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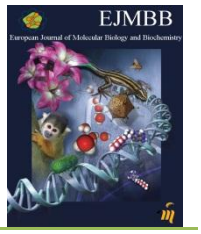

PREDATORY EFFICIENCY OF *DIPLONYCHUS RUSTICUS* (FABRICIUS, 1871) AGAINST *CULEX* LARVAE

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ABSTRACT

Insects adapt themselves to aquatic habitats in spite of their terrestrial origin. *Diplonychus rusticus* inhabits both temporary and permanent freshwater bodies and they are found in abundant. Since it is an active predator on *Culex* larvae it is of great interest to verify the predator-prey relationship in relation to various factors such as prey density, prey size, period of exposure and the nutritional status of the predator controlling them. Hence the present study was conducted in laboratory condition to determine the predatory efficiency of well fed and starved *Diplonychus rusticus* using small and large sized *Culex* larvae in 1 litre and 5 litres water volume. The well-fed male and female bugs were subsequently exposed to different prey density (25, 50,100, 200 and 400) prey size (small and large *Culex* larvae) in 1 litre and 5 litres water volume. The number of prey killed after one hour and 24 hours duration was recorded for male and female water bugs separately. The number of prey killed by the predator were subjected to the procedure of random predator equation of Roger's (1972) under non-linear square technique was used for statistical analysis. The predatory performances of both well fed and starved (male and female) bugs were highest after 24 hours not only at prey density 200in 1 litre water volume but, also at prey density 400 in 5 litres water volume. The predator preferred large sized *Culex* larvae than the small sized ones under well fed and starved condition. Based on the nutritional status, the predation rate was found to be high in starved condition than the well fed ones. With reference to the statistical constants of the predatory performance, attack rate (a) and handling time (Th), the present study revealed that the attack rate increased as the handling time of the bug decreased at various prey densities.

INTRODUCTION

Most of the insects become accustomed to aquatic habitat inspite of their terrestrial origin [1]. They are secondarily adapted to freshwater and very few are marine and estuarine in existence. Suborder Heteroptera of order Hemiptera include the water bugs. These are either aquatic or semi aquatic in existence. They prefer slow moving freshwater streams and ponds with aquatic vegetation. The presence of aquatic vegetation for these bugs is very essential for oviposition in Ranatra [2] or for the escape from its predators by clinging to the roots of *Eichorrnea* plant by *Diplonychus* [3]. Aquatic and semi aquatic bugs play a vital role in the food web of fresh water communities [4]. Bugs of the family Belostomatidae are fierce predators which stalk, capture and feed on few molluscans [5,6], fish [7,8] and amphibians [9]. They often lie motionless at the bottom of a body of water, attached to various objects, where they wait for the prey to come near. They then strike and paralyze the prey by injecting powerful digestive saliva with their mandible, and sucking out the liquefied remains [10]. Aquatic bugs are the important predators of mosquito larvae which carry many pathogens and parasites [11].

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Predator-prey relationship studies involving aquatic insects under laboratory condition have been very widely carried out in *Laccophilus* [12], *Diplonychus* [13], *Notonecta* [14] and *Ranatra* [15]. The predation rate is governed by many factors; some of the factors are prey density, prey size, vegetation, period of exposure, water volume, and hunger level. The developmental response theory states that the predator's growth rate depends on the feeding rate which in turn depends on the prey density [16]. Predation is highly influenced by density of prey to which the predator gets exposed. The response of the predatory bug changes in relation to its prey density. The number of *Aedes* larvae killed was decreased with increasing prey density in *Notonecta* [17]. Prey density influences the duration of the meal in *Ranatra linearis* [18]. Prey size plays a significant role on the predatory performance in which the *Notonecta undulate* preferred the second instar mosquito larvae [17]. It has been observed the *Belostoma bakeri* selected larger amphipod adults over smaller juveniles [4]. *Ranatra filiformis* is an efficient predator of large sized *Culex* larvae [19]. The aquatic bug gets influenced by the nature and abundance of vegetation. Aquatic bugs show an affinity to a specific type of vegetation either for oviposition such as *Hydrilla* by *Ranatra* species [2] or for the escape from predators by clinging on to the roots of *Eichhornea* by *Diplonychus* [3]. Effect of water volume on predation rate of *Anisops bouvieri* recorded higher prey death rates in one day than in one hour [20]. The state of hunger or satiation has a greater impact on the efficacy of the predator in search of prey. It has been observed that starved *Gerris aegentatus and Gerris lacustris* were more successful at prey capture than fed bugs, whose prey capture success decreases irrespective of prey size [21]. In *Diplonychus rusticus*, hunger induces the bug to switch from "sit and wait" attitude to active search for prey [22].

In the above mentioned literature, it was noted that *Diplonychus rusticus* inhabits both temporary and permanent freshwater bodies and they are found in abundant. Since *Diplonychus rusticus* is an active predator of the *Culex/Anopheline* larvae, it is of great interest to verify the predatory- prey relationship to various factors controlling them. Hence the aim of the present study was undertaken on the following aspects:

1. To determine the predatory efficiency of *Diplonychus rusticus* using small and large sized *Culex* larvae under well fed and starved condition in 1 litre water volume.
2. To determine the predatory efficiency of *Diplonychus rusticus* using small and large sized *Culex* larvae under well fed and starved condition in 5 litre water volume.
3. To analyze the attack rate and handling time of the predator against the prey item.

METHODOLOGY

The adult *Diplonychus rusticus* were collected at Coovum river, near Koyambedu, Chennai and the male and female bugs were segregated and transferred to a large transparent glass trough containing dechlorinated tap water with few twigs of *Hydrilla* to avoid cannibalistic action. The larvae of *Culex* mosquitoes were used as the prey item which was collected on daily basis from the stagnant water bodies at Coovum river near Nungambakkam, Chennai. The large and small sized *Culex* larvae measured about 0.7 cm and 0.2 cm respectively were separated and kept in a glass trough containing dechlorinated tap water.Having different prey densities viz. 50, 100, 200 and 400, prey size (large and small *Culex* larvae), predator (male and female), satiation level (well fed and starved condition), and the time period (1 hour and 24 hours), the experiment was conducted at different water level (1 litre and 5 litre).The predation by the bugs was observed for 1 hour and 24 hour. To determine the optimum prey density preferred by the male and the female bug, sets of experiments were conducted with 10 trials. The short term behavioral response by an individual predator and its attack is called functional response. This type of functional response is distinguished as type II functional response depends on the prey density and two statistical constant namely the attack rate (a) and handling time (Th). The number of prey killed by the predator were subjected to the procedure of modified random predator equation of Roger's (1972) under non-linear square technique was used for statistical analysis. $Na = \{N (1-\exp [-a (PT-Na\ Th)])\}$ was used to estimate the attack rate and handling time.

RESULTS

Predatory performance of both starved and well fed *Diplonychus rusticus* bugs exposed to different prey size at different prey density in 1 litre and 5 litre water volume was recorded after 1hour and 24 hour separately (Table 1). The predatory performances of both well fed and starved (male and female) bugs were highest after 24 hours at prey density 200 in 1 litre water volume. The predatory efficiency of starved male and female bugs was recorded to be highest than the well fed ones at prey density 200 in 1 litre water volume. Predatory performance of both starved and well fed (male and female) *Diplonychus rusticus* in 5 litre water volume after 24 hours was noted to be highest at prey density 400.The predatory efficiency of starved male and female bugs was recorded to be highest than the well fed ones at prey density 400 in 5 litre water volume. The male and female *Diplonychus rusticus* preferred the large sized *Culex* larvae than the small sized ones.

The attack rate (a) and handling time (Th) of both starved and well fed *Diplonychus rusticus* exposed to different prey size at different prey density in 1 litre water volume and 5 litre water volume was noted after 1hour and 24 hour separately (Table 2). The attack rate of both well fed and starved (male and female) bugs were highest after 24 hours at prey density of 200 in 1 litre water volume. The attack rate of starved male and female bugs was recorded to be highest than the well fed ones at prey density of 200 in 1 litre water volume. Attack rate of both starved and well fed (male and female) *Diplonychus*

rusticus in 5 litre water volume after 24 hours was noted to be highest at prey density of 400. The attack rate of starved male and female bugs was recorded to be highest than the well fed ones at prey density of 400 in 5 litre water volume.

With reference to the statistical constants of the predatory performance, attack rate (a) and handling time (Th), the present study revealed that the attack rate increased as the handling time of the bug decreased at various prey densities.

Table 1. showing the predatory efficiency of *Diplonychus rusticus*

Nutritional status	Water Volume	Predator's Sex	Prey size	Prey Density	No. of prey killed in 1 h.	No. of prey killed in 24h.
Starved	1 litre	Male	Large	50	22.5±0.63	48.9±0.33
				100	24±0.78	96.7±0.53
				200	62.1±1.05	182.7±2.91
				400	21.7±1.18	132±1.49
			Small	50	14.4±1.08	48±0.72
				100	19.3±1.11	73.5±2.99
				200	29.7±1.68	123±5.75
				400	18±1.42	115.3±3.14
		Female	Large	50	18.5±0.99	45.9±0.53
				100	14.8±0.44	85.2±2.11
				200	20.1±0.47	156.4±4.08
				400	17.7±1.94	117.4±2.97
			Small	50	10.4±0.83	48±0.72
				100	11.8±1.06	76.8±2.58
				200	38.3±0.82	115.9±2.38
				400	18.1±1.21	113.7±2.95
Well fed	1 litre	Male	Large	50	2.5±0.32	31.5±1.31
				100	6.2±0.63	43.5±2.12
				200	8.4±0.63	43.9±1.85
				400	2.7±0.40	35.4±1.83
			Small	50	2±0.28	29.7±0.83
				100	2.9±0.41	31.5±1.47
				200	3±0.48	35.4±1.74
				400	2.1±0.33	27.3±1.01
		Female	Large	50	4.7±0.44	35.7±1.11
				100	10±0.95	50±2.55
				200	12.1±0.91	52.6±2.26
				400	7.5±1.11	52.5±1.76
			Small	50	2.9±0.57	32.1±1.01
				100	3.6±0.56	37.8±2.76
				200	6.1±1.03	42.8±1.30
				400	2.3±0.42	36±1.68
Starved	5 litre	Male	Large	50	2.6±0.32	30.1±0.32
				100	5.7±0.44	54±0.63
				200	10.4±0.56	85.2±1.04
				400	27.9±0.75	161.7±3.07
			Small	50	1.1±0.17	21.1±0.62
				100	2.2±1.38	45.1±1.38
				200	8.3±0.71	75.9±1.84
				400	16.8±0.86	138.2±3.97
		Female	Large	50	3.3±0.49	32.2±1.15
				100	9.6±0.65	60.1±1.26
				200	12.4±0.56	89.9±1.95
				400	26.1±0.84	166.4±1.26
			Small	50	3.3±0.64	30±0.56
				100	7.5±0.69	46.6±1.65
				200	7.5±0.96	74.1±1.35
				400	20.5±1.06	164.2±2.71

Well fed	5 litre	Male	Large	50	1.09±0.16	15.1±0.57
				100	2.7±0.34	35.5±0.58
				200	6.2±0.34	68.9±0.57
				400	18.6±0.42	95.6±1.13
			Small	50	0.7±0.20	12.4±0.35
				100	1.4±0.20	29.9±0.38
				200	4.4±0.51	61.8±0.75
				400	16.4±0.32	81.6±0.56
		Female	Large	50	0.5±0.15	12.4±0.56
				100	1.5±0.25	27.6±0.40
				200	5.6±0.35	63.6±0.68
				400	16.5±0.53	81±0.56
			Small	50	0.5±0.15	10±0.54
				100	1±0.20	27.7±0.51
				200	3.8±0.23	54±1.41
				400	15±0.63	73±0.83

Table 2. Attack rate (a) and Handling time (Th) of *Diplonychus rusticus*

Nutritional status	Water Volume	Predator's Sex	Prey size	Prey Density	Attack Rate (a)		Handling Time (Th)	
					1 h	24 h	1 h	24 h
Starved	1 litre	Male	Large	50	- 0.553	- 4.506	0.057	0.026
				100	- 0.958	- 1.636	0.022	0.018
				200	- 1.004	- 3.352	0.005	0.003
				400	- 0.896	- 0.940	0.001	0.005
			Small	50	- 0.997	- 0.903	0.049	0.007
				100	- 0.999	- 1.001	0.023	0.023
				200	- 0.998	- 0.986	0.005	0.011
				400	- 1.003	- 0.962	0.011	0.005
		Female	Large	50	- 0.703	- 0.998	0.065	0.046
				100	- 0.998	- 1.001	0.023	0.023
				200	- 0.994	- 1.001	0.011	0.011
				400	- 1.000	- 0.998	0.005	0.005
			Small	50	- 0.999	- 0.995	0.046	0.046
				100	- 0.995	- 1.035	0.023	0.022
				200	- 0.997	- 1.670	0.005	0.006
				400	- 1.008	- 0.385	0.011	0.016
Well fed	1 litre	Male	Large	50	- 1.001	- 1.003	0.046	0.046
				100	- 1.000	- 1.003	0.002	0.022
				200	- 0.998	- 0.973	0.012	0.011
				400	- 0.997	- 0.973	0.004	0.011
			Small	50	- 1.002	- 0.969	0.046	0.026
				100	- 0.999	- 1.015	0.023	0.023
				200	- 0.998	- 0.981	0.011	0.011
				400	- 0.994	- 1.012	0.003	0.006
		Female	Large	50	- 0.989	- 1.012	0.046	0.006
				100	- 1.002	- 0.967	0.045	0.003
				200	- 1.003	- 0.986	0.011	0.011
				400	- 0.863	- 0.962	0.010	0.008
			Small	50	- 0.998	- 1.023	0.045	0.045
				100	- 1.001	- 0.999	0.023	0.023
				200	- 0.996	- 0.973	0.011	0.011
				400	- 0.997	- 0.992	0.005	0.005
Starved	5 litre	Male	Large	50	- 0.997	- 1.025	0.046	0.045
				100	- 0.989	- 0.998	0.023	0.023
				200	- 0.999	- 0.998	0.011	0.011

				400	- 0.998	- 0.990	0.005	0.005
			Small	50	- 0.994	- 1.000	0.041	0.045
				100	- 0.938	- 1.077	0.024	0.021
				200	- 0.999	- 1.000	0.011	0.001
				400	- 0.996	- 1.005	0.005	0.065
		Female	Large	50	- 0.999	- 0.998	0.046	0.046
				100	- 0.994	- 0.988	0.023	0.024
				200	- 1.000	- 1.001	0.011	0.001
				400	- 0.986	- 0.992	0.005	0.005
			Small	50	- 0.999	- 1.023	0.045	0.002
				100	- 0.997	- 1.001	0.022	0.023
				200	- 1.002	- 0.960	0.011	0.012
				400	- 1.000	- 1.078	0.005	0.005
Well fed	5 litre	Male	Large	50	- 0.896	- 1.010	0.052	0.056
				100	- 0.980	- 1.007	0.032	0.045
				200	- 0.998	- 0.973	0.012	0.011
				400	- 0.987	- 0.732	0.004	0.017
			Small	50	- 1.013	- 0.979	0.046	0.026
				100	- 0.989	- 1.005	0.026	0.023
				200	- 0.998	- 0.984	0.011	0.012
				400	- 0.894	- 1.012	0.013	0.006
		Female	Large	50	- 0.998	- 1.000	0.032	0.006
				100	- 1.001	- 0.976	0.045	0.005
				200	- 0.992	- 0.986	0.011	0.012
				400	- 0.843	- 0.977	0.011	0.009
			Small	50	- 0.987	- 1.023	0.054	0.044
				100	- 1.001	- 0.999	0.023	0.023
				200	- 0.896	- 0.979	0.011	0.019
				400	- 0.997	- 0.983	0.015	0.005

DISCUSSION AND CONCLUSION

Aquatic bugs plays a vital role in food web in which their role has been largely unexplored. Their importance of predation has been unknown [23]. Since early workers have emphasized their importance in the fresh water bodies, the predation potential of *Diplonychus rusticus* have been studied in detail. The results of the present study reveal as to how far the adult Diplonychus rusticus predates on the larvae population of Culex mosquitoes. The individual predator attacks more prey as the prey density increases. Enormous increase in prey density might have led the predator to confusion. A similar work was reported in *Ranatra linearis* [18], and *Notonecta undulate* [24]. In the present study, *Diplonychus rusticus* preferred large sized *Culex* larvae that the small sized ones under well fed and starved conditions. It has been reported two hypotheses stating the size of the prey affects the predatory performance in *Ilyocoris cimicoides* [25]. Based on the nutritional status the result reveals that in starved condition the predation rate of bugs was found to be high than the well fed ones. A similar work of predatory behavior was reported in *Rhynocoris kumarii* [26] and in *Gerris aegentatus* and *Gerris lacustris* [21]. In relation to the period of exposure the water bugs showed an increased predation rate at 24 hours than in 1 hour. It has been reported the predatory performance increase with increase in the period of exposure in Belostomatids [22, 27]. Increase in water volume reduced the predatory efficiency. Decreased predation on snails with an increase in volume of water was also reported [6].

With reference to the statistical constants of the predatory performance –attack rate (a) and handling time (Th), the present study reveals that the attack rate increases as the handling time of the bug decreases at various prey densities. The trend in the attack rate and handling time obtained in the present study suggested that increasing attack rate could be interpreted by its sub component and one of its sub components is palatability [13]. The suggestion given by the early researchers agrees with the fact that the time factor is not greatly involved in eating and digesting the prey. Further the result revealed that attack rate was high at low prey density of large sized *Culex* larvae. The reactivity and success rate of the prey capture increases with specific prey size group [28]. Based on the above result it's well understood that *Diplonychus rusticus* feeds voraciously on *Culex* larvae even after attaining satiation. Hence, this water bug Diplonychus *rusticus* can be introduced in biological control programmes.

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