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LABORATORY STUDIES ON THE LONGEVITY, INSTAR DURATION, GROWTH, REPRODUCTION AND EMBRYONIC DEVELOPMENT IN SCAPHOLEBERIS KINGI SARS (1903) (CLADOCERA: DAPHNIDAE)

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Abstract

Kept in the laboratory at 28°-30° C, the cosmopolitan cladoceran, *Scapholeberis kingi* produces about 239 eggs during a life of 20.56 days duration. It has two pre-adult and seventeen adult instars. The duration of preadult and adult instars was compared with other tropical Cladocera. Egg production was found to be uniformly high with minor fluctuations. The various events in the life cycle and their significance have been compared with those of related species. The rate of egg production, expressed on a cumulative basis was found to be higher (a = 1.3326) than that of *Simocephalus acutirostratus* King, *Moina micrura* Kurz and *Ceriodaphnia cornuta* Sars and lower than that of *Daphnia carinata* King.

The general pattern of embryonic development of *S. kingi* shows close similarities to that of allied tropical and temperate species, though differences in duration of the embryonic period were recorded.

Introduction

While there are many published accounts on the seasonal occurrence and general ecology of both temperate and tropical zooplankton, there are as yet few laboratory observations on the life cycle patterns of individual species. A beginning in this direction has recently been made in some tropical species of Cladocera like *Daphnia carinata* King (Navaneethakrishnan & Michael, 1971). *Simocephalus acutirostratus* King (Murugan & Sivaramakrishnan, 1973) and *Moina micrura* Kurz (Murugan, 1975) from astatic ponds in the Southern Peninsular India.

The present report is another contribution along similar lines and refers to the epineustic cladoceran, *Scapholeberis kingi,* whose occurrence is sporadic in astatic ponds around Madurai (Long: 78° 8′ Lat: 9° 56′ N).

S. kingi appears to be a cosmopolitan species having been recorded from Senegal, Corfu, Germany, China, India, Siam, the East Indies, Australia, South Africa, (Harding, 1961) and North America (Brooks, 1959). In India, Gurney (1907) reported this species from the Indian Museum tank, Calcutta. Subsequently it was reported to occur in three lakes in Kashmir and in a lake in the Nilgiri Hills, South India, though the validity of the latter record is considered doubtful (Brehm, 1936). The present occurrence of this species in Madurai area is a new record extending its distribution further South into Peninsular India.

Observations on its longevity, instar duration, growth, reproduction and embryonic development are reported here. It is thought that this information will be of value in our understanding of its biology, and the computation of secondary productivity and as well for purposes of comparison of events in the life cycle with other Cladocera.

Material and methods

Samples were collected from a seasonal pond in the Madura College campus at Madurai, South India. Several adult parthenogenetic females were isolated and reared in separate Petri dishes. The methods adopted in rearing the animals in the laboratory are the same as followed in earlier work (Murugan & Sivaramakrishnan, 1973).

About twenty healthy neonates were reared individually

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for the purpose of collecting data regarding the length increment, number of moults and the number of young released at each instar. Two sets of twenty parthenogenetic females were reared individually in Petri dishes in order to study the different embryonic stages. It was not possible to follow clearly the details of embryonic development in the brood chamber itself in view of the dark brown colour and opacity of the carapace. Hence, a few parthenogenetic females were killed at fixed time intervals and their brood chambers carefully dissected out to release the developing eggs showing the distinct stages of development.

Results

The neonates which are but miniature adults, have a mean length of 0.288 mm. Each individual passes through two preadult instars and seventeen adult instars. The mean length of the first adult instar is 0.528 mm and a maximum length of 0.920 mm is attained at the sixteenth adult instar. The relationship between the mean length of the animal and the instar number is graphically represented in Fig I (F). The total life span is 20.56 days (Table I). While the preadult instars have a uniform duration of 24 hours, that of adult instars varies between 24 and 38.4 hours. These variations as well as number of eggs per brood are shown in relation to age (Fig. II).

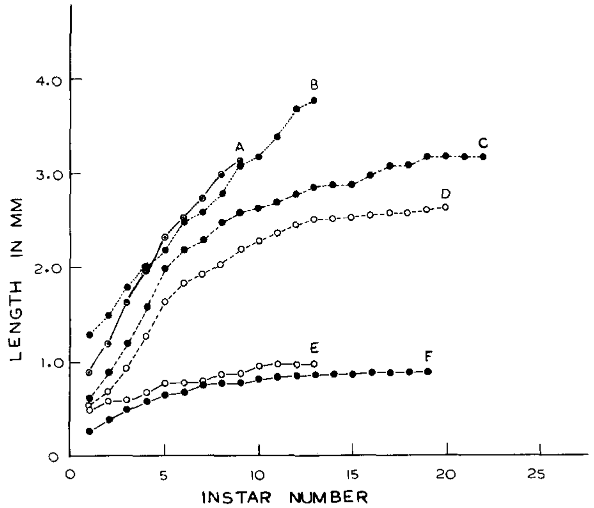


Fig. I. Relationship between mean length and instar number in A. Daphnia middendorffiana (arctic). B. Daphnia carinata (tropical). C. Simocephalus acutirostratus (tropical). D. Daphnia pulex (temperate). E. Moina micrura (tropical). F. Scapholeberis kingi (tropical).

Table 1: Mean length, egg production and instar duration of *S. kingi* at 28° - 30°C.

Instar number	Mean length mm	Number of eggs per brood	Total of eggs produced	Duration of each instar (h)	Cumulative duration of each instar (h)
1	0.288	--	--	24.0	24.0
2	0.422	--	--	24.0	48.0
3	0.528	6.1	6.1	24.0	72.0
4	0.624	9.9	16.0	24.0	96.0
5	0.694	13.3	29.3	24.0	120.0
6	0.734	16.9	46.2	24.0	144.0
7	0.774	19.6	65.8	24.0	168.0
8	0.798	20.5	86.3	38.4	206.4
9	0.818	20.3	106.6	31.2	237.6
10	0.84	17.5	124.1	24.4	262.0
11	0.85	17.8	141.9	24.0	286.0
12	0.86	19.6	161.5	24.0	310.0
13	0.875	20.3	181.8	24.0	334.0
14	0.887	19.0	200.8	30.0	364.0
15	0.888	15.0	215.8	33.6	397.6
16	0.910	14.6	230.4	24.0	421.6
17	0.910	5.0	235.4	24.0	445.6
18	0.92	4.0	239.4	24.0	469.6
19	0.92	--	239.4	24.0	493.6

The cumulative egg production of the present species and of two other tropical cladocerans is plotted against adult instar number showing the rates of egg production (Fig. III). The salient morphological features characteristic of distinctive embryonic stages of *S. kingi* (Plate I) are given below, using the terminology of Green (1965) provided for an allied temperate cladoceran *Daphnia magna*.

Stages in Embryonic Development of S. kingi

I. Early Stage

a) Early: The egg is oval, translucent with a transparent peripheral zone.

b) Late: The central region of the egg has fat cells surrounded by cleaved peripheral granulated cells. At this stage, both the outer egg membrane as well as the inner naupliar membrane (Hoshi, 1951) are seen (Plate IA).

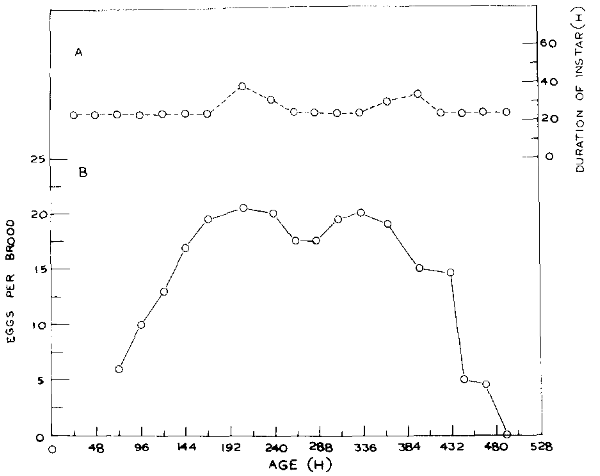


Fig. II. (a) Age in hours and duration of instars in *Scapholeberis kingi*. (b) Egg production per brood in *Scapholeberis kingi* with reference to age in hours.

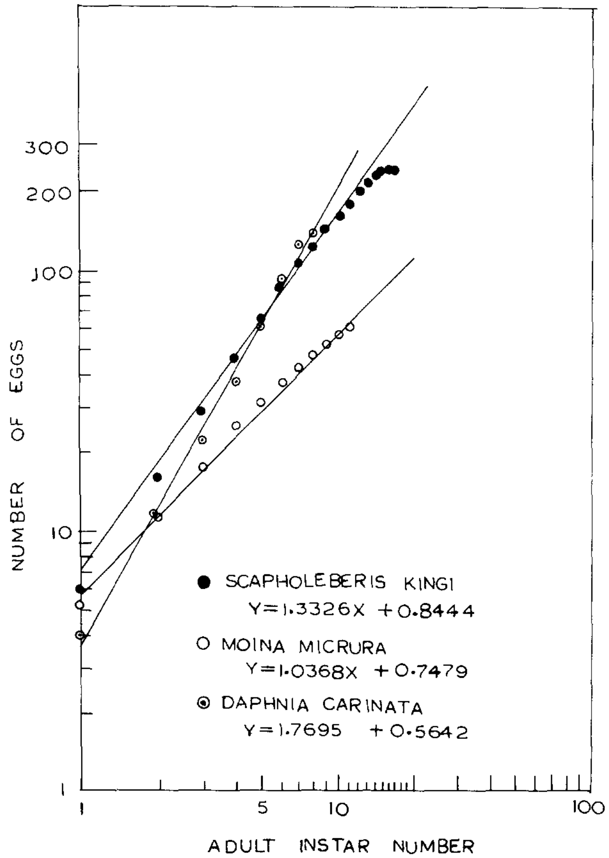
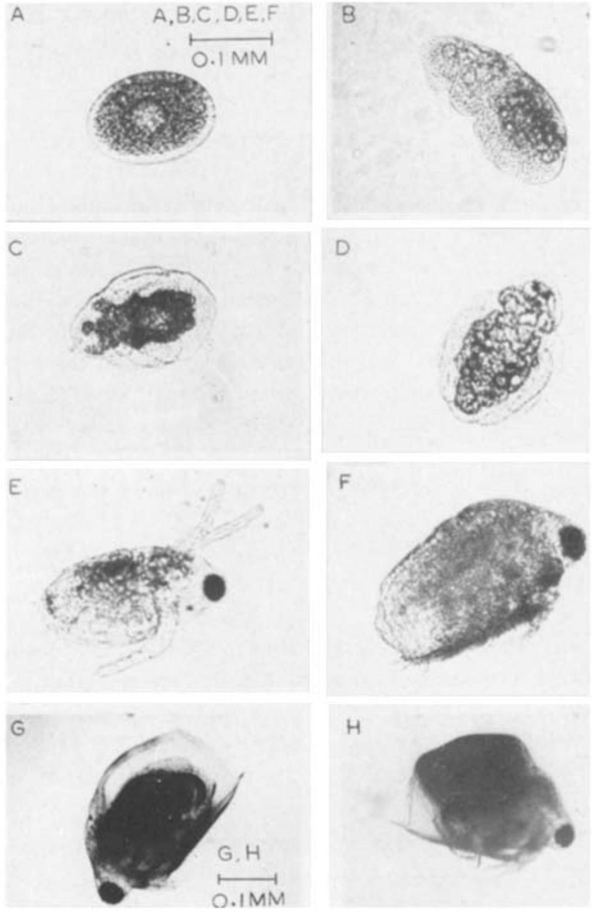


Fig. III. Cumulative egg production related to adult instar numbers in *Scapholeberis kingi*, *Moina micrura* and *Daphnia carinata*.



A. The oval egg of Scapholeberis kingi. B. Elongated headless embryo showing antennary rudiment. C. Dorsal view of the embryo showing the extention of cleaved cells in the cephalic region. D. Embryo with the head and limb rudiments. E. Late stage embryo with dark eyes and cervical depression. F. Neonate. G. Parthenogenetic female. H. Ephippial female.

II. Middle Stage

a) Early: The embryo has become elongated anteroposteriorly. The egg membrane is cast off. The lateral view of the embryo at this stage reveals that the cleaved cells are found more towards the dorsal side. Stumpy antennary rudiments have developed (Plate IB).

B) Middle: The dorsal view shows that the cleaved cells have extended into the cephalic region on either side of the eye. The central fat cells have not yet disappeared. The antennae have elongated. The head rudiment is formed (Plate IC).

c) Late: Distinct head and limb rudiments have been formed (Plate ID).

III. Late Stage

a) Early Distinct dark eyes are formed. The cervical depression is clear (Plate IE).

b) Late: The embryo has reached maximum elongation. Characters of adult morphology such as the straight ventral margin of the shell ending posteriorly in a spine, the quadrate shape, the fine short setae on the ventral margin of the shell and the reddish brown colour have developed (Plate IF).

Parthenogenetic and ephippial females of *S. kingi* are shown in Plate I, G and H.

Discussion

The present study reveals that at 28°-30° C *S. kingi* has a total of nineteen, two preadult and seventeen adult instars. It may be relevant to point out that the same number of instars was recorded in *S. mucronata* (O. F. Muller) by Rammner (1927). There is considerable variation in the number of preadult and adult instars in different tropical, temperate and arctic cladocerans (Table II). These differences are understandable as it had been sugested that hereditary factors and even differences in the culture media may cause variation in the number of instars (Anderson & Jenkins, 1942; Murugan & Sivaramakrishnan, 1973).

The preadult instars in *S. kingi* have an uniform duration of 24 hours. Most adult instars also have the same duration except the 8th, 9th, 10th, 14th and 15th whose duration varies from 24.4 to 38.4 hours (Fig. II). Normally in Cladocera, the first adult instar, during which the females are primiparous, is distinctly longer than the longest preadult instar as observed in *Daphnia carinata* (Navaneethakrishnan & Michael, 1971) and in *Simocephalus acutirostratus* (Murugan & Sivaramakrishnan, 1973). Even certain temperate species of *Daphnia*, though reared at much lower temperatures, still showed relatively longer duration of first and subsequent adult instars (Anderson *et al.*, 1937; Anderson & Jenkins, 1942; Ingle *et al.*, 1937). However, these earlier reports are not in conformity with observations on *S. kingi* where the preadult and primiparous instars were of similar duration. Yet another instance where the duration of preadult and all adult instars are remarkably constant, extending to 24

Table II: Comparative Data on the Life Cycles of Five Tropical Cladocerans

Name of the animal	Total eggs	a value	Mean number of eggs: Total No. of eggs / No. of adult instars	Number of preadult instars	Number of adult instars	Mean length mm.	Total life span (Days)	Duration of embryonic development (h)
Simocephalus acutirostratus King	248.0	1.1389	13.7	4	18	3.200	44.0	46 at 28 ° - 30°C
Daphnia carinata King	142.4	1.7695	17.8	5	8	2.900	24.0	40,8 at 28 °. 31°C
Scapholeberis kingi Sars	239.4	1.3326	14.8	2	17	0.920	20.5	24 at 28 ° - 30°C
Moina micrura Kurz	61.2	1.0368	5.6	2	11	1.008	13.0	24 at 28 ° - 30°C
Ceriodaphnia cornuta Sars	42.0	1.1959	4.6	2	9.	0.660	12.0	38 to 40 at 28 ° - 31°C

hours each, is in the tropical cladoceran *Moina micrura* Kurz, as recently reported (Murugan, 1975). Thus, in the light of the above data, it may be stated that it is probably not always a characteristic feature of the daphnid life cycle for the primiparous instar to be of longer duration than the preadult and adult instars as suggested earlier by the present authors (Murugan & Sivaramakrishnan, 1973). The mean number of eggs per brood is plotted against age (in hours) for *S. kingi* in Fig. II. There is a gradual increase from the first adult instar till the 6th and an uniformly high rate of egg production in the succeeding 8 instars with minor fluctuations. There is a sharp decline after the 14th adult instar with no eggs in the last instar. It is of interest to compare the pattern of egg production of *S. kingi* and other tropical species. In *D. carinata* the number of eggs produced increases until the penultimate instar (Navaneethakrishnan & Michael, 1971). In *S. acutirostratus* there is a bimodel pattern of egg production (Murugan & Sivaramakrishnan, 1973). In *Moina micrura* there is a single peak of egg production at the 4th adult instar followed by a very gradual decline until the last instar (Murugan, 1975). *S. kingi* exhibits no sharp peak in egg production. A decline in egg production towards the end of the life cycle seems to be the only feature that it shares with the above mentioned species. Clearly the pattern of egg production varies from one species to another even among tropical cladocerans. Suggested causes of such variations in egg production are fluctuations in the amount of food (Dunham, 1938; Anderson & Jenkins, 1942), or temperature (MacArthur & Baillie, 1929) and genetic differences in varous strains of the same species (Banta & Wood, 1939).

Fig. III shows the cumulative egg production in *S. kingi* and also of *Moina micrura* and *Daphnia carinata*. The angle of slope of the regression line in *S. kingi* (a value = 1.3326) indicates the rate of egg production. Similar data for the rate of egg production for other tropical cladocerans along with other parameters are shown in Table II. The rate of egg production as revealed by the a values could not be directly related to total egg production in the different species. However, the total number of eggs produced in each species is related to their mean length and total life span. It appears that similar correlation could even be extended to the mean number of eggs and the number of adult instars in relation to total egg production. Although these relationships appear valid, yet each species is characterized by its own unique life cycle pattern as revealed in the data (Table II). It is likely that while the similarities are brought about by the tropical habitat in which they live, the differences are imposed by their genetic make up.

The progressive increase in size of the individual in each instar is a measure of growth rate. The mean size at each instar has been plotted against instar number for five cladocerans, *Daphnia middendorffiana* (Arctic), *D. pulex* (temperate), *D. carinata* (tropical), *S. acutirostratus* (tropical), *Moina micrura* (tropical) in addition to the present species (Fig. I). In *S. kingi* the growth rate is very gradual in the reproductive phase though it is rapid in the preadult phase. The present study regarding the growth pattern of *S. kingi* further confirms the already expressed view that rapid preadult growth seems to be a common feature for cladocerans irrespective of climatic differences (Murugan & Sivaramakrishnan, 1973). The amount of growth per instar is said to be positively correlated with the food supply (Hutchinson, 1967), but studies on the growth pattern of *S. kingi* at different food and temperature levels have not been attempted. Anderson (1932) has also shown convincingly that reproductive maturity ordinarily corresponds to the inflection point of the growth curve.

Analysis of the growth rate of the early phase in the life cycle of a few tropical cladocerans reveals that maximum growth was between the third and fourth preadult instars in *S. acutirostratus* (0.45 mm – Murugan & Sivaramakrishnan, 1973), between the first and second preadult instars in *Moina micrura* (0.085 mm – Murugan, 1975), between the second and third and the fifth and sixth instars in *D-carinata* (0-3 mm – Navaneethakrishnan and Michael, 1971) and between the first and second instars in the present species (0.134 mm). These findings are in agreement with those of Green (1956) who reported that in many Cladocera the maximum growth was in early preadult instars.

Comparison of the embryonic stages of *S. kingi* with those of other cladocerans reveals a close similarity of the general developmental pattern, though there are variations in the duration of the embryonic period (Table II). It is well known that the duration of brooding, while the young are still in the pouch, depends on the length of the instar (Hutchinson, 1967). However, the rate of development is relatively faster in tropical species than their temperate allies, which may be a device rapidly to build up the population before adverse environmental conditions set in as pointed out earlier (Murugan & Sivaramakrishnan, 1973).

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