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RESEARCH PAPER

Effect of temperature and search area on the functional response of Anisops sardea (Hemiptera: Notonectidae) against Anopheles stephensi in laboratory bioassay

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ABSTRACT

Present study was carried out to establish the influence of abiotic factors on foraging activities of a predatory hemipteran insect *Anisops sardea* against *Anopheles stephensi* larvae. The functional response of *A. sardea* was evaluated in variable density of prey items with variation in search area (100, 250, 500 and 1000 ml water volume) and temperatures (20, 25 and 30 °C). The results of laboratory bioassay revealed that prey consumption rate of predator species was positively related with increasing temperature and inversely related with increasing search area. Polynomial logistic regression equations and associated parameters showed that *A. sardea* exhibited a type II functional response in variable search area and type-III response at variable temperatures. Related response specific attack rates and handling times were also evaluated in presence of specific abiotic factors.

1. Introduction

Mosquitoes are vectors of many human diseases like malaria, filaria, dengue etc. that cause serious problems to human health as well as affect economic health of modern civilization. Female Anopheles stephensi is the principal vector of *Plasmodium spp.*, which spread the noxious disease malaria throughout the world especially in tropical countries. WHO has reported a global 219 million malarial cases with 1.2 million deaths in 2010 (Nayyar et al., 2012). India contributes to 61% of global malaria cases and 41% of malaria deaths in SEAR (South East Asia Region) countries (Sharma et al., 2015).

Emergence of insecticide resistance in vector population in a large scale and the appearance of pesticide pollulation due to over use of synthetic insecticides necessitated the application of biocontrol agents in vector control programme. Many bio control agents mainly larvivorous fishes (Chandra et al., 2008) and aquatic insect predators (Mandal et al., 2008; Kumar and Hwang, 2005) were investigated for their effective mosquito control efficacy in laboratory and field conditions. But, before recommending the use of a specific natural enemy in a biological control programme, detailed quantitative and qualitative understanding of the interactions of the predator and prey in variable environmental conditions are necessary. One important method for assessing the efficacy of natural enemies in quantitative term is the analysis of functional response. It refers to the number of prey attacked by an individual natural enemy/predator in relation to variable prey densities over a given time interval (Solomon, 1949) and represents an increasing linear relationship (Type I), a decelerating curve (Type II), or a sigmoidal relationship (Type III). Type II response is characterized by an increase in the number of prey attacked over the lower prey densities that reach an upper limit (asymptote) at higher prey densities and thereafter almost remains unchanged due to satiation (Jalali et al., 2010). Shape of Type III functional response curve is almost similar to type II response; but here, ratio of prey consumed and given prey density is a more than linearly increasing function.

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In any bioassay experiment the resultant functional response is always expressed by two essential parameters viz. attack rate and handling time. Attack rate estimates the steepness of the increase in consumption rate as a function of increasing prey densities and handling time estimate the time required to attack and consume a prey item. A review of available literatures suggest that generally insect predators exhibit a type-II functional response which may be influenced by presence of abiotic factors like temperature and search area (Menon et al., 2002; Timms et al., 2008; Singh et al., 2008; Ghosh and Chandra, 2011).

Anisops sardea Herrich-Schaeffer (Hemiptera: Notonectidae)is a predatory back swimmer belongs to family Notonectidae. It has cosmopolitan distribution and abundant in late-season temporary pools (Lahr et al., 1999), as well as in permanent pools (Barry, 1997). The results of laboratory bioassay indicated that *A. sardea* has a high consumption rate against larvae of *Culex* mosquitoes (Tawfik et al., 1986; Sridharan et al., 2000). The size selective prey preference of *A. sardea* against *Daphnia sp* was reported by Lindholm and Hessen, 2007. It was also found that presence of this backswimmer in aquatic pools has a significant effect on oviposition habitat selection of mosquitoes and other dipterans and on community structure in experimental aquatic pools (Eitam et al., 2002). The functional responses of *A.sardea* against larvae of *Cx. quinquefasciatus* was also studied by Mondal et al., (2014). But no studied have been carried out so far on the analysis of influence of abiotic factors on functional responses of this predatory species against *An. stephensi*, the most common malarial vector in the South East Asia.

The objective of the current study is to investigate the effects of temperature and search area on the functional response of *A. sardea* to different densities of *An. stephensi*. A detailed quantitative assay on one type of predator–prey interactions between these two species may be helpful to optimize the augmentative release of this predator species in biological control programme against the vector mosquitoes.

2. Materials and methods

2.1. Collection of A. sardea and mosquito larvae

Adults of *A. sardea* were collected from the different temporary and permanent aquatic pools of Bankura, West Bengal, India during the month of June–July 2015. The surface of the pools were sieved by an insect net having 200-μm mesh size. After collection the predators were maintained within glass aquaria (30 × 20 × 20 in.) containing pond water (10 l) and a few aquatic weeds (*Pistia sp*, *Hydrilla sp* etc.) in laboratory. Five adults were identified upto species level from the Zoological Survey of India. The insects were acclimatized with *An.stephensi* larvae and artificial food for 10 days in laboratory. The average body lengths of the *A. sardea* used in the experiments was 5–7 mm.

Mosquito larvae were collected from clean and stagnant water of rice fields and grassy ditches of the same area and maintained in laboratory in plastic trays containing the water collected from the same habitat for 3 days with a diet containing powder of Brewer yeast, dog biscuits and algae mixture in 3:1:1 ratio (Kamaraj et al., 2011). The third instar larvae of *An.stephensi* were carefully separated according to their length and maturity and kept in a separate enamel trays in the laboratory for further bioassay experiments. The laboratory bioassay was carried out with relative humidity of 55% and 12 h light/dark cycle within a BOD incubator.

2.2. Functional response analysis

To determine the type of predator specific functional response, each of the adult specimens of *A. sardea* was supplied with III rd instar larvae of *An. stephensi* at variable densities in separate glass beakers containing pond water and was allowed to predate for 24 h. The functional responses were analyzed in two different combinations:

a) Functional responses at various prey densities (10, 20, 30, 40, 50, 60, 70, 80 and 90 larvae per 400 ml of pond water) were assessed in three different water temperatures, viz. 20, 25, and 30 °C in a temperature controlled BOD incubator. The selected temperatures reflect thermal conditions frequently experienced by the predator in aquatic ecosystem of the study area.
b) Functional responses was analyzed at almost similar prey densities (10, 20, 30, 40, 50, 60 and 70, larvae) in three different water volumes viz. 100 ml, 250 ml, 500 ml and 1 l of pond water respectively. The water pH ranged from 7.8–8.3 and water temperature ranged from 21 °C to 24 °C.

Three replicates for each of the prey densities were carried out to different adults with almost similar body length.

2.3. Data analysis

In the present study, the data were analyzed for functional responses using R statistical software (© The R Foundation, 2013). The functional response of the predator was analyzed in two steps. In the first step, the type or shape of the functional response curve was determined following a polynomial logistic regression model (Eq. (1)) by considering the proportion of prey eaten $\left(N_a/N_0\right)$ as a function of initial prey density (N_0) (Juliano, 2001).

$$\frac{N_a}{N_0} = \frac{\exp\left(P_0 + P_1N_0 + P_2N_0^2 + P_3N_0^3\right)}{1 + exp\left(P_0 + P_1N_0 + P_2N_0^2 + P_3N_0^3\right)} \quad (1)$$

In this equation $N_a$represents the number of prey consumed by a predator, N_0 is the prey density allowed to feed;P_0, P_1, $P_2$and $P_3$are the intercept, linear, quadratic and cubic coefficients respectively. The coefficients of the logistic regression were estimated by using the function "**glm**" in R software.

In the second step the parameters of the type II functional response viz. attack rate and handling time of the predator species were estimated by using Holling Disc equation (Eq. (2))

$$N_a = \frac{aN_0T}{1 + aN_0T_h} \quad (2)$$

where$a$ = the attack rate constant, T_h = handling time per prey and T = total time available (here, 24 h). The parameters $a$and T_h were obtained by using non-linear least square regression with the help of "**nls**" function of R software. Holling's equation is used for the present study due to small size of predators, and they do not interfere with one another's prey capture activities and competition among predators for food (if any) occurs only due to the depletion of prey density.

As the functional response curve exhibits a Type −III type in bio assay experiments carried out at variable temperatures, the Holling Disc equation (Eq. (2)) was modified by considering the attack rate constant a as a function of prey density N_0 (Hassell, 1978) (Eq. (3)). The most general form of a is

$$a = \frac{d + bN_0}{1 + cN_0} \quad (3)$$

where$b$, c, and dare constants. This value of awhen substituted in the Disc equation (Eq. (2)), yields (Eq. (4)),

$$N_a = \frac{dN_0T + bN_0^2T}{1 + cN_0 + dN_0T_h + bN_0^2T_h} \quad (4)$$