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Population dynamics of *Moina micrura* Kurz (Cladocera: Moinidae) inhabiting a eutrophic pond of Madurai (south India)*

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Abstract. Population density, composition, age structure and fecundity of *Moina micrura* have been studied in a eutrophic pond. The average clutch size of this species ranged from 1–4·4 eggs. The relationship between mean brood size and body length has been established. The volume of parthenogenetic eggs of this cladoceran ranges between 0·2 and 0·9 millions μ^3 and the adaptive significance of this has been discussed. The mean instantaneous birth rate which preceded maximum density of population resulted in a value of more than one.

Keywords. *Moina micrura*; population density; composition; age structure; fecundity; egg volume.

1. Introduction

Moina micrura, a member of the family Moinidae primarily inhabits astatic ponds and pools in tropical and subtropical regions. This species is highly adapted to survive frequent dry periods and propagate rapidly in newly formed ponds. The review of literature on zooplankton species of *Moina* shows that the information about the population dynamics of *M. micrura* from tropical Indian waters is far from complete. Hence, an attempt has been made to investigate its population density and composition, fecundity and age structure in natural habitats.

2. Study area

The present study was carried out in a seasonal shallow pond (figure 1) located in the Madura College campus at Madurai (Long: 78′8′ E; Lat: 9′56′ N), south India. The pond is exclusively rainfed with no outlets. On the southern and western sides, trees belonging to the species *Pongamia glabra*, *Azadiracta indica* and *Morinda tinctorea* encircle the margin of the pond. The trees give great stability to the margin of the pond and the litter in the form of dry fallen leaves allows enormous growth of zooplankton. There are no submerged aquatic plants although the microflora belonging to the family Cyanophyceae and the free floating macrophytes of the family Lemnaceae appear during certain periods.

3. Materials and methods

3.1 *Field data*

Zooplankton samples were collected at weekly intervals between August 26, 1976 to

*Part of the doctoral thesis.

Figure 1. A view of the eutrophic pond.

July 15, 1977 from the surface and just above the bottom using a plastic bucket. The samples were concentrated by filtration through a bolting silk sieve of 120 μ mesh size. A total of 20 l of water was normally sieved. A total of 33 samples were obtained covering a period of 12 months. The samples collected on a given date were mixed and the concentrated plankton preserved in 4% formalin was used for the following biometric analyses.

(i) To identify the species and for counting population density and composition.
(ii) To identify the age structure.
(iii) To determine the fecundity.
(iv) To calculate birth and death rates.

3.2 *Species identification*

The recent revision of the genus *Moina* by Goulden (1968) was adopted for identifying the species as *micrura*. *Moina dubia* Gurney and Richard has been regarded as synonym of *M. micrura*.

3.3 *Population density and composition*

For counting the population densities 1/20 of the concentrate representing 20 l of pond water was used. The arithmetic mean densities of the species were expressed in numbers per litre. The population composition of *M. micrura* was grouped into the following categories based on Green (1955).

(i) Immature females between 0·45 and 0·6 mm length.
(ii) Mature females without eggs (over 0·60 mm).
(iii) Females with parthenogenetic eggs or embryos.
(iv) Ephippial females.
(v) Males.

3.4 *Age structure*

Since *Moina* has no specific morphologic features to indicate age, it is difficult to analyse age structure from natural populations. However, it is possible to trace the same under laboratory conditions. Therefore different size classes were chosen after studying its ontogenic development under laboratory conditions. Thus 4 size groups viz. (i) <0.60 mm, (ii) $>0.60-<0.79$ mm, (iii) $>0.79-<0.98$ mm and (iv) >0.98 mm are recognised.

3.5 *Fecundity*

To determine the fecundity of the population from a mixed sample, the individuals were dissected out and eggs and embryos counted under a stereo binocular microscope. The mean number of eggs was calculated from the sample of 25 females with eggs in brood pouch. The number of eggs produced by a female varies with environmental conditions. The conditions which favour growth will also favour egg production (Elden 1943; Green 1954, 1955) and thus the two tend to fluctuate together. To test this, animals with eggs are measured from the crown to the posterior border of carapace using an ocular micrometer besides counting egg number. This measurement corresponds to the total length of Anderson (1932), the length of Edmondson (1955) and the body length of Lei and Clifford (1974).

3.6 *Egg volume*

The eggs from the parthenogenetic females were dissected out from the brood chambers in different sized individuals. The egg volume was calculated by using the formula $1/6\ gs^2$ where g is the maximum diameter and s is the minimum diameter (Green 1956; Lei and Clifford 1974).

3.7 *Birth rate, rate of population change and death rate*

The values obtained from counting the samples were analysed for birth rate, rate of population changes and death rate following Hall (1964) and George and Edwards (1974). This study enables to identify the population parameters of *M. micrura* in natural habitats and to some extent recognise the effect of environmental factors influencing the population. This method was first proposed by Edmondson (1960, 1968) for studying rotifer population dynamics and was applied to zooplanktonic populations by Hall (1964), Wright (1965), Cummins *et al* (1969), Dodson (1972) and George and Edwards (1974).

4. Results

The results of routine physical parameters of Madura College pond are given in figure 2. The day time oxygen concentrations in the pond water during the study period fluctuated around an average of 5 ppm. The pH fluctuation was between 7.2 and 9·5. Changes in the numerical standing crop of *M. micrura* are shown in figure 3. Figure 4 shows the seasonal variations in the mean length of the mature females and the number of eggs carried by them. The relationship between the mean brood size and the individual body length is represented in figure 5. Figure 6 illustrates the variations in the size distribution of *M. micrura*.

The percentage composition of the population of *M. micrura* are shown in table 1. Table 2 represents the diameters and volumes of parthenogenetic eggs of tropical and temperate Cladocera. Table 3 depicts the parameters of instantaneous birth rate, instantaneous rate of population increase and death rate of *M. micrura* population.

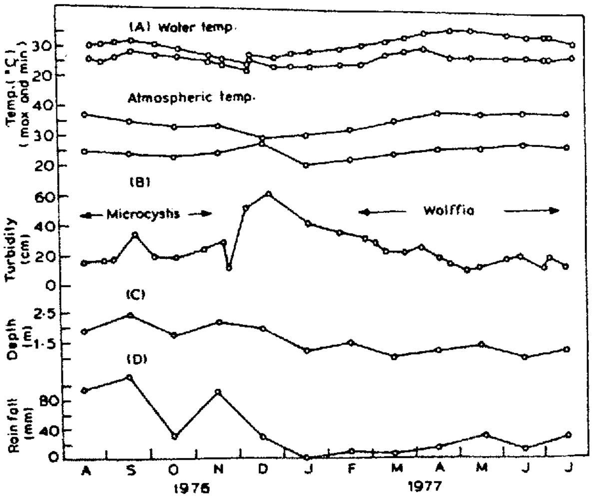


Figure 2. Seasonal variations in the physical parameters.

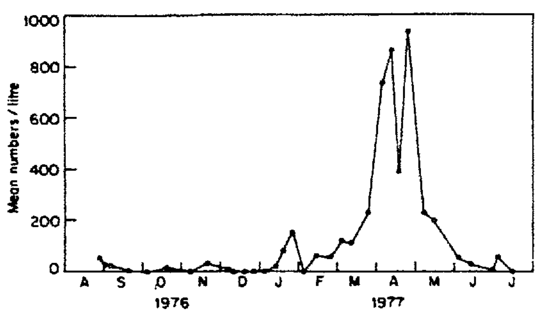


Figure 3. Changes in the standing crop of *M. micrura*.

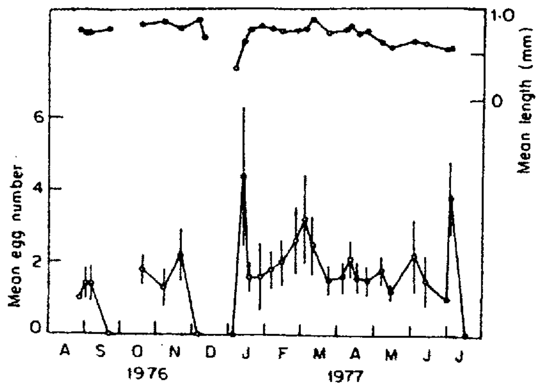
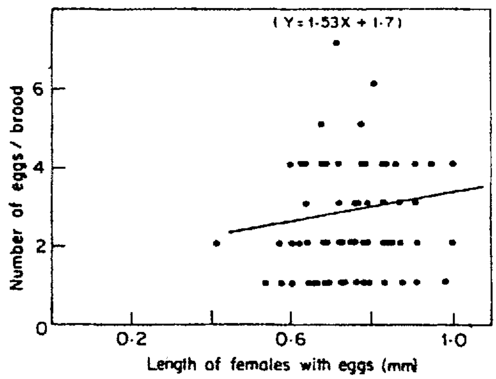


Figure 4. Seasonal variations in the mean length of mature females and mean number of eggs per brood.



Figurè 5. Relationship between the mean brood size and the body length in *M. micrura.*

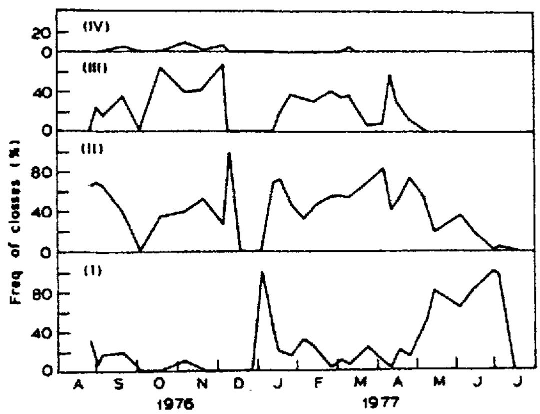


Figure 6. Seasonal changes in the size classes of *M. micrura.*

Table 1. Seasonal variation in the percentage composition of the population of *M. micrura* in Madura College pond.

Date	Immature females (%)	Females of mature size without eggs (%)	Females with partheno-genetic eggs (%)	Ephippial females (%)	Males (%)	No. of indivi-duals counted
1976						
26 Aug	32	64	4	0	0	50
29 Aug	8	48	44	0	0	50
5 Sept	18	54	8	20	0	50
19 Sept	20	65	0	15	0	20
3 Oct	0	0	0	0	0	0
18 Oct	0	36	64	0	0	25
6 Nov	10	50	40	0	0	10
19 Nov	0	13·3	86·6	0	0	30
5 Dec	0	100	0	0	0	15
9 Dec	0	0	0	0	0	0
18 Dec	0	0	0	0	0	0
25 Dec	0	0	0	0	0	0
1977						
3 Jan	100	0	0	0	0	5
12 Jan	40	24	36	0	0	25
17 Jan	18	42	26	4	10	50
25 Jan	16	44	40	0	0	50
4 Feb	33·3	0	66·6	0	0	6
14 Feb	23·3	33·6	40	0	0	30
25 Feb	4	28	68	0	0	50
3 Mar	10	26	64	0	0	50
10 Mar	6	46	20	18	10	50
23 Mar	21·81	38·18	29·09	1·81	9·09	55
4 Apr	8	26	48	14	4	50
11 Apr	2	34	56	8	0	50
17 Apr	20	28	52	0	0	50
24 Apr	14	22	62	0	2	50
6 May	48	14	38	0	0	50
14 May	70	10	20	0	0	50
3 Jun	48	4	44	4	0	25
12 Jun	60	0	40	0	0	5
29 Jun	70	0	30	0	0	10
3 Jul	84	0	16	0	0	25
15 Jul	0	0	0	0	0	0

5. Discussion

5.1 *Biology*

The life span of *M. micrura* is typical of many species of Cladocera. Reproduction occurs mostly by parthenogenesis. Early laboratory experiments on *Moina* species revealed that it has a life span of about two weeks and it produces approximately 61 young ones in 11 clutches (Murugan 1975). The parthenogenetic eggs are released into a dorsally located brood pouch where growth and development take place. The embryos are nourished through an unique structure

Table 2. Diameter and volume of parthenogenetic eggs of tropical (*M. micrura* and *S. acutirostratus*) and temperate (*S. vetulus*) Cladocera.

Date	Average water temp. (°C)	Size of individual (mm)	Number of eggs		Mean egg diameter (μ)		Mean egg volume (millions μ^3)
			Counted	Measured	Largest (g)	Least (g)	
M. micrura							
1976							
5 Sep	30·25	0·76	4	4	102·6	91·2	0·4
1977							
12 Jan	25·25	0·72	7	7	83·6	79·2	0·2
		0·60	4	4	91·2	87·4	0·3
		0·68	5	5	87·4	79·8	0·2
17 Jan	25·25	0·77	1	1	114·0	114·0	0·7
14 Feb	26·50	0·79	4	4	114·0	106·4	0·6
		0·83	2	2	127·5	106·4	0·7
		0·83	2	2	102·6	95·0	0·4
25 Feb		0·76	2	2	121·6	114·0	0·8
			2	2	136·8	114·0	0·9
3 Mar	29·25	0·91	2	2	125·4	117·8	0·9
S. acutirostratus							
1976							
18 Dec	26·00	2·38	15	14	239·0	224·0	6·2
25 Dec	24·50	2·50	25	12	245·0	204·0	5·3
	24·50	2.95	39	13	217·0	209·0	4·9
	24·50	3·86	70	25	208·0	195·0	4·1
1977							
17 Jan	25·25	2·32	7	7	224·0	212·0	5·2
24 Feb	26·50	2·54	27	14	247·0	245·0	7·7
25 Feb	27·00	2·38	26	11	256·0	246·0	8·1
3 Mar	29·75	2·31	13	6	212·0	204·0	4·6
10 Mar	29·75	2·27	13	8	207·0	194·0	4·0
S. vetulus							
1963							
30 Apr	15·00	—	—	60	246·0	218·0	6·1
14 May	14·00	—	—	40	248·0	228·0	6·7
10 Jun	21·00	—	—	70	245·0	216·0	6·0
13 Aug	18·00	—	—	50	252·0	223·0	6·6
28 Aug	16·00	—	—	40	255·0	233·0	7·3
25 Sep	14·50	—	—	12	262·0	235·0	7·6
16 Oct	12·00	—	—	20	272·0	247·0	8·6
6 Nov	10·00	—	—	30	270·0	243·0	8·3
27 Nov	7·50	—	—	55	270·0	250·0	8·8
4 Dec	6·00	—	—	20	271·0	244·0	8·4
11 Dec	3·50	—	—	30	287·0	259·0	10·1
20 Dec	0·50	—	—	50	280·0	254·0	9·5
S. vetulus (Greenland)							
1961							
28 Jul	11·00	—	—	22	308·0	273·0	12·0

Table 3. Population data for *M. micrura*.

	1	2	3	4	5	6	7	8
Date	N_o	N_A	E	L/D (day)	B	b	r	d
1976								
Aug 26	2700	1836	1·00	1	0·68	0·52	−0·17	0·69
29	1600	1472	1·41	1	1·29	0·83	−0·04	0·87
Sep 5	1200	984	1·41	1	1·15	0·77	−0·10	0·87
19	275	220	0·	1	0·80	0·59	−0·40	0·99
Oct 3	0	0	0	1	0	0	0	0
18	700	700	1·78	1	1·78	1·02	−0·10	1·12
Nov 6	100	90	1·33	1	1·19	0·79	+0·21	0·58
19	1675	1675	2·21	1	2·21	1·17	−0·06	1·23
Dec 5	625	625	0	1	1·00	0·70	−0·80	1·50
9	25	25	0	1	1·00	0·70	−0·35	1·05
18	0	0	0	1	0	0	0	0
25	0	0	0	1	0	0	0	0
1977								
Jan 3	50	0	0	1	0	0	+0·34	−0·34
12	1080	648	4·42	1	2·65	1·30	+0·26	1·04
17	3980	2865	1·66	1	1·19	0·79	+0·08	0·71
25	7775	6531	1·66	1	1·39	0·87	−0·40	1·27
Feb 4	130	86	1·75	1	1·16	0·77	+0·32	0·45
14	3225	2373	1·97	1	1·44	0·90	0	0·90
25	2915	2798	2·66	1	2·55	1·27	+0·12	1·15
Mar 3	6125	5512	3·20	1	2·88	1·36	−0·01	1·37
10	5550	4662	2·50	1	2·10	1·13	+0·06	1·07
23	11500	7944	1·50	1	1·03	0·71	+0·96	−0·25
Apr 4	36750	33810	1·63	1	1·49	0·92	+0·02	0·90
11	43000	42140	2·10	1	2·05	1·11	−0·13	1·24
17	19500	15600	1·58	1	1·26	0·82	+0·13	0·69
24	46800	40248	1·47	1	1·26	0·82	−0·12	0·94
May 6	11300	5876	1·76	1	0·91	0·65	−0·01	0·66
14	10000	3000	1·20	1	0·36	0·31	−0·06	0·37
Jun 3	2665	1385	2·20	1	1·14	0·76	−0·06	0·82
12	1500	600	1·50	1	0·60	0·47	0·08	0·55
29	333	99	1·00	1	0·30	0·26	+0·53	−0·27
Jul 3	2830	452	3·80	1	0·61	0·47	−0·66	1·13
15	0	0	0	1	0	0	0	0

1, Total population size/50 litres.
2, Total adults (adults/50 litres).
3, Mean number of eggs/brood.
4, Rate of growth or development of eggs.
5, Finite birth rate.
6, Instantaneous birth rate.
7, Observed instantaneous rate of population increase.
8, Estimated instantaneous mortality or death rate.

called "nahrboden" or "placenta" by the parthenogenetic adult females (Goulden 1968). The newly hatched young or neonates are born viviparously and resemble the adult in all respects except in size and the non-development of the ovaries. The neonates go through at least two pre-adult instars. The third instar is primiparous when the female lays her first batch of eggs into the brood pouch. The main sexual dimorphism exhibited by the genus *Moina* lies in the antennules which are long and broadly curved in males adapted for clasping the females at the time of copulatory activities. In the female the antennules are cigarette shaped.

5.2 *Population density (standing crop) and composition*

The population of *M. micrura* has a single conspicuous peak in population density in April amounting to 936 units/l (figure 3). The brood size which is important in determining the total number of eggs in a population, had been increased gradually preceding the population maximum in *M. micrura.* The density was extremely low (few individuals/l) between August and December 1976. The possible reasons for low density may probably be explained by external factors viz. southwest (June–August) and northeast monsoons (October–December) which not only lowered the temperature (figure 2A) but also reduced the concentration of food in the medium. Further, the population phenomenon of low and discontinuous egg production (figure 4) resulted in decrease in density. Khalaf and Shihaf (1979) reported two population maxima in a year in *M. micrura.* The population composition of *M. micrura* has been analysed to determine when bisexual reproduction occurred and the extent to which females changed from parthenogenetic to gamogenesis (production of sexual eggs). Three periods of sexual reproduction, one in the beginning of September, second in the middle of January and the third in the second week of March 1977 occurred (table 1). The percentage of ephippial females varied between 15 and 20, 4 and 1·8 to 18. No males were found in September although the samples were thoroughly observed. The percentage of males recorded in the two latter periods amounted to 10. The repeated occurrence of ephippial females reflect the instability in the population structure of *M. micrura* which was extensively controlled by various factors such as food, temperature crowding etc. At this stage of our knowledge it would be premature to precisely interpret the causes for the switch over from parthenogenetic to gamogametic phase. However, it is interesting to observe that the occurrence of ephippial females (March–April) when the population was at its maximum, finds support from earlier observations of Berg (1931) and Green (1955), who also found that in *Daphnia* ephippial females appeared when the populations were densely crowded.

5.3 *Seasonal variations in egg production and body length*

The mean egg number is calculated by dividing the total number of eggs counted by the number of females with eggs. The changes in the brood size followed the general pattern of the mean length of females in *M. micrura* (figure 4). It has been already pointed out that the conditions which favour growth also favour egg production, the adult size and the brood size tend to fluctuate synchronously.

The mature females of this species formed 71·69% of the total population. The average clutch size ranged from 1–4·4 eggs. About 48·6% of the natural population has two eggs and 31·15% only a single egg. The percentage of females with 3 or 4 eggs was 18·84. Only 1·3% of the population has more than 5 eggs at any time. The maximum individual clutch size was 7 eggs. Almost similar clutch sizes were reported during an earlier laboratory investigation of this species (Murugan 1975).

5.4 *Mean brood size vs body length*

The number of eggs produced by a female is known to be influenced by a variety of factors which may be either intrinsic or extrinsic (Green 1956). The mean number of eggs potentially carried increases with the size of the female and the small body size naturally will restrict the egg laying capacity of the female (Green 1954, 1956). In the present study when the samples of parthenogenetically reproducing females of *M. micrura* was examined, there was found to be a low positive correlation ($r = 0{\cdot}13$) between the length and the number of eggs per brood. The regression equation was $Y = 1{\cdot}53 + 1{\cdot}7$ and the slope of the regression line $1{\cdot}53 \pm 2{\cdot}7$. It may be interesting to note that the egg number increases with the body length less rapidly since the body length of the females carrying eggs were in a narrow range which varied between 0·4 and 1 mm. This finding is in agreement with Green (1954, 1956) who already stated that small body size would restrict the egg laying capacity. It also appears that the space within the brood is an important limiting factor (Kerfoot 1974).

5.5 *Size distribution*

All size groups are well represented except class IV with two population size cycles. It may be assumed that the first generation of population which appeared in June took 6 months to reach the maximum percentage length of class III. Class IV individuals form a small percentage.

The development of a second size cycle of the population which appeared in January can be traced by successive length classes of II and III. The maximum population density in *M. micrura* in summer coincided with the length groups of classes II and III individuals which formed 84 and 56% respectively. The survival of class IV in this cycle was only 4%. It is sufficiently clear that the size distribution of *Moina* showed a marked variation in the natural habitats. The peaks of population density in this species coincided with the maximum proportion of mature individuals rather than immature forms.

5.6 *Egg volume*

The egg volume in *M. micrura* ranged from 0·2–0·9 millions μ^3 while that of the large sized *Simocephalus acutirostratus* (Murugan 1980) ranged from 4·1–8·1 millions μ^3 (table 2) which indicates the range of lowest and highest egg volumes in the two tropical species. Parallel comparison with forms living in temperate latitude indicated that *S. vetulus* (Green 1966) showed a range of 6–10·1 millions μ^3. The same species in Greenland, however, showed a mean egg volume of 12 millions μ^3. Thus there is an increase of about 1·5–3 times in the egg volume of more or less similar sized species with the change of latitude from tropics to temperate and arctic regions. This could be a positive effect of temperature (latitude) on egg volume. No such comparison could be made in the absence of ubiquitous of distribution and extensive studies on the species of *Moina* from cold, temperate and arctic regions. The adaptive significance of latitudinal differences in egg size has been described by Green (1966). A large egg gives rise to a larger neonate and there is a tendency within a species for the larger neonates to become mature at an earlier instar than do the small neonate. In warm water the greater number of smaller eggs ensured a greater rate of population growth (Green 1966). It may be relevant to mention here that the smaller egg volume in *M. micrura* is likely to be an adaptation for rapid build up of population in the tropics. Green (1956) and Kerfoot (1974) indicated that the parthenogenetic eggs show size variation during different seasons. Hutchinson (1951) and Lack (1954) ascribed these changes of egg size as evolutionary responses that anticipated resource abundance i.e. when the food materials are in abundance the animal produced small eggs whereas the opposite was true when the food became scarce. The reserve food materials in the egg had to be stored in bigger eggs in view of the scarcity of food in the environment so that for a larger period the embryo can utilize the stored food in the food scarce environment.

5.7 *Population dynamics*

The observed instantaneous rates of population increase (r), calculated from successive pairs of population density data, and instantaneous birth rates (b), calculated on the basis of egg development time from the laboratory study are shown (table 3). These functions are applicable only to a population with stable age distribution and continuous reproduction. But this may also be applied for descriptive purposes to a population without a stable age distribution as has been previously used by Hall (1964), Edmondson (1968) and George and Edwards (1974). It is noted that potential rate of population increase (b) was higher in all months than the observed rate of population increase (r). The mean instantaneous birth rate value is more than 1 in March which preceded the population density maximum in April 1977. The increase in mean brood size from mid January to March 1977 (figure 4) and rise in water temperature (figure 2) are other causative factors for population maximum. The estimated instantaneous death rate (d) exceeding the instantaneous birth rate (b) were of considerable significance to account for the absence of population maxima of *M. micrura* in the early months of the study period. The population decline can be seen due to fall of birth rates and lesser number of eggs in the brood.

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