ORDER CTENOPODA

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Chapter 4

ORDER CTENOPODA

Family Sididae Baird, 1850

4. 1 ***Pseudosida bidentata*** Herrick, 1884

var. ***Szalayi*** (Daday, 1898)

Pseudosida bidentata var. *szalayi* is a littoral cladoceran found in a variety of habitats like ponds, marshes, and rice fields. They were generally collected from among the vegetation and from shallow water bodies. This species was described first by Herrick (1884). Subsequently Daday (1898) described var. *szalayi*. Thomas (1961) reviewed the validity of the name *P. bidentata* and suggested that the species name *bidentata* should be retained. The character that differentiated var. *szalayi* from *P. bidentata* is a spine-like projection on the distal margin of the postabdomen. *P. bidentata* was reported from the shallow water bodies of tropical countries especially from Sumatra, Sri-Lanka, Malaysia, South Africa and Southern United States.

The first record of this species in Kerala is from the collections of Nayar, C.K. G. from Irinjalakuda, reported by Michael and Sharma (1988). A spine-like projection was clearly visible in the specimens collected for the present study and hence described it as *P. bidentata* var. *szalayi*. The biology of *P. bidentata* has not been investigated so far and hence a detailed study of the life cycle of the parthenogenetic female and male have been made.

4. 1. 1 External Morphology

Parthenogenetic female (Plate 3. Fig. B)

Body elongated and oval-shaped, with short head and rostrum. Eye relatively small, situated near the anteroventral corner (Plate 2. Fig. A). Antennules unsegmented, rather long and attached to posteroventral part of the head, with a group of short setae half way along its length and a long sensory seta at the tip (Plate 2. Fig. C). Antennae stout, do not extend beyond the posterior margin of valves; with 2-segmented dorsal ramus and 3-segmented ventral ramus; setation of antenna: (5-10)/ (0-1-3). Dorsal and ventral margin of the valves convex, while the posterior margin rounded. Postabdomen short and broad, with a median projection at its apex (Plate 2. Fig. B); anal denticles absent, lateral surface armed with about 10 clusters of spinules and groups of fine setules; claw long, curved and sharply pointed dorsally; convex surface serrated along the entire length, concave surface with a series of short setules and 3 basal spines; groups of short spinules on the ventral and lateral side of the basal spine; proximal end of the postabdomen has 2 long natatorial setae.

Mean size: 1.925 × 0.908 mm

Male (Plate 3. Fig. C)

Male smaller than female. Antennule elongated (Plate 2. Fig. E). First thoracic leg modified to form a curved hook. Postabdomen with two sperm ducts, one on each side (Plate 3. Fig. D). Mean size: 1.266 × 0.616 mm.

Ephippial female (Plate 3. Fig. E)

Ephippial female similar to parthenogenetic female in external morphology. Most often each female carries 2 to 4 separate ephippia on either side; each enclosing single egg (Plate 3. Fig. E). The ephippium oval, comparatively small, white in colour without pigmentation; anterior broad end with an air space, and a few spines on its surface (Plate 3. Fig. F).

Mean size of ephippial female: 1.386 × 0.750 mm. Mean size of ephippium: 0.366× 0.291 mm

4. 1. 2 Reproduction

The population developed during the laboratory culture comprised asexually reproducing females, ephippia bearing females and males. The parthenogenetic females produced male and female neonates from a single clutch. Thus the individuals produced from a single clutch were all females, all males or both males and females. Among this the parthenogenetic females dominated the culture.

The appearance of males was followed by the production of ephippial females in the culture. The ephippial females appeared when the stock culture was crowded. These ephippial females were produced during their early instars, which resumes parthenogenetic reproduction after 1-2 generations. Although, each ephippial female produced two ephippia at a time, each ephippium enclosed single egg within it. Some of the ephippia were also produced without eggs within it. The ephippium was released into the medium during moulting after being completely detached from the carapace.

Life cycle of male

Males appeared in the culture before the production of ephippial females and were produced from the parthenogenetic females. The males could be identified early in life by the presence of their relative smaller size and elongated antennule. Twenty male neonates were sorted out and individually reared in 10 ml test tubes as cited in section 3. 2. 3.

The male neonates had mean Size at Birth (SaB) of 0.672 × 0.236 mm. The 1st and 2nd moulting occurred in same duration of 30.5 hrs each, while the 3rd moulting took place after an interval of 37 hrs. The first pre-adult neonates had mean TL of 0.683 and attained TL of 0.975 mm after 1st moulting. The CH was 0.241 and 0.341 mm respectively during first and second instars. They attained mean size of 1.142 × 0.440 mm during 3rd instar and became mature (Table 4). They underwent 3 moults in a total pre-adult duration of 98.0 hrs.

The maximum increment in TL (42.75%) and CH (41.49%) was recorded after the 1st moulting (Table 4). The increment after 2nd moulting was TL (23.08%) and CH (26.10%) respectively. The increment of TL and CH decreased after the third moulting (5th day) and there was no moulting further till death. The maximum increment of growth occurred during the pre-adult instars (Fig. 1 b). The mean life span is calculated as 10.43 days while the maximum life span of *P. bidentata* male observed in the present study (Lmax) was 22.5 days (Fig. 1 e).

Life cycle of parthenogenetic female

The population developed during laboratory culture of *P. bidentata* comprised a sufficient number of parthenogenetic females. The reproduction and life cycle of *P. bidentata* female was studied by culturing them individually following the methodology given in section 3. 2. 3.

The features characteristic of the reproduction and life cycle are given as follows.

Pre-adult instar

The neonates produced from the parthenogenetic females had an average Size at Birth (SaB) of 0.697 × 0.246 mm. Both the first and second moulting occurred in a uniform duration of 21.5 hrs while the third moulting took place after an interval of 29.0 hrs. The total pre-adult instar duration was 72.0 hrs and the mean Pre-adult Instar Duration (PID) was 24.0 hrs.

Attainment of maturity

Although, the development of ovary in the parthenogenetic female started very early in the life cycle the ovary became conspicuous at 68±1.2 hrs of life (Plate 3. Fig. A). The ovary appeared as elongated structures on either side of the alimentary canal. They started to bear eggs after completion of 3rd moult at 72 hrs; and hence the Age at First Reproduction (AFR) was 3.0 days. The Size at First Reproduction (SFR) was 1.300 × 0.533 mm (Table 1). The Relative Length (RL) and Relative Height (RH) of neonates were 0.420 and 0.349 mm respectively.

Egg production

Eggs were deposited into brood pouch after completion of three moults. The eggs very soon attained an elongated shape with slight yellow-green colour. There was an accumulation of yolk and lipid droplets after deposition into the brood pouch and the eggs measured a length of 0.300 mm. During this primiparous instar (4^{th} instar) egg production started with a mean of 4.37 eggs/ brood. The primiparous instar was completed in 38.0 hrs and the First Generation Time (FGT) is calculated as (72hrs + 38hrs) = 110.0 hrs.

During the subsequent instars there was a steady increase in egg production to 15.2 eggs/ brood. This maximum clutch size (Emax) was attained in the 11^{th} instar (Table 1). The egg production of *P. bidentata* showed a single peak with maximum egg production in the 11^{th} instar followed by a steady decrease (Fig. 1 c). The egg production continued upto 15^{th} instar followed by 2 instars without egg production.

The female underwent moulting towards the end of each instar. Each clutch in the early adult instar consisted of 1-2 rows of eggs on either side of the brood pouch, which were very clearly observed in live animals. The adult instar duration varied from 36.0 to 45.0 hrs, with a mean Adult Instar Duration (AID) of 38.42 hrs. The relationship of egg production with instar number is represented in Fig. 1 c.

Fecundity

The range of egg production of a single female varied from 2 to 16 with an egg production of 4.83 eggs/day of adult life. The cumulative number

of eggs produced (Σmx) during the entire life span was 108.13 (Table 1). Twelve broods were produced during the entire life with a mean of 9.0 eggs/ brood. The cumulative egg production (Σmx) was linearly correlated with instar number (Fig. 1 d) to obtain the Rate of Egg Production (REP). The angle of slope of regression line gives the rate of egg production and hence the REP of *P. bidentata* is calculated as 9.0919.

4. 1. 3 Growth

The first pre-adult neonates had a mean Total Length (TL) of 0.721 mm and the 2nd instar had TL of 0. 808 mm. During the 3rd instar it attained TL of 1.100 mm. Primiparous stage was attained during the 4th instar when the mean TL was 1.300 mm. The maximum mean TL of 2.046 mm was attained at the end of 17th instar (Table 2).

The mean Carapace Height (CH) during the first pre-adult instar was 0.250 mm and attained CH of 0.285 mm at second instar. During the third instar it attained CH of 0.391 mm. They attained a mean CH of 0.533 mm during the primiparous condition. Maximum mean CH was attained in 16th instar with CH of 0.906 mm which remained unchanged during 17th instar (Table 2). During the life span each individual has undergone three pre-adult and fourteen adult moults.

The increment of TL and CH during each instar is given in Table 2. The maximum growth increment recorded during the life cycle was in 3rd instar; however the most significant decrease in growth increment occurred only after the 8th instar. The relationship between TL, CH and instar

number of *P. bidentata* is represented in Fig. 1 a. The correlation coefficients of life history characters in *P. bidentata* are given in Table 3. The TL and CH are positively correlated ($r = 0.997$).

4. 1. 4 Embryonic Development

The stages of embryonic development of *P. bidentata* are represented in Plate 4. The most conspicuous features of the developmental stages are given below.

Stage I: This stage is recognized by the presence of spherical eggs which are yellow in colour. Mean duration: 0.5 hrs. Mean size: 0.310 mm

Stage II: The embryo becomes pear-shaped with yellow colour. The yolk granules are centrally placed.

Mean duration: 2.4 hrs. Mean size: 0.332 mm

Stage III: The embryo is more elongated during this stage. The outer transparent area of the embryo shows cellular division and the inner area appeared granular with the centrally placed fat globule.

Mean duration: 8.1 hrs. Mean size: 0.398 mm.

Stage IV: During this stage the cellular divisions are distinguishable and the embryo is more elongated in anterio-posterior axis. The rudiments of head and antennae are visible during this stage.

Mean duration: 9.5 hrs. Mean size: 0.465 mm

Stage V: The rudiments of head, antennule, antennae, and postabdomen appear. The yolk granules are conspicuous and appeared green coloured. Mean duration**:** 4.3 hrs. Mean size: 0.508 mm

Stage VI: This stage can be recognized by the presence of pink eyes. The rudiments of antennae antennules and the postabdomen are clearly visible. Mean duration: 4.5 hrs. Mean size: 0.510 mm.

Stage VII: This stage can be recognized by the presence of black eyes. The rudiments of antennae antennules, thoracic legs and postabdomen are distinct. Mean duration: 6.5 hrs. Mean size: 0.546 mm.

Stage VIII: This stage can be recognized by the presence of black eyes and ocellus. The antennae antennules, thoracic legs and the postabdomen are distinct. Some movements are also initiated in the embryo.Mean duration: 1.7 hrs. Mean size: 0.558 mm

Release of neonates: The neonates are released to the exterior by the jerking movements of the mother. This could be regarded as the final event of embryonic development. The embryonic development of primiparous instar of *P. bidentata* was completed in 37.5 hrs.

4. 1. 5 Life Span and Survivorship

The survivorship curve (Fig.1 e) indicated the relationship of age (days) and percentage survival of *P. bidentata.* The mean life span (Σlx) of female is calculated as 9.85 days while the maximum life span (L max) of female observed during the present study was 25.41 days.

4. 2 *Latonopsis australis* Sars, 1888

L. australis was described first by Sars (1888) from Australia. Harding and Petkovski (1963) after examining a number of important characters concluded that *L. australis* was the only valid name; and considered name *L. occidentalis* Birge as a synonym. The first report of this species from India is by Biswas (1971) from Rajasthan and subsequently recorded from Tamil Nadu by Michael and Sharma (1988) and Venkataraman (1993). Babu and Nayar (2004) reported this species from Thekkady, Kerala.

The available literature shows that the biology of *L australis* has not been studied so far and hence an investigation of the life cycle of the parthenogenetic female has been made.

4. 2. 1 External Morphology

Parthenogenetic female (Plate 5. Fig. C)

Body elongated; short and thick head, indistinctly separated from the rest of body. Eye located very near to anterior margin of head, ocellus minute (Plate 9. Fig. A). Antennule segmented with a long flagellum beset with sensory setae (Plate 9. Fig. B). Antennae short and broad about half the maximum length of the body, with 2-segmented dorsal ramus and 3-segmented ventral ramus; setation of antenna: (4-7)/ (0-1-4). Valves slightly convex dorsally and broadly rounded ventrally; ventral margin with a series

of long and movable setae; 3 long plumose setae at posteroventral corner along with other setae decreasing in length dorsally (Plate 9. Fig. A). Postabdomen short, with 8-9 marginal spines and claw with 2 long basal spines (Plate 9. Fig. C). Mean size: 1.125×0.642 mm.

Male (Plate 5. Fig. D)

Male smaller than female. Head short and thick, visually not separated from the body. Antennules long, attached to the anteroventral corner of head; with club-shaped series of setae on the proximal end; segmentation in antennule not clearly visible (Plate 9. Fig. D). Postabdomen short with two long sperm ducts; lateral surface armed with a series of 4-5 denticles (Plate 9. Fig. E). Mean size: 0.825×0.418 mm.

Ephippial female (Plate 5. Figs. E & F)

The general features of ephippial female similar to parthenogenetic female. Ephippium oval, relatively small, white in colour and located dorsally; most often carry 1-2 ephippia; each enclosing single egg; anterior broad end with an air space and a few spines on its surface (Plate 5. Fig. G). Mean size : 1.03×0.717 mm. Size of ephippium: 0.316×0.250 mm

4. 2. 2 Reproduction

The population developed during the laboratory culture comprised asexually reproducing females, ephippia bearing females and males. Among this the parthenogenetic females dominated the culture. Ephippial females were found to be produced either directly from primiparous individuals

or from parthenogenetic individuals who have already undergone 1-2 generations of parthenogenetic instars. Ephippial females appeared soon after the production of males. 1-2 ephippial eggs are produced at a time and released after completion of development, each enclosed single egg containing abundant yolk (Plate 5. Fig. G). They also produced ephippium without enclosing egg within it (Plate 5. Fig. H). The air space, present at the upper surface of ephippia enables floating. When the eggs get dried up, they float on the surface for some time and most often get attached to other objects in water.

Life cycle of parthenogenetic female

The features characteristic of the reproduction and life cycle of *L. australis* are given as follows.

Pre-adult instar

The neonates produced from the parthenogenetic females had an average birth size (SaB) of 0.512 × 0.208 mm. The first moulting occurred in an interval of 26.0 hrs while both the second and third moulting took place in a uniform duration of 28.0 hrs. The total pre-adult instar duration was 82.0 hrs and the mean PID was 27.33 hrs.

Attainment of maturity

Although, the development of ovary in the parthenogenetic female started very early in the life cycle, the ovary was clearly visible at 74±2.5 hrs (Plate 5, Fig. B). They started to bear eggs after completion of 3rd moult at

82.0 hrs; and hence the AFR was 3.42 days. The SFR was 1.104×0.472 mm. The RL and RH of neonates were 0.464 and 0.441 mm respectively.

Egg production

The eggs were deposited into the brood pouch after the completion of three moults. Soon after the deposition into the brood pouch there was a rapid increase in size due to the accumulation of lipid droplets and yolk. The eggs thus attained an elongated shape with green colour and measured a mean length of 0.208 mm. During this primiparous instar (4^{th} instar) egg production started with a mean of 4.2 eggs/ brood. The primiparous instar was completed in 31.50 hrs and the first generation time (FGT) is calculated as 113.5 hrs.

During the subsequent instars there was a steady increase in egg production to 13.4 eggs/ brood. This maximum clutch size (Emax) was attained in the 8^{th} instar (Table 5). The egg production of *L. australis* showed a single peak with maximum egg production in 8^{th} instar followed by a steady decrease (Fig. 2 b). The egg production continued upto 12^{th} instar towards the end of life span. Each clutch in the early adult instar consisted of 1-2 rows of eggs placed on either side of the brood pouch. The female underwent moulting towards the end of each adult instar. The adult instar duration varied from 32.0 to 50.0 hrs (Table 5), with a mean AID of 42.85 hrs.

Fecundity

The relationship of egg production with instar number is represented in Fig. 2 b. The range of egg production of a single female varied from 2 to 15

with an egg production of 4.40 eggs/day of adult life. The cumulative number of eggs produced (Σmx) during entire life span was 73.1 (Table 5). Nine broods were produced during the entire life with a mean of 8.12 eggs/ brood. The cumulative egg production (Σmx) is linearly correlated with adult instar number (Fig. 2 c). The rate of egg production (REP) of *L. australis* is calculated as 7.9021.

4. 2. 3 Growth

The first pre-adult neonates had a mean TL of 0.608 mm and 2nd instar had TL of 0. 728 mm. During the 3rd instar it attained a TL of 0.888 mm. Primiparous stage was attained during the 4th instar when the mean TL was 1.104 mm. The maximum mean TL of 2.016 mm was attained at the end of 12th instar (Table 6). The mean CH during the first pre-adult instar was 0.256 mm and attained CH of 0.312 mm at 2nd instar. During the 3rd instar it attained CH of 0.356 mm. A mean CH of 0.472 mm was attained during the primiparous instar. Maximum mean CH of 0.840 mm was attained in 12th instar (Table 6). During the life span each individual has undergone three pre-adult and nine adult moults.

The size increment during each instar has been represented in Table 6. Maximum growth increment recorded during the life cycle was in 6th instar; and decreased during the subsequent instars. The relationship between TL, CH and instar number of *L. australis* is represented in Fig. 2 a. The correlation coefficients of life history characters are given in Table 7. Positive correlation was obtained between TL and CH ($r = 0.996$).

4. 2. 4 Embryonic Development

The embryonic stages are described based on Plate 6 and the conspicuous characters are mentioned below. The embryonic development of primiparous instar of *L. australis* was completed in 30.5 hrs.

Stage I: This stage is recognized by the presence of oval-shaped egg which appears green in colour. The inner zone of the egg appeared granular and contains abundant yolk granules. Mean duration: 1.0 hrs. Mean size: 0.229 mm

Stage II: The embryo shows elongation. The outer transparent zone becomes more distinct. Fat globules are centrally placed in green coloured yolk granules. Mean duration: 1.5 hrs. Mean size: 0.246 mm

Stage III: The embryo is more elongated during this stage. The outer transparent zone of embryo shows cellular division. Mean duration: 4.6 hrs. Mean size: 0.269 mm

Stage IV: During this stage the embryo is more elongated in the anterio-posterior axis. The head lobe appears during this stage. Mean duration: 2.2 hrs. Mean size: 0.302 mm

Stage V: The cellular divisions are visible and rudiments of head appear at the anterior region. Mean duration: 4.0 hrs. Mean size: 0.307 mm.

Stage VI: The head lobe becomes more distinct with the appearance of complete segmentation over the outer transparent area. Mean duration: 3.5 hrs. Mean size: 0.317 mm

Stage VII: The rudiment of antennae is more distinctly visible. The posterior region shows distinct cellular divisions with initiation of the development of thoracic legs and postabdomen. Mean duration: 1.2 hrs. Mean size: 0.317 mm

Stage VIII: The outer membrane is cast off and the rudiments of head antennae and thoracic legs are more clearly visible. Mean duration: 3.40 hrs. Mean size: 0.347 mm

Stage IX: The presence of eye is noticed for the first time during this stage. The head, antennules, rudiments of legs and postabdomen are very distinct. The amount of yolk gets decreased. Mean duration: 4.8 hrs. Mean size: 0.370 mm.

Stage X: The eye and postabdomen become distinct. Setae appear on the antennules, antennae and thoracic legs. Yolk completely disappears. Movements are also initiated in the embryo during this stage. Mean duration: 4.3 hrs. Mean size: 0.586 mm.

4. 2. 5 Life Span and Survivorship

The survivorship curve (Fig. 2 d) indicates the relationship of age (days) and percentage survival of *L. australis*. Survival was higher near the age of maturity and declined steadily further after maturity. The mean life span (Σlx) of female is calculated as 7.95 days; while the maximum life span (Lmax) observed in the present study was 19.49 days.

4. 3 *Diaphanosoma sarsi* Richard, 1894

Diaphanosoma sarsi is a planktonic cladoceran which often dominates the limnetic region of lakes, man made reservoirs, marshes and rice fields. This species was described first by Richard (1894). *D. sarsi* was first reported in India from Bihar (Gurney, 1907) and later from Rajasthan (Biswas, 1971); Meghalaya (Patil, 1976); West Bengal (Sharma, 1978) and Delhi (Michael and Sharma, 1988). Raghunathan (1989a) made the first record of *D. sarsi* from Wynad, Kerala. The first report of the males of this species from India is that of Babu and Nayar (2004) collected from Thekkady, Kerala.

4. 3. 1 External Morphology

Parthenogenetic female (Plate 7. Fig. B)

The body elongated and highly transparent. Head small, without rostrum. Eye relatively large (Plate 9. Fig. G). Antennules small, cigarette-shaped with terminal setae. Antennae large but not reaching the posterior margin of valves; dorsal ramus 2-segmented and ventral ramus 3-segmented (Plate 9. Fig. F). Thoracic legs six pairs, of similar structure. Valves with varying number of denticles followed by a series of fine setules (Plate 9. Fig. H); ventral margin inflexed to form a broad flap. Postabdomen narrow, without anal spines; claw with 3 long and sharply pointed basal spines (Plate 9. Fig. I). Mean size: 1.022×0.404 mm

Male (Plate 7. Fig. C)

Smaller than female, characterized by the presence of long whip-like antennule (Plate 9. Fig. J). Postabdomen with two long sperm ducts. Endopodite of first thoracic leg modified to form a sickle-shaped hook. Mean size: 0.690 mm.

Ephippial female (Plate 7. Fig. D)

Ephippial female similar to parthenogenetic female in external morphology. Most often each female carried 2 to 4 ephippia, on either side, each enclosing single egg. The ephippium sphere-shaped, comparatively small, white in colour, having finger like outgrowths over the surface (Plate 7. Fig. E). Mean size: 0.730 mm. Size of ephippium: 0.180 mm

4. 3. 2 Reproduction

The population developed in the laboratory comprised asexually reproducing females, ephippia bearing females and males. Ephippial females were produced directly from individuals during their early adult instars, and resumed parthenogenetic reproduction after 1-4 sexual generations. The ephippia were spherical, comparatively smaller, with finger shaped outgrowths on their surface and released during moulting. The number of ephippia produced by each ephippial female ranged from 2 to 4. They are placed on either side, each enclosed single egg. The outgrowths present on the surface of ephippium helps to float on the water surface or clinging to the vegetation.

Males appeared just before the production of ephippial females. However, the parthenogenetic reproduction was dominant during its life.

Life cycle of parthenogenetic female

Parthenogenetic population dominated in the *D. sarsi* culture throughout the study period. The parthenogenetic females were individually cultured to study the following features characteristic of the life cycle.

Pre-adult instar

The neonates produced from the parthenogenetic females had a mean SaB of 0.522 × 0.184 mm. The first and second moulting occurred in duration of 24.0 hrs and 24.5 hrs respectively. The total pre-adult instar duration was 48.5 hrs and the mean PID was 24.25 hrs.

Attainment of maturity

The ovary appeared as elongated structures on either side of the alimentary canal and was clearly visible at 39±2 hrs of life (Plate 7. Fig. A). However, they started to bear eggs after completion of 2nd moult at 48.5 hrs; and hence the AFR was 2. 02 days. The SFR was 0.809 ×0.302 mm. The RL and RH of neonates were 0.522 and 0.609 mm respectively.

Egg production

Eggs were deposited into the brood pouch after the completion of two moults. The egg production started during the primiparous instar (3rd instar) with a mean number of 4.2 eggs/ brood. The amount of yolk and lipid

droplets was very low even after deposition into brood pouch and hence the eggs appeared transparent. The eggs measured a mean length of 0.299 mm during this stage; and having an elongated shape with slight green colour. The primiparous instar was completed in 32.0 hrs and the FGT is calculated as 80.5 hrs.

During the subsequent instars there was a steady increase in egg production to 13.0 eggs/ brood (Table 8). This maximum clutch size (Emax) was attained in the 9th instar. The egg production of *D. sarsi* showed a single peak with maximum egg production in 9th instar (Fig. 3 b). Although, egg production decreased subsequently; there was the production of a uniform number of eggs in each brood. The egg production continued throughout the life span up to the 15th instar (Table 8). Each clutch produced in the early adult instar consisted of 1-2 rows of eggs on either side of the brood pouch. The adult instar duration varied from 30.0 to 39.0 hrs, with a mean AID of 35.04 hrs.

Fecundity

The relationship between egg production and instar number is represented in Fig. 3 b. The range of egg production of a single female varied from 4 to 16 with an egg production of 6.17 eggs/day of adult life. The cumulative number of eggs produced (Σmx) during the entire life span was 117.3 (Table 8). Thirteen broods were produced during the entire life with a mean of 9.02 eggs/ brood. The cumulative eggs produced (Σmx) is linearly

correlated with instar number (Fig. 3 c). The rate of egg production (REP) of *D. sarsi* is calculated as 9.2632.

4. 3. 3 Growth

The first pre-adult neonates had a mean TL of 0.552 mm and the 2nd instar had TL of 0.732 mm. The percentage of increment in TL during the pre-adult stage was 32.60%. The primiparous stage was attained during the 3rd instar when the mean TL was 0.809 mm. The maximum mean TL of 1.320 mm was attained at the end of 15th instar (Table 9).

The mean CH during the first pre-adult instar was 0.184 mm and attained CH of 0.248 mm at 2nd instar. The percentage of increment in CH after the completion of pre-adult instar was 34.78%. During the 3rd instar it attained the primiparous condition with a mean CH of 0.302 mm. The maximum mean CH of 0.486 mm was attained in 15th instar (Table 9). During the life span each individual has undergone two pre-adult and thirteen adult instars. Maximum growth increment recorded during the life cycle was in 2nd instar and further decreased during the subsequent instars (Table 9).

The relationship between TL, CH and instar number of *D. sarsi* is represented in Fig. 3 a. The correlation coefficients of life history characters in *D. sarsi* are given in Table 10. The TL and CH shows positive correlation ($r = 0.985$).

4. 3. 4 Embryonic Development

The stages of embryonic development of *D. sarsi* are represented in Plate 8. The most conspicuous features of the developmental stages are given below.

Stage I: This stage is recognized by the presence of oval-shaped eggs containing yolk and fat globule. Mean duration: 1.2 hrs. Mean size: 0.303 mm

Stage II: The embryo is more elongated during this stage. Yolk granules are centrally placed. Mean duration: 4.8 hrs. Mean size: 0.314 mm.

Stage III: The outer transparent area of the embryo shows cellular division. Head rudiment appears and yolk gets concentrated towards the centre. Mean duration: 5.2 hrs. Mean size: 0.324 mm.

Stage IV: The embryo is more elongated in anterio-posterior axis and the cellular divisions at the posterior region become more distinct during this stage. The rudiments of head, antennules and antennae appeared. Mean duration: 3.5 hrs. Mean size: 0.365 mm

Stage V: This stage is recognized by the presence of pink eye. The rudiments of antennae and thoracic legs are more visible. Mean duration: 3.2 hrs. Mean size: 0.412 mm

Stage VI: This stage is recognized by the presence of black eye. The rudiments of antennae, antennules, thoracic legs and postabdomen become more distinct. Mean duration: 5.6 hrs. Mean size: 0.426mm.

Stage VII: During this stage setae appear on the antennae, antennules, thoracic legs. Postabdomen become more visible. The amount of yolk gets decreased. Mean duration: 3.8 hrs. Mean size: 0.460 mm

Stage VIII: The eye, antennules, antennae, thoracic legs, postabdomen and valves are well developed during this stage. Movements are also observed in the embryo. Mean duration: 3.5 hrs. Mean size: 0.506 mm.

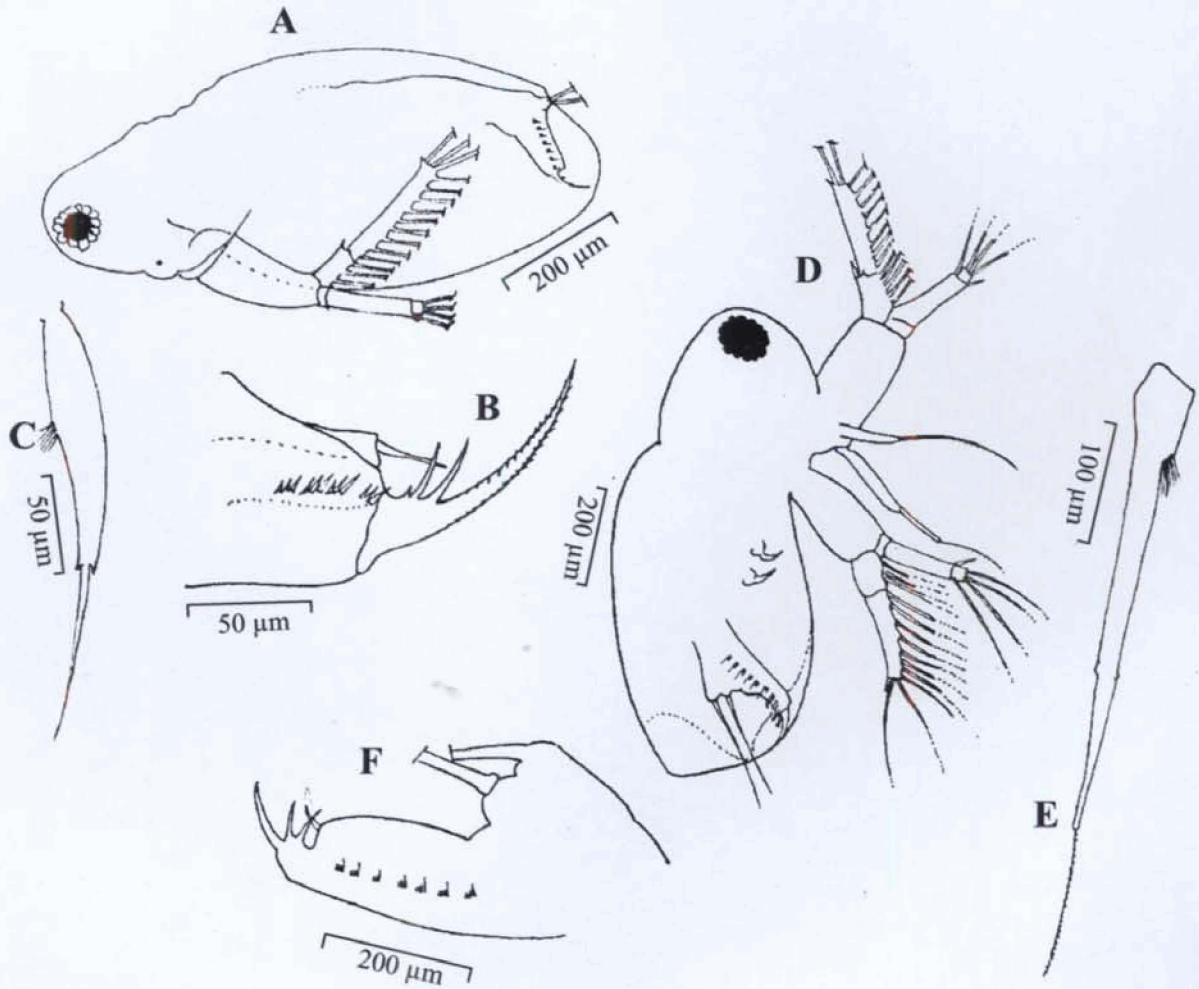
Release of neonates

The embryonic development of primiparous instar of *D. sarsi* was completed in 30.8 hrs and the neonates were released from the brood pouch prior to moulting.

4. 3. 5 Life Span and Survivorship

The survivorship curve (Fig. 3 d) indicates the relationship of age (days) and percentage survival of *D. sarsi*. As evident from the data survival was higher near the age of maturity and declined slowly further after maturity. The mean life span (Σlx) of female is calculated as 9.0 days; while the maximum life span (Lmax) observed during the present study was 21.0 days.

Plate 2

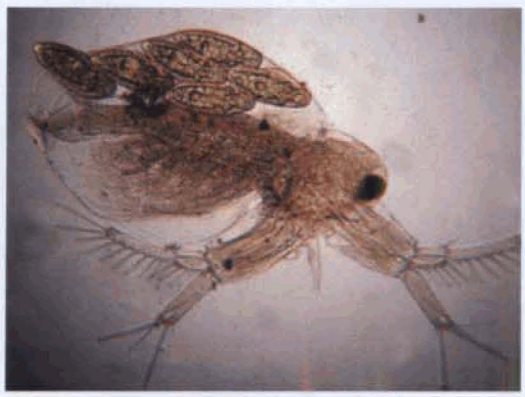


Pseudosida bidentata (Daday)

Fig. **A.** Female, **B.** Postabdomen of female, **C.** Antennule of female, **D.** Male, **E.** Antennule of male, **F.** Postabdomen of male.

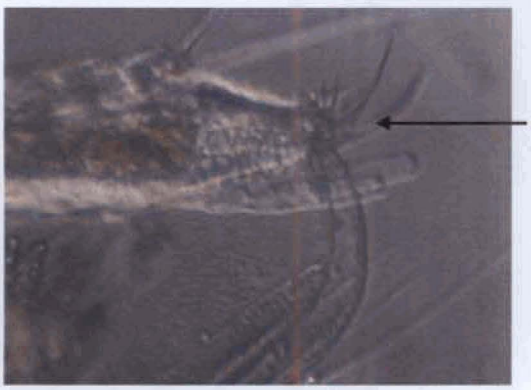
Plate 3

A



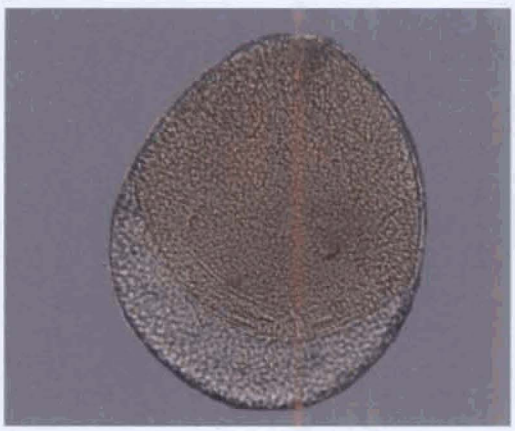
B

C



D

E



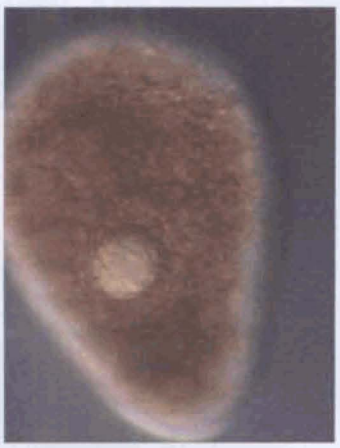
F

Pseudosida bidentata

Fig. **A.** Female with ovary (1.028 mm), **B.** Parthenogenetic female with embryo (1. 436 mm), **C.** Male (1.004 mm), **D.** Postabdomen of male enlarged **E.** Ephippial female (1.372 mm), **F.** Ephippium with egg (0.366 mm).

Plate 4

Stage-I (0.316 mm)



Stage-II (0.336 mm)

Stage-III (0.408 mm)

Stage-IV (0.469 mm)

Stage-V (0.506 mm)

Stage-VI (0.510 mm)

Stage-VII (0.546 mm)

Stage-VIII (0.556 mm)

Pseudosida bidentata Embryonic development

Plate 5

A

B

C

D

E

F

G

H

Latonopsis australis

Fig. **A.** Pre-adult (0.598 mm) **B.** Female with ovary (0.988 mm),
C. Parthenogenetic female (1.130 mm),
D. Male (0.822 mm), **E.** Ephippial female (1.08 mm), **F.** Ephippial female ventral view (1.16 mm)
G. Ephippium with egg (0.316 mm), **H.** Ephippium without egg (0.266 mm).

Plate 6

Stage-I (0.226 mm)

Stage-II (0.244 mm)

Stage-III (0.268 mm)

Stage-IV (0.296 mm)

Stage-V (0.306 mm)

Stage-VI (0.318 mm)

Stage-VII (0.320 mm)

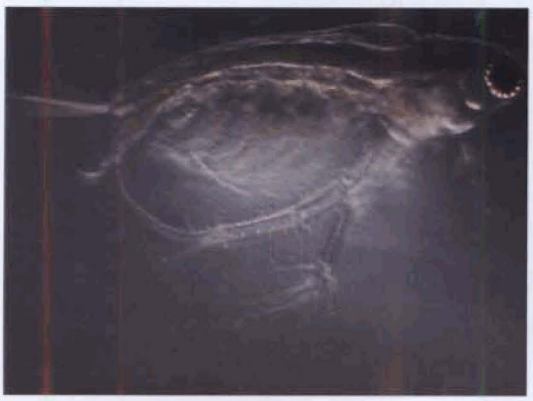
Stage-VIII (0.342 mm)

Stage-IX (0.384 mm)

Stage-X (0.602 mm)

Latonopsis australis Embryonic development

Plate 7

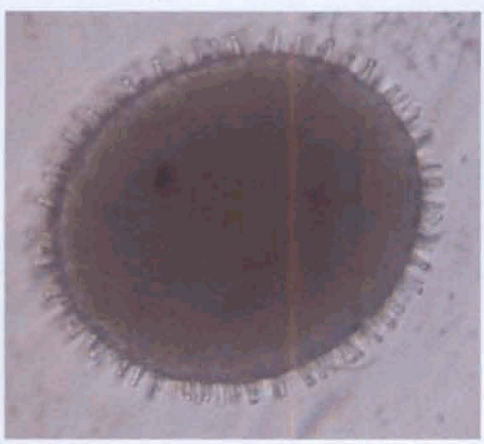


A

B

C

D



E

Diaphanosoma sarsi

Fig. **A.** Pre-adult (0.698 mm) **B.** Parthenogenetic female (0.946 mm)
C. Male (0.686 mm) **D.** Ephippial female 0.766 mm **E.** Ephippium (0.188 mm)

Plate 8

Stage-I (0.306 mm)

Stage-II (0.313 mm)

Stage-III (0.325 mm)

Stage-IV (0.368 mm)

Stage-V (0.418 mm)

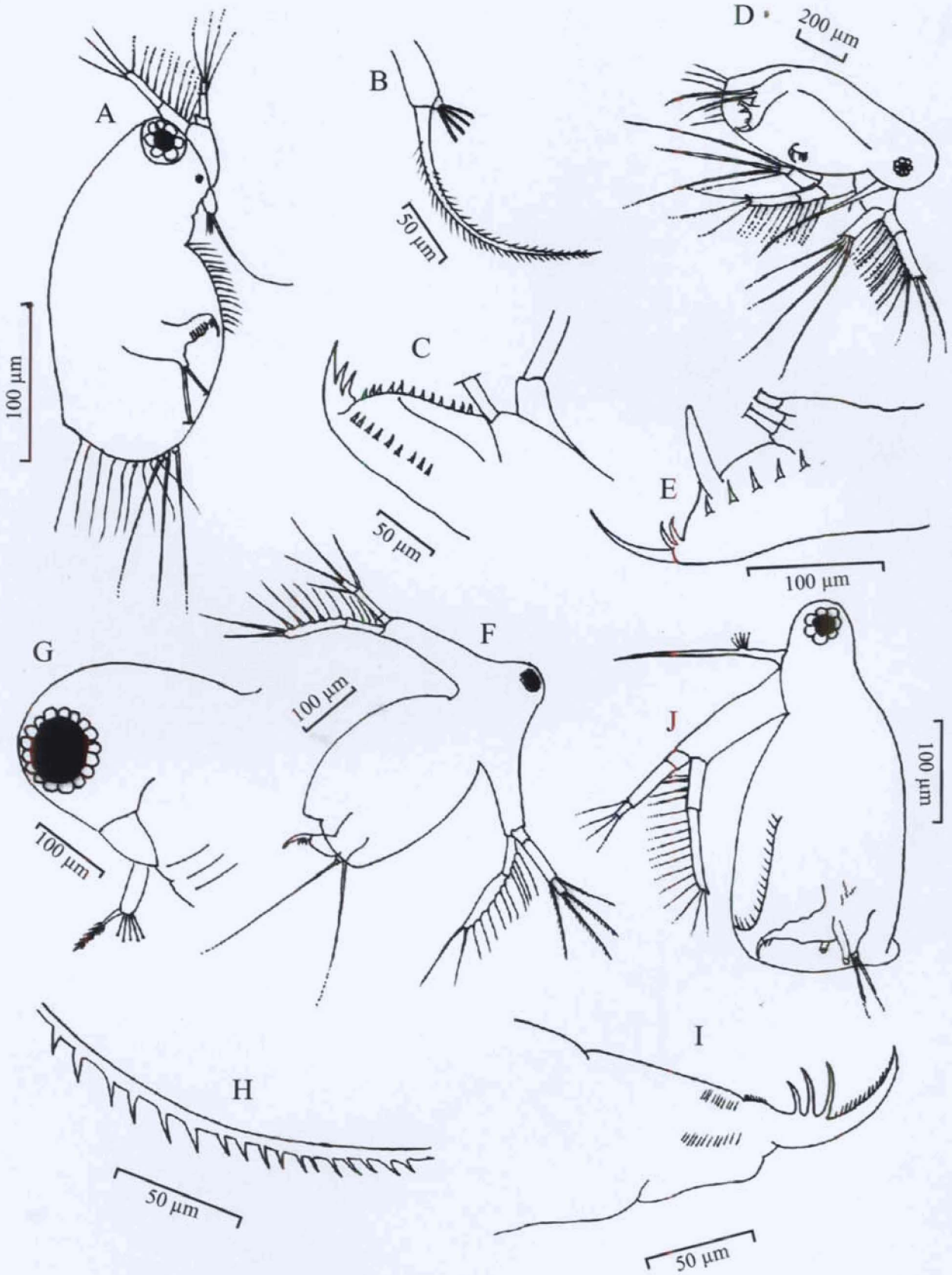
Stage-VI (0.426 mm)

Stage VII (0.462 mm)

Stage-VIII (0.502 mm)

Diaphanosoma sarsi Embryonic development

Plate 9



Latonopsis australis Sars Fig. **A.** Female, **B.** Antennule of female.
C. Postabdomen of female, **D.** Male, **E.** Postabdomen of male
Diaphanosoma sarsi Richard **F.** Female, **G.** Head with antennule,
H. Posteroventral margin of shell, **I.** Postabdomen of female. **J.** Male.

Pseudosida bidentata

Fig.1 a Relationship between Total length (TL), Carapace height (CH) and instar number in female

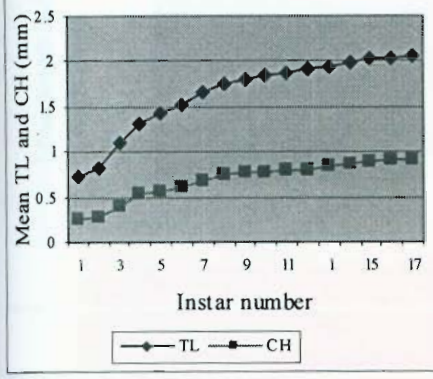


Fig. 1 b Relationship between Total length (TL), Carapace height (CH) and age in male

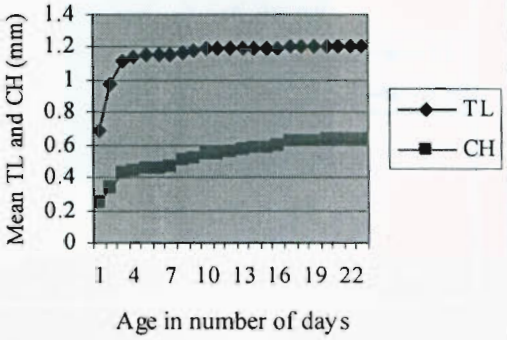


Fig. 1. c. Egg production in relation to instar number

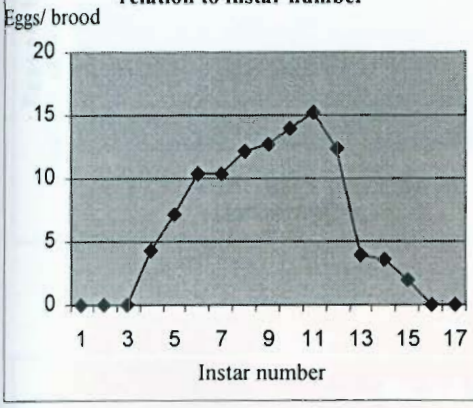


Fig. 1 d. Cumulative egg production related to adult instar number

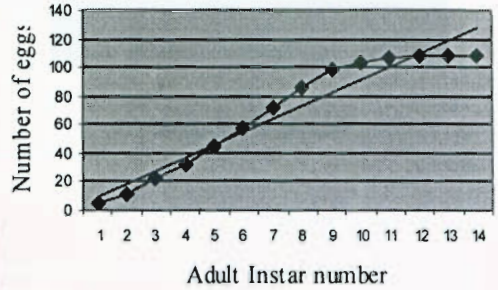
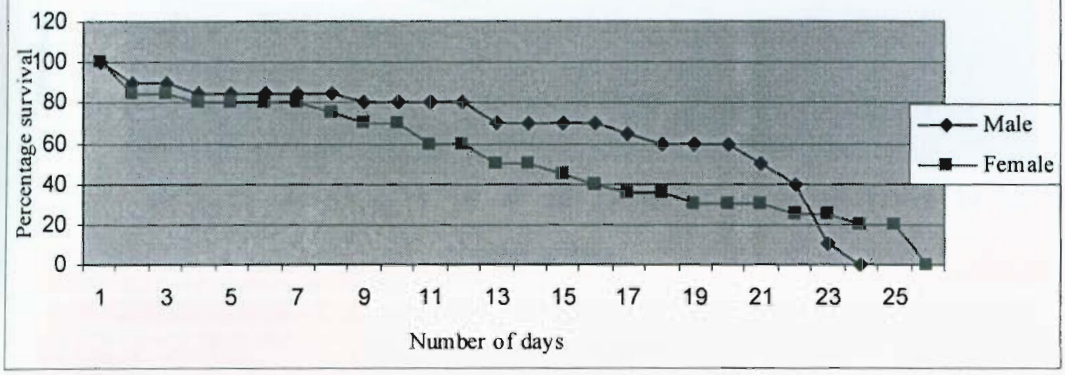


Fig. 1. e. Survivorship curve



Latonopsis australis

Fig. 2 a Relationship between Total length (TL), Carapace height (CH) and instar number.

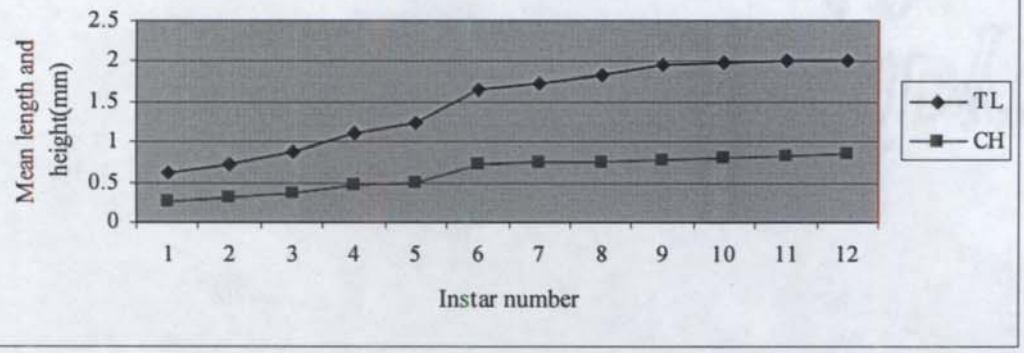


Fig. 2 b Egg production in relation to instar number

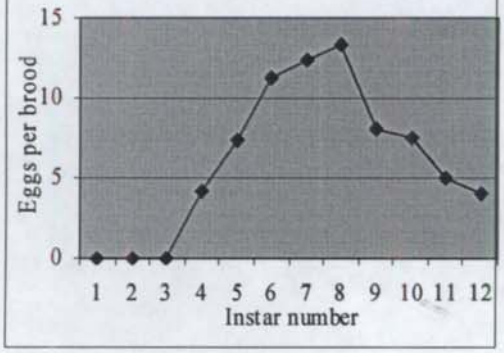


Fig. 2 c Cumulative egg production related to adult instar number

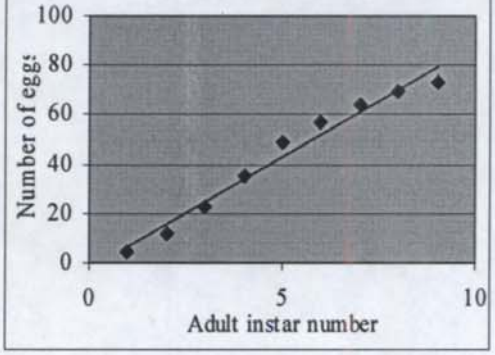
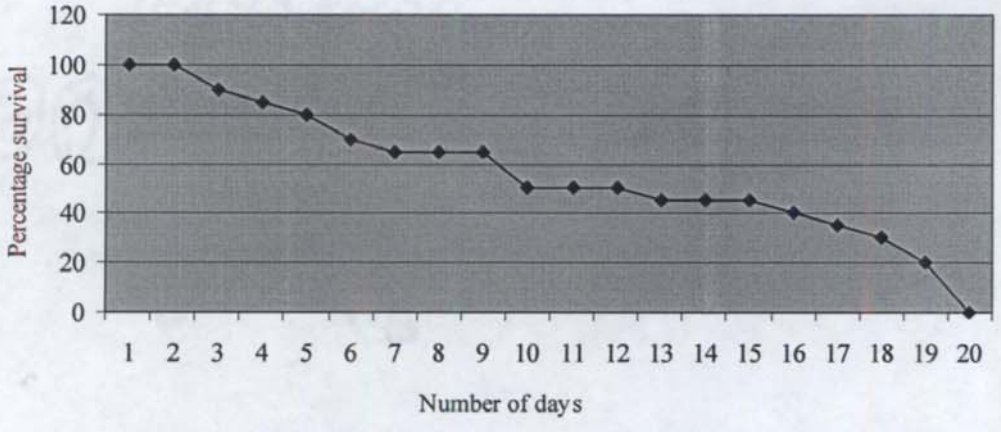


Fig. 2 d Survivorship curve



Diaphanosoma sarsi

Fig. 3 a Relationship between Total length (TL), carapace height (CH) and instar number

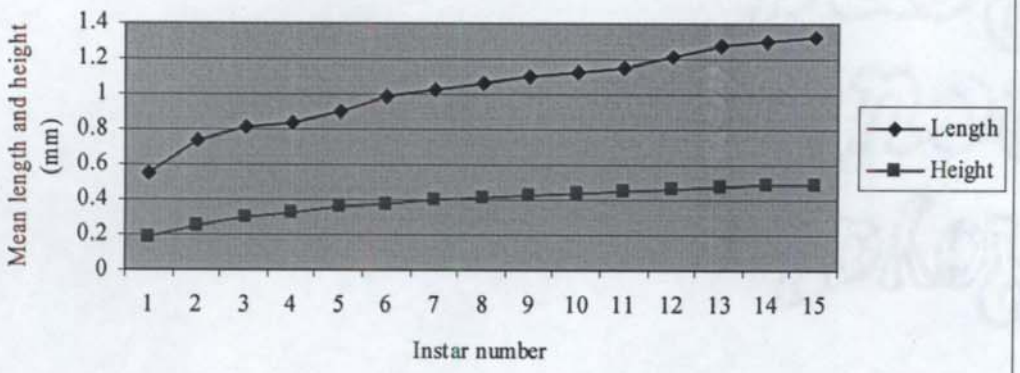


Fig. 3 b Egg production in relation to instar number

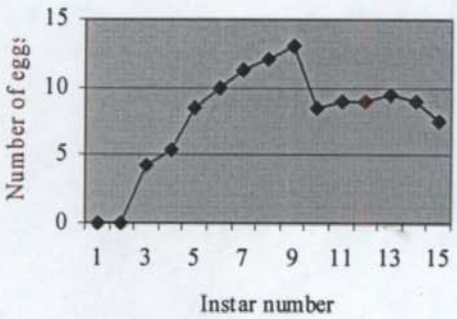


Fig. 3 c Cumulative egg production related to instar number

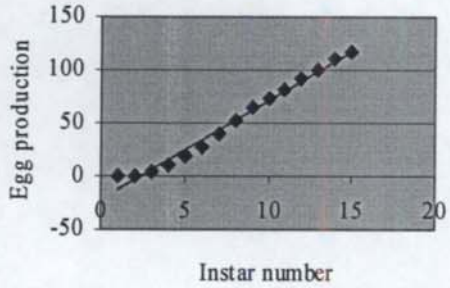


Fig. 3 d Survivorship curve

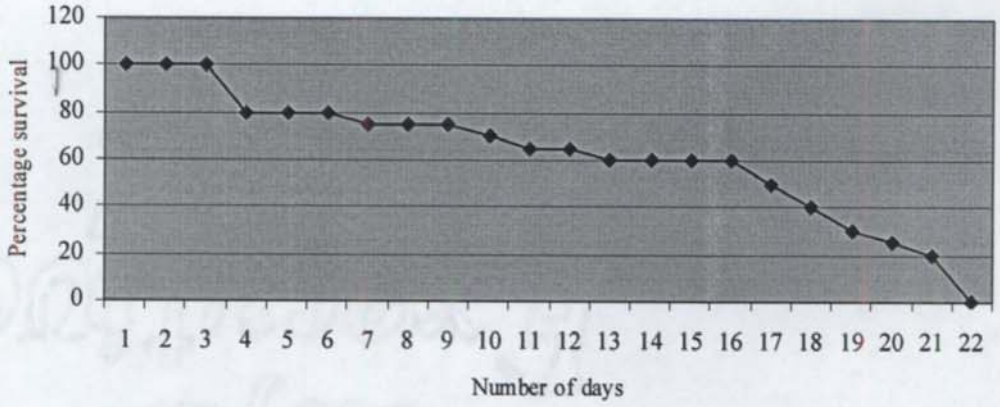


Fig. 4 Growth increment in Sididae

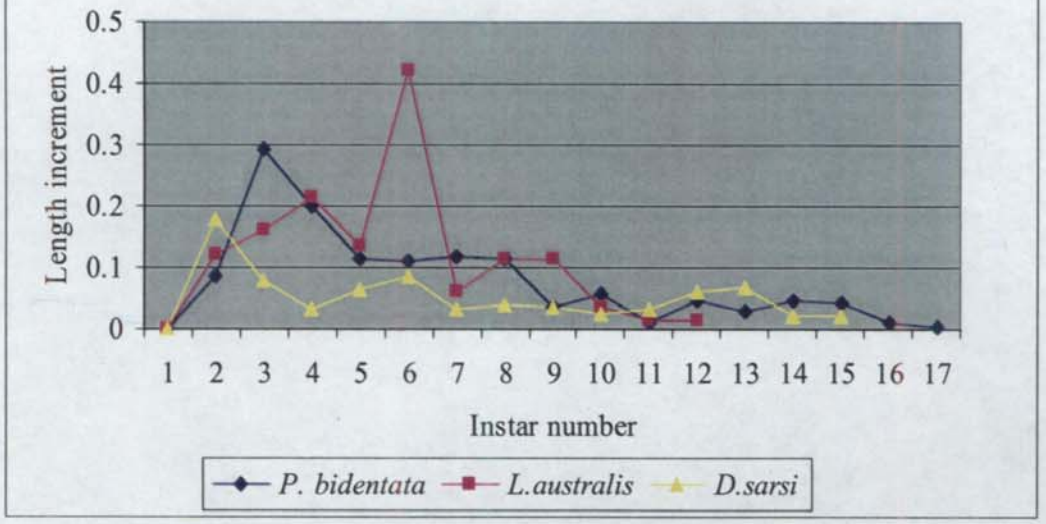


Fig. 5 Instar duration in Sididae