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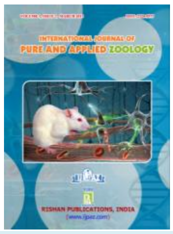

RESEARCH ARTICLE **OPEN ACCESS**

PREDATORY BEHAVIOUR AND EFFICIENCY OF THE WATER BUG *SPHAERODEMA RUSTICUM* ON MOSQUITO LARVAE *CULEX QUINQUEFASCIATUS*

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ABSRACT

The predatory efficiency of *Sphaerodema rusticum* on *Culex quenquefasciatus* has been assessed based on its predatory behaviour and the predator-prey relationship. Sequential behavioural strategies and duration of each event of the predation on prey were observed. Predator efficiency was assessed by prey death in different densities of prey groups, sex of predators and the prey sizes. *S. rusticum* recognizes and approaches its prey, *C. quiquefasciatus.* Sometimes the predator waits until a prey reaches its vicinity. At higher prey density, they quickly capture the prey by their fore legs, pierce the body using their proboscis and suck the contents. *S. rusticum* uses its visual sense to recognize and capture the prey. Blocking the visual sense experimentally resulted in poor predatory efficiency, when compared to that of the control. The predatory efficiency was much less in those insects whose tibial hairs of the fore legs were coated with moulten wax. Studies on the predator-prey relationship indicate that the rate of predation increases along with predator size. The fifth nymphal instar and adult stage show the maximum predatory efficiency than the earlier nymphal instars. Between the sexes, rate of predation is higher in females than in males. The rate of predation significantly increases with an increase in the density of the prey. The nymphs and adults of *S. rusticum* feed on all the larval stages of the mosquito. Hence, *S. rusticum* can be used as an efficient bio-controlling predator of mosquito larvae in fresh water bodies.

Key words: Predatory behaviour, predator-prey relationship, efficiency, *Sphaerodema rusticum.*

INTRODUCTION

Mosquitoes are the potential vectors of some important human diseases viz., malaria, filariasis, encephalitis, dengue fever, yellow fever and brain fever. Several methods have been adopted to control these vectors. Chemical control methods employing insecticides have failed due to the resistance developed by the mosquitoes. Further, the extensive and indiscriminate applications of insecticides affect the non-target organisms also. Biological control is considered to be an efficient method in controlling the mosquito population. Control of mosquitoes is feasible and efficient at larval stage rather than adult stage. In the aquatic medium, the mosquito larvae are consumed by the predatory aquatic insects, larvivorous fishes and other vertebrates. Many workers investigated the predatory efficiency of the belostomalids such as *Belostoma migantulum* (Consoli *et al.*, 1989), *Lethocerus indicus* (Jayachandra and Venkatesan, 1988), *Sphaerodema annulatum* (Pal and Ghosh, 1988 and Aditya *et al.*, 2004) and *Diplonychus indicus* (Prabakaran, 1992 and Shaalan *et al*., 2007).

A survey of literature reveals that although several workers have reported the predatory efficiency of many belostomatids, such studies are wanting in the water bug *Sphaerodema rusticum* (Fabricius). Therefore, the present study was undertaken to investigate the predatory behaviour and predatory efficiency of *S. rusticum* on the mosquito larvae.

MATERIALS AND METHODS

Predator*:* The egg-bearing males of *S. rusticum* (Heteroptera: Belostomatidae) were collected in large numbers from local shallow pond in and around Adirampattinam, Tamil Nadu. They were brought to the laboratory in plastic bucket and maintained in round plastic containers (18 cm diameter and 13 cm depth filled with tap water up to 8 cm). These rearing containers were provided with a few twigs of *Hydrilla* plant to provide shelter for the bugs and to make the medium a natural habitat. After hatching, the first instar nymphs were isolated and reared in the rearing containers. They were fed *ad libitum* with mosquito larvae which were collected from nearby ditches. The water in the rearing containers was changed every day to avoid fouling due to decay of the prey and faecal matter, and to maintain the quality of water to avoid mortality in the rearing containers. The successive instars and the emerged adults were isolated and maintained in separate containers. They were used as stock for the experiments. In order to study the predatory efficiency, all the nymphal instars and adults of *S. rusticum* were selected from the stock culture and used as predators. They were tested 3 days after moulting.

Prey*:* The egg rafts of the mosquito *C. quinquefasciatus* Say (Diptera: Culicidae) were procured from Vector Control Research Centre (VCRC) at Puducherry. They were maintained at 70-85% RH, 28 ± 2°C temperature and 12:12 light and dark photoperiod cycle. The emerged larvae were fed on powdered mixture of dog biscuits and yeast tablets in 3:1 ratio. The trays were covered with mosquito mesh to avoid entry of other mosquitoes for oviposition and to prevent the escape of the emerged adults from the laboratory populations. The blood meal was given to the female adult mosquitoes and 5.0% glucose solution and honey were given to the male adult mosquitoes. The emerged larval instars and adults were used for the experiments. As and when they were required, they were taken out and transferred to the experimental containers.

Experimental design: In order to assess the predatory efficiency of *S. rusticum*, the predatory behaviour and the predator-prey relationship were studied in the laboratory. Different nymphal instars and adults were kept under starvation for 24 hours prior to the commencement of the experiments, since starved predators consumed more number of preys than well fed. Each evaluation was carried out in the absence of vegetation in order to get a correct estimation of mosquito larvae in the water column.

Predatory behaviour: In order to observe the predatory behaviour, randomly selected bug was introduced into a plastic tray (20 x 15 x 5 cm) filled with 500 ml of water and mosquito larvae as prey. Sequential behavioural strategies and duration of each event were observed.

Experiments were conducted to investigate the role of eyes and fore legs on the predatory efficiency of *S. rusticum*. Randomly selected predator eyes were coated with black enamel paint to block visual sense in predation and tibial hairs of the fore legs were coated with moulten paraffin wax to block sensation (Ambrose *et al.*, 1983). They were acclimatized and starved for twenty four hours before commencement of the experiments.

Predator efficiency: To assess the relationship between the predator and the prey size, all the five nymphal instars and adults of *S. rusticum* were used as predators and all the four larval instars of *C. quiquefasciatus* larvae were used as prey. Individual male and female predators were introduced into four different densities of prey groups (25, 50, 75 and 100) to assess the prey density and the sex wise predation efficiency. The experiments were carried out in 250 ml glass beakers containing 250 ml of water using a single predator and a single prey group. Ten such trials were carried out for each experiment for a period of one hour. At the end of the experimental period the predator was removed from the container. The killed or attacked preys were easily identified from their distorted shape and were counted. The number of prey killed by each predator in a given time was recorded and represented as the prey death rate. Simultaneously, the container having the prey only served as a control in which 0 to 2 percent mortality was observed.

Statistical analysis: Statistical analysis was performed to obtain the mean number of mosquito larvae killed in each treatment. The students ' test was applied to analyze the experimental data. Two way analysis variance (ANOVA) was computed to test whether there is any significant difference between the predator and the prey sizes. The variance ratio was calculated at 1% or 5% level of significance and compared with critical F values (Sokal and Rohlf, 1981).

RESULTS AND DISCUSSION

Predatory behavior: The sequence of predatory behaviour of *S. rusticum* (Figs. 1 to 4) includes recognition and approaching, capture, piercing and sucking. The duration of each event is presented in Table 1.

Recognition and approaching: *S. rusticum* recognizes the prey from a particular distance by visual stimuli perceived through the eyes (Fig. 1) or by vibrating stimuli perceived through the forelegs or both. After recognition, it orients itself horizontally or vertically towards the prey (Fig. 2).

Capturing: Both the sexes are capable of capturing and foraging the prey by two ways namely ambushing and active searching. Similar observations have been reported in *D. indicus* (Venkatesan and D'Sylva, 1990). In the first category, the predator remains in ambush and waits until the prey reaches the vicinity or comes in contact with the forelegs. Then, the predator captures the prey either by a sudden stroke or as a simple capture of the prey by its raptorial fore legs. In the second category, the predator actively searches throughout the water column and captures the prey. The starved predator makes active predatory attempts by swimming and diving and captures the prey as reported by Cloarec (1990) in *D. indicus*. Then, it either comes to the water surface or rests on a nearby perch to feed on the prey. The predator frequently changes its strategy to capture the prey. At higher prey density, they capture the prey quickly and easily.

Piercing and sucking: *S. rusticum* captures the prey with its foreleg and sucks the body contents by its piercing and sucking proboscis (Fig. 3). A similar way of feeding has been reported by Pal and Ghosh (1988) in *S. annulatum*. At a high prey density, the predator is very active in killing the prey and sucking the contents rapidly. After sucking, the predator drops the body carcass of the prey (Fig. 4) And cleans its proboscis with its forelegs. Sometimes, during a meal, the predator captures another prey that reaches its vicinity. The second prey is held by the claws of the raptorial legs until the first prey is consumed. This hoarding behaviour is seen in *S. rusticum*. A starved predator consumes more than a well-fed one.

Impact of eye blocking on predatory behaviour: In *S. rusticum*, recognition and capturing were delayed when both eyes were blocked. The predator is capable of capturing the prey only when the prey comes in contact with its forelegs. Thus, the predator exhibits poor predatory efficiency compared to that of the control group (Table 1). This indicates the significant involvement of the visual sense in predation. This type of visual recognition is observed in *Ranatra linearis* (Cloarec, 1976).

Impact of tibial wax coating on predatory behaviour: When the tibial hairs of the fore legs were coated with moulten paraffin wax, the predator did not perceive the prey movement as it is unable to detect the mechanical vibratory stimuli. As a result, there is a delay in recognition of the prey which leads to affect the predatory efficiency (Table 1). *S. rusticum* is capable of perceiving the movement of prey even from a long distance through the sensory hairs located in the forelegs as seen in *Ranatra linearis* (Cloarec, 1976). Thus, it is evident that *S. rusticum* uses both the mechanical and visual stimuli to capture the prey.

Predatory efficiency: The predatory efficiency of *S. rusticum* was assessed from the predator-prey relationship experiments.

Impact of predator and prey sizes on the death rate of prey: All the nymphal and adult stages of *S. rusticum* capture and consume the contents of all larval sizes (Table 2). The prey death rate increases with the increasing predator size. The rate of predation is higher for adults than for nymphs. Among the nymphs, the predatory efficiency is more in the fourth and fifth instars and in the adult than in other stages. The ANOVA test indicates that the variation in the sizes of the predators has significant impact on the prey death rate.

The prey death rate is more significant in larger prey size than in smaller ones. All the stages of predators prefer large sized prey (fourth and fifth instar larvae) except the I instar nymph which prefers the smaller ones, either I or II instar larvae. ANOVA test reveals that the number of prey killed by a predator significantly differs from the prey size. This is in agreement with the observations reported in *Belostoma oxyuram* (Kehr and Schnack, 1991) and *D. indicus* (Prabakaran, 1992). The large sized predators have the high searching capacity, successful capturing and the fast handling of the prey. The low rate of predation in younger predators may be due to the difficulties in capturing and handling the prey.

Impact of prey density and the sex of predator on the death rate of prey: The number of prey killed in an hour by male and female predator of *S. rusticum* when exposed to different densities of *C. quiquefasciatus* larvae shows an increasing trend from lower to higher prey densities (Table 3). The prey death rate is more significant at higher prey densities (75 and 100) than at lower prey densities (25 and 50). The predators predate more actively when the density of mosquito larvae is high. Similar observations have been made by *D. indicus* (Prabakaran, 1992) and *Aeshna flavifrons* (Mandal *et al*., 2008). In the present study, *S. rusticum* shows high rate of predation in the high prey density and this may be due to the killing tendency of the predator rather than sucking the content of the prey.

The pattern of predation seems to be the same in both the sexes. However, the females predate more prey than the males. Similar results have been reported in *D. indicus* (Prabakaran, 1992). The female dominance in predatory efficiency in *S. rusticum* may be due to high energy requirements for the physiological activities such as vitellogenesis, egg maturation and oviposition.

CONCLUSION

The predatory behaviour and predatory efficiency studies obviously indicate that the nymphal instars and the adults of *S. rusticum* efficiently capture and consume large number of mosquito larvae. Therefore, *S. rusticum* can be used as an efficient bio-agent to control the mosquito larvae in water bodies. Further investigation in the field may be fruitful before its application in the anti-mosquito programmes.

Table 1. Sequential events of predatory behaviour and their duration of *Sphaerodema rusticum* on larvae of *Culex quiquefasciatus.*

Events	**Control (Sec)**	**Experimental insects**	
		Eye blocking (Sec)	**Tibial coating (Sec)**
Prey recognition and capturing	04.3 ± 2.5	85.3±13.7*	20.3±4.9*
Approaching	21.3 ± 7.9	62.3±12.4*	31.5±6.2*
Capturing	05.2 ± 1.5	04.5±11.5*	09.8±2.7*
Piercing and sucking	39.5 ± 7.0	47.2±10.4*	44.3±9.5*

Each value is mean ± SD of 6 Observation. Significant at $P<0.05$.

Table 2. Predatory efficiency of the nymphs and adults of *Sphaerodema rusticum* exposed to different sizes of *Culex quiquefasciatus* larvae (Predator: Prey density=1:100).

Predator sizes	**Death rate of prey/hour**			
	I instar larvae	**II instar**	**III instar**	**IV instar**
I instar nymph	6.3±0.8	13.8±0.8	8.5±0.7	7.8±0.7
II instar nymph	9.3±0.9	15.7±0.3	18.0±1.5	19.8±1.8
III instar nymph	10.7±1.2	17.4±1.8	20.7±2.1	22.3±2.3
IV instar nymph	11.2±1.7	18.1±2.1	21.3±2.0	23.6±1.2
V instar nymph	16.4±1.8	23.7±2.7	28.9±2.6	30.5±2.8
Adult	17.8±1.9	24.9±2.3	30.3±2.3	34.7±2.1

Two ways Anova table

Source of variation	**Sum of quare**	**Degrees of freedom**	**Mean square**	**F**
Between prey size	430.42	3	86.08	11.59*
Between predator size	830.89	5	276.59	37.28*
Residual error	111.43	15	7.43	-
Total		23		

*The number of prey killed is significant between prey sizes and predator size at $P<0.01$.

Table 3. Predatory efficiency of the male and female *Sphaerodema rusticum* exposed to different prey densities of *Culex quiquefasciatus* larvae.

Sex of the Predator	**Death rate of prey/hour in different prey densities**			
	25	**50**	**75**	**100**
Male	18.7±1.9	23.5±2.3	29.8±3.0	34.2±3.1*
Female	19.3±2.1	25.2±2.7	32.3±2.4	36. ±2.7*

Each value is mean ± SD of 6 observation. Significant at P<0.01.

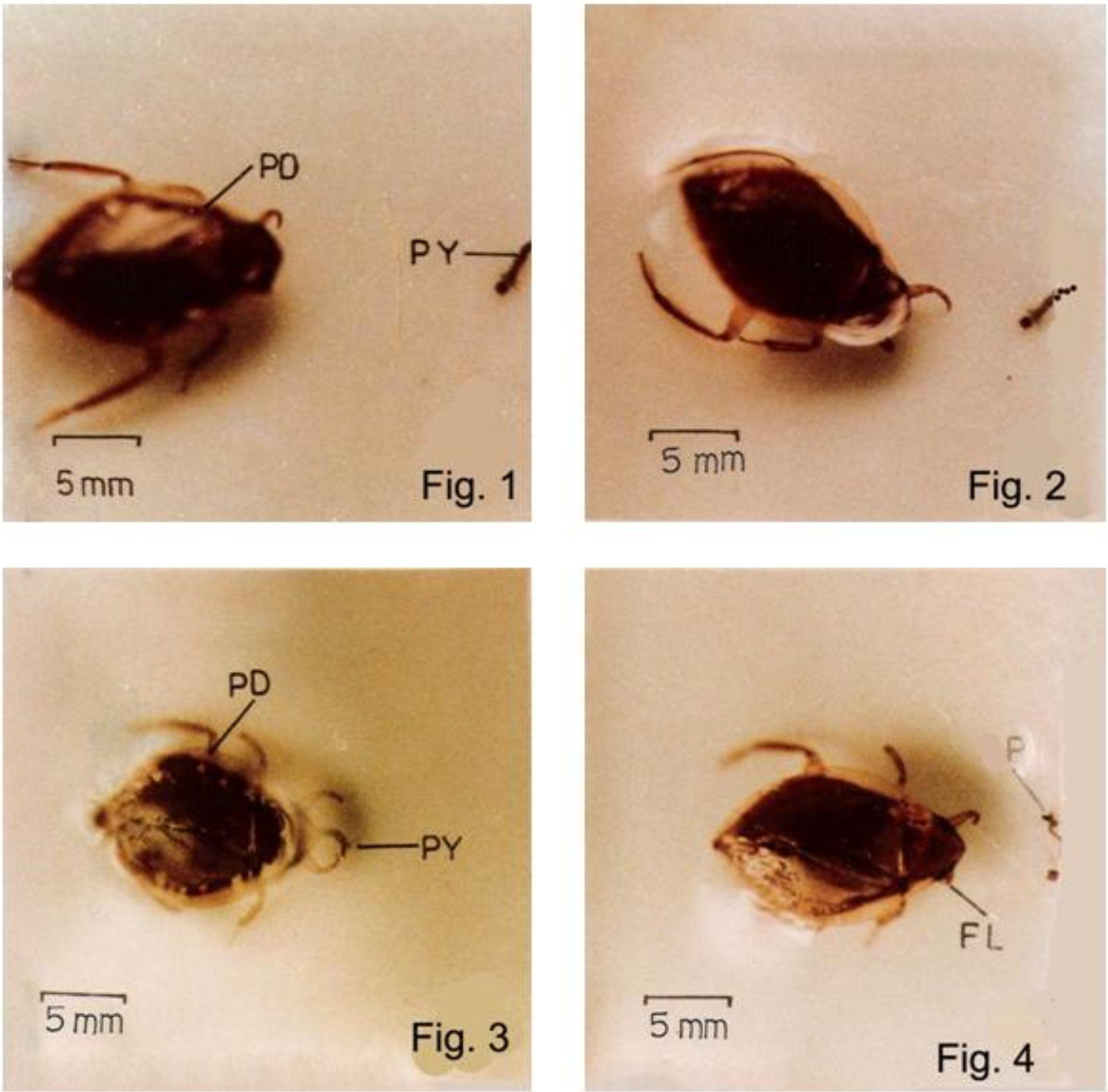

Figure 1. The predator (PD) *Sphaerodema rusticum* along with *Culex quinquefasciatus, the prey* (PY). Fig. 2. The predator recognizes its prey. Fig. 3. After catching the prey, the predator sucks the contents of the prey. Fig. 4. After sucking, the predator drops the prey as carcasss and cleans its proboscis by its fore legs (FL).

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