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REDESCRIPTION, BIOLOGY, LIFE TABLE, BEHAVIOUR AND ECOTYPISM OF *Sphedanolestes minusculus* Bergroth (Hemiptera: Reduviidae)

Dunston P. AMBROSE, S. Prasanna KUMAR*, Kalimuthu NAGARAJAN, S. Sam Manohar DAS* & Balachandran RAVICHANDRAN

Entomology Research Unit, St. Xavier's College, Palayankottai - 627 002. Tamil Nadu, India.
E. mail: *eruxavier@sancharnet.in* * Present address: Dept. Zoology, Scott Christian College, Nagercoil, 629 003, Tamil Nadu, India.

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Sphedanolestes minusculus Bergroth lays pale yellow eggs in batches. Eggs are glued to each other and to the substratum with cementing material. The average number of eggs per female was 63.33 ± 21.77. The eggs hatch in 7.80 ± 0.41 days. The average developmental period from I instar to V instar was 48.43 ± 7.39days. The longevity of the male (80.16 ± 5.23) was shorter (96.77 ± 11.88) than that of the female. The preoviposition period was 12.55 ± 3.43 days and the male and female sex ratio was 1: 1.5. The innate capacity of natural increase (r_c) was 0.061 with a gross reproduction rate (mx) of 91.671 females per female. Mean length of generation (T_c) was 76.310 days. Redescriptions of adult and descriptions of egg and nymphal instars are given with illustrations. Predatory and mating behaviour exhibited sequential events as in other reduviids. Prey-deprived predators took less time to approach, capture and pin the prey. Individuals of *S. minusculus* collected from three different ecological and geomorphological habitats viz., Olavakod tropical rainforest, Sunkankadai scrub jungle and Aralvaimozhi semiarid zone exhibited pronounced diversities in their oviposition pattern, hatchability, incubation and stadial periods, nymphal mortality, adult longevity and sex ratio. These diversities are considered a specially adapted biological function collectively called ecotypism.

***Sphedanolestes minusculus*, redescription, biology, life table, predation, mating, ecotypism**

D. P. AMBROSE, S. P. KUMAR*, K. NAGARAJAN, S. S. M. DAS*, B. RAVICHANDRAN, Ponovni opis, biologija, životni ciklus, ponašanje i ekotip *Sphedanolestes minusculus* Bergroth (Hemiptera: Reduviidae): Entomol. Croat. 2006, Vol. 10. Num. 1-2: 47-66

Sphedanolestes minusculus Bergroth polaže blijedo žuta jaja u gomilicama. Jaja su ljepljivom tvari slijepljena međusobno kao i za podlogu. Srednja vrijednost broja jaja po ženki je bila 63,33 ± 21,77. Ličinke su se izvalile u 7,80 ± 0,41 dana. Srednja vrijednost razvojnog perioda od I do V stadija bila je 48,43 ± 7.39 dana. Dužina života mužjaka (80,16 ± 5,23) bila je kraća (96,77 ± 11,88) nego ženki. Preovipozicija jaja je trajala 12,55 ± 3.43 dana a omjer između mužjaka i ženki je bio 1:1,5. Urođen, svojstven kapacitet prirodnog porasta (rc) je bio 0,061 s maksimalnim omjerom reprodukcije (mx) od 91,671 ženki. Prosječna dužina života jedne generacije (Tc) bila je 76, 310 dana. Ponovo su opisani odrasli, a na novo jaja i ličinački stadiji prikazani slikama. Složeno predatorsko ponašanje i ponašanje tijekom parenja slijedilo je pravilan tok kao kod drugih vrsta porodice Reduviidae. Ovi predatori su brzi u lovu i pridržavanju ulova. Jedinke *Sphedanolestes minusculus* su bile sakupljane u tri različita ekološka i geomorfološka staništa: Olavakod - tropska kišna šuma, Sunkankadai - guštara đungle i Aralvaimozhi - semiaridna zona. Opisane su različitosti u: njihovim ovipozicijskim uzorcima, izlijeganju jaja, vremenu inkubacije, trajanju razvojnih stadija, ličinačkoj smrtnosti, dužini života odraslih, te omjeru spolova. Te razlike u opisanim karakteristikama smatraju se posebno prilagođenim biološkim funkcijama koje zajednički nazivamo ekotip.

***Sphedanolestes minusculus*, ponovni opis, biologija, životni ciklus, grabežljivost, parenje, ekotip**

Introduction

The Reduviidae is the largest family of predaceous land Heteroptera. They are abundant, occur worldwide and are voracious predators. Generally, reduviid predators are larger than other predaceous land bugs and as nymphal instars and adults they consume considerable numbers of prey. They are further reported as potential biological control agents, an important component of Integrated Pest Management (IPM) programmes (Ambrose, 1999; 2000; 2003).

Studies on the biology and the construction of a life table for a predator species is an important component in the understanding of its population dynamics (Hill, 1975; Pressat, 1985; Carey, 1993). Moreover, individuals of a particular species collected from different habitats exhibit substantially different colours, shapes and size from each other and yet members of one habitat could successfully breed with members of another habitat. Such apparent diversities seen among individuals of the same species collected from different habitats are collectively referred to as ecotypism (Ambrose, 1999).

Hence, this present investigation was undertaken to understand the biology, life table, behaviour and ecotypic diversity of *Sphedanolestes minusculus* Bergroth. Such an understanding will enable one to develop suitable rearing techniques for the predator and to evaluate its relative potential against insect pests.

Materials and methods

Biology: The adult males and females of *Sphedanolestes minusculus* Bergroth were collected from Olavakod tropical rainforest (altitude 399 MSL, latitude 76.39°E 10.45°N) Palakkad District, Kerala, South India. The adults were reared in plastic containers (5.5 × 6.5 cm) in the laboratory on the larvae of the rice moth *Corcyra cephalonica* Stainton (temperature 30 ± 1°C, 75 ± 5% relative humidity and photoperiod 12 ± 1 hrs). Once adults emerged, they were allowed to mate. The containers were carefully examined at regular intervals to record the number of eggs laid as well as the spermatophore capsules ejected after successful copulation. The eggs laid in the laboratory were allowed to hatch separately in Petri dishes (9.2 × 2.0cm) with wet cotton swabs for maintaining optimum humidity (85%). The cotton swabs were changed periodically in order to prevent fungal attack. Mated females were maintained individually in order to record the number of batches of eggs and number of eggs in each batch. Each batch of eggs was allowed to hatch in individual plastic containers (5 × 5.5cm). The predators were reared in the laboratory for two generations to determine the fecundity, hatchability, incubation and stadial periods, nymphal mortality and longevity.

Life table: To construct the life table, the rate of increase was determined by using the following formula:

$$\sum e^{-rmx} lxmx = 1 (or) \sum e^{7-rmx} lxmx = 1096.6$$

Net reproductive rate, (R_0 = lxmx), the rate of multiplication of the population in each generation was measured in terms of females produced per generation. The approximate value of cohort generation (Tc) was calculated as

$$Tc = \frac{\sum lxmxX}{R_o}$$

The arbitrary value of innate capacity for increase (rc) was calculated using the formula

$$rc = \frac{\log e\ R_o}{T_c}$$

This was the arbitrary value of 'rm'. Since the value of exponents of $e^{-r}mx$ obtained from experiments often lay outside the range, both sides of the equation were multiplied by a factor of $\sum e^{7-rmx}$ lxmx=1096.6 (Birch, 1948; Watson, 1964). The precise generation time (T) was then calculated as $T= \log e\ R_o$ / rm (or) $T = InR_o$/rm. The finite rate of increase (λ) was calculated as λ = antilog e^{rm}/ female/ day. The weekly multiplication of the predator was calculated as (antilog $e^{rm})^7$. The doubling time (DT) (Campbell & Mackauer, 1975) was calculated as $DT = \log {}^2/\log \lambda$ or In^2/rm.

The sequences of predatory behaviour were observed in fed and different levels of prey-deprived predators at 0, 24, 48 and 72 hr. The laboratory-emerged sex-starved adults were allowed to mate and the sequential pattern of mating was observed.

Ecotypism: To understand the ecotypic diversity in *S. minusculus* the data on morphometric and biological parameters of three ecotypes viz., Olavakod tropical rainforest (Kerala), Sunkankadai scrub jungle (Tamil Nadu) (Kumar, 1993) and Aralvaimozhi semiarid zone (Tamil Nadu) (Das, 1996) of South India were compared. Biological parameters such as oviposition pattern, index of oviposition days, hatchability, incubation and stadial periods, adult longevity and sex ratio and morphometric indices were compared and analysed (Ambrose, 1980; 1999; Ambrose & Ambrose, 2004).

Biology

The biological information presented here belongs to the Olavakod ecotype (Table 1).

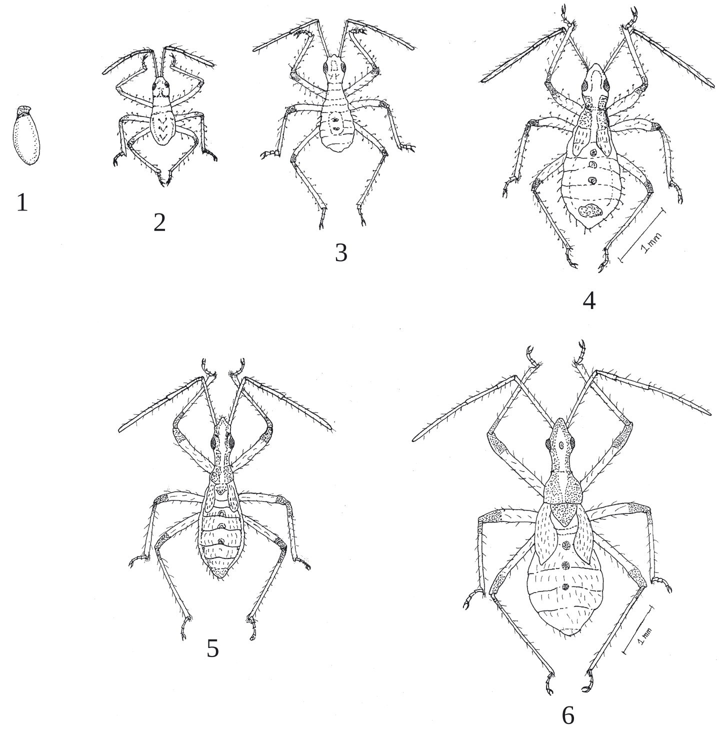
Preoviposition period

The *S. minusculus* laid pale yellow eggs 12.55 ± 3.43 days after emergence (preoviposition period) singly, as well as in small clusters (Figure 1). The

Table 1. Biological parameters of *Sphedanolestes minusculus* on *Corcyra cephalonica* larva under the laboratory conditions (n =30; $\overline{X}$ ± SD)

Biological parameters		
Incubation period (days)		7.80 ± 0.41
Stadial period (days)		
I instar		6.53 ± 1.24
II instar		8.66 ± 1.34
III instar		9.06 ± 1.86
IV instar		10.26 ± 1.75
V instar		13.92 ± 1.20
Total stadial period (in days)	Male	48.00 ± 1.54
	Female	49.22 ± 2.48
Fecundity/ female (no.)		63.33 ± 21.77
Hatchability (%)		95
Nymphal mortality (%)		21.06
Survival rate (%)		78.94
Sex ratio (M: F)		1: 1.5
Preoviposition period (days)		12.55 ± 3.43
Oviposition period (days)		31.12 ± 4.25
Postoviposition period (days)		19.44 ± 1.66
Adult longevity (days)	Male	30.00 ± 3.16
	Female	45.11 ± 11.15
Total longevity (I instar to adult) (days)	Male	80.16 ± 5.23
	Female	96.77 ± 11.88

preoviposition period of the harpactorine *S. minusculus* was longer than that of Ectrichodinae (7.0 days), Salyavatinae (6.7 days) and closer to that of Stenopodainae (14.3 days), Triatominae (14.83 days) and lower than that of Reduviinae (30.4 ± 14.71 days) Peiratinae (16.86 ± 4.36 days) (Ambrose, 1999). Among harpactorines, the preoviposition period of *S. minusculus* was shorter than that of *Rhynocoris marginatus* (Fabricius) (33.30 days) and *R. kumarii* Ambrose and Livingstone (26 days), but closer to that of *Rhynocoris longifrons* (Stål) (11.80 days) (Ambrose, 1999). Among *Sphedanolestes,* it was shorter than that of *Sphedanolestes pubinotum* Reuter (42.00 days) (Kumarasami & Ambrose, 1993) and longer than that of *Sphedanolestes himalayensis* Distant (9.80 days) and *Sphedanolestes* sp. (3.60 days) (Das, 1996) *Sphedanolestes signatus* Distant (9.30 days) (Vennison & Ambrose, 1990).



Figures 1-6. *Sphedanolestus minusculus* egg and nymphal instars I-V:
1 - Egg; 2 - I nymphal instar; 3 - II nymphal instar; 4 - III nymphal instar;
5 - IV nymphal instar; 6 - V nymphal instar.

The eggs were attached basally to the substratum with spumaline as in other harpactorines. Though the minimum number of eggs per batch is a species-specific character of different groups of assassin bugs, harpactorines typically lay a high number of eggs per batch (Ambrose, 1999). They laid on average 6.33 ± 2.2 clusters with 63.33 ± 21.77 eggs, a comparatively moderate fecundity when compared to other *Sphedanolestes* species such as *Sphedanolestes aterimus* Distant (71.5 ± 22.5 eggs), *S. pubinotum* (54.0 ± 5.4 eggs) and *S. signatus* (15.33 ± 6.41 eggs) (Ambrose, 1999). The eggs hatched during the morning after 7.80 ± 0.41 days (incubation period). However, Kumar (1993) also observed hatching both during morning (5 to 10 AM) and evening hours (1 to 4 PM) in the Sunkankadai ecotype. The incubation period of *S. minusculus* was shorter than that of its sister species *S. pubinotum* (10.20 days) (Kumaraswami & Ambrose, 1993), *S. signatus* (12.30 days) (Vennison & Ambrose, 1990) and *S. himalayensis* (9.60 days) (Das, 1996). However, many harpactorines had shorter oviposition periods than that of *S. minusculus* (Ambrose, 1999).

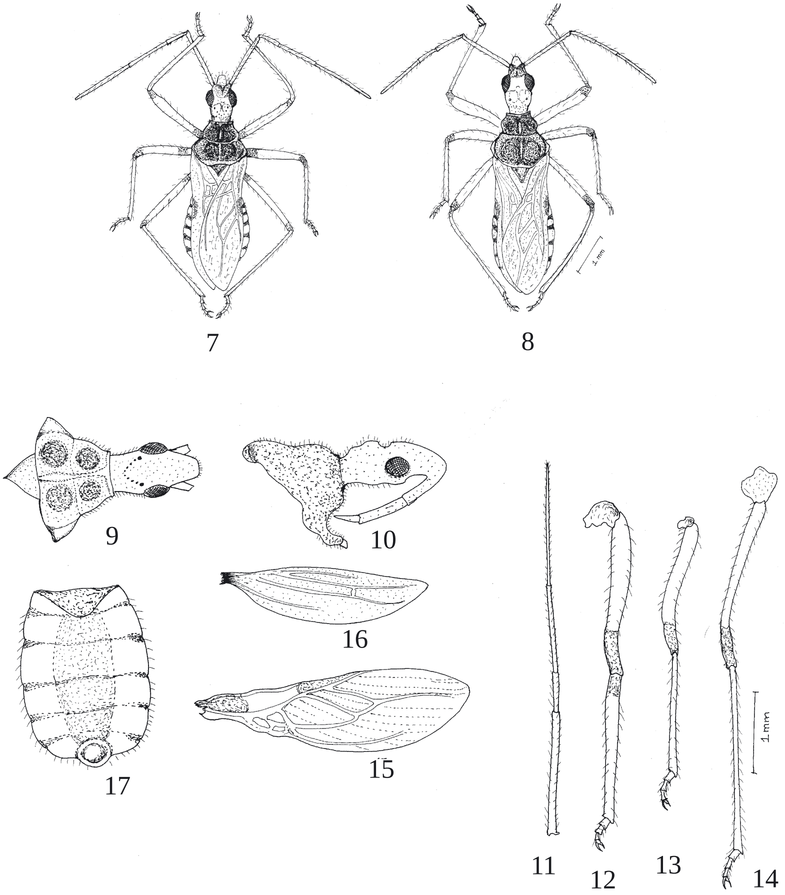
The stadial periods of I, II, III, IV and V nymphal instars were 6.53 ± 1.24, 8.66 ± 1.34, 9.06 ± 1.86, 10.26 ± 1.75 and 13.92 ± 1.20 days, respectively, and the total stadial periods of *S. minusculus* male and female (I nymphal instar to adult) were 48.00 ± 1.54 days and 49.22 ± 2.48 days. The total stadial period (male and female average) of *S. minusculus* was comparatively shorter than that of non-harpactorine reduviids and longer than that of other harpactorines such as *R. fuscipes* (41.2 days), *Coranus* sp. (39.7 days), *C. soosai* (41.7 days) *C. nodulosus* (39.1 days) and closer to that of its sister species *S. himalayensis* (52.8 days), *S. pubinotum* (52.3 days) and *Sphedanolestes* sp. (48.8 days) and longer than that of *R. marginatus* (99.7 days), *S. pyrrhomelas* (102.9 days) and *I. armipes* (104.3 days) (Ambrose, 1999).

The total nymphal mortality of *S. minusculus* was 21.06 % with a survival rate of 78.94 %. As observed in other harpactorines, it is lower than that of non-harpactorine reduviids (Ambrose, 1999). Among *Sphedanolestes* species, the lowest nymphal mortality was observed in *S. himalayensis* (13.00 %) and the highest in *S. pubinotum* (89.30 %) (Ambrose, 1999).

The females lived longer (adult and total longevities: 45.11 ± 11.5 and 96.77 ± 11.88 days) than the males (adult and total longevities: 30.0 ± 3.16 and 80.16 ± 5.23 days). A longer female adult longevity was also recorded for its sister species *S. pubinotum* and *S. himalayensis*; other harpactorines such as *Coranus* spp., *Endochus* spp., *Euagoras* spp. and *Sycanus* spp. and member of other subfamilies Ectrichodinae, Peiratinae, Salyavatinae, Stenopodainae and Triatominae (Ambrose, 1999). Out of two generations raised in the laboratory, males and females emerged with the sex ratio of 1: 1.5. Such a female-biased sex ratio is not uncommon among the harpactorine reduviids (Ambrose, 1999).

Adult redescription

A redescription of *Sphedanolestus minusculus* Bergroth adult male is given as the description by Distant (1910) is inadequate.



Figures 7 - 17. *Sphedanolestus minusculus* Male & Female, (Male) somatic structures: 7 - Male; 8 - Female; 9 & 10: Head and pronotum dorsal and lateral aspects; 11 - Antenna; 12 - Foreleg; 13 - Midleg; 14 - Hind leg; 15 - Hemelytra; 16 - Hind wing; 17

Entire length 6 mm; width across eyes 0.39 mm; across prothorax 1.55 mm and across abdomen 1.59 mm (Table 2 & 3 and Figures 7-17).

Black, sternum grayish testaceous, membrane shining and fuscous, abdomen beneath luteous; head (1.56 mm) as long as pronotum, bulbous postocular area (0.65 mm) distinctly longer than the anteocular area (0.62 mm); compound

Table 2. Morphometric analysis of head and cephalic appendages of life stages of *Sphedanolestes minusculus* (in min; n = 6; $\overline{X}$ ± SD).

LIFE STAGES (Instars)	HEAD					ANTENNA					ROSTRUM			
	AOL	**POL**	**DE**	**WBE**	**HL (AOL+POL+DE)**	**SCL**	**PDL**	**F1L**	**F2L**	**EAL**	**BRL**	**MRL**	**TRL**	**ERL**
I	0.20 ± 0.06	0.19 ± 0.05	0.08 ± 0.01	0.18 ± 0	0.49 ± 0.12	0.54 ± 0.06	0.19 ± 0.02	0.24 ± 0.09	0.37 ± 0.14	1.36 ± 0.02	0.22 ± 0	0.21 ± 0.03	0.20 ± 0.02	0.64 ± 0.05
II	0.22 ± 0	0.23 ± 0.01	0.07 ± 0.02	0.24 ± 0.04	0.53 ± 0.03	0.54 ± 0.05	0.20 ± 0.02	0.25 ± 0.02	0.35 ± 0.09	1.37 ± 0.16	0.21 ± 0.02	0.20 ± 0.02	0.19 ± 0.03	0.61 ± 0.07
III	0.65 ± 0.05	0.59 ± 0.11	0.16 ± 0.02	0.37 ± 0.04	1.41 ± 0.15	1.16 ± 0.02	0.43 ± 0.04	0.46 ± 0.18	0.66 ± 0.17	2.73 ± 0.23	0.49 ± 0.07	0.35 ± 0.04	0.43 ± 0.03	1.28 ± 0.06
IV	0.74 ± 0.07	0.72 ± 0.04	0.18 ± 0	0.49 ± 0.01	1.65 ± 0.12	1.55 ± 0.14	0.38 ± 0.06	0.62 ± 0.05	1.41 ± 0.16	3.95 ± 0.23	0.20 ± 0.02	0.46 ± 0.02	1.29 ± 0.54	1.66 ± 0.08
V	0.89 ± 0.02	0.58 ± 0.04	0.18 ± 0	0.54 ± 0	1.67 ± 0.04	1.50 ± 0.07	0.46 ± 0.06	0.92 ± 0.32	1.33 ± 0.27	3.53 ± 1.64	0.21 ± 0.01	0.53 ± 0.02	1.03 ± 0.04	1.78 ± 0.07
Adult	0.90 ± 0	0.87 ± 0.07	0.21 ± 0.01	0.51 ± 0.04	2.00 ± 0.08	1.81 ± 0.13	0.80 ± 0.07	1.28 ± 0.17	2.12 ± 0.42	6.01 ± 0.57	0.62 ± 0.18	0.43 ± 0.11	0.49 ± 0.19	1.56 ± 0.35

HEAD: AOL- anteocular length; POL- postocular length; DE- diameter of eye; WBE- width between eyes; HL - head length.
ANTENNAE: SCL- scape length; PDL - pedicel length; F1L- flagella 1 length; F2L- flagella 2 length; EAL- entire antennae length.
ROSTRUM: BRL- basal rostral segment length; MRL- midrostral segment length; TRL- terminal rostral segment length; ERL- entire rostral length.

Table 3**.** Morphometric analysis of prothorax, thoracic appendages and abdomen of life stages of *Sphedanolestes minusculus* (in min; n = 6; $\overline{X}$ ± SD).

LIFE STAGES	PROTHORAX		TIBIAL			WING / WING BUD		ABDOMEN	
	PTL	**PTW**	**FTL**	**MTL**	**HTL**	**WL / WBL**	**WW / WBW**	**AL**	**AW**
I instar	0.22 ± 0.04	0.29 ± 0.03	0.53 ± 0.13	0.52 ± 0.16	0.59 ± 0.15	-	-	0.16 ± 0.03	0.24 ± 0.06
II instar	0.20 ± 0.02	0.32 ± 0.03	0.53 ± 0.14	0.51 ± 0.08	0.61 ± 0.09	-	-	0.53 ± 0.09	0.37 ± 0.04
III instar	0.49 ± 0.04	0.73 ± 0.06	1.40 ± 0.30	1.20 ± 0.21	1.74 ± 0.21	0.58 ± 0.08	0.21 ± 0.02	1.51 ± 0.54	1.41 ± 0.39
IV instar	0.56 ± 0.12	0.89 ± 0.02	1.52 ± 0.12	1.43 ± 0.04	2.09 ± 0.17	0.90 ± 0	0.45 ± 0	2.87 ± 0.18	2.33 ± 0.14
V instar	0.71 ± 0.01	1.03 ± 0.01	1.66 ± 0.23	1.38 ± 0.26	2.01 ± 0.06	0.90 ± 0.01	0.46 ± 0.02	3.82 ± 0.11	2.67 ± 0.03
Adult	1.76 ± 0.20	1.97 ± 0.13	2.27 ± 0.35	2.17 ± 0.12	3.33 ± 0.27	5.25 ± 0.47	1.76 ± 0.08	3.51 ± 0.26	3.08 ± 0.21

PROTHORAX : PTL - prothoracic length; PTW - prothoracic width.
TIBIAL : FTL - foretibial length; MTL - midtibial length; HTL - hind tibial length.
WING / WING BUD : WL- wing length; WBL - wing bud length; WW - wing width; WBW - wing bud width.
ABDOMEN : AL - abdomen length; AW - abdomen width. ($\overline{X}$ ± SD)

eyes laterally produced, a pair of ocelli behind each eye, neck distinct; terminal flagellar segment the longest (2.04 mm) and the pedicel the shortest (0.63 mm), scape and the first flagellar segment almost equal in length and about as long as head, separately; rostrum moderately curved, the terminal segment the shortest, basal and medial segments subequal in length, terminal rostral segment reaching the prosternal groove; antreolateral angles of pronotum prominently pointed, posterolateral angles of pronotum rounded, anterior lobe shorter than the posterior lobe, anterior lobe profoundly and posterior lobe less profoundly longitudinally sulcate, basal margin of anterior lobe almost straight, anterior angles shortly tuberculous and subacute, posterior angles truncately rounded and sub- prominent; apex of scutellum stramineous, scultellar spine not prominent; prothorax slightly broader (1.55 mm) than longer (1.37 mm); femorae slightly nodulose, midtibiae the shortest (1.87 mm) and hind tibiae the longest (2.91 mm), richly pilose, three segmented tarsi with the longest terminal segment, fore- and midtibiae with rudimentary tibial pads and tibial combs; corium slightly rugulose; membrane passing well beyond the abdominal apex; discoidal cell almost as long as broad; connexivum slightly deflexed.

Type specimen:

Male collected from the Sunkankadai scrub jungle, Kanyakumari District.

Description of nymphal instars:

Sanguineous, except the black head, basal region of rostrum, terminal femoral and basal tibial annulations, wing rudiments, anal abdominal spot older instars more reddish; pilose, more clubbed hairs in early instars and more straight hairs in older instars; head elongate, moderately anteriorly produced, anteocular almost equals postocular length, head transversely divided immediately behind the eyes; antennae four segmented, pedicel the shortest and almost equal to first flagellar segment in the fourth and fifth instars, terminal flagellar segment the longest; rostral rostrum slightly curved, terminal segment the shortest, medial segment the longest, rostral tip resting at the posternal groove; pronotum longer than broader in older instars (IV and V) and almost equal in early instars (I to III), longitudinally impressed, convex, shinning, sparingly pilose; legs unicolorous except the black annulations, midleg the shortest, hind leg the longest, fore- and midtibiae with tibial combs, longly pilose, three segmented tarsi, basal segment the shortest, terminal segment the longest; abdomen sparingly longly pilose, longer than broader in all the instars, three dorsal abdominal black scent gland orifices seen in between 3rd and 6th abdominal segments (Figures 2-6). Morphometric analyses of nymphal instars are given in Tables 2 & 3.

Key for the identification of nymphal instars:

1. Postocular equals basal rostral segment in length; head width exactly equal to twice the length of basal rostral segment .... I instar

   Postocular length unequal to basal rostral segment in length, head width less than twice the length of basal rostral segment .... (2)

2. Pedicel and first flagellar lengths together equal to pronotal width; interocular width equal to postocular length .... (3)

   Pedicel and first flagellar lengths together subequal to pronotal width; interocular width lesser than postocular length .... (4)

3. Wing rudiments not visible .... II instar

   Wing rudiments visible .... III instar

4. Width between eyes exactly equal to pedicel length; wing rudiments developing up to 2nd abdominal segment......................... IV instar

   Width between eyes subequal to pedicel length; wing rudiments developing up to 4th abdominal segment .... V instar

Life table

The net reproductive rate (R_o) observed for *S. minusculus* was comparatively higher (79.35) than that of other harpactorine reduviids (Table 4). For instance, the net reproductive rate of harpactorines *R. marginatus* on *C. cephalonica* was 27.90 and *Sycanus collaris* Fabricius on *S. litura* was 30.46 (George, 2000a; George et al., 1998). The innate capacity of natural increase of *S. minusculus* was 0.061/female/day and almost a similar innate capacity was reported for another harpactorine reduviid *R. kumarii* (George, 2000b). Daily finite rate of increase and weekly multiplication rate of *S. minusculus* were 1.0628 days and 1.532 days with a doubling time of 11.4015 days. Almost a similar daily finite rate of increase and doubling time were recorded for *R. kumarii* on different prey species (George, 2000b).

Table 4. Life table parameters of *Sphedanolestus minusculus* on *C. cephalonica* under labaratory conditions.

Parameters	
Net reproductive rate (R_0)	79.354
Mean lenght of generation (Tc)	76.310
Innate capacity of natural increase (rc)	0.062
Rate of natural increase	0.061
Weekly multiplication rate (WMR)	1.532
Daily finite rate of increase (λ)	1.0628
Hypothetical population in F2 generation	6297.057

Behaviour

Predatory behaviour

The sequence of predatory behaviour of *S. minusculus* to *C. cephalonica* larva was observed as follows: arousal - approach - capturing - paralysing - rostral probing and sucking and postpredatory behaviour (Tables 5 & 6). The sequential pattern of predatory behaviour in *S. minusculus* was similar to that of other harpactorines (Ambrose, 1999) and especially to that of *R. fuscipes* (Ambrose & Mayamuthu, 1994). The visual stimuli played a major role in eliciting the arousal response on seeing the moving prey (Ambrose, 1999). Predatory behaviour was observed in both fed and 24, 48 and 72 hr prey-deprived predators.

The prey-deprived predators took less time to approach a prey when compared to the fed predators as a function of prey-deprivation. A similar observation was reported in other reduviids (Ambrose, 1999).

The prey-deprived predators (24, 48 and 72 hr) also took less time for capturing and pinning the prey (0.03 ± 0.02, 0.03 ± 0.01 and 0.02 ± 0.01 min. respectively) when compared to the fed predators (0.56 ± 0.46 min.). The prey capturing time varied in other harpactorines due to their prey capturing potential, as well as the prey types (Ambrose, 1999). After the successful capturing of the prey the predator paralysed the prey by injecting its toxic saliva. The prey-deprived predators (24 hr, 48 hr and 72 hrs) quickly paralysed the prey (0.05 ± 0.01; 0.04 ± 0.02 and 0.0 ± 0 min., respectively) when compared to the fed predators (0.05 ± 0.02 min.). Prey deprivation causes accumulation of toxic saliva in the principal salivary glands, which causes quick paralysis of the prey (Ambrose, 1999).

S. minusculus often selected the sucking sites from abdominal regions and less often from the cephalic and thoracic regions as reported by Kumar (1993).

Table 5. Chronological analysis of sequential pattern of predation of nymphal instars of *Sphedanoletes minusculus* (in min; n = 6; $\overline{X}$ ± SD)

Nymphal instars	**Predatory acts**						**No. of piercing sites**
	Arousal	**Approach**	**Capturing**	**Paralysing**	**Sucking**	**Postpredatory acts**	
II	3.66 ± 1.63	3.33 ± 1.21	1.75 ± 0.40	8.33 ± 4.36	148.33 ± 13.23	6.50 ± 1.87	2.00 ± 1.09
III	3.50 ± 1.04	2.89 ± 1.10	0.06 ± 0.02	0.091 ± 0.01	120.05 ± 27.97	5.11 ± 0.45	1.28 ± 0.48
IV	1.87 ± 0.20	2.65 ± 0.86	0.04 ± 0.02	0.06 ± 0.02	118.66 ± 10.61	4.66 ± 1.03	1.66 ± 0.81
V	1.78 ± 0.33	2.45 ± 0.60	0.03 ± 0.08	0.04 ± 0	96.66 ± 11.25	5.10 ± 0.46	5.00 ± 1.78

Table 6. Chronological analysis of sequential pattern of predation of adult *Sphedanolestes minusculus* at different periods of prey deprivation (in min; n = 6; $\overline{X}$ ± SD)

Duration of prey deprivation in hrs.	**Predatory acts**						**No. of piercing Sites**
	Arousal	**Approach**	**Capturing**	**Paralysing**	**Sucking**	**Postpredatory acts**	
0	1.12 ± 0.35	1.04 ± 0.14	0.56 ± 0.46	0.05 ± 0.02	57.50 ± 10.36	6.00 ± 0.89	12.16 ± 3.48
24	0.645 ± 0.62	0.64 ± 0.80	0.03 ± 0.02	0.05 ± 0.01	67.90 ± 20.48	6.33 ± 1.50	9.66 ± 5.08
48	0.53 ± 0.38	0.49 ± 0.79	0.03 ± 0.01	0.04 ± 0.02	72.69 ± 13.72	5.00 ± 0.60	11.16 ± 2.56
72	0.21 ± 0.33	0.21 ± 0.30	0.02 ± 0.01	0.02 ± 0	80.00 ± 10.95	6.00 ± 0.89	10.50 ± 2.42

Table 7. Chronological analysis of sequential pattern of mating in *Sphedanolestes minusculus* (in min; n = 6; $\overline{X}$ ± SD).

Mating acts				
Arousal	**Approach**	**Riding over**	**Copulation**	**Postcopulatory acts**
5.33 ± 2.87	2.21 ± 2.83	9.69 ± 6.91	9.34 ± 3.18	4.30 ± 2.03

The preferred site of first attack of reduviids was the neck region (Ambrose, 1999). However, Kumar (1993) reported that *R. longifrons* attacked at the rear end of the prey, while *Coranus* sp. attacked the lateral regions of abdomen.

The prey-deprived predators sucked the prey for greater durations (67.90 ± 20.48; 78.69 ± 13.72 and 80.00 ± 10.95 min. for 24, 48 and 72 hr. prey-deprived predators, respectively) when compared to the fed predators (57.50 ± 10.36 min.) due to prolonged starvation that affected the sucking efficiency (Ambrose, 1999).

The number of piercing and sucking sites of the predator did not significantly deviate among fed and prey-deprived predators though it was marginally higher in prey deprived reduviids (Ambrose, 1999). After starvation, both fed and prey-deprived *S. minusculus* performed the postpredatory cleaning of their antennae, rostrum and legs. The antennae and rostrum were cleaned by keeping and drawing them out between the foretibiae. The legs were cleaned by being rubbed against each other. The duration of post-predatory activities of the predator did not significantly deviate among fed and prey deprived predators.

Chronological analysis of the sequential activities of predatory behaviour of life stages of *S. minusculus* is presented in Table 2. The sequences of predatory behaviour were similar to those of the typical harpactorine ‘pin and jab’ type predators (Ambrose, 1999).

Mating behaviour

The sequential pattern of mating behaviour of the predator *S. minusculus* was observed as follows: arousal - approach – riding-over - genitalia extension and connection achievement - copula - postcopulatory acts. The sex-starved males were found being aroused to mate after sighting a female as reported in other reduviids (Ambrose, 1999) (Table 7).

The visually excited males started chasing the females as observed in *Sphedanolestes* sp., *Coranus* sp. (Kumar, 1993) and thus sight played a very important role in the arousal of mating partners. However, *S. minusculus* were aroused slowly (5.33 ± 2.87 min) when compared to its sister species *S. himalayensis* (1.31 min) (Das, 1996); *S. pubinotum* (0.71 min) (Kumaraswami & Ambrose, 1993), S. *signatus* (0.65 min) (Vennison & Ambrose, 1990). *S. minusculus* also exhibited the characteristic harpactorine precopulatory riding-over for 9.69 ± 6.91 min. before achieving connection (Ambrose, 1999). However, several longer durations of riding- over were observed in other harpactorine reduviids (Ambrose, 1999). *S. minusculus* exhibited a dorsolateral position of copulation for 9.34 ± 3.18 min. as observed in other harpactorine reduviids (Ambrose,1999). The duration of copulation in *S. minusculus* (9.34 ± 3.18 min) was comparatively shorter than in its sister species *S. himalayensis* (28.40 min) (Das, 1996); *S. pubinotum* (15.62 min) (Kumaraswami & Ambrose, 1993) *S. signatus* (19.83 min.) (Vennison & Ambrose, 1990).

The postcopulatory acts such grooming the genitalia, vigorously rubbing the hind tibiae, extension of rostrum etc., of *S. minusculus* were observed as in other reduviids (Ambrose, 1999).

Ecotypic diversity

The Olavakod (altitude 300 MSL, latitude 76°39’ E 10°45’ N) tropical rainforest in Palakkad district, Kerala, South India is characterised by luxuriant growth of cover crops on the forest floor and a rich canopy. The average relative humidity and temperature are 85% and 27°C.

The Aralvaimozhi ecotype (77°31’ E and 8°11’ N) is a semiarid zone on the eastern section of Kanyakumari District, Tamil Nadu, South India. *S. minusculus* the volant reduviid, which occurs here in large numbers from May to November, was found active between 6 and 10 AM and 4 to 6 PM. They were observed predating upon the midge *Erosomyia indica* Grover & Prasad (Das, 1996).

The Sunkankadai (77°22’ E and 8°11’ N) scrub jungle is located 2 km of north of Nagercoil, Kanyakumari District, Tamil Nadu, South India. It is a hilly terrain with small hillocks and boulders and rubbles cover the entire area. *S. minusculus* inhabited this habitat almost throughout the year and was abundant between November and February (Kumar, 1993).

The shortest incubation period was recorded in the Aralvaimozhi ecotype followed by the Sunkankadai ecotype while the longest was in the Olavakod ecotype. Shorter and closer stadial periods were recorded for the Olavakod and Aralvaimozhi ecotypes, whereas the longest incubation period was recorded for the Sunkankadai ecotype (Table 8).

The longest lived males (80.16 ±5.23 days) and females (96.77 ± 11.88 days) of *S. minusculus* were found in the Olavakod ecotype and the shortest lived male (68.9 ± 5.2 days) in the Aralvaimozhi ecotype and the shortest lived females in the inSunkankadai and Aralvaimozhi ecotypes (77.0 ± 6.81, 72.4 ±2.2 days, respectively).

Female biased sex ratios were observed in the Olavakod (1:1.5), Aralvaimozhi (0.8: 1) and Sunkankadai ecotypes (1: 0.89) (Table 8). Since multiple mating was reported as a rule in reduviids (Ambrose & Livingstone, 1979; 1985), lower numbers of males emerging from the Aralvaimozhi and Olavakod ecotype might have reduced the possibility of multiple matings and thereby might have caused lower fecundity (Ambrose, 1980). Females of the Olavakod and Aralvaimozhi ecotypes that laid fewer numbers of eggs lived longer.

In contrast, the Sunkankadai ecotype with a male-biased population might have pronounced multiple matings and consequently had a higher fecundity. However, fecundity showed no correlation with hatchability (Table 9). Interestingly, higher and closer index of oviposition days (number of egg-laying days in the adult female life span Ambrose, 1999) were recorded in the Olavakod and Sunkankadai ecotypes, whereas a comparatively lower oviposition day index was recorded for the Aralvaimozhi ecotype. Moreover, the Aralvaimozhi ecotype with a shorter adult life span showed earlier oviposition.. Such a sex ratio-influenced fecundity of ecotypes reveals the biological significance of the ecotypism.

The Olavakod ecotype laid the lowest number of egg batches with highest number of eggs per batch, when compared to the Sunkankadai and Aralvaimozhi ecotypes. These ecotypes laid a comparatively higher number of batches of eggs with a fewer number of eggs per batch.

Higher fecundity was recorded by the Sunkankadai ecotype when compared to the Olavakod and Aralvaimozhi ecotypes. Though the Olavakod and Aralvaimozhi ecotypes laid lower numbers of eggs, interestingly, their hatchability was higher than that of Sunkankadai ecotype. Thus, the lower fecundities of Olavakod and Aralvaimozhi ecotypes were compensated by higher hatchabilities (Table 9). The higher hatchability was due to the lower 0 % and higher 100 % frequencies of hatching as observed by Ambrose & Livingstone (1979) in *A. pedestris*; Ambrose & Alexander (1989) in *Coranus soosaii* Ambrose & Vennison. Such a fine biological balance was found operating among the ecotypes.

The morphometric index values also exhibited the closeness and variations among the three ecotypes (Table 10). The Olavakod ecotype varied from the other two ecotypes in TRL: ERL, ERL: PO, ERL: HL, PTL: PTW, PTL: HL, PTL: FT, PTL: MT and PTL: HT. This could be correlated with the wait-and-

Table 8. Ecotypic diversity of incubation period, stadial period, adult longevity and sex ratio of *Sphedanolestes minusculus*

Ecotype	**Incubation period (days)**	**Stadial period (days)**					**Total Stadial Period (days)**	**Adult longevity**		**Sex ratio**	
		I	**II**	**III**	**IV**	**V**		**Male**	**Female**	**Male**	**Female**
Olavakkode	7.80 ± 0.41	6.53 ± 1.24	8.66 ± 1.34	9.06 ± 1.86	10.26 ± 1.75	13.92 ± 1.20	48.61 ± 2.01	80.16 ± 5.23	96.77 ± 11.88	1.0	1.5
Aralvaimozhi	5.82 ± 0.52	8.40 ± 0.58	7.8 ± 0.65	9.6 ± 0.82	10.5 ± 0.95	10.8 ± 0.68	48.60 ± 5.20	68.9 ± 5.2	72.4 ± 2.2	0.8	1.0
Sunkankadai	6.68 ± 0.77	9.2 ± 2.24	7.56 ± 1.78	8.12 ± 1.36	13.22 ± 1.59	13.55 ± 1.9	50.44 ± 2.50	73.2 ± 1.15	77.0 ± 6.81	1.0	0.89

Table 9. Ecotypic diversity of oviposition pattern and hatchability in *Sphedanolestes minusculus.*

Parameters	**Ecotypes**		
	Olavakod	**Aralvaimozhi**	**Sunkankadai**
Preoviposition period (in days)	12.55 ± 3.43	14.25 ± 1.1	10.83 ± 0.7
Index of oviposition days	31.12 ± 4.25	26.9 ± 3.1	30.28 ± 1.55
Total number of batches of eggs laid	06.33 ± 2.2	16.8 ± 1.9	23.33 ± 2.58
Average no. of eggs per batch	1.00 ± 0.66	3.8 ± 0.5	4.7 ± 0.3
Total no. of eggs laid	63.33 ± 21.77	63.94 ± 4.2	109.33 ± 7.08
Minimum no. of eggs per batch	1.88 ± 0.99	1.15 ± 0.99	1.33 ± 0.5
Maximum no. of eggs per batch	2.22 ± 1.39	5.28 ± 0.92	6.33 ± 1.03
Hatching percentage	95	80.76 ± 6.2	85.79 ± 8.1

pin mode of predation in the tropical rainforest ecotype due to the abundance of litter-dwelling prey and the chase-and-pin mode of predation in scrub jungle and semiarid zone habitats where prey is scarce, the two subtypes of the pin-and-jab mode of predation. The elongation of rostrum in tropical rainforest ecotype might have facilitated effective pinning whereas the reduction of legs in the scrub jungle and semiarid zone ecotypes might have facilitated active chasing of prey. Thus, the Sunkankadai (scrub jungle) and Aralvaimozhi (semiarid zone) ecotypes exhibited closeness and distanced themselves from the Olavakod (Tropical rainforest) ecotype.

Table 10. Morphometric indices of *Sphedanolestes minusculus* ecotypes.

No.	**Morphometric parameters**	**Ecotypes**		
		Olavakod	**Sunkankadai**	**Aralvaimozhi**
1	AOL: POL	1: 0.96	1: 0.98	1: 0.98
2	AOL: HL	1: 2.22	1: 2.64	1: 2.67
3	POL: HL	1: 2.29	1: 2.71	1: 2.69
4	DE: WBE	1: 2.42	1: 1.09	1: 1.13
5	SCL: PDL: F1L: F2L	1: 0.28: 0.46: 0.58	1: 0.35: 0.6: 1.18	1: 0.35: 0.55: 1.39
6	SCL: EAL	1: 2.33	1: 3.3	1: 3.29
7	F1L: EAL	1: 5.05	1: 5.46	1: 5.99
8	F2L: EAL	1: 4.00	1: 2.77	1: 2.36
9	EAL: AOL	1: 0.19	1: 0.12	1: 0.13
10	EAL: HL	1: 0.43	1: 0.32	1: 0.33
11	PTL: EAL	1: 2.64	1: 4	1: 4.24
12	BRL: MRL: TRL	1: 1.44: 0.69	1: 1.25: 0.32	1: 1.23: 0.33
13	BRL: ERL	1: 2.51	1: 2.58	1: 2.56
14	MRL: ERL	1: 3.62	1: 2.05	1: 2.09
15	TRL: ERL	1: 3.18	1: 8.08	1: 7.67
16	ERL: AOL	1: 0.57	1: 0.34	1: 0.35
17	ERL: HL	1: 1.28	1: 0.92	1: 0.92
18	PTL: PTW	1: 1.11	1: 0.97	1: 0.98
19	PTL: HL	1: 1.13	1: 1.29	1: 1.41
20	PTL: FT	1: 1.28	1: 1.73	1: 1.65
21	PTL: MT	1: 1.23	1: 1.45	1: 1.42
22	PTL: HT	1: 1.89	1: 2.09	1: 1.97
23	WL: WW	1: 0.33	1: 0.39	1: 0.42
24	AL: AW	1: 0.87	1: 0.69	1: 0.71

The observations suggest that the biological, ecological and behavioural interactions operate in a special manner in this reduviid leading to ecotypical specialization without adversely affecting the genome that might cause reproductive isolation in a prolonged period of ecological isolation. This type of ecotypic specialization has been reported as ecological races or habitat races otherwise referred to as ecotypes, and there is no evidence to distinguish an ecological race from a geographical race, because every race is simultaneously a geographical race and an ecological race (Mayer, 1963, 1969; Ambrose, 1999).

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