual was the lowest (275) observed among the 586 females examined. *Evadne* of the size class 801-900 µm GL and those of 501 to 550 µm SL dominated the collections. There was positive correlation (r=0.912) between the gross length and standard length of these organisms and it was higher (r=0.915) in the night samples (Table 2).

The GL of *Penilia* varied from 400 to 900 µm and the females of 701 to 750 µm GL constituted the dominant size class in the collections. The variations in the size composition of the individuals collected during day and nighttime samples were more pronounced in both the species. While bigger parthenogenetic females of *Evadne* of

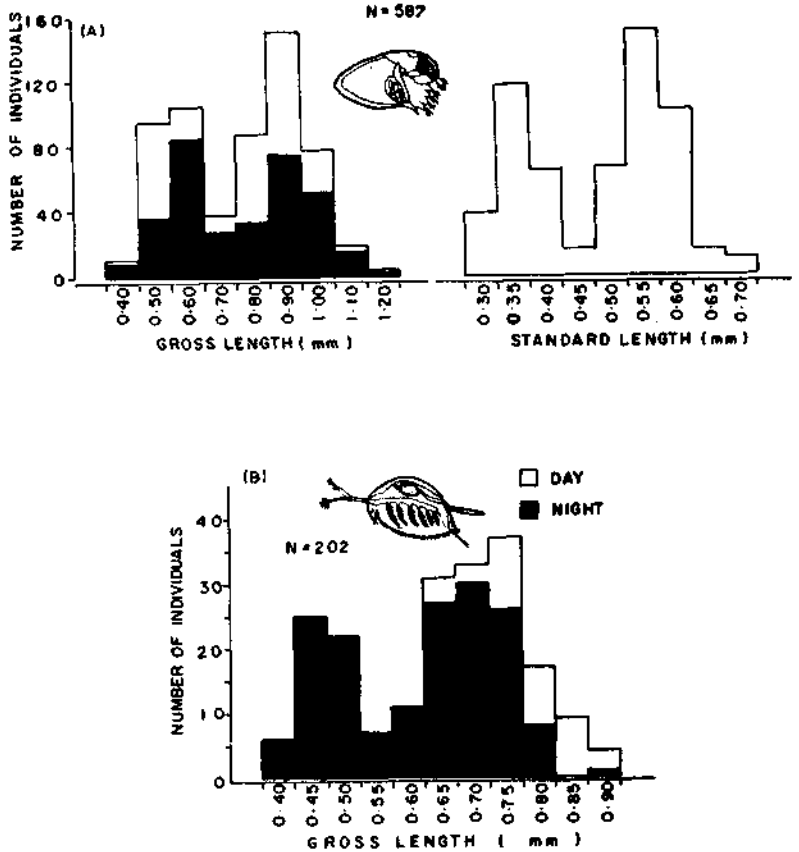

Fig.4 — Length frequency distribution of *Evadne* (A) and *Penilia* (B)

900 µm and more in GL dominated the night collections,smaller females of 400-600 µm GL constituted the night samples in the case of *Penilia*. Larger females of *Penilia* of size 800-900 µm GL were observed in the day collections (Fig.4). In the night samples *Evadne* of size 776-1175 µm GL carried 1-12 embryos of 150-600 µm GL in their brood pouches and the individuals containing advanced embryos with well developed eyes were found only in the night collections. However, *Evadne* of the day collections of 750-775 µm in size were found to have the same number of embryos but smaller in the size range of 73-325 µm GL. There was no significant correlation between the size of the parent and the number of embryos per batch.

The difference recorded in the length of embryos contained in the brood pouches of *Evadne* was well marked with early stage (75-275 µm GL), advanced (175-600 µm GL) and paedogenetic (225-425 µm GL). There was no clear demarcation in the growth and development of these three different embryos of *Evadne* in the brood

Table 2 — *Evadne tergestina* Claus: Relationship between mean GL, SL, embryo number and embryo length [* Day and night. (n: 586); ** Night. (n: 333)]

Sl no	Mean of the measurement (μm)	Students' *t* value	Probability	Correlation
1.	* GL: 735.39 * SL: 471.04	53.620	0.000	0.912
2.	* GL: 735.39 * Emb. leng.121.64	17.070	0.000	0.577
3.	* SL: 471.04 * Emb. leng.121.64	12.438	0.000	0.457
4.	** GL: 733.18 ** SL: 458.63	41.156	0.000	0.915
5.	** GL: 733.18 ** Emb. leng.140.32	13.304	0.000	0.590
6.	** SL: 458.63 ** Emb. leng.140.32	10.509	0.000	0.500

pouches. The size of the smallest individual in the plankton was 375 μm GL. Positive correlation was observed between the mean embryo length and GL (r=0.577) and SL (0.457) for the total number of individuals (n=587) and the same recorded exclusively for the night samples (n=333) was higher for GL (r=0.590) and SL (r=0.500) as shown in Table 2. This indicates the predominance of advanced stages at night when the developing embryos cause increase in GL and expansion of the brood pouch while the increase in SL is marginal. According to Mullin & Onbe (1992), the broods mature at night and the young ones are released towards dawn and the nocturnal maturation and release of broods reduce visual predation of gravid females of *Evadne*.

Whereas, the parthenogenetic females of *Penilia* of 578-800 μm GL in size present in the night samples were having 1-10 well developed embryos of 250-325 μm GL in their brood pouches and still larger females of 625-875 μm GL occurring in the day collections were with 1-9 embryos of 125-250 μm GL. Prevalence of smaller individuals and the presence of well developed embryos in the night samples suggested brood maturation of *Penilia* in the night. Mullin & Onbe (1992) concluded that *Penilia* could contain mature embryos at anytime but more likely at night.

Seasonal fluctuations in the different size groups of both the species and their fecundity (Fig.5) showed that *Evadne* of 501 to 550 μm SL increased during the premonsoon and monsoon seasons and their fecundity was maximum in the monsoon months. Almost all the size groups of *Penilia* occurred in moderate abundance during

the monsoon months. Larger *Evadne* (551-600 μm SL) and *Penilia* (750- 850 μm GL) were preponderant in the postmonsoon period and their percentage frequency of fecundity recorded highest values during the period. Maximum number of eggs or embryos up to 12 per brood was registered during July-September and October in *Evadne* and up to 10 per brood in *Penilia* in August. Gamogenetic *Evadne* encountered were two in October and three in November. The only one gamogenetic *Penilia* observed was in August. At no time the male of either species was observed in the collections. Paedogenesis in *Evadne* was encountered in February and June. Della Croce & Venugopal (1972) reported a maximum of 6 embryos per brood in *Penilia* and 7-10 embryos in *Evadne* from the Indian Ocean. However, remarkable variations occur in the reproductive potential of parthenogenetic females of the different regions (Raymont,1983) and in the same region from time to time to maintain or accelerate the rapid production of parthenogenetic populations.

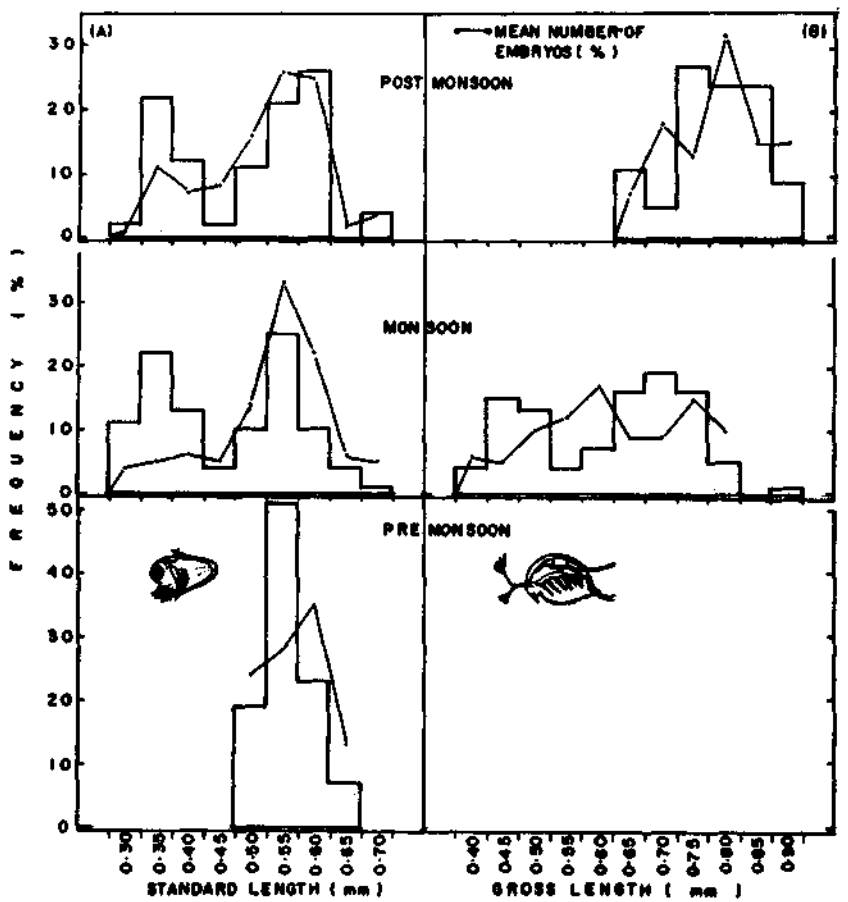

Fig.5 — Mean fecundity and size frequency distribution of *Evadne* (A) and *Penilia* (B) in different seasons

It was observed that there was variation in the occurrence of the frequency of the different size groups of both *Evadne* and *Penilia* in the different latitudinal sectors (Figs.6,7). *Evadne* of 350- 400 µm SL dominated in the southern sectors (09°01'N-15°00'N lat.) while still bigger individuals of 551-600 µm SL in the northern sectors (15°01'N-19°00'N lat.). Though the frequency percentage of fecundity was higher in the size class 501-550 µm SL in the southern region (07°00'N-13°00'N lat.) the highest (39%) was observed in the size group 551-600 µm SL in the northern region (13°00'N-19°00'N lat.). Larger *Evadne* of 651-700 µm SL were confined to the northernmost region (17°01'N- 19°00'N lat.) as shown in Fig.6. A distinct increase in the abundance of the size groups of *Penilia* from south to north was indicated with the exception of the region 13°01'N-15°00'N lat. where moderate fecundity was observed

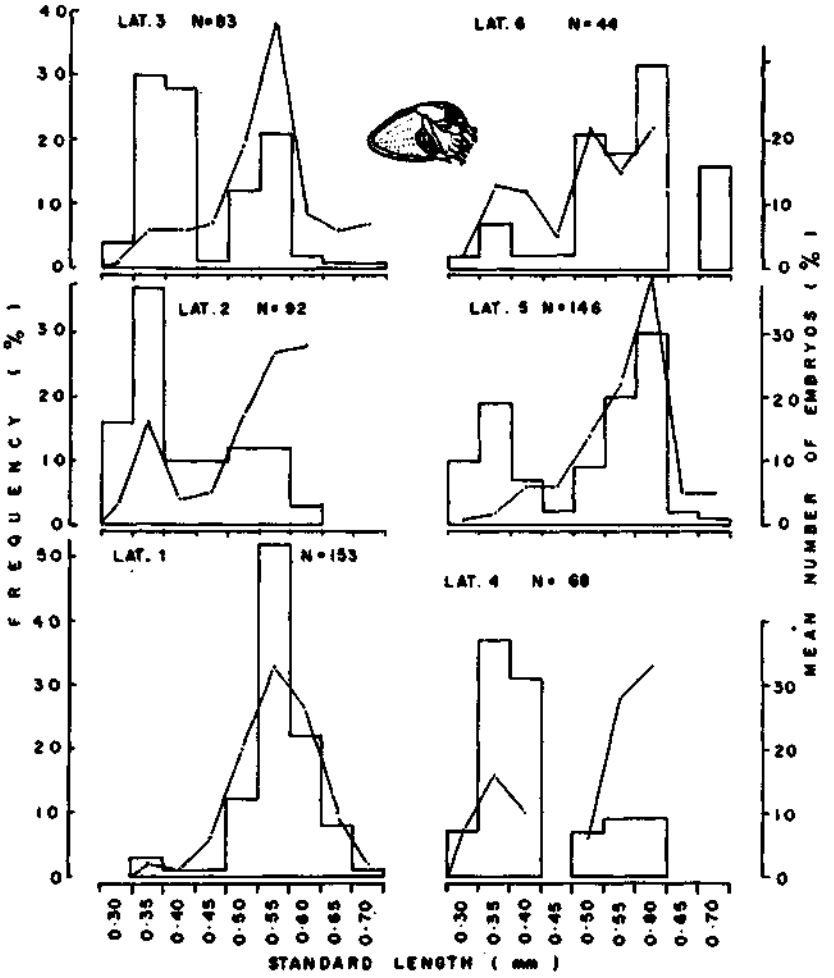

Fig.6 — Mean fecundity and size frequency distribution of *Evadne* in different latitudes

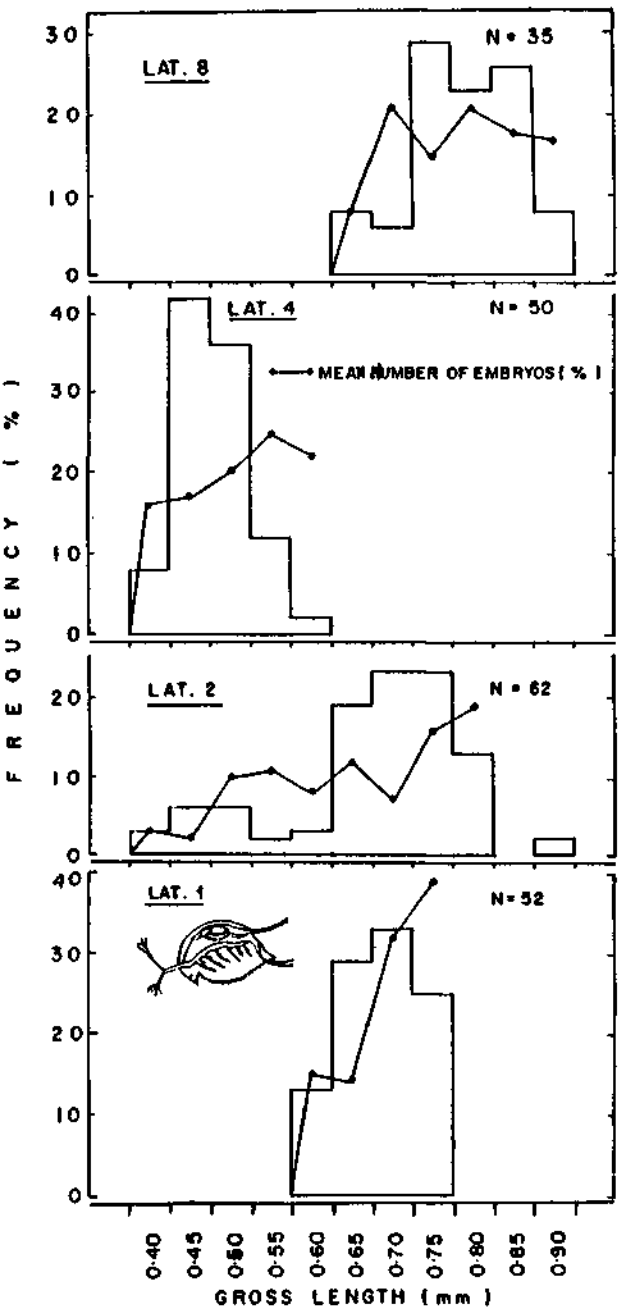

Fig.7 — Mean fecundity and size frequency distribution of *Penilia* in different latitudes

in the size class 501-550 µm GL. Fecundity was usually high in the larger sized *Penilia* of 701-800 µm GL and the maximum was encountered in the southernmost region between 07°00'N- 09°00'N lat. Similar observations on the geographic variations of size and fecundity of *Podon schmackeri* in the northwestern Pacific were reported by Kim & Onbe (1989).

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