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R. Avila Varshini
Ph. D Scholar
Department of Zoology and Research Centre,
Scott Christian College (Autonomous), Nagercoil. 629003

M. Kanagappan
Associate Professor Department of Zoology and Research Centre,
Scott Christian College (Autonomous), Nagercoil, 629003.

Correspondence:
R. Avila Varshini
Ph. D Scholar
Department of Zoology and Research Centre, Scott Christian College (Autonomous), Nagercoil. 629003.

Effect of quantity of water on the feeding efficiency of dragonfly Nymph - *Bradynopyga geminata* (Rambur)

R. Avila Varshini, M. Kanagappan

Abstract
Vector-borne diseases such as malaria, filariasis, Japanese encephalitis, dengue and many other arboviral diseases are emerging and resurging as serious public health problems. Chemical pesticides and insecticides failed to give sustained control. Among various predators of mosquito larvae, dragonfly nymphs are efficient, found naturally, safe for human beings, and are also economical in their application. Many factors that affect the feeding efficiency of dragonfly nymphs were studied in the present experiment and one among them was the quantity of water, which negatively correlated (-0.96304) with the feeding efficiency of odonate larvae *Bradynopyga geminata*. The maximum prey consumption 33.37 was recorded when the quantity of water was 100 ml and minimum predation 12.33 was recorded when it was 500 ml.

Keywords: Biological control, dragonfly nymph, mosquito immatures, odonates, predators.

1. Introduction
Repeated use of synthetic insecticides for mosquito control has disrupted natural biological control systems and led to resurgence in mosquito populations. It has also resulted in the development of insecticide resistance in mosquitoes and undesirable effects on non-target organisms and fostered environmental and human health concern, initiating a search for alternative control measures. Management of mosquito immatures through biological control is being tried world over [1, 2]. Some of the previous studies observed that nymphal odonates are voracious predators of mosquito larvae in controlled settings and small natural habitats [3, 4, 5, 6]. Immature Odonata occupy a great diversity of aquatic habitats but are generally most abundant in lowland streams and ponds. The predatory nymphs are an important part of aquatic food webs and the aquatic stages of mosquitoes comprise a significant part of the diet of many immature odonates [7, 8].
The rate at which food is consumed (intake rate) by many organisms is known to increase as local food density rises [9]. In addition to food density, there are many physical, chemical and biological factors affecting the feeding efficiency of dragonfly nymph. Some of them are prey species, prey size, prey stage, predator species, predator size, predator stage, aquatic vegetation, quality and quantity of water, illumination, space [10], both direct [11, 12, 13] and indirect competition [14], and feeding method [15]. Understanding the interspecific interactions controlling species coexistence and their spatial distribution is a fundamental topic in both terrestrial and aquatic ecology [16]. The objective of this work is to study the effect of quantity of water on the feeding efficiency of dragonfly nymph *Bradynopyga geminata*.

2. Materials and methods
2.1 Collection of mosquito larvae
The present study was carried out from May 2013 to April 2014. Mosquito larvae were collected from nearby freshwater bodies, stagnant water in domestic settlements using small D-frame nets. The larvae were carefully sorted and allowed into 200 ml plastic beakers. The larvae grown in the laboratory were fed with powdered dog biscuits (Arjunan, 2012). The water in the beakers was renewed daily to keep the larvae healthy. The larvae were segregated as *Aedes* complex, *Culicine* aggregations and *Anopheles* life stages.

2.2 Collection of *Bradynopyga geminata* naiads
Bradynopyga geminata adults, caught from the Botanical Garden, Scott Christian College, Nagercoil were reared in a wire-netted cage about 18 cu ft in which a large fish tank was placed with about 3 litre water, 1.0 kg of sand and 0.5 kg pebbles.

Small twigs were placed in the fish tank which served as moats for the dragonfly adult to settle down while laying eggs. The eggs of *B. geminata* were carefully watched and the egg emerging young ones were initially fed with *Paramecium* soup and after one week the nymphs were fed with *Artemia*, cultured in the laboratory. The larvae were all allowed to develop further for about 20 days. During this period, the larvae were fed with chironomus larvae and fresh earth worm cuts (young larvae). Larvae older than 6 weeks were used to study the effect of quantity of water on their feeding efficiency.

2.3 Experimental set up

Five 1 litre beakers were taken and each filled with 100 ml, 200 ml, 300 ml, 400 ml and 500 ml of water respectively. Twenty mosquito larvae were first introduced into the basin and after 10 minutes of acclimatization, a single predator was released into each beaker. After every hour the number of prey consumed was counted and the prey density was maintained constant by replacing the prey removed. Counting was continued throughout the period of the experiment (8 hours). Three replicates were maintained and values were tabulated. Mean and standard deviation were calculated and a chart was drawn based on those values.

3. Results

The effect of quantity of water on the feeding efficiency of dragonfly nymph was studied for eight hours. The observation was recorded at the end of each hour till the completion of experiment. The results have been presented in Table 1 and Figure 1.

3.1 Prey intake at the end of first half of the experiment at different quantity of water

When the quantity of water was 100 ml, the feeding efficiency was high and the maximum prey intake was 12.83±2.11 in the first hour. It gradually decreased as the time passed on and at the fourth hour the prey intake was abruptly decreased to 2.77±1.21. When the quantity of water was 300 ml, the feeding efficiency was high and the maximum prey intake was 7.5±1.5 in the first hour and the prey intake was gradually decreased as the time passed on and at the fourth hour the prey intake was decreased to 1±0.57. When the quantity of water was 500 ml, the maximum prey intake was 4.5±1.28 in the first hour and the prey intake was gradually decreased as the time passed on and at the fourth hour the prey intake was abruptly decreased to 1±0.75. The above findings revealed that irrespective of the quantity of water the prey intake by the predator was maximum at the first hour. As the time passed on the prey intake was lesser when compared to the first hour. Abrupt change was recorded at the end of the 4th hour. This shows that the predator starved for two days voraciously feed at the beginning and at the later hours, it reached the saturation point and the prey intake was gradually decreased in the following hours.

3.2 Prey intake at the end of second half of the experiment

When the quantity of water was 100 ml, the feeding efficiency was further reduced to 2.77±0.75 at the fifth hour. After that there was a gradual decrease in the intake and it was 1.0±0.8, 0.83± 0.68 and 0.67+0.47 at the 6th, 7th and 8th hour of the experiment. When the quantity of water was 300 ml, the feeding efficiency was further reduced to 0.83±0.68 the fifth hour. It was 1.67±0.68 at the 6th hour and at the 7th hour it was 0.67± 0.47, which was slightly lower than that of the sixth hour. At the 8th hour it was 1.17+0.68, which was again slightly higher than the 7th hour of the experiment. When the quantity of water was 500 ml, the feeding efficiency was further reduced to 0.5±0.46 at the fifth hour and 0.67±0.44 at the sixth hour, which is slightly higher than the fifth hour of the experiment. But after that there was a slight increase in the intake and it was 0.83± 0.63 at the 7th hour and 1+0.53 at the 8th hour which was slightly higher than that of the 6th and 7th hours of the experiment. At the second half of the experiment, the prey intake was lesser but at a steady state. As the hours passed by and at end of the eight hour the prey intake was slightly increased than the previous hours of the second half of the experiment.

Table 1: Feeding efficiency of dragonfly nymph at different water quantity level – ml

S. No	Hour	Prey eaten at different quantity of water (ml)				
		100	**200**	**300**	**400**	**500**
1	**1**	12.83±2.11	11.5±0.96	7.5±1.5	6±0.82	4.5±1.28
2	**2**	7.83±1.34	4.67±1.25	4±0.82	3±1	2.5±0.70
3	**3**	4.67±1.34	2±1.41	1.67±0.94	1.17±0.69	1.33±0.87
4	**4**	2.77±1.21	0.83±0.69	1±0.57	1±0.82	1±0.75
5	**5**	2.77±0.75	1.33±0.94	0.83±0.68	0.83±0.37	0.5±0.46
6	**6**	1.0±0.8	0.67±0.47	1.67±0.68	0.67±0.47	0.67±0.44
7	**7**	0.83± 0.68	1.5± 0.76	0.67± 0.47	0.83± 0.37	0.83± 0.63
8	**8**	0.67+0.47	1+0.58	1.17+0.68	1+0.58	1+0.53
Σ		33.37 ± 3.97	23.5 ± 3.45	18.51 ± 2.19	14.5± 1.72	12.33 ± 1.25

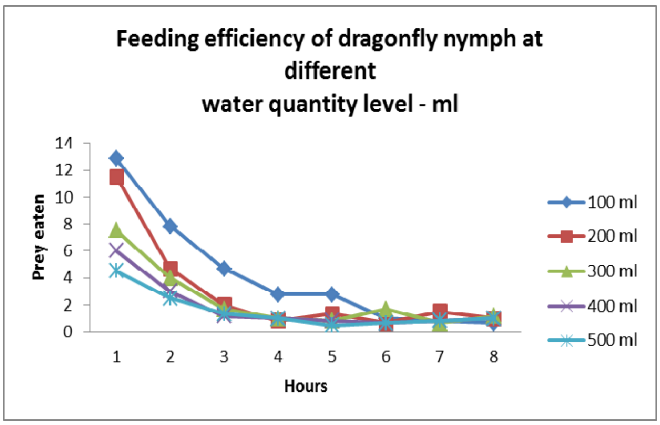

Fig 1: Feeding efficiency of dragonfly nymph at different water quantity level - ml

4. Discussion

The present study shows negative correlation (-0.96304) between the increasing quantity of water and decreasing feeding efficiency of dragonfly nymphs. When the depth of the water increases, the prey scatter far away from the predators and so the searching time for predation was increased, that led to decline in the feeding efficiency of the predator. This study was supported by the study of [18], who reported that when density of the prey varied more prey will be consumed as the prey density increased.

This study also confirmed that the dragonfly nymphs prey on all stages of mosquito larvae except eggs [19]. The results from the experiments on prey choice among the four larval stages suggest that prey size does not affect predatory capacity. Younger larvae spent more time near the water surface than did older larvae during the experiments, and this behaviour keeps them away from the predator and have lesser chance for predation while the older larvae especially *Ae. aegypti* are bottom feeders and the larger body size of older larvae may also draw more attention from the predator and so they have more chance for predation by the dragonfly nymphs, which were also found to rest at the bottom most of the time. Thus, both small and large larvae have some advantages and disadvantages in avoiding predation by *B. geminata* nymphs. The findings of the present study also coincide with the findings of [19] when the quantity of water decreases or depth decreases, the prey larvae are forced to be in a limited area that enables increase in prey density and that ultimately leads to the increasing feeding efficiency of dragonfly nymph. The same observation is made by [20] in *Acilius sulcatus* (Linnaeus, 1758). They studied that the prey consumption of the larvae of *A. sulcatus* differed significantly with different prey, predator and volume combination. According to them feeding rate decreased with the increasing volume of water.

5. Conclusion

In conclusion, the results of the present investigation revealed that when the quantity of water decreased the prey density increased and so the feeding efficiency of dragonfly nymph *B. geminata* was increased. When the quantity of water increased, the prey density decreased and so the feeding efficiency of dragonfly nymph *B. geminata* was decreased under laboratory condition. But this may vary in the field study because various factors in the environment affect the feeding efficiency of predators. When foods are changed from random to clump in dispersion, the predators increase their total use and feeding efficiency will be increased. By altering the ecological setting over a wide range, the general trend in the organism's response to single environmental variables can be determined and such experiments will prove very informative in the future in determining the effects of ecological change on the general behaviour of organisms.

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