BIOLOGY, BEHAVIOUR AND FUNCTIONAL RESPONSE OF *Sphedanolestes variabilis* Distant (INSECTA: HEMIPTERA: REDUVIIDAE: HARPACTORINAE), A POTENTIAL PREDATOR OF LEPIDOPTERAN PESTS

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Sphedanolestes variabilis Distant laid light brown colour eggs singly as well as in small clusters of 5 to 10 eggs. The incubation period was 6.92±0.29 days. The stadial durations of I,II,III,IV and V instar nymphs were 6.83±0.58, 6.83±0.94, 6.58±1.56, 8.42±2.68 and 8.67±2.23 and 19.67±3.44 days respectively. Adult males and females lived for 93.83±13.04 and 102.83±12.69 days and their sex ratio was 1: 1 (male and female). The sequential acts of predation as well as that of mating conform to these of other harpactorine reduviids. *S. variabilis* exhibited Holling's type II functional response as indicated by the positive correlation obtained between the prey density and the number of prey killed by the predator. The attack ratio decreased as the prey density was increased. A negative correlation was obtained between the searching time and the prey density.

Sphedanolestes variabilis, **assassin bug, biology, behaviour, functional response**

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Vrsta *Sphedanolestes variabilis* Distant odlaže jaja svijetlosmeđe boje pojedinačno ili u skupinama po 5 do 10 jaja. Inkubacijsko razdoblje traje 6,92 ± 0,29 dana. Razvojni stadiji I., II., III., IV. i V. faze nimfe jesu 6,83 ± 0,58, 6,83 ± 0,94, 6,58 ± 1,56, 8,42 ± 2,68 i 8,67 ± 2,23 i 19,67 ± 3,44 dana. Odrasli mužjaci i ženke živjeli su 93,83 ± 13,04 i 102,83 ± 12,69 dana, a omjer spolova bio je 1:1 (muški i ženski). Prema predatorstvu i parenju ta je vrsta u skladu s

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drugim vrstama iz porodice Readuviidae. Da bi se opisao odnos žrtva-plijen, korišten je model Holling tip II., koji je pokazao pozitivnu korelaciju između gustoće plijena i broja plijena ubijenih od predatora. Omjer napada smanjen je kako je gustoća plijena bila povećana. Negativna korelacija dobivena je između vremena pronalaska plijena i gustoće plijena.

Sphedanolestes variabilis, **predator, biologija, ponašanje, odnos žrtva-predator**

Introduction

The Reduviidae is the largest family of predaceous land Heteroptera and many of its members are found to be potential predators of a number of insect pests (Ambrose, 1999, 2000, 2003). Since they are polyphagous they may not be effective on specific pests, but they are valuable predators in situations where a variety of insect pests occur. *Sphedanolestes* is a predominant genus of Oriental harpactorine reduviids inhabiting tropical rainforests, scrub jungles, and semiarid zones bordering agroecosystems. They predate upon a wide array of insect pests (Ambrose, 1999). The knowledge on bioecology, behaviour, and pest suppression efficacy of any organism is a prerequisite for its utilization as a biological control agent. Hence, an attempt was made to study the biology, behaviour, and the functional response of *Sphedanolestes variabilis* Distant. Though information on biology, behaviour, and functional response of many reduviids is available, no such information is documented for *S. variabilis*.

Materials and Methods

The adult males and females of *Sphedanolestes variabilis* Distant were collected from Marunthuvazhmalai scrub jungle (latitude 77°55'E and 8°7'N) and Aralvaimozhi scrub jungle (latitude 77°31'E and 8°11'N) both in Kanyakumari District, Tamil Nadu, South India. They were maintained in plastic containers (7 x 15 cm) on the larvae of rice meal moth *Corcyra cephalonica* (Stainton) under laboratory conditions (temp. 32±2 °C, 75±5 % rh and 12±1 hrs photoperiod). The adults that emerged were allowed to mate. The containers were carefully examined at regular intervals to record the eggs laid as well as the spermatophore capsules ejected after successful copulation. The eggs laid in the laboratory were allowed to hatch in petri dishes (9.2 x 2.0 cm) with wet cotton swabs for maintaining optimum humidity (85 %), separately. The cotton swabs were changed periodically in order to prevent fungal attack. Mated females were maintained

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individually in order to record the number of batches of eggs and number of eggs in each batch laid by them. Each batch of eggs was allowed to hatch in individual containers. The predators were reared in the laboratory for two generations to find out the incubation period, stadial period, nymphal mortality, fecundity, longevity and sex ratio.

The functional response of predators was assessed separately at four different prey densities viz., 1,2,4 and 8 prey/predator for 5 days. A predator and the prey were introduced into the plastic containers (7.0 x 7.5 cm). Thus, six replicates were maintained for each category. After 24 hrs the number of prey consumed or killed was monitored and the prey number was maintained constant by the introduction of fresh prey throughout the experiment. In the present study the 'disc' equation of Holling (1959) was used to describe the functional response of *S. variabilis*. The following parameters were studied for 'disc' equation: x = prey density; y = total number of prey killed in given period of time (T_t); y/x = attack ratio; T_t = total time in days when prey was exposed to the predator; b = time spent handling each prey by the predator (T_t / k); and a = rate of discovery per unit of searching time $[(y/x)/T_s]$.

The parameters 'b', 'k', and 'a' were directly measured in the present study. The handling time 'b' was estimated as the time spent for pursuing, subduing, feeding and digesting each prey. The maximum predation was represented by the 'k' value and it was restricted to the higher prey density. Another parameter 'a', the rate of discovery, was defined as the proportion of the prey attacked successfully by the predator per unit of searching time.

Assuming the predatory efficiency is proportional to the prey density and to the time spent by the predator in searching the prey (T_s), the expression of relationship is:

$$y = a\, T_s\, x \qquad\qquad\qquad (1)$$

Since, time available for searching is not a constant it is deducted from the total time (T_t) by the time spent for handling the prey. If one presumes that each prey requires a constant amount of time 'b' for consumption, then

$$T_s = T_t - by \qquad\qquad\qquad (2)$$

Substituting (2) in (1), Holling's 'disc' equation is

$$y^1 = a\, (T_t - by)\, x \qquad\qquad\qquad (3)$$

The data were subjected to linear regression analysis (Daniel, 1987).

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Results and Discussion

Biology

S. variabilis laid brown eggs attached basally to the substratum by cementing material. Eggs were laid singly as well as in small clusters of 5 to 10 as observed in other *Sphedanolestes* species (Ambrose, 1999; Ambrose et al., 2006) (Figure 1). *S. variabilis* laid 34.33±5.08 eggs. The fecundity of *S. variabilis* was higher than that of *S. signatus* (15.33 ± 6.41 eggs) (Vennison & Ambrose, 1990) and lower than that of *S. himalayensis* (74.8 ± 5.2 eggs) (Das, 1996), *S. pubinotum* (54.0 ± 5.4 eggs) (Kumaraswami & Ambrose, 1993), and *S. minusculus* (63.33 ± 21.77 eggs) (Ambrose et al., 2006). The fertilized eggs turned reddish prior to hatching whereas the unfertilized eggs became shrunken.

Figure 1. Eggs of *Sphedanolestes variabilis* Distant laid as a cluster.

The preoviposition period of *S. variabilis* was shorter than that of harpactorines such as *Rhynocoris marginatus* (Fabricius) (33.3 days and *Rhynocoris kumarii* Ambrose and Livingstone (26.0 days), and closer to *Rhynocoris fuscipes* (Fabricius) (19.0 days). Among *Sphedanolestes* species, it was longer than that of *S. signatus* (9.33 ± 1.19 days), *S. pubinotum* (11.7 ± 0.88 days), *Sphedanolestes* sp. (8.6 ± 0.52 days) and *S. minusculus* Bergroth (12.55 ± 3.43 days) (Das, 1996; Ambrose, 1999; Ambrose et al., 2006).

Under laboratory conditions the eggs of *S. variabilis* hatched in 6.92 ± 0.29 days both percentage was 71.29 % during morning (8 to 11 AM) and afternoon (1 to 3 PM) hours. The higher hatching percentage is a diagnostic characteristic feature of harpactorines, especially *Sphedanolestes* as observed in its sister species viz., *S. signatus* (76.29 ± 5.76%), *S. pubinotum* (81.48 ± 4.66%), *S. himalayensis*

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Figure 2. First instar nymphs of *S. variabilis* just hatching from the eggs.

(77.81 ± 6.3%), *Sphedanolestes* sp. (92.92 ± 7.8%), and *S. minusculus* (95%) (Ambrose, 1999, Ambrose et al., 2006).

The incubation period of *S. variabilis* was shorter than that of all of its sister species. *S. signatus*, *S. himalayensis* (9.6 ± 0.86 days), *S. pubinotum* (10.2 days), and *S. minusculus* (7.8 ± 0.41 days) (Ambrose, 1999; Ambrose et al., 2006). The eclosion lasted for about 3 to 4 min. The newly hatched nymphal instars started feeding 6 to 7 hrs after eclosion, showing a preference for small and sluggish prey (Figure 2).

Table 1. Biological parameters of *Spedanolestes variabilis* on *Corcyra cephalonica* under laboratory conditions (n = 12; $\overline{X} \pm SD$)

Parameters	(in days)
Incubation period (days)	69.92±0.29
Stadial period (days)	
I instar	6.83±0.58
II instar	6.83±0.94
III instar	6.58±1.56
IV instar	8.42±2.68
V instar	8.67±2.23
I – V instars	37.33±4.40

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Continuation of the Table 1

Total stadial period (days)		
	Male	37.17±4.35
	Female	39.83±2.64
Fecundity / female (no.)		34.33±5.08
Hatchability (%)		71.29
Survival rate (I – V) (%)		60
Sex ratio (male : female)		1:1
Preoviposition period (days)		18.67±1.37
Oviposition period (days)		23.33±2.88
Postoviposition period (days)		19.67±3.44
Adult longevity (days)		
	Male	55.66±9.42
	Female	64.0±12.37
Total longevity (days)		
	Male	93.83±13.04
	Female	102.83±12.69

The stadial durations of I, II, III, IV and V nymphal instars were 6.83±0.58, 6.83±0.94, 6.58±1.56, 8.42±2.68, and 8.67±2.23 days respectively (Table 1). The total stadial period of *S. variabilis* from egg to adult was 37.33±4.40 days. It was shorter than that of its sister species *S. pubinotum* (66.70 days) and almost closer to that of another sister species *S. signatus* (46.90 days), *S. himalayensis* and *S. minusclus* (50.4 days) (Ambrose, 1999; Ambrose et al., 2006). Abnormal hatching and moulting caused 40 % nymphal mortality from I to V instar and thus the nymphal instars had a survival rate of 60 %. The nymphal mortality of *S. variabilis* was lower when compared to that of *S. pubinotum* (89.30 %) and greater than that of *S. minusculus* (21.06%) and *S. himalayensis* (13.0 %) (Ambrose, 1999). The adult male longevity and total male longevity were shorter (56.66±9.42 and

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93.83±13.04 days) than that of female (64.0±12.37 and 102.83±12.69 days). The preoviposition and postoviposition periods were 18.67±1.37 and 19.67±3.44days. The oviposition period of *S. variabilis* lasted for 23.33±2.88 days.

The laboratory emerged adults exhibited an unbiased sex ratio (male: female 1:1). Among harpactorines the unbiased sex ratio was also observed in *Brassivola hystrix* Distant and *Coranus siva* Kirkaldy (Ambrose, 1999). Laboratory breeding experiments indicated that *S. variabilis* is a multivoltine species.

Behaviour

Predatory Behaviour

S. variabilis predated in a sequential pattern: arousal – approach – capturing – probing – piercing and sucking (Figure 3) postpredatory cleaning as observed in other nontibial pad harpactorine reduviids (Ambrose, 1999).

Figure 3. *S. variabilis* adult female extending the rostrum and probing the *C. cephalonica* to select suitable sites for piercing and sucking.

Mating Behaviour

S. variabilis was found mating in the laboratory as follows: arousal – approach – riding over (Figure 4) – extension of genitalia – copulation (Figure 5) – ejection of spermatophore capsule by the female and post mating cleaning. The mating behaviour of *S. variabilis* with the characteristic riding over phenomenon represented its harpactorine character (Ambrose, 1999).

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Figure 4. *S. variabilis* a male riding over a female while another male approaching the female.

Figure 5. *S. variabilis* at copula.

Functional Response

S. variabilis responded to increasing prey density of *C. cephalonica* by killing more prey than at lower prey densities. It exhibited a typical functional response and thus established the applicability of the second model of Holling 'disc' equation (1959). The type II functional response is typical of most heteropteran predators (Cohen & Byrne 1992). The number of prey killed (y) by the individual predator increased as the prey density (x) was increased from one prey / predator to 4 prey/predator (Table 2 and Figure 6). Thus, the predation rate showed a steep rise from 1 to 4 prey densities and thereafter a plateau was maintained up

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to 8 prey densities. This was further confirmed by the positive correlation (y = 1.191±0.2156x; r = 0.8667) obtained between the prey density and prey killed. A similar result of positive correlation obtained between prey density and prey killed by Ambrose (1999), Ambrose & Claver (1995, 1997), Claver & Ambrose (2002), Claver et al. (2004), Ravichandran & Ambrose (2006).

Table 2. Functional response of *Sphedanolestes variabilis* to *Corcyra cephalonica* larva (n = 12).

Prey density (x)	Prey attacked (y)	Max 'y' (k)	Days /y b=Tt/k	All y's days (by)	Searching days Ts = Tt-by	Attack ratio y/x	Rate of discovery (y/x)/Ts=a	Disc equation y' = a(Tt-by)x
1	1.0			1.85	3.15	1.00	0.32	
2	1.8			3.33	1.67	0.90	0.54	y' = 2.56
4	2.5	2.7	1.85	4.63	0.37	0.63	1.70	(5-1.85y)x
8	2.7			4.99	0.01	0.34	-	
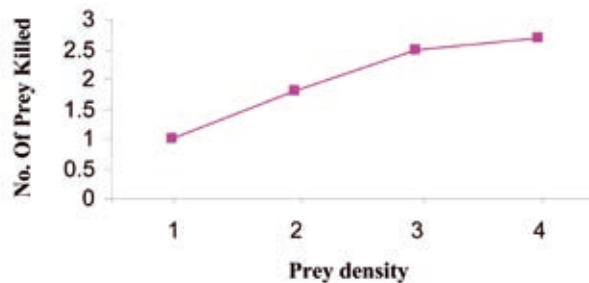
Figure 6. Cumulative functional response curve of *Sphedanolestes variabilis* to *Corcyra cephalonica*.

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The increase in the number of prey killed by the individual predator as a function of increasing prey density confirmed the observation of earlier reports of Awadallah et al. (1984), Ambrose (1999), Ambrose & Claver (1995, 1997), Claver & Ambrose (2002), Ambrose (2003), Claver et al. (2004), Ravichandran & Ambrose (2006).

The maximum predation represented by 'k' value (2.7) was always found restricted to the higher prey densities.

The highest attack ratio was observed at the density of 1 prey /predator and the lowest attack ratio was found at the density of 8 prey /predator. Hence, the attack ratio decreased as the prey density was increased [y = 91.073-0.0947x; r = 0.9896)]. The indirectly proportional relationship found between the attack ratio and the prey level was similar to the observations of Mukerji & Leroux (1969) in *Podisus maculiventris* (Say) and Propp (1982) in *Nabis americoferus* Carayon. It is presumed that the predator took less time on nonsearching activities, which in return might have caused a perceptive decline in the attack rate until the hunger was established (Claver et al., 2002, 2004). This type of searching time was also observed in *R. marginatus* to *Clavigralla gibbosa* Spinola and *Hieroglyphus banian* (F.) (Ambrose et al., 2000). Hassell et al. (1976) stated that the attack rate decreased with the increasing prey density with predators having type II functional response.

A negative correlation was obtained between prey density and searching time (y= 1.956 - 0.093x, r = - 0.225) of the predator at all prey densities.

The searching efficacy and rate of consumption were at their maximum at a density of 4 *C. cephalonica* larva. Thus, *S. variabilis* released at a ratio of 1:4 (predator-prey) may be optimal to realize this predator biological control potential against similar lepidopteran pests in agroecosystems.

Acknowledgements

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