ISSN: 2642-9020

Review Article

Journal of Marine Science Research and Oceanography

Use of Aquatic Insects For Biological Control of Mosquitoes (Diptera; Culicidae), Vectors of Different Diseases

Mohammad Nasrabadi[1], **Amrollah Azarm**[1], **Maryam Molaeezadeh**[1], **Faramarz Bozorgomid**[1], **Fatemeh Shahidi**[1], **Hasssan Vatandoost** [1,2*]

[1]*Department of Medical Entomology & Vector Control, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran*

[2]*Department of Chemical Pollutants and Pesticides, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran*

***Corresponding Author**
Hasssan Vatandoost, Department of Medical Entomology & Vector Control, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran, Department of Chemical Pollutants and Pesticides, Institute for Environmental Research, Tehran University of Medical Sciences, Tehran, Iran

Submitted: 13 Oct 2022; **Accepted:** 25 Oct 2022 **Published:** 06 Dec 2022

Citation: Nasrabadi, M., Azarm, A., Molaeezadeh, M., Bozorgomid, F., Shahidi, F., et al. (2022). Use of Aquatic Insects For Biological Control of Mosquitoes (Diptera; Culicidae), Vectors of Different Diseases. *J Mari Scie Res Ocean*, 5(4), 247-252.

Review Article

Mosquitoes are important insects not only as nuisance biters but also as vectors of important diseases such as malaria, dengue, West Nile virus, chikungunya, yellow fever, filariasis, tularemia, dirofilariasis, Japanese encephalitis, Saint Louis encephalitis, Western equine encephalitis, Eastern equine encephalitis, Venezuelan equine encephalitis, Ross River fever, Barmah Forest fever, La Crosse encephalitis, and Zika fever, as well as newly detected Keystone virus and Rift Valley fever [1]. (Caraballo and King 2014) Nearly 700 million people get a mosquito-borne illness each year resulting in over one million deaths. More than 3000 species of mosquitoes are responsible for millions of death annually. The World Health Organization adopted Mosquito Control as the only method to prevent or control such diseases. Vector control strategies have traditionally focused on killing mosquitoes using a variety of insecticides. The use of chemical insecticides for controlling mosquitoes is limited because they develop resistance against these insecticides. So, efforts have been made to control the mosquito vectors by eco-friendly techniques. Biological control is the use of living organisms or their products to control vector and pest insects. The organisms used include viruses, bacteria, protozoa, fungi, plants, parasitic worms, Predatory mosquitos and fish. Dragonflies (Odonata) are conspicuous predators of mosquitoes during both larval and adult stages. Odonata naiads are generalists and voracious predators that detect their prey by means of compound eyes and mechanoreceptors and suddenly capture them with the labium or labial palps (Figure.1).

Figure 1: Dragonfly nymph and adult

Various families of aquatic and semiaquatic bugs from Hemiptera order including: Gelastocoridae, Naucoridae, Nepidae, Belostomatidae and Notonectidae are important for biological control of mosquitoes. Notonectids or backswimmers have been considered the most promising. The greater values of search capacity represent the better entomophagous insects, revealing hemipterans of the family Notonectidae and especially *N. irrorata* as the most successful and thus the best candidates for biological control programs (Figure.2)

Figure 2: Notonectids insect

From order of Coleoptera only Dytiscidae and Hydrophilidae have received attention. Dytiscidae larvae and adults include in their diet a variety of organisms ranging from aquatic invertebrates to tadpoles and fishes. Species of the genera *Dytiscus, Laccophilus, Agabus and Rhantus* have been reported as potential agents of biological control (Figure.3).

Figure 3: Dytiscidae family from Coleoptera order , adult and larvae eating from mosquito larvae

From Diptera family the genus Toxorhynchites is unusual and large, non-biting mosquitoes. The larvae are predaceous on other mosquitoes and aquatic organisms that inhabit both natural and artificial containers. Ability of Toxorhynchites to fast and survive weeks without prey allows the production of what may be called a biological residual (Figure.4).

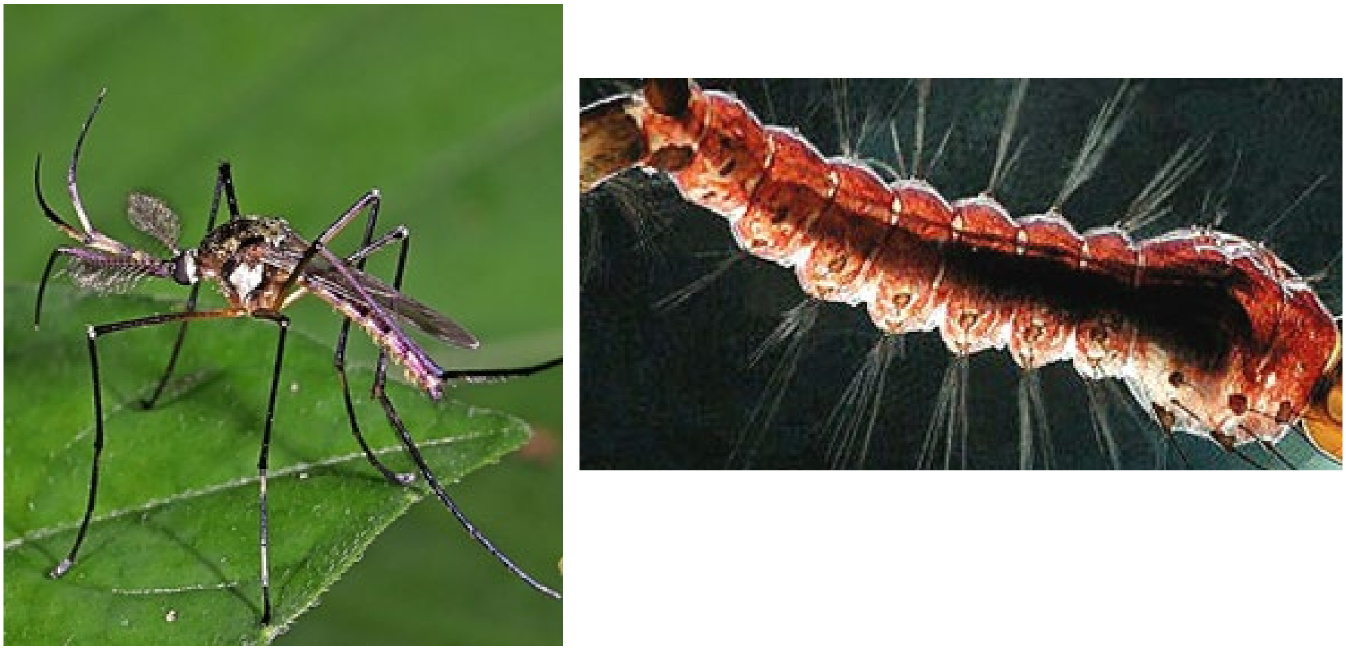

Figure 4: Toxorhynchites adult and larvae

The mosquito prey preferences of water bugs and larvae of odonate species were evaluated using chironomid larvae, fish fingerlings and tadpoles as alternative prey wetlands of Kolkata, India. They used Diplonychus (Sphaerodema) annulatus (Belostomatidae) . Diplonychus rusticus and Anisops bouvieri (Notonectidae), Brachydiplax chalybea (Libellulidae) Ceriagrion coromandelianum (Coenagrionidae). On a comparative scale, chironomid larvae had the highest impact as alternative prey. In a multiple-prey experiment, predators showed a similar pattern of preference for mosquito larvae over alternative prey. The results suggest that, in a laboratory setting, these insect predators can effectively reduce mosquito density in the presence of multiple alternative prey. Predatory potential of 12th instar larvae of Bradinopyga geminata on Aedes mosquito immatures was observed. The dragonfly larvae were collected from the cement pond ecosystem which are located in Tamil Nadu Agricultural College campus Madurai –India.One and five 12th instar larvae of B. geminata were provided with 200 (SET A) and 1000 (SET B) I, II, III & IV instars of Aedes aegypti larvae as prey, for a period of 24 hours in plastic containers containing 1 and 5 litres of water respectively. Predation rate of B. geminata was more for 1st instar. The predatory impact values for I instar in both Set A and B were 4.12+0.05 and 3.6+0.02 respectively. This study revealed that B. geminata larvae is an Efficient predator of mosquito larvae. The rate of consumption was dependent on the size of the prey and the density of the predator. The Predatory Impact of B. geminata was more for the first instar Ae. aegypti, owing to its size and energy requirements.To conclude, B. geminata is an efficient bio-control agent for container breeding Ae. aegypti and can be an effective tool in the integrated vector control programe [2].

The Predatory Potential of Bradinopyga geminata, Crocothemis servilia and Ceriagrion cerinorubellum larvae on Aedes aegypti larvae were recorded for 8 hours with three replicates under laboratory condition Prey and predators (25:1). The maximum consumption rate of Bradinopyga geminata was on 1st instar larvae of Aedes aegypti was 75%. Crocothemis servilia and Ceriagrion cerinorubellum shows maximum consumption rate on 2nd instar larvae of Aedes aegypti. (70.15%). Bradinopyga geminata shows highest Predatory Impact on all the instars of Aedes aegypti. This study reveals that the release of odonata nymphs especially Bradinopyga geminata in areas of dengue epidemics will effectively control the Aedes aegypti larval production and thereby dengue epidemics[3].

Predatory potential of five odonate nymphs namely Anax parthenope, Bradinopyga geminate, Ischnura forcipata, Rhinocypha quadrimaculata, and Orthetrum sabina were evaluated against the 4th instar larvae of the dengue vector mosquito, Aedes aegypti, under laboratory conditions. The consumption of the mosquito larvae (100 4th instar larvae of Ae. Aegypti) was evaluated at three water volume levels viz., 1 liter, 2 liter and 3 liter (after 24 h). The number of Ae. aegypti larvae consumed varied significantly among the five species, and at different levels of water volume ($P < 0.01$). Ischnura forcipata consumed the highest number of Ae. aegypti larvae (n=56) followed by A. parthenope (n=47) and B. geminate (n=46). The number of larvae consumed was decreased with increasing search area or water volume, and the highest predation was observed at 1-liter water volume.The odonate nymphs could be a good source of biological agents for the management of the mosquitoes at larval stages [4].

In a study the effect of water conditioned by potential predators of immature mosquitoes on mosquito oviposition in the laboratory were evaluated. The response of egg-laying Culex tarsalis to water conditioned by three fish species used for mosquito control and Three Predatory aquatic insect species was examined in laboratory binary choice experiments. Mosquito oviposition on water conditioned with the predatory insects (nymphs: Sympetrum corruptum (Odonata: Libellulidae); adults: Thermonectus basillaris or Cybister fimbriolatus (Coleoptera: Dytiscidae)) did not differ significantly relative to that onto water aged for 24 h. As compared with water aged 24 h and water conditioned with diving beetles, oviposition by Cx. tarsalis was significantly lower (>53%) when live predatory diving beetles were present in oviposition cups. Aquatic coleopteran larvae were associated with the largest declines of Culex tarsalis populations in fishless habitats.Results indicate that gravid Cx.tarsalis females respond to cues [visual, mechanical (e.g., vibrations on the surface of the water caused by the movement of the beetles) or chemical (i.e., feces)] from the beetles [5].

Several studies have shown a reduction in oviposition rate by female mosquitoes into habitats Containing Hemipteran Predators (Notonecta Spp).Culiseta longiareolata was deterred from egg laying by volatile chemicals produced by the predatory backswimmer Notonecta maculata .Cu. longiareolata reduced egg-laying only when Anax nymphs were allowed to roam freely in temporary pools but did not reduce oviposition when dragonfly nymphs were enclosed in cages. The study examined the predatory impacts of two aquatic invertebrates, Notonecta glauca (water boatman; Ng) and Gammarus pulex (river shrimp; Gp), against larval prey of the medically important mosquito Culex pipiens. Both predators were able to feed on Cx. pipiens across their larval ontogeny; however, Ng consumed significantly more larvae than Gp. Both predators preferred late instar mosquitoes (Ng: fourth instar; Gp: third instar). Anisops debilis displayed Type II FR towards larval Cx. pipiens .Attack rates were highest in simple environments. Maximum feeding rates of A. debilis towards Cx. pipiens larvae were thus robust to habitat complexity variations. Results demonstrate the substantial predatory impacts of notonectids towards larval mosquito prey irrespective of habitat complexities, which may assist in the biological control of pests and vectors in aquatic systems [6].

Study was carried out from May 2013 to April 2014 . Bradynopyga geminata adults, caught from the botanical garden, scott Christian college, Nagercoil, India. 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. 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 [7].

In a research carried out by Saparai et al 2019, this research was consists of two phases. First phase involved an ecosystem study of a man-made container that had become populated and established with Micronectidae .Second experiment involved an application of such ecosystem for mosquito control. Three samples of Micronectidae (30,50,100) each were prepared in 100 mL of rain water in universal bottles .Each population was given 50 mosquito larvae during the first day of the experiment. There were no mosquito larvae found in the habitat. Results from the experiment on the predatory pattern of Micronectidae showed that they can consume both larvae and pupae. the 30-Micronectidae consume 28 mosquito larvae (56% of the larvae). Results showed that 50-Micronectidae predated 37 (74%) within 24-hand 100-Micronectidae consumed 45 out of 50-mosquito larvae (90%). The findings of this research suggest that mosquito breeding in engineering structures such as drains can be controlled by using Micronecta polhemus Nieser, a water insect that predate on mosquito larvae.This insect required clean water that is exposed to direct sunlight [8].

The predatory efficiency of nymphs of six coexisting odonate species i.e., Ischnura. elegans, Trithemis. aurora, Pantala. flavescens, Libellula. fulva, Sympetrum. decoloratum and Crocothemis. servilia was studied by using the 3rd instar larvae of Cx. quinquefasciatus as prey. Several puddles on the bank of River swat near the campus of University of Malakand, were visited during April and May 2017 and September 2017. Three odonate species (one nymph of each Species) i.e., Ischnura elegans, Trithemis aurora and Pantala flavescens, were placed separately to each container 80 3rd instar larvae were added. dragonfly nymphs of L. fulva, S. decoloratum and C. servilia on 3rd instar larvae of Culex quinquefasciatus were compared. These three dragonfly nymphs were placed separately into each container 50 3rd instar larvae were added. Feeding rate of odonate nymphs during light and dark phases in April, 2017 During April 2017, the feeding rates of Ischnura elegans, Trithemis aurora and Pantala flavescens on 3rd instar larvae of Cx. quinquefasciatus were studied during the light (day time) and dark (night time) phases. Durations of light phase (5:00 to19:00 h) and dark phase (19:00 to 5:00 h) .Eighty 3rd instar larvae of Cx. quinquefasciatus were added. Feeding rate of odonate nymphs during light and dark phases in September, 2017 During September 2017 Libellula sympetrum and C. servilia Fifty 3rd instar larvae of Cx. quinquefasciatus were added light phase (6:00 h to 18:09 h) and dark phase (18:09 to 6:00 h). The highest number of mosquito larvae was ingested by the P. flavescens nymph. The feeding rate of nymphs of most odonate species was significantly higher during the daytime as compared to night-time. Feeding rate of nymphs of each odonate species was positively correlated with increase in predator and prey density but was negatively correlated with increase in water volume. From the findings it was concluded that P. flavescens species is more efficient predator of Cx. quinquefasciatus 3rd instar larvae and is highly resistant to increasing water level of NH4+ and NO3 [9].

In course of the survey on the dengue vectors in Kolkata and adjoining areas, India were checked.The prey preference of Toxorhynchites splendens was evaluated using the larval stages of the mosquitoes Culex quinquefasciatus, Aedes aegypti and chironomid larvae to substantiate the predatory efficacy and thus use in the biological control of mosquitoes. The larval stages of T. splendens consumed mosquito significantly more than the chironomid larvae, irrespective of combinations.Although, overall consumption of the prey is reduced due to the presence of chironomid, the results suggest that mosquito larvae may be preferred over chironomid larvae in situations where both the prey are available [10].

The predatory potential of B. geminata and C. coromandelianum larvae on Aedes aegypti larvae was investigated under laboratory condition. The feeding rate of 8th instar B. geminata on Ae. aegypti showed maximum predation on 1st instar larvae (86%), followed by 2nd, 3rd and 4th instars (72%, 66% and 48%). In 12th instar B. geminate larvae maximum predation was observed for the 1st and 2nd instar larvae (98%) of Ae. aegypti, followed by 3rd and 4th instars (92% and 78%). The feeding rate of 12th instar C. coromandelianum larvae on Ae. aegypti larvae showed that the maximum predation was of the 1st instar larvae (82%), followed by 2nd, 3rd and 4th instars (51%, 35% and 24%). The predation of Aedes larvae by the 2 spp. of odonate larvae (ANOVA) No significant difference was found between them for 1st instar larvae of Ae. aegypti. A single anisopteran larva is sufficient [11].

In a study they evaluated the influence of the predator, Anisops sardea on mosquito Culex pipiens molestus population. Anisops sardea H.S. (Hemiptera: Notonectidae) is a smaller bodied backswimmer, very common in temporary pools and permanent water bodies native in Asia and Africa. Nonectid A. sardea will effectively control C. pipiens molestus by predation and besides decrease number of generations through immature stages extension. showed that, the daily predation of the backswimmer Anisops sardea was affected by the mosquito prey density in case constant water volume, the average of consumed larvae at the 50 larvae/ predator density was 18.1 larvae, but if the density 100 larvae, the predation increased to 27.1 larvae consumed every day [12].

Conclusion

Several factors should be considered for the success of biological control programs for mosquitoes including: preference or selectivity of the prey, species diversity in mosquito breeding sites, stability of the aquatic system, larval density, position of the predator in the water column, appropriate number of predators, recovery of the larval population, predator-prey synchronization, and refuge.

Acknowledgment

This research is supported by Ministry of Health and Medical Education, Iran.

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