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Predation potential of odonates on mosquito larvae: Implications for biological control

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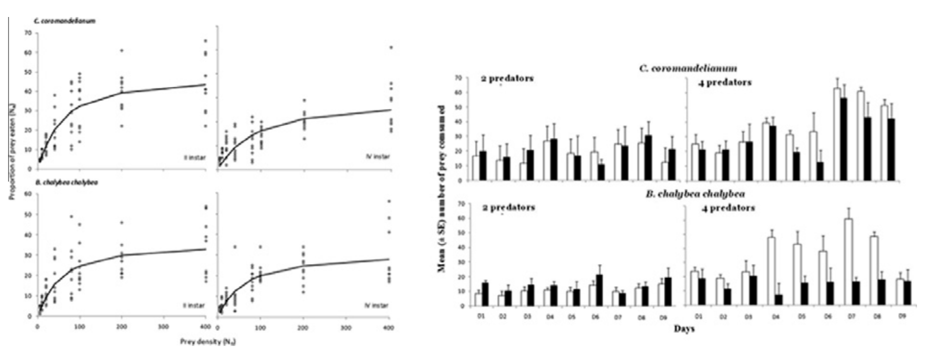
HIGHLIGHTS

- ▶ Predation of larval odonates was evaluated against larvae of *Culex quinquefasciatus.*
- ▶ Prey consumption was positive function of prey density, type II functional response.
- ▶ The attack rate and handling time varied with the prey size.
- ▶ Prey consumption differed under simple and complex habitat conditions.
- ▶ Larval odonates can be used in biological control of mosquitoes.

GRAPHICAL ABSTRACT



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ABSTRACT

Predation potential of the larval odonates *Ceriagrion coromandelianum* and *Brachydiplax chalybea chalybea* on the II and IV instar larvae of *Culex quinquefasciatus* was evaluated under simulated natural conditions in the laboratory. A type II functional response was exhibited by the odonates, with the attack rate and handling time differing significantly between prey sizes for *C. coromandelianum*. The per capita prey consumption varied between vegetated and open habitat conditions and between the days as reflected through the Clearance Rate (CR). Results of univariate ANOVA revealed that prey consumption varied significantly ($P < 0.05$) with the prey and predator densities for both the odonate predators, whereas habitat structure had significant effects only in case of *B. chalybea chalybea*. Thus, the use of larvae of *C. coromandelianum* and *B. chalybea chalybea* can facilitate conservation and biological control simultaneously under suitable habitat conditions.

1. Introduction

In mosquito larval habitats such as rice fields and other wetlands, regulation of mosquito population using natural predators can be a feasible option. Predatory insects and larvivorous fish, which are common predatory groups in such habitats, bear the potential to control mosquitoes, a fact substantiated by several empirical and theoretical studies. Among the predatory insects in wetlands, damselfly (Odonata: Anisoptera) and dragonfly (Odonata: Zygoptera) larvae are important predators of various macroinvertebrates including mosquito immature (E1-Rayah, 1975; Corbet, 1980; Quiroz-Martinez and Rodriguez-Castro, 2007). The trophic interactions and diversity of these insects favour their use in mosquito regulation in these habitats, as evident from the studies on the different species of damselfly and dragonfly larvae throughout the world (Miura and Takahashi, 1988; Sebastian et al., 1990; Stav et al., 2000, 2005; Chatterjee et al., 2007; Mandal et al., 2008). Even in smaller mosquito larval habitats like tree-holes the larvae of damselfly exhibit predation on mosquito immature (Fincke et al., 1997; Yanoviak, 2001). In addition, the

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larvae of dragonfly *Crocothemis servilia* have also been employed in regulation of larval *Aedes* population in Burma (Sebastian et al., 1990). In Indian context, odonate larvae such as *Mesogomphus lineatus* (Mathavan, 1976), *Sympetrum durum* (Chatterjee et al., 2007), *Ceriagrion coromandelianum*, *Brachydiplax chalybea chalybea* (Saha et al., 2009) has been recorded as predators of mosquito larvae. Since odonate larval assemblage is a part of the species ensemble in rice fields and allied wetlands (Bambaradeniya et al., 2004; Das et al., 2006), their use in biological control of mosquitoes can supplement conservation and aid in the maintenance of diversity of these insects as a part of conservation biological control.

The odonate larvae are generalist predators with wide range of dietary choice (Corbet, 1980). In contrast, predators such as the larvae of *Toxorhynchites* spp. (Pramanik and Raut, 2003; Alto et al., 2005; Aditya et al., 2006a, 2007) and *Lutzia* spp. (Pramanik and Aditya, 2009) have a narrow range of dietary choice (Jin et al., 2006), and are common in smaller mosquito larval habitats (Stefan and Evenhuis, 1981; Focks 2007), such as sewage drains (Aditya et al., 2007). Though, the larvae of *Lutzia fuscana* are reported from ricefields (Pramanik and Aditya, 2009), they proportionately consume lower number of mosquito immature compared to heteropteran bugs such as *Diplonychus* spp., and *Anisops* spp. (Saha et al., 2007a,b, 2009), dytiscid beetles such as *Rhantus* spp. (Aditya et al., 2006b; Aditya and Saha, 2006) and odonate larvae (Chatterjee et al., 2007; Mandal et al., 2008; Saha et al., 2009). Compared to other taxonomic groups, the high richness and abundance of insects in the wetlands of tropical countries support their utilization as biological control agents in wetland habitats.

In view of these facts, the present study was aimed at evaluating the predation potential of larvae of the damselfly *Ceriagrion coromandelianum* (Fabrecius, 1798) (Zygoptera, Coenagrionidae), and the dragonfly *Brachydiplax chalybea chalybea* Brauer, 1868 (Anisoptera, Libellulidae), under varied habitat conditions. These odonate species are common in wetlands of India (Mitra, 2003), and preliminary observations have revealed their competence as predators of larval mosquito (Saha et al., 2009). An extension of this observation is being highlighted in the present study that includes analyses of the functional responses, and long term predation under diverse habitat conditions. The results are expected to indicate about the possible trophic interactions in the wetlands. Use of these odonate species as model organisms would justify the suitability of conservation biological control and support the use of similar insect species which are facing threats owing to wetland degradation. Wetlands are common source of mosquitoes (Dale and Knight, 2008) and the evaluation of predation will enable to comment on the utility of odonate larvae in mosquito regulation vis-a-vis sustenance of wetland ecosystem services.

2. Materials and methods

2.1. Collection of prey and predators

The predatory larvae of *C. coromandelianum* and *B. chalybea chalybea* were collected from the 'Zoology pond' within Ballygunge Science College campus, University of Calcutta, Kolkata with the help of plankton net of 200 μm mesh size attached to a long wooden handle that allowed dredging of the bottom sediment. The samples collected contained a heterogeneous mixture of different size classes of the larvae, from which the desired size class to be used in the experiment were segregated (15.1–19.5 mm in length; head to abdomen excluding gills; 4.1–4.2 mm length between eyes, 40.5–53.8 mg in wet weight; for *C. coromandelianum* and 16.5–20.8 mm in length; 4.3–5.4 mm length between eyes; 172.5–397.4 mg in wet weight for *B. chalybea chalybe*) and maintained under laboratory conditions within glass aquaria of 28,000 cm^3 volume. The glass aquaria contained sieved pond water, sufficient amount of mosquito or chironomid larvae as food and some specimens of aquatic plants like *Chara* spp., and *Vallisneria spiralis* to provide resting sites to the larvae. The odonate larvae collected from field were a heterogeneous mixture of different species. In the laboratory the larvae of damselflies and dragonflies were separated based on the family and genus characters (Edmondson, 1963; Mitra, 2003). It was difficult to identify the larvae up to species level in the laboratory due to paucity of literature as well as specific expertise. The larvae used in the experiments were allowed to moult to adults for identification. The resulting adults were identified up to species level from the Zoological Survey of India, Kolkata, India as *Ceriagrion cormandelianum* (damselfly) or *Brachydiplax chalybea chalybea* (dragonfly). In the present study, the results of larvae of these species were considered. Data of few replicates were discarded due to the confusion. The pond from where these dragonfly and damselfly were collected showed consistency in species composition revealed through continuous monitoring.

The mosquito larvae were collected from the drains of the same area, at regular intervals, during the course of the experiments. The samples contained a mixture of different sizes of the larvae, which were sieved sequentially in a medium containing equal volume of drain and dechlorinated tap water to separate out the larger (4.9–6.1 mm in length, IV instar; 1.9–2.3 mg) and smaller (1.4–2.5 mm in length, II instar 0.7–1.1 mg) size classes to be used in the experiments. The rest of the larval population were maintained within enamel trays of $9 \times 27 \times 54$ cm^3 capacity containing adequate amount of food (1 Leviest capsule/300 larvae, approximately) and some sewage sediment for growth to IV instar stage.

The experimental animals were maintained in the laboratory under optimal conditions of temperature ranging from 25 to 30 °C, humidity 80–85%, and photoperiod 14 h L: 10 h D. Prior to the experiments the predators were fed to satiation and starved for 24 h. Only those predators that have been acclimatized to laboratory conditions were used in the experiments.

2.2. Experimental design

2.2.1. Experiment I: functional response

One odonate larva was separately exposed to 10, 20, 40, 80, 100, 200 and 400 numbers of II and IV instar larvae of *C. quinquefasciatus* in plastic trays containing 5L of water. The number of prey alive was counted after 24 h. Ten replicates were performed for each predator species, prey density and size class.

Data obtained was used to analyse the functional response following Juliano (2001). A logistic regression was carried out with the proportion of prey eaten (N_a/N_o) as function of initial prey density (N_o). The observed data was fitted to a polynomial model describing the relationship between N_a/N_o and N_o:

$$N_a/N_o = \exp\left(P_o + P_1N_o + P_2N_o^2 + P_3N_o^3\right)/1 + \left(P_o + P_1N_o + P_2N_o^2 + P_3N_o^3\right) \quad (1)$$

where, N_a = number of prey eaten, N_o = initial prey density, P_0 = intercept, P_1, P_2 and P_3 the linear, quadratic and cubic coefficients, respectively. If $P_1 < 0$, the number of prey eaten reaches asymptote hyperbolically as prey density increases, describing a type II functional response. If $P_1 > 0$ and $P_2 < 0$, the number of prey killed reaches asymptote as a sigmoid function, indicating a type III functional response. The parameters were estimated by maximum likelihood method, using PROC CATMOD, SAS Institute 2002. Once the shape of functional response curve was determined, the attack rate and handling time coefficients were estimated using the Hol-