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Predatory Efficiency of the Semi-aquatic Bug *Microvelia douglasi* Scott 1874 (Hemiptera: Veliidae) with a Note on Factors Influencing its Predatory Performance

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ABSTRACT: The present work centers on the predatory efficiency of *Microvelia douglasi* adults. To investigate the test hypothesis of this study, as well as density-dependent predation of *Microvelia douglasi* adults, this experiment was designed. *Microvelia douglasi* adults were categorized as predators, and all the larval instars of *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus* formed the prey. The first and second instar of the prey were categorized as 'small prey', while their third and fourth instar as 'large prey'. The effectiveness of predation was investigated at prey densities of 25, 50, 75 and 100. Experiments were carried in six containers containing dechlorinated tap water wherein volume of three containers were 500mL and the volume of the other three containers were 1000mL. The predators (predator density of two) comprised of three categories (male, female, and both male and female) were introduced into the 500mL and 1000mL containers offered with each prey species separately of varied prey size. Control lacked predators to ensure mortality does not occur in any prey. All tests lasted for an hour only. Predation varied with regard to varied prey densities, however, maximum predation was at 25 prey density irrespective of prey species. The number of prey killed by *Microvelia douglasi* adults irrespective of their sex, prey size, and prey type varied. Highest successful attacks were noticed in female followed by male. *Microvelia douglasi* male and female adults preyed on 111.8 and 116.6 *Aedes aegypti*, 121.8 and 141.0 *Anopheles stephensi*, and 60.6 and 70.8 *Culex quinquefasciatus*, respectively, and their respective percentage of predation was 56.91 and 60.11; 53.26 and 62.13; 32.58 and 31.78. Prey consumed was high in I and II instars of all prey species, and predation was low as the prey death rate declined from III to IV instars, irrespective of the prey species. In *Aedes aegypti*, 237.8 and 104.0 number of small and large prey were consumed, while for *Anopheles stephensi*, it was 285.2 and 131.0, and in the case of *Culex quinquefasciatus*, it was 138.4 and 65.2, respectively, and their respective percentage of predation was 41.0 and 16.9; 42.7 and 21.0; 23.6 and 11.2. Amongst the prey types, *Anopheles stephensi* was more preferred, as they were found floating parallel to the water surface, and was easier to attack them, followed by *Aedes aegypti* and *Culex quinquefasciatus*. The total number of larvae predated by *Microvelia douglasi* adults in *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus* were 341.8, 416.2 and 203.6, respectively.

Keywords: *Microvelia douglasi*, *Aedes aegypti*, *Anopheles stephensi*, *Culex quinquefasciatus*, predator-prey interaction, predatory performance, prey density, prey size, prey type.

INTRODUCTION

Aquatic bugs of the family Veliidae popularly known as 'small water striders', water crickets' or 'ripple bugs' characterized by pre-apical claws inhabit freshwater ponds, streams, springs, rice fields and marshes. *Microvelia* genera housed under this family have a worldwide distribution with several species predominantly present in south and Southeast Asia, Indonesia, Japan and Sri Lanka (Polhemus, 1979, 1999; Polhemus and Polhemus, 1991; Polhemus and Copeland 1996; Yanoviak, 1999; Das *et al*., 2016), and in India, they are reported in states of Manipur, Odisha, Tamil Nadu and West Bengal (Thirumalai, 1994; Das *et al*., 2016). *Microvelia* adults are minute in size upto 2mm in length (Das *et al*., 2016), inhabit the water surface, and play an important role in the aquatic ecosystem (Dunbar *et al*., 2010). Although *Microvelia* have been known to prey on a variety of small aquatic organisms that occur in their habitat, they seem to be most adapted to prey on the organisms which frequent the surface film. They are more predaceous on mosquito larvae (Miura and Takahashi 1988; Yanoviak, 2001; Ohba *et al*., 2011), as it was reported that

Microvelia species derive nutrients from them for their growth, reproduction and survival (Miura and Takahashi 1988). They also associate themselves with the rice ecosystem as natural enemies of rice insect pests by feeding on plant hoppers (Nakasuji and Dyck 1984; Heong *et al*., 1992; Way and Heong 1994), brown plant hopper, *Nilaparvata lugens*, white-backed planthopper, *Sogatella furcifera* (Gupta and Pawer 1989; Heong *et al*., 2009), leaf hoppers (Reissig *et al*., 1982), leaf folders (Pathak *et al*., 2020), and on other rice pests of paddy fields (Numazawa and Kobayashi 1985; Bambaradeniya and Edirisinghe 2008; Pathak *et al*., 2020) which thwarts rice production. Studies concerning aquatic insect's predator prey relationship often involves mosquito larvae as prey (Nasrabadi *et al*., 2022). The present work centers on the predatory efficiency of *Microvelia douglasi* adults governed by factors, *viz*., predator's performance, prey recognition and capture, prey density, prey size, and prey type.

MATERIALS AND METHODS

Microvelia douglasi. Adults of *Microvelia douglasi* collected from the water surface of paddy fields from Vellore, Tamil Nadu, India using an insect net (200-m mesh size) were transported to the laboratory and reared in glass aquariums (30" × 20" × 20") filled with rice field water (10L). To recreate natural settings, *Azolla* leaves were dusted within the aquarium. The insects were maintained at room temperature (30±2°C) with a photoperiod of 12 hours light: 12 hours dark cycle, and were fed with *Culex* larvae on a regular basis. After copulation, the eggs laid were isolated from the aquarium and transferred to small troughs for the emergence of nymphs, and subsequently adult emergence.

Mosquito larvae. Immatures of *Aedes* and *Culex* species were collected from cisterns with the aid of a dipper and from open drains using a ladle, respectively. They were transported in plastic containers to the laboratory and then moved to enamel larval trays till adult emergence. Species of *Anopheles* adults were collected from cattle sheds, transferred to one feet mosquito cage, and transported to the laboratory. Adults of each vector mosquito were identified with the help of a mosquito identification key (Tyagi *et al*., 2015; World Health Organization, 2020), and species were confirmed before rearing. Subsequently, the cyclical generations of each vector mosquito were provided a blood meal, and each vector mosquito species was maintained separately in two feet mosquito cages (27 ±2°C, 70-80% RH) inside an insectary. Ovitraps inside the mosquito cages collected the oviposited eggs, which were shifted to the larval rearing room in enamel larval trays, and the larvae on hatching were provided larval feed (yeast and dog biscuits in ratio of 1:3). The larvae, on turning into pupae, were moved to another mosquito cage in enamel bowls for adult emergence.

Experimental design. Experiments were conducted at room temperature (26-30°C). The predatory efficiency of *Microvelia douglasi* adults was investigated on all the larval instars (I, II, III and IV) of *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus* at prey densities of 25, 50, 75 and 100 each. The first and second instars of the prey were categorized as 'small prey', while their third and fourth instars as 'large prey'. Experiments were carried in six containers containing dechlorinated tap water wherein volume of three containers were 500mL and the volume of the other three containers were 1000mL. The predators (predator density of two) comprised of three categories (male, female, and both male and female) were introduced into the 500mL and 1000mL containers offered with each prey species separately of varied prey size. Different volume containers were used in order to verify the effect of volume of water and surface area on the predatory performance of the adult bugs. Control lacked predators to ensure mortality does not occur in any prey. All tests lasted for an hour only. The prey killed by the predator was not replaced. A total of five trials were performed to investigate maximum predation Data on prey death rate were analysed with student's 't' test, and statistical differences were determined to be significant at $P<0.05$ level (SPSS, 2021).

RESULTS AND DISCUSSION

No prey mortality was reported in any of the control sets. Data showed a pattern of variation on the predatory efficiency of *Microvelia douglasi* adults. *Microvelia douglasi* is a semi aquatic bug, and the volume of the water did not make much impact. However, the surface area of the water mattered a lot, and prey death rate was more in surface area of 500mL than 1000mL. The total prey predated in 500mL was 166, 207 and 105, and in 1000mL it was 173, 213 and 93 for *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus*, respectively. Predation varied with regard to varied prey densities, however, maximum predation was at 25 prey density irrespective of prey species. The number of prey killed by *Microvelia douglasi* adults irrespective of their sex, prey size, and prey type varied (Table 1-3), and their respective percentage of predation are presented in Fig. 1. Highest successful attacks were noticed in female followed by male. *Microvelia douglasi* male and female adults preyed on 111.8 and 116.6 *Aedes aegypti*, 121.8 and 141 *Anopheles stephensi*, and 60.6 and 70.8 *Culex quinquefasciatus*, respectively, and their respective percentage of predation was 56.91 and 60.11; 53.26 and 62.13; 32.58 and 31.78 (Fig. 2). Both male and female together showed a normal predation. Prey consumed was high in I and II instars of all prey species, and predation was low as the prey death rate declined from III to IV instars, irrespective of the prey species. In *Aedes aegypti*, 237.8 and 104.0 number of small and large prey were consumed, while for *Anopheles stephensi*, it was 285.2 and 131, and in the case of *Culex quinquefasciatus*, it was 138.4 and 65.2, respectively, and their respective percentage of predation was 41.0 and 16.9; 42.7 and 21; 23.6 and 11.2 (Fig. 3). Amongst the prey types, *Anopheles stephensi* was more preferred, as they were found floating parallel to the water surface, and was easier to attack them, followed by *Aedes aegypti* and *Culex quinquefasciatus*. The total number of larvae predated by *Microvelia douglasi* adults in *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus* were 341.8, 416.2 and 203.6, respectively.

The basics in predator prey relationship are to evaluate the functional response of a predator which reflects on the function relating to the number of prey consumed per unit time by a single average predator (Oaten and Murdoch 1975). Predation in veliids are generally studied with reference to a short period or with reference to a particular stage of the predator. The same was experimented in the present study too with a time factor of one hour, and on the adult stages of *Microvelia douglasi*. The present study testified how far *Microvelia douglasi* predated on mosquito larvae which were governed by factors, *viz.*, predator's stage and performance, prey recognition and capture, prey density, prey size, and prey type.

Predator's performance. *Microvelia douglasi* adults predated on the prey, and its predatory performance was reflected to the degree to which the larvae were sucked dry of their body fluids, and were badly shrunken. The response of a predator is strongly affected by its size and stage which reflect on the attack rate and handling time during predator-prey interactions. This was noted in the present study, as the adults preferred more on small prey. Secondly, the searching and feeding behaviour changed as the prey density increased. This behaviour is referred as functional response. It explains the change in the number of prey consumed per unit time in relation to prey density. Holling's (1976) functional response model predicts that when the prey density remains constant, the rate of successful search and encounter rate, and inter catch interval, should decline with increasing queue size. The description of a predator's instantaneous, feeding rate or predatory impact, as a function of prey density, is its functional response which describes the rate at which a predator kills its prey at different prey densities, and thereby determining the efficiency of a predator (Murdoch and Oaten 1975). Further, functional responses are evaluated by parameters, *viz.*, attack rate and handling time (time spent by predator in attacking, killing, subduing, and digesting the prey), wherein attack rate estimates the steepness of the increase in the rate of predation with increasing prey density, while handling time is vital for estimation of satiation threshold.

Prey recognition and capture. Observations from the present study revealed that this bug spends less time in capturing the prey, and takes more time to suck the content. This was well reflected in their predatory behaviour. Veliids inhabit the surface waters, and prey on aquatic insects which visits the surface of water, and on other wind-borne insects which get entangled on the surface of the water. *Microvelia douglasi* possess well developed projecting eyes and sensory structures on its forelegs which assist in prey detection, subsequently striding towards the prey, and effectively catching the prey with the help of its forelegs. They run and walk freely on the water surface searching for prey, and during prey search, senses the wave action caused by prey movement on the water surface (Nakasuji and Dyck 1984). Capturing of the prey by *Microvelia* species have been brought about more by the water surface tension than by the action of the bugs contacting the prey. Jackson and Walls (1998) reported that the surface vibrations generated by the prey are important cues for *Microvelia* species and they moved directly towards the source of the vibrations. Thereafter, they orient themselves towards the prey, surround the prey, and inject their secretion into them and suck the contents of the prey. They seize their prey by flexing their tarsus against femur and tibia in the direction opposite to that exhibited by *Ranatra* species. After prey capture, they bring their forelegs very close to its rostrum and prick the prey at various points to make an easy puncture. Thereafter, once the spot is identified for penetration, it pushes its rostrum and sucks the entire content, and thereafter, the prey is discarded with the help of its forelegs, which is left afloat on the water surface. It is to be noted if another prey is encountered or offered during the feeding process, they never leave the prey on hand, but try to catch the prey with the help of the other foreleg which is free (Nakasuji and Dyck 1984). All these were observed in the present study too.

Prey density. This study provided an idea about the change in the predatory efficiency with change in the prey density. Predation varied with regard to varied prey densities, however, maximum predation was at 25 prey density, irrespective of prey species. When the predator attacks more, prey density decreases. At higher prey densities, the predator spends more time for non-searching activities, which in turn caused a perceptive decline in the attack rate until hunger was stabilized. The satiated ones would not search for another prey and the attack rate decreased with increasing prey density. Holling (1959a,b) stated this as a very effective parameter in the determination of actual feeding rate as it is possible to determine the number of predators that should be introduced in response to a particular prey density and available volume of search area. The same was confirmed by the research works of Marin *et al.* (2021) and Arivoli *et al.* (2023).

Prey size. When a predator has a choice of prey differing only by size, it often selects the biggest ones. However, chances are where the smaller items are captured too. This was observed in the present study, wherein, *Microvelia douglasi* adults predated uniformly on the first and second instar larvae. This may be due to the fact that the bug is small and it predated on the prey present on the surface film of the water, rather than the larger prey (third and fourth instar) which it finds difficult to prey upon. Certain factors channelize selection of a given prey size class. When the most profitable prey type is abundant and easily found, the predator should specialize on that prey type, under the influence of prey size. Holling's (1976) concept refers to the optimum prey size that a predator can handle with its foreleg. Difference in size between two groups of prey is marked more important, as the predator's preference is for the larger prey. However, this concept was found contradictory in the present study.

Venkatesan and Sivaraman (1984) reported that the behaviour of the predator could be concentrated on the selection of the prey, and its eating ability operates secondarily depending upon the efficiency and the size of the prey.

Prey type. In the present study, *Microvelia douglasi* adults preferred the larvae of *Anopheles stephensi* more when compared to *Aedes aegypti* and *Culex quinquefasciatus*. Species of *Anopheles* larvae are found inhabiting rice water ecosystems which would have made the adults to prefer them more, since they too inhabit the same aquatic habitat. Further, as *Anopheles stephensi* larvae lie parallel to the water surface, it provides more area for attack, hence the predatory rate was more in it. On the other hand, the larvae of *Aedes aegypti* and *Culex quinquefasciatus* hang at an angle of 45°C within the surface film of the water, and thereby might have provided less area for attack.

Table 1: Predatory efficiency of *Microvelia douglasi* adults on *Aedes aegypti* larval instars.

Predator sex	Prey size (instar)	Prey density							
		25		50		75		100	
		500mL	1000mL	500mL	1000mL	500mL	1000mL	500mL	1000mL
♂	I	7.00±2.23*	6.60±2.96	4.20±1.64*	3.80±1.30	6.80±3.96	6.40±2.19	6.00±3.53	4.20±3.34
	II	3.40±0.89*	3.00±1.00	4.40±1.41*	3.80±1.09	4.00±1.87	4.40±1.51	4.20±2.68	4.20±1.30
	III	2.00±0.70*	1.60±1.14	3.80±1.78	3.40±1.67*	3.40±1.51	4.00±1.41	1.20±0.83	1.00±0.70
	IV	1.80±0.44*	1.00±0.70	1.40±1.14*	1.20±0.83	1.20±0.83	1.80±1.30	2.80±1.30	3.80±1.64
♀	I	7.00±2.73*	7.20±2.38	3.00±1.22*	5.40±2.60	4.80±0.83	8.20±2.48	4.40±1.51	4.20±2.16
	II	3.00±1.00*	5.20±2.16	5.40±1.94*	6.80±0.83	3.00±1.00	4.00±2.34	6.60±1.51	6.40±1.67
	III	2.60±0.54*	2.20±1.09	3.60±1.51*	2.60±1.81	2.60±1.34	3.60±0.89	3.60±1.14	3.00±1.22
	IV	0.80±0.44*	0.40±0.54	1.00±0.70	1.20±0.83*	1.40±0.89	1.40±0.89	1.00±0.70	1.00±1.22
♂ + ♀	I	4.60±1.67*	3.40±0.54*	4.40±2.07	5.80±2.49	3.40±2.07	5.00±1.41	6.00±3.24	4.80±1.92
	II	4.40±1.14*	3.40±1.51*	5.80±1.30	5.00±0.70	5.00±1.58	4.20±0.83	5.80±1.64	5.00±1.00
	III	3.20±1.78*	2.60±1.14*	3.80±1.09	3.20±1.30	3.00±1.87	3.40±1.67	2.40±1.34	4.00±1.22
	IV	1.20±0.44*	1.20±1.09*	1.40±0.54	2.00±1.58	1.80±0.83	1.80±0.83	1.00±0.70	1.00±0.70

*Values significant at $P<0.05$

Table 2: Predatory efficiency of *Microvelia douglasi* adults on *Anopheles stephensi* larval instars.

Predator sex	Prey size (instar)	Prey density							
		25		50		75		100	
		500mL	1000mL	500mL	1000mL	500mL	1000mL	500mL	1000mL
♂	I	3.20±0.83*	2.80±1.78*	5.40±1.34	5.60±0.54*	7.00±1.00	6.60±1.14	6.20±1.92	6.00±2.34
	II	2.80±1.30*	2.20±0.83	5.20±1.92	4.80±1.30*	5.60±2.40	7.00±1.87	6.80±1.30	7.20±1.30
	III	2.40±1.81*	2.40±1.14	1.80±1.78*	1.40±1.14	4.60±1.34	5.60±1.34	5.60±1.14	5.40±1.67
	IV	0.80±0.83*	0.80±0.83	1.00±0.70*	1.00±0.70	1.20±0.83	1.00±0.70	1.40±1.14	1.00±1.22
♀	I	4.00±1.00*	3.40±1.67*	6.80±1.92	7.80±2.16	6.00±1.00	6.40±3.36	8.60±3.64	9.40±1.67
	II	2.80±0.83	2.80±0.83*	5.80±1.78*	5.20±1.64*	6.20±1.78	6.80±1.92	6.40±6.89	6.40±1.81
	III	2.20±1.30*	2.00±1.73	3.60±3.04	5.00±3.74	3.20±0.64	6.20±1.30	5.40±1.14	6.20±1.92
	IV	1.20±1.30*	1.00±0.70*	1.20±0.44	1.40±0.89	1.40±0.89	1.40±0.89	2.40±1.67	2.40±1.14
♂ + ♀	I	5.20±1.09*	4.60±2.40*	6.80±1.64	7.00±1.22	6.80±1.30	6.60±2.88	8.20±2.28	7.80±2.58
	II	5.40±0.83*	3.60±1.51*	6.60±2.03	5.80±1.48	7.00±2.00	6.80±1.30	8.60±1.34	9.40±1.14
	III	4.80±0.83*	3.40±2.07*	5.80±2.71	6.00±1.58	5.80±1.30	6.40±1.81	6.60±1.94	6.60±1.14
	IV	0.80±0.44*	1.20±0.44*	1.00±1.70	0.80±0.83	1.00±0.70	1.40±1.14	2.20±1.92	2.00±1.41

*Values significant at $P<0.05$

Table 3: Predatory efficiency of *Microvelia douglasi* adults on *Culex quinquefasciatus* larval instars.

Predator sex	Prey size (instar)	Prey density							
		25		50		75		100	
		500mL	1000mL	500mL	1000mL	500mL	1000mL	500mL	1000mL
♂	I	4.20±2.48*	3.20±2.77*	4.00±1.22	3.80±1.64	2.20±0.83	1.80±0.83	3.40±1.34	1.60±0.89
	II	2.60±2.30*	2.20±1.78*	3.00±1.58	4.20±1.64	2.00±1.00	1.80±0.44	2.20±1.30	1.60±0.89
	III	0.80±0.83*	0.60±0.89	1.60±1.14	2.00±1.00*	1.60±1.14	0.80±0.83	1.80±0.44	1.00±1.41
	IV	0.20±0.45	1.00±1.22*	1.80±0.83*	1.20±1.30	0.60±0.89	0.40±0.54	0.40±0.54	1.00±1.41
♀	I	2.80±1.30*	1.60±1.51*	3.80±0.83	2.80±1.48	4.00±3.16	2.80±1.64	2.80±0.83	2.80±0.83
	II	1.00±0.70	2.00±1.58*	3.60±1.67*	1.20±0.44	4.20±1.09	3.80±1.48	4.40±2.30	3.20±1.92
	III	1.00±1.22*	1.60±1.51*	1.80±0.83	0.80±0.83	2.20±0.83	2.40±0.89	3.00±1.00	2.80±0.83
	IV	0.20±0.44	1.00±0.70*	0.80±1.30*	0.60±0.89	0.80±1.09	1.80±0.44	1.20±1.30	2.00±1.41
♂ + ♀	I	2.60±2.19*	3.00±0.70*	2.20±1.30	1.80±1.48	4.60±2.40	3.60±2.70	2.60±0.54	2.80±0.83
	II	3.80±2.58*	3.40±1.51*	2.40±1.14	2.20±1.30	3.80±1.92	3.20±1.92	3.00±1.87	2.60±1.94
	III	2.20±0.83*	2.00±1.22*	1.80±1.22	1.40±0.54	1.80±0.83	2.20±0.83	2.60±1.94	2.00±1.00
	IV	2.00±1.22*	2.20±1.30*	1.20±0.83	0.60±0.89	0.60±0.24	1.00±1.00	0.20±0.44	1.20±1.78

*Values significant at $P<0.05$

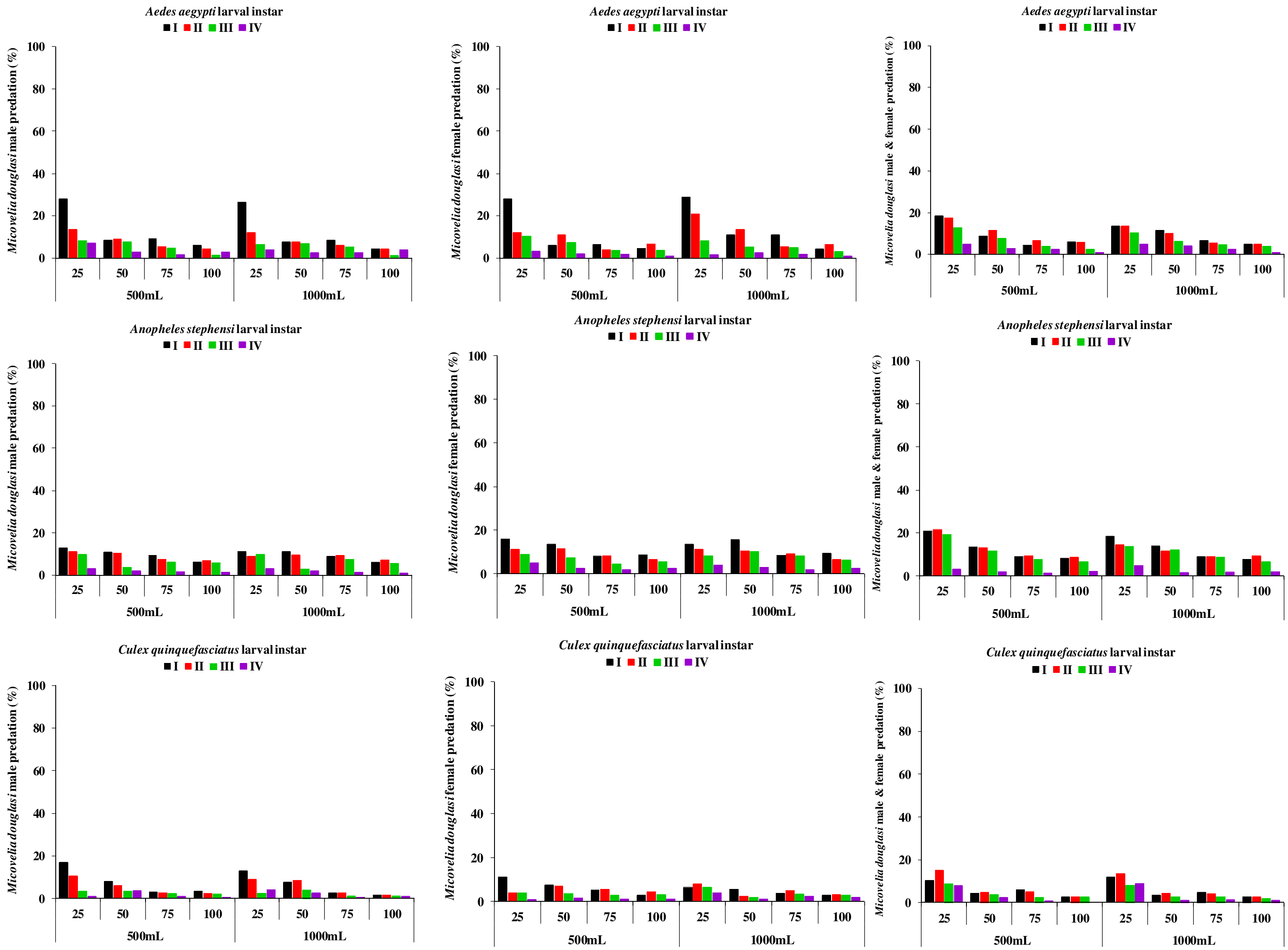

Fig. 1. Percentage of predation by *Microvelia douglasi* adults.

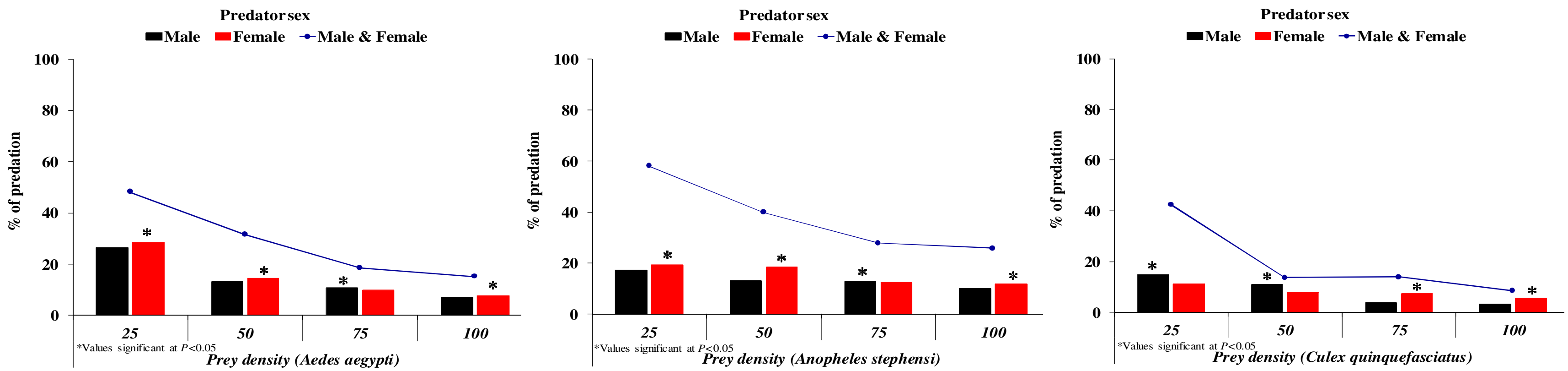

Fig. 2. Percentage of predation with reference to predator's sex.

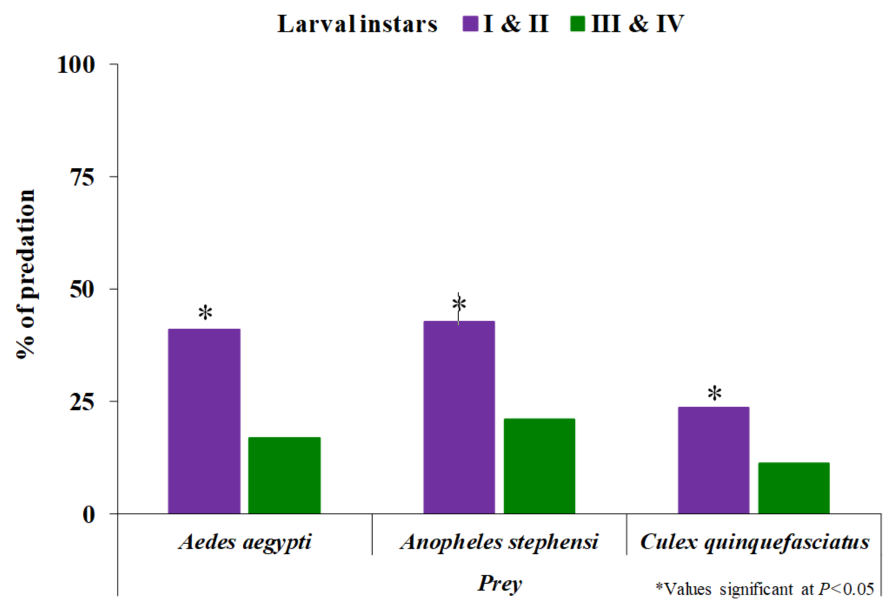

Fig. 3. Percentage of predation with reference to prey size.

CONCLUSIONS

The current investigation portrayed the predatory performance of *Microvelia douglasi* adults governed by factors, *viz*., predator's performance, irrespective of its, stage and sex, its prey recognition and capture, and by the type, size and density of prey.

FUTURE SCOPE

Future experimental work on *Microvelia douglasi* predator-prey interaction involving its nymphal stages, based on various factors will play a pivotal role on its predatory performance.

Conflict of Interest. None.

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