SURVEY OF MOSQUITO PREDATORS IN DHAKA DISTRICT AND AN ASSESSMENT OF THEIR PREDATORIAL CAPACITY AGAINST MOSQUITO (*Culex sp.)*

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CERTIFICATE

This is to certify that the thesis entitled '**SURVEY OF MOSQUITO PREDATORS IN DHAKA DISTRICT AND AN ASSESSMENT OF THEIR PREDATORIAL CAPACITY AGAINST MOSQUITO *(Culex sp.)*'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of *bonafide* research work carried out by **MD. Al Mamun Hossain, Registration number: 12-04859** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated: June, 2020
Dhaka, Bangladesh

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Dedicated

To

My Beloved Parents

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ABSTRACT

Two experiments were conducted on the survey of mosquito predators in Dhaka districts and an assessment of their predatorial capacity against immatures of mosquito/*Culex annulirostris* during the period of October, 2018 to February, 2019. For survey water logged area in Dhaka city and selected water logging areas of Dhaka district (different upazila nearby Dhaka city and selected different location or point in Dhaka city) in Bangladesh were selected to find out the inspection of mosquito's predators. As a result, the order of survey of mosquito predators found in terms of plenty of the different locations were different upazila nearby Dhaka city > selected different point in Dhaka city. Lab experiments were laid out in a Completely Randomized Design (CRD) with five replications. Firstly three aquatics predators such as Giant water bug, *Belostomata indica*; Diplonychus bug, *Diplonychus* sp and W*ater* striders, *Aquarius adelaides* were used to determine the mosquito consumption capacity for assessment of their predatorial capacity against mosquito *(C. annulirostris).* Secondly, the experiment consists of six treatments to determine the immature mortality of mosquito for assessment of predatorial capacity of mosquito predators . Six treatments, viz. T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High Density (40 Larvae); T_3= Water Boatman Adult + Low Density (20 Larvae); T_4= Water Boatman Adult + High Density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae) were used. In considering percentage of mosquito consumption by aquatic predators in different hours on the multifarious developing stages of mosquito, larval consumption rate and predatorial capacity was the highest in Giant water bug, *Belostomata indica* , whereas the lowest in Water striders, *A. adelaides. But* the highest percentage of mosquito pupae consumption capacity was in Diplonychus bug, *Diplonychus* sp, the lowest percentage of mosquito consumption capacity in Giant water bug, *B. indica* and no mosquito consumption capacity (0.0%) recorded in aquatic predator W*ater* striders, *A. adelaides.* In considering the predatory potentiality, the highest percentage of mortality after different days, in case of 1^{st}, 2^{nd}, 3^{rd}, 4^{th} instar larvae and pupae of mosquito were observed from T_3 treatment, whereas the lowest percentage of mortality were recorded in T_5 treatment, but in case of 4^{th} instar larvae and pupae of mosquito the lowest percentage of mortality were recorded in T_6 treatment. The percentage mortality rate decreased with the increase of prey size. But, the predatory capacity of adult was observed higher than the nymph.

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LISTS OF ABBREVIATIONS	
Full word	Abbreviation
and others	*Et al.*
Co-efficient of Variation	CV
Completely Randomized Design	CRD
Gram	g
Id est	i.e.,
Journal	*j*.
Least significant difference	LSD
Videlicet	Viz.,

CHAPTER I

INTRODUCTION

Mosquitoes are serious biting pests and obligate vectors of many vertebrate pathogens. In particular, mosquitoes (Diptera: Culicidae) represent a key threat for millions of people worldwide, since they act as vectors for devastating pathogens and parasites, including malaria, yellow fever, West Nile, chikungunya, Japanese encephalitis, dengue, dengue haemorrhagic fever and filariasis. Among various types of mosquito-borne diseases, filariasis, malaria and dengue fever are most common, bring serious threat to modern civilization due to mortality, morbidity and economic loss. Mosquitoes immature larval and pupal life stages are a common feature in most tropical and many temperate water bodies and often form a significant proportion of the biomass. A variety of aquatic insects in the orders Odonata, Hemiptera, Coleoptera, and Diptera are known to prey upon mosquito larvae. One major part of understanding influences on mosquito production is to look at the influence of mosquito predators. Predators can strongly influence on populations of mosquitoes both by disturbing their development rate and also by consuming mosquito larvae and adults.

Generalist predators that feed on a broad range of prey species are polyphagous, while specialist predators with a restricted range of prey can be oligophagous or monophagous with a limited range or single species of prey. Although most predators of mosquitoes tend to be generalists (Collins and Washino 1985), there are exceptions. The ability to regulate mosquito population through consumption is a basis for considering predatory insects as biocontrol agent against mosquitoes, as evident from mosquito consumption by water bugs (Aditya *et al.* 2004), dytiscid beetles (Lundkvist *et al*. 2003), and odonate larvae (Saha *et al*. 2012) of rice fields and allied wetlands. While use of predatory insects favours sustenance of ecosystem functions and biological integrity of the community, prey selectivity (Saha *et al*. 2009) and indirect interactions (Blaustein *et al*. 2007) are important determinants of the efficacy of the mosquito regulation. Washino (1969) found that corixids fed less upon mosquito larvae than any other hemipteran predators (*Corisella sp*, *Belostoma flumineum*, and the giant water bug, *Abedus indentatus*) when tested experimentally. On the other hand, *Notonecta undulata* was found to prefer mosquito larvae over other prey like corixids, ephemedrids, chironomids, and chaoborids when given a choice, indicating a degree of predatory specialization. Although predation may occur during any prey life stage, research has focused on the immature larval and pupal stages. Egg predation appears to be a minor component of mosquito mortality and predation on the adult stage is unlikely to provide reliable levels of control (Collins and Washino 1985). Few predators, particularly *Toxorhynchites* larvae, kill mosquito pupae without ingesting them afterwards. This killing activity is fortunate in the context of control, because pupal production is most highly correlated with subsequent adult densities. Laboratory research into aquatic insect predation is fairly common and studies of aquatic bugs have shown that they are quite effective predators of mosquito larvae. For instance, *Microvelia pulchella* (Hemiptera: Vellidae) is able to derive nutrients from mosquito larvae to survive, grow, and reproduce. The predation potential of the water bug *Diplonychus indicus* (Hemiptera: Belostomatidae) against larval instars of two different mosquito prey species, *Aedes aegypti* and *Cx. fatigans*, at varying densities. The largest predator (5th instar) was more effective than smaller instars at killing the smallest prey (1st instar). This was due to larger predator instars exhibiting more successful attacks and a shorter handling time than smaller predator instars. Similarly, the backswimmer *Notonecta huffmani* was fed on mosquito larvae under laboratory conditions, its appetite decreased with increasing prey size. The same behavior was observed in the notonectid bug *Enithares indica*. The feeding rates of *E. indica* on the immature stages of *Anopheles stephensi* and *Cx. quinquefasciatus* decreased with increasing mosquito larval stage. Maximum predation was observed on 1^{st} instar larvae while minimum predation was observed for the pupal stage. The factors that limit the colonization of cities by some rural malaria vectors may also present an obstacle to colonization of cities by mosquito predators. In rural areas, there is a tremendous diversity of predators that prey on the aquatic mosquito larvae, reducing mosquito survivorship. Little is known about the ecology of urban mosquitoes or the aquatic predators that help regulate larval population levels in urban areas of Africa. Mosquito larvae have been found in a variety of aquatic urban environments, including wells and other sources of drinking water, stagnant drainage systems, and other depressions resulting from human activities (Robert *et al*. 1998). Documented insecticide resistance in mosquito species raises the concern that pesticide use leads to the selective removal of mosquito predators from mosquito larval habitats, causing an increase in potential vector populations (Roberts and Andre 1994). Some fish species have been studied as potential bio-control agents of larval and pupal mosquitoes. Even though it is possible to find many studies on larvivorous mosquito species (Hurst *et al*. 2004) to our knowledge there are no reports from Argentina. The mosquito fish *Gambusia affinis* (Baird and Girard) has been the most studied fish species for use as a biological control agent worldwide, but the World

Mosquitoes breed in varied habitats such as ponds, marshes, ditches, pools, drains, water containers and other similar water collections (Rozendaal 1997). Different genera have shown specific breeding preferences. *Anopheles sp* are associated with fresh water habitats whereas *Culex sp* and *Mansonia sp* may also be found in polluted conditions, including septic tanks and *Aedes* breeds in domestic, peri-domestic and other small water collection including desert coolers (Parthiban and David 2007). Frogs introduced into segregated mosquito larval breeding habitats such as ponds, puddles, tanks, etc., may prey on larvae and subsequently reduce vector population and vector borne disease burden.

The aforementioned studies investigated the predation potential of some hemipteran predators and their prey preference against immature stages of different mosquito species. Hence the present work located in Dhaka district and surrounding water logging area, advanced this research by investigating the predatorial capacity of *Corixa sp* and *Gerris sp* using *Cx. annulirostris* (Skuse) as prey. It also addressed how two factors, the size of foraging area and the presence of vegetation, might affect predatorial capacity. This research work which will help to formulate appropriate future plan for developing suitable eco-friendly management approach without chemical for controlling mosquitoes in urban area. However, the proper management only using bio-control agent is a burning issue in respect of socio economic and environmental aspect.

Objective:

In view of the above facts, the main focus of this paper is lying in the following specific objectives:

- To study predominance of the predators of different insect species on mosquito in the selected area of Dhaka district
- To study and determine predatorial capacity of water boatman (*Corixa sp.*) and water striders (*Gerris sp.)* against *Culex annulirostris* mosquito immatures
- To highlight the establishment of an environmentally safe control measure of mosquitoes which help reduce the use of chemical pesticide

CHAPTER II

REVIEW OF LITERATURE

Health Organization (1982) discourages the introduction of exotic species because of the potential for negative ecological consequences (CDC 1973). In New Zealand, the common mosquito predators seen in natural and anthropogenic water bodies are the notonectid backswimmer *Anisops* spp. (Hemiptera), diving beetles in the genus *Rhantus* (Coleoptera), and damselfly larvae (Odonata) (Graham 1939). Few genera of mosquitoes are major vectors of human diseases such as malaria, filariasis and viral diseases like Japanese encephalitis, dengue, dengue haemorrhagic fever, yellow fever, chikungunya, etc.

Carlson *et al.* (2004) observed that urban malaria cases are becoming common in Africa as more people move into cities and industrialization proceeds. While many species of *Anopheles* mosquitoes vector malaria in rural areas, only a few are found within cities. The success of anthropophilic species in cities, such as members of the *An. gambiae* complex, may be explained by limitations on colonization by predator species in urban environments. Habitats that are temporal or structurally simple have lower predator survivorship in a variety of ecosystems, but these have not been investigated previously in an urban area. Areas within and around the Kenyan coastal town of Malindi were previously sampled for the presence of standing water using a geographic sampling strategy with probability proportional to size sampling of planned well-drained, unplanned poorly-drained, unplanned poorly-drained, planned poorly-drained, unplanned well-drained, and peri-urban locations. Standing aquatic habitats in these areas were reassessed. During monthly sampling, presence/absence of mosquitoes and predator taxa were noted, as were ecological habitat variables: structural complexity and presence of water. Lambda statistics were calculated to associate predator guilds, habitat types, location variables, and ecological variables. All predator guilds found in habitats were strongly associated with habitat type, as were the structural complexity and temporal nature of the habitats. Types of habitat were heterogeneously distributed throughout Malindi, with swimming pools as a common habitat type in planned urban areas and tire track pools a common habitat type in periurban areas of Malindi. Predator colonization of aquatic habitats in Malindi was strongly influenced by habitat type, and not associated with location characteristics. Ecological variables were affected by the type of habitats, which are co-associated with planning and drainage in Malindi. While habitat types are distributed heterogeneously within Malindi, habitats with low predation pressure are available for mosquito colonization in both urban and peri-urban areas. The temporal, peri-urban tire track pools and the structural simplicity of urban swimming pools may discourage predator colonization, thereby increasing the probability of malaria vectors in these areas of Malindi. Future studies should evaluate habitats for use in malaria surveillance and experimentally test the effects of structural complexity and temporal nature of urban habitats on the densities of mosquito larvae and their aquatic predators.

Shaalan *et al.* (2007) showed that a twelve-month survey for mosquito predators was conducted in Townsville, Queensl and, Australia, which is located in the arid tropics. The survey revealed the presence of five predaceous insects but only *Anisops sp* (backswimmers) and *Diplonychus sp* were common. Predatorial capacity and factors influencing this capacity were then assessed for adult *Anisops sp* and adult and nymph stages of *Diplonychus sp* against *Culex annulirostris* mosquito immatures under laboratory conditions. Predatorial capacity bioassays showed that adult *Diplonychus sp* preyed upon both larval and pupal stages of *Cx. Annulirostris* quite successfully.Nymphsof *Diplonychus* sp. proved to be more successful with smaller prey immatures, and *Anisops* sp adults did not prey successfully on any prey pupae.Increasing the foraging area and introducing aquatic vegetation significantly reduced the predatorial capacity of *Diplonychus sp* nymphs, while only vegetation and not foraging area had a significant effect on adult *Diplonychus* sp Predation capacity. Overall, adult *Diplonychus sp* proved to be a more efficient predator than *Anisops sp*., and field trials are now recommended to further assess the potential of *Diplonychus sp* as a bio-control agent.

Marti *et al.* (2006) found that two neotropical fresh water fish species, *Cnesterodom decemmaculatus* (Poeciliidae) and *Jenynsia multidentata* (Anablepidae), were collected from human-made ditches, a common habitat of the house mosquito *Culex pipiens* in La Plata, Argentina. *Cnesterodom decemmaculatus* was recorded in 62 of the 100 examined ditches, whereas *J. multidentata* was collected from only 21 ditches sympatrically with *C. decemmaculatus. Culex pipiens* was the only mosquito species collected, and its larvae and pupae were found in 38 of the 100 ditches. Fish and mosquito larvae and pupae were collected together in only two ditches and were significantly negatively correlated. Siphons of larval *Culex* and remnants of chironomid larvae, copepods, aquatic mites, and fish were present in the gut contents of two *C. decemmaculatus* from mosquito-positive ditches, while diatoms and filamentous algae were recorded in every fish dissected. Adult *C. decemmaculatus* and *J. multidentata* needed approximately 6.2 h to completely digest one *Cx. pipiens* 4th instar larva under laboratory conditions. When fish were confined with a density of 60 or fewer *Cx. pipiens* 4th instar larvae, *C. decemmaculatus* and *J. multidentata* adults consumed 100% of them in one day but only 35% and 42%, respectively, when confined with 150 larvae. Eradication of *Cx. pipiens* from a ditch, where densities had averaged 250 immatures per dip, was achieved 17 days after the introduction of 1,700 *C. decemmaculatus.*

Benelli *et al*. (2016) demonstrated that mosquitoes represent the major arthropod vectors of human disease worldwide transmitting malaria, lymphatic filariasis, and arboviruses such as dengue virus and Zika virus. Unfortunately, no treatment (in the form of vaccines or drugs) is available for most of these diseases and vector control is still the main form of prevention. The limitations of traditional insecticide-based strategies, particularly the development of insecticide resistance, have resulted in significant efforts to develop alternative eco-friendly methods. Bio-control strategies aim to be sustainable and target a range of different mosquito species to reduce the current reliance on insecticide-based mosquito control. In this review, we outline non-insecticide based strategies that have been implemented or are currently being tested. We also highlight the use of mosquito behavioral knowledge that can be exploited for control strategies.

Benelli (2015) observed that mosquitoes (Diptera: Culicidae) are a key threat for millions of people worldwide, since they act as vectors for devastating pathogens and parasites. In this scenario, vector control is crucial. Mosquito larvae are usually targeted using organophosphates, insect growth regulators, and microbial agents. Indoor residual spraying and insecticide-treated bed nets are also employed. However, these chemicals have negative effects on human health and the environment and induce resistance in a number of vectors. Newer and safer tools have been recently implemented to enhance control of mosquitoes. Here, I focus on some crucial challenges about eco-friendly control of mosquito vectors, mainly the improvement of behavior-based control strategies (sterile insect technique (BSIT) and Bboosted SIT) and plant-borne mosquitocidals, including green synthesized nano-particles. A number of hot areas that need further research and cooperation among parasitologists, entomologists, and behavioral ecologists are highlighted.

Chandraa *et al*. (2016) showed that laboratory bioassay was conducted to establish the bio-control potentiality of naiads (aquatic nymphal stage) of *Rhodothemis rufa* (Rambur, 1842) against larvae of *Culex quinquefasciatus*, a common vector of filariasis in Tropical countries. From the study, it was noticed that in laboratory condition, the rate of predation of males of *R. rufa* was higher than that of females of almost same size and same species. The results of the present study revealed that both sexes displayed a density-dependent decelerating type-II functional response as the logistic regression estimated a significant negative linear parameter (P1 value of ¡0.330 and ¡0.151 for males and females, respectively). Attack rate was almost similar for both sexes (0.082); however, handling time is less in males (0.62 min) than in females (0.852 min). The predators species usually coexist co-exist in the same aquatic habitat to that of mosquito larvae and can be effectively used in field condition to reduce the larval densities of mosquitoes in temporary or permanent aquatic water bodies.

Thullen *et al*.(2002) found that the impact of three vegetation management strategies on wet land treatment function and mosquito production was assessed in eight free water surface wet land test cells in southern California during 1998–1999. The effectiveness of the strategies to limit bulrush *Schoenoplectus californicus* culm density within the cells was also investigated. Removing accumulated emergent biomass and physically limiting the area in which vegetation could reestablish, significantly improved the ammonia–nitrogen removal efficiency of the wetland cells, which received an ammonia dominated municipal wastewater effluent (average loading rate=9.88 kg/ha per day NH4-N). We determined that interspersing open water with emergent vegetation is critical for maintaining the wetland's treatment capability, particularly for systems high in NH4-N. Burning aboveground plant parts and thinning rhizomes only temporarily curtailed vegetation proliferation in shallow zones, whereas creating hummocks surrounded by deeper water successfully restricted the emergent vegetation to the shallower hummock areas. Since the hummock configuration kept open water areas interspersed throughout the stands of emergent vegetation, the strategy was also effective in reducing mosquito production. Decreasing vegetation biomass reduced mosquito refuge areas while increasing mosquito predator habitat. Therefore, the combined goals of water quality improvement and mosquito management were achieved by managing the spatial pattern of emergent vegetation to mimic an early successional growth stage, i.e. actively growing plants interspersed with open water.

Ellis (2013) demonstrated that mosquito-borne diseases have become of great concern in the world today, as many are reemerging. This has prompted an interest in better understanding what factors drive or control mosquito populations. One promising bio-control agent of mosquitoes is through the use of mosquito predators as a way of controlling the population. A predator of mosquitoes that has not been researched fully is the dragonfly. The following research examined the influence of dragonfly larvae on several different aspects of a mosquito's lifecycle. This study was done in two parts, first by performing biweekly field surveys of semi-permanent, intermittent, and ephemeral pools. Secondly, experimental mesocosms were done with mosquito larvae both with and without dragonfly larvae present. Mesocosm experiments were done to test the survival, development rate, and reproductive behavior of mosquito larvae (*Aedes* and *Culex*) in the presence of dragonfly larvae (Tetragoneuria). Dragonfly larvae were only found to be present in the semi-permanent and intermittent ponds. It was also found that the semi-permanent and intermittent ponds had significantly lower adult mosquito emergence. The results of mesocosm experiments identified dragonfly larvae being able to eat large numbers of mosquito larvae in very short periods of time, but dragonfly larvae did not seem to have a significant effect on the development rate of mosquitoes. Ovipositing behavior of mosquitoes did not seem to be affected by the presence of dragonfly larvae. These results suggest that dragonfly larvae could play a role in the regulation of mosquito populations.

Zuharah and Lester (2010) observed that the occurrence and abundance of mosquito populations may be associated with the abundance of predators. We examined the relationship between aquatic predators and populations of mosquitoes in animal water troughs in Waikanae, New Zealand. We also investigated the effects of water volume and environmental factors (temperature, rainfall, wind speed, humidity, and pressure) in order to further understand factors influencing mosquito and predator populations. Logistic regression indicated that the presence or absence of mosquitoes was primarily affected by three factors: predator abundance, week of observation, and water volume. Pearson's correlation indicated that the presence of predators had a positive correlation with water volume ($r2= 0.176$, $p< 0.05$). Otherwise, the presence of mosquito larvae in water troughs was negatively correlated with water volume ($r2=-0.159$, $p=0.022$) and wind speed ($r2=0.142$, $p=0.041$). We established a translocation experiment in which predators or mosquitoes were moved between troughs in order to examine the prey survival rate after exposure to *Anisops wakefieldi* predators. The survival rate of mosquitoes was not significantly different, between 0-0.1%, irrespective of the number of predators translocated (1-9) or the initial mosquito density (20-70 larvae). Our results suggested that *A. wakefieldi* predators may have the potential to be a promising biological control tool for the control of mosquito populations by altering mosquito population dynamics.

Lacey (1994) showed that since the discovery of *Bacillus thuringiensis* (Berliner) *serovariety israelensis de Barjac* (Bti) and efficacious isolates of *Bacillus sphaericus* Neide, formulations of these bacteria have become the predominant non-chemical means employed for control of mosquito larvae at several locations in the United States and other countries. An overview of developments in the past 20 years is presented in this chapter regarding the toxins of Bti and *B. sphaericus*, their modes of action, efficacy and factors that affect larvicidal activity, development of resistance, safety, and their roles in integrated mosquito control. The efficacy of Bti formulations has been demonstrated in a variety of habitats against a multitude of species of mosquitoes. *B. sphaericus* formulations have been utilized predominantly in organically enriched habitats against *Culex* species, but they are also active in a variety of habitats having low organic enrichment, against numerous species, and across several genera. *Stegomyia spp* are not susceptible to practical doses of *B. sphaericus* formulations. *B. sphaericus* has been shown to persist longer than Bti in polluted habitats and, under certain circumstances, can recycle in larval cadavers. A disadvantage of *B. sphaericus* has been the development of resistance in certain populations of *Cx. quinquefasciatus* Say and *Cx. pipiens* Linnaeus. Biotic and abiotic factors that influence the larvicidal activity of Bti and *B. sphaericus* include species of mosquito and their respective feeding strategies, rate of ingestion, age and density of larvae, habitat factors (temperature, solar radiation, depth of water, turbidity, tannin and organic content, presence of vegetation, etc.), formulation factors (type of formulation, toxin content, how effectively the material reaches the target, and settling rate), storage conditions, production factors, means of application and frequency of treatments. Due to their efficacy and relative specificity, both Bti and *B. sphaericus* can be ideal control agents in integrated programs especially where other biological control agents, environmental management, personal protection and the judicious use of insecticides are combined.

Aditya *et al*. (2006) demonstrated that predation potential of the dytiscid beetle, *Rhantus sikkimensis* Regimbart 1899 and the larvae of *Toxorhynchites splendens* Wiedemann 1819 occurring along with the larval stages of the mosquitoes in the annual lentic water bodies of Darjeeling was evaluated using the larvae of *Culex quinquefasciatus* Say 1823 as preys, in the laboratory under simulated natural conditions. Field collected *R. sikkimensis* and larvae of *Tx.*

splendens were offered IV instar larvae of *Cx. quinquefasciatus* to observe the rate of predation, at varying prey and predator densities. Based on the data obtained on the predation for a period of three consecutive days, two indices of predation, predatory impact (PI) and clearance rate (CR) values were estimated, and compared between the predator species.The rate of predation of IV instar *Cx. quinquefasciatus* larvae by *R. sikkimensis* ranged between 21.56 and 86.89 larvae per day, depending on the prey and predator densities. The PI value remained between 18.67 and 35.33 larvae/day depending on prey densities, while the CR ranged between 2.21 and 2.23 larvae litres/day/predator. Compared to these, the *Tx. splendens* larvae consumed the prey larvae at the rate of 0.67 to 34.22 larvae per day, depending on the prey and predator densities. The PI value ranged between 7.67 and 11.33 larvae/day, and the CR value ranged between 1.41 and 1.76 larvae litres/day/predator. The rate of predation, CR values and PI values of *R. sikkimensis* and *Tx. splendens* varied significantly. Both the predators *R. sikkimensis* and larvae of *Tx. splendens* can consume a good number of mosquito larvae, though the rate of consumption between the two predators vary owing to the difference in the life history traits and features. It can be assumed that these predators play an important role in larval population regulation of mosquitoes and thereby impart an effect on species composition and interactions in the aquatic insect communities of Darjeeling Hills, India.

Raghavendra *et al*. (2008) observed that the use of frogs and tadpoles for disease vector control is still largely unexplored. Frogs are an important part of the ecosystem with a role for insect and pest control including mosquitoes. Available information suggests the existence of many direct and indirect factors affecting the growth and survival of both prey and predators. Other controphic species that have influence on this relationship also show considerable effect. Still, the associations of different prey and predator relationships in the environment to assess the feasibility of use of a species as bio-control agent for vector control and management. However, frogs cannot be used as an independent intervention for disease vector control and more research is needed to use them effectively for mosquito control.

Shaalan and Canyon (2009) showed that mosquitoes are serious biting pests and obligate vectors of many vertebrate pathogens. Their immature larval and pupal life stages are a common feature in most tropical and many temperate water bodies and often form a significant proportion of the biomass. Control strategies rely primarily on the use of larvicides and environmental modification to reduce recruitment and adulticides during periods of disease transmission.

Larvicides are usually chemical but can involve biological toxins, agents or organisms. The use of insect predators in mosquito control has been exploited in a limited fashion and there is much room for further investigation and implementation. Insects that are recognized as having predatorial capacity with regard to mosquito prey have been identified in the Orders Odonata, Coleoptera, Diptera (primarily aquatic predators), and Hemiptera (primarily surface predators). Although their cpacity is affected by certain biological and physical factors, they could play a major role in mosquito control. Furthermore, better understanding for the mosquitoes-predators relationship(s) could probably lead to satisfactory reduction of mosquito-borne diseases by utilizing either these predators in control programs, for instance biological and/or integrated control, or their kairomones as mosquitoes' ovipoisting repellents. This review covers the predation of different insect species on mosquito larvae, predator prey-habitat relationships, co-habitation developmental issues, survival and abundance, oviposition avoidance, predatorial capacity and integrated vector control.

Couret *et al*. (2020) found that Biological controls with predators of larval mosquito vectors have historically focused almost exclusively on insectivorous animals, with few studies examining predatory plants as potential larvacidal agents. In this study, we experimentally evaluate a generalist plant predator of North America, *Utricularia macrorhiza*, the common bladderwort, and evaluate its larvacidal efficiency for the mosquito vectors *Aedes aegypti* and *Aedes albopictus* in nochoice, laboratory experiments. We sought to determine first, whether *U. macrorhiza* is a competent predator of container breeding mosquitoes, and secondly, its predation efficiency for early and late instar larvae of each mosquito species. Newly hatched, first instar *Ae. albopictus* and *Ae. aegypti* larvae were separately exposed in cohorts of 10 to field collected *U. macrorhiza* cuttings. Data on development time and larval survival were collected on a daily basis to ascertain the effectiveness of *U. macrorhiza* as a larval predator. Survival models were used to assess differences in larval survival between cohorts that were exposed to *U. macrorhiza* and those that were not. A permutation analysis was used to investigate whether storing *U. macrorhiza* in laboratory conditions for extended periods of time (1 month vs 6 months) affected its predation efficiency. Our results indicated a 100% and 95% reduction of survival of *Ae. aegypti* and *Ae. albopictus* larvae, respectively, in the presence of *U. macrorhiza* relative to controls within five days, with peak larvacidal efficiency in plant cuttings from ponds collected in August. *Utricularia macrorhiza* cuttings, which were prey deprived, and maintained in laboratory conditions for 6 months were more effective larval predators than cuttings, which were maintained prey free for 1 month. Due to the combination of high predation efficiency and the unique biological feature of facultative predation, we suggest that *U. macrorhiza* warrants further development as a method for larval mosquito control.

Huang *et al*. (2017) demonstrated that historically, biological control utilizes predatory species and pathogenic microorganisms to reduce the population of mosquitoes as disease vectors. This is particularly important for the control of mosquito-borne arboviruses, which normally do not have specific antiviral therapies available. Although development of resistance is likely, the advantages of biological control are that the resources used are typically biodegradable and ecologically friendly. Over the past decade, the advancement of molecular biology has enabled optimization by the manipulation of genetic materials associated with biological control agents. Two significant advancements are the discovery of cytoplasmic incompatibility induced by *Wolbachia bacteria*, which has enhanced replacement programs, and the introduction of dominant lethal genes in to local mosquito populations through the release of genetically modified mosquitoes. As various arboviruses continue to be significant public health threats, biological control strategies have evolved to be more diverse and become critical tools to reduce the disease burden of arboviruses.

Blaustein *et al.* (1995) observed that 1. We assessed experimentally the effects of the predatory backswimmer, *Notonecta maculata*, on naturally colonizing mosquito populations in artificial outdoor pools in the Negev Desert, Israel. A single Notonecta adult per pool (8-15 litres water) had a very large negative impact on populations of *Culiseta longiareolata*, the most common species found in natural local pools. *Notonecta* caused large reductions of Culisetaegg rafts and early-instar larvae (instarsI and II) and virtually 100%reductions of late-instar *Culiseta* larvae (instars III and IV) and pupae. 2. Notonecta also caused a trophic cascade in the experimental pools; by preying on periphyton-feeding *Culiseta* larvae, *Notonecta* indirectly caused significantly higher densities of diatoms, the major component of the periphyton. 3. Surveys of nearby natural pools taken between March and May supported the experimental results: a strongnegative associationbetween*Notonecta* and *Culisetaamong* pools occurred as *Notonecta* increased in numbers and became more widely distributed. *Anopheles* (occurring only in May) and *Culexmosquito* immatures were not negatively associated with *Notonecta*. *Culiseta* was not associated with surface vegetation whereas both *Culex* and *Anopheles* showed strong positive associations with surface vegetation both among and with in pools. We attribute the negative association between the predator and *Culiseta* to local prey extinctions caused by *Notonecta* in individual pools.*Culiseta*, being an open water species, is apparently more prone to predation by *Notonecta* than the vegetation-dwelling *Culex* and *Anopheles*.

Aditya *et al*. (2007) showed that the rate of predation by stage IV instar *Toxorhynchites splendens* larvae on the equivalent instar stage larvae of *Culex quinquefasciatus* and *Armigeres subalbatus*, co-occurring in sewage drains, were noted for a period of three consecutive days in the laboratory using different prey densities and combinations. The rate of predation varied by age of the predator, density of prey, and prey type. The number of *Ar. subalbatus* larvae consumed by a single *Tx. splendens* larva ranged between 0.50 – 0.71 and 16.40 – 2.01; while for *Cx. quinquefasciatus* larvae, the number consumed ranged from 0.20 – 0.42 to 20.40 – 1.43 per day. The pupation rates of the prey species varied in respect to control, with a minimum of 0.20 – 0.42 pupa/day to a maximum of 12.20 – 2.30 pupa/day in the presence of *Tx. splendens*. The values for the controls were 1.00 – 0.87 and 14.44 – 2.83 pupa/day, respectively. Irrespective of prey densities and combinations, a single *Tx. splendens* fourth instar larvae was found to consume on average 10.07 larvae on the first day 16.57 larvae on the second day and 4.38 larvae on the third day, killing a total of 17.70 to 45.10 larvae, in three days. In the presence of *Tx. splendens*, the cumulative pupation, irrespective of prey, remained between 12.20 and 45.10, and differed significantly from control where the values were between 13.90 and 54.70. The results indicate that *Tx. splendens* can significantly reduce immature numbers and lower the rate of pupation of *Cx. quinquefasciatus* and *Ar. subalbatus. Tx. splendens* may be a potential biological resource in the control of mosquitoes inhabiting sewage drains.

Blaustein and Jonathan (2007) found that ecological theory predicts, and empirical research shows, that species sharing the same trophic level as a target species (hereafter controphic species) can have large direct and indirect effects on the target species by sharing resources and/or by serving as alternative prey to predators. Yet, the roles of controphic species of mosquito larvae in affecting mosquito populations have received little attention. Published empirical evidence, although scarce, suggests that controphic species such as zooplankton and anuran larvae compete with mosquito larvae, can positively affect mosquito larvae by consuming bacteria that are pathogenic to mosquito larvae, reduce predation on mosquito larvae by serving as alternative prey, and ultimately cause increased predation on mosquito larvae by causing a numerical response in the predator. We conclude that more extensive theoretical and empirical studies in elucidating the roles of controphic species will better allow us to predict mosquito population dynamics and allow for better management of mosquitoes.

Kumar and Hwang (2006) demonstrated that biological control of mosquito larvae with predators and other bio-control agents would be a more-effective and eco-friendly approach, avoiding the use of synthetic chemicals and concomitant damage to the environment. Manipulating or introducing an auto-reproducing predator into the ecosystem may provide sustained biological control of pest populations. The selection of a biological control agent should be based on its self-replicating capacity, preference for the target pest population in the presence of alternate natural prey, adaptability to the introduced environment, and overall interaction with indigenous organisms. In order to achieve an acceptable range of control, a sound knowledge of various attributes of interactions between a pest population and the predator to be introduced is desirable. Herein, we qualitatively review a wide range of literature sources discussing the ability of different aquatic predators to control mosquito larval populations in environments where mosquitoes naturally breed. Different predators of mosquito larvae include amphibian tadpoles, fish, dragonfly larvae, aquatic bugs, mites, malacostracans, anostracans, cyclopoid copepods, and helminths. The most widely used bio-control agents of mosquito populations are the western mosquito fish, *Gambusia affinis*, and the eastern mosquito fish, *G. holbrooki*. The effect of these fishes on native faunal composition and their inability to survive in small containers, tree holes etc., which are ideal breeding sites of vectorially important mosquitoes, make them inefficient in controlling mosquito populations. On the basis of larvicidal efficiency, the ability to produce dormant eggs, the hatchability of dormant eggs after rehydration, faster developmental rates, and higher fecundity, various tadpole shrimp can be considered to be ideal control agents in temporary water bodies and rice paddy fields. Among various predators of mosquito larvae, the cyclopoid copepods are efficient, found naturally, are safe for human beings, and are also economical in their application. The mosquito larval selectivity patterns of many cyclopoids, their adaptability to variable aquatic environments which are ideal breeding sites for mosquitoes, their resistance to starvation, and their day-night prey detection ability using hydro-mechanical signals make them an ideal bio-control agent. Therefore, there is a need to test the feasibility of cyclopoid copepods by putting them into operational use as eco-compatible means of bio-control.

Juliano (2009) observed that biotic interactions involving mosquito larvae are context dependent, with effects of interactions on populations altered by ecological conditions. Relative impacts of competition and predation change across a gradient of habitat size and permanence. Asymmetrical competition is common and ecological context changes competitive advantage, potentially facilitating landscape-level coexistence of competitors. Predator effects on mosquito populations sometimes depend on habitat structure and on emergent effects of multiple predators, particularly interference among predators. Nonlethal effects of predators on mosquito oviposition, foraging, and life history are common, and their consequences for populations and for mosquito-borne disease are poorly understood. Context dependent beneficial effects of detritus shredders on mosquitoes occur in container habitats, but these interactions appear to involve more than simple resource modification by shredders. Investigations of context-dependent interactions among mosquito larvae will yield greater understanding of mosquito population dynamics and provide useful model systems for testing theories of context dependence in communities.

Hearnden and Kay (1997) showed that from November 1990 to November 1992, immature mosquitoes were sampled from the shoreline and from emergent beds of submerged aquatic plant *Hydrilla*, *Verticillalata* at the Ross River reservoir, northern Australia. Aerial mapping of Hydrilla bed was done in conjunction with sampling to estimate total immature mosquito numbers. Larvae of 7 species were found. *Culex ainulirostris, Anophles annulipes*s., l and *Anopheles amicus* comprised 80.4% of the total. Peak larval densities occurred in the iatet wet season period in both habitat types (March to May) but Hydrilla generally supported higher densities, particularly of *Anopheles annulipes* s.l. (43.7% of the total sample), than the shoreline habitat. *Anopheles annulipes* replaced *Culex annulirostis* as the predominant taxon when l99O-92 data were compared with data for 1985-86. The Hydriua beds supported on theorder of 5.6 x l0e immatures during the period of peak density. This suggests that where human eiposure is of concern, mosquito control in habitats such as Hydrilla is warranted.

Bhattacharya and Basu (2016) found that *Culex quinquefasciatus* is the principal vector of *bancroftian filariasis* and a potential vector of *Dirofilaria immitis*. This mosquito species is also a potential vector of several arboviruses like West Nile virus (WNV), Rift Valley fever virus, avian pox and protozoa like Plasmodium relictum that causes bird malaria. This species has the ability to transmit other nematodes like *Saurofilaria sp*., *Oswaldofilaria sp*. In the USA, it is a potential vector of St. Louis encephalitis virus (SLEV). Japanese encephalitis virus (JEV) has been isolated from this mosquito in several occasions in Asia. Furthermore, it can transmit several other arboviruses in the laboratory conditions. This article is an attempt to review the bio-ecology, medical and veterinary importance of *Culex quinquefasciatus*. It acts as an important "urban bridge vector" which bridges different reservoir/amplifier hosts to humans because of its encounter with different vertebrates. *Culex quinquefasciatus* also creates an ecological bridge between urban, periurban and rural areas owing to its presence and adaptability in diverse ecological niches. *Culex quinquefasciatus* emerged as a smart vector because of the adaptive fitness, ecological plasticity, invasive behaviour, host specificity and high reproductive potential along with expanded immune gene repertoire property at the genetic level. This mosquito possesses the necessary potential to initiate and facilitate the disease transmission by establishing an effective vector-host transmission cycle for diverse pathogens in different environments. Thus, in the changing ecological conditions this mosquito might enhance its epidemiological importance in the near future as a smart vector for those pathogens which were isolated from this mosquito species but are presently not having any public health importance.

Aditya *et al*. (2012) demonstrated that indigenous larvivorous fishes bear potential for regulating vector mosquitoes through trophic interactions. The mosquito prey preference of five indigenous larvivorous fishes in the presence of alternative food items was assessed to highlight their use in mosquito vector management. Laboratory experiments were carried out using the larvivorous fishes *Ambassis* (Chanda) nama, Parambassis (Chanda) ranga, *Colisa fasciatus*, *Esomus danricus* and *Aplocheilus panchax*, as predators and IV instar *Culex quinquefasciatus* larvae as target prey. Mosquito prey preference of these fishes in the presence of chironomid larvae, tubificid worms and artificial fish foods, in varied proportions, were assessed using preference index. Results: The fishes consumed considerable amount of mosquito larvae both in absence and presence of alternative food items. However, the positive selectivity for mosquito larvae at all densities were significantly ($p < 0.05$) affected by the alternative foods. The chironomid larvae and tubificid worms were consumed proportionately higher than expected ($p < 0.05$), while the artificial fish food was consumed at lower than expected proportions ($p < 0.05$). The niche overlap was significantly similar among the fish species suggesting likeliness in predation pattern and prey preference. The results reflect that the alternative food items influence the mosquito prey selectivity and thus the efficacy of indigenous larvivorous fishes. While use of these fishes in the wetlands and allied mosquito larval habitats in different parts of the country is suggested, impact of the alternative prey may affect the successful regulation of mosquitoes. Assessment of appropriate predator-prey ratio under natural habitat conditions is recommended to enhance successful mosquito control by these fishes.

Kundu *et al*. (2014) observed that the present commentary highlights the likelihood of indirect interactions in rice fields and allied wetlands using the water bugs, odonate larvae and dytiscid beetles as insect predators of mosquito. The biomass and linkage density of the species were used as input to construct the network and estimate the opportunity of intraguild predation (IGP) and apparent competition (AC). It was evident that IGP increased as a function of insect predator body weight ($r= + 0.907$; $P < 0. 05$), while an increase in prey biomass decreased its involvement in AC ($r = - 0.864$; $P < 0.05$). The interaction between mosquito prey and the predators appears to be affected by the biomass and composition of the species assemblage. Assuming chances of IGP and AC, positive preference for mosquito by the insect predators seems to be an important criterion for effective biological control.

Moirangthem *et al*. (2018) showed that mosquitoes are menace to human for centuries with their capability to spread dreaded diseases like malaria, dengue, filariasis etc. the control or managing them is the first priority of the humans ever since the cause of such diseases has been revealed. The usual ways to control include the spraying of insecticides or fumigation. Utilization of predacious insect larvae as well as the mosquito larvae are eco-friendly, sustainable and cost effective methods for the purposes. In the present study three insect larvae viz, Odonata (*Sympatrum sp*.), Hemiptera (*Diplonychus* sp.) and Diptera (*Lutzia tigripes*) were reared in the laboratory to check their efficacy on controlling the mosquito larvae efficiently. The larvae feeding them were the *Culex* species larvae. To find out the insect consuming larvae significantly more than others Turkey's HSD for 3 means and 2 means are calculated and is found to be 61.19 and 48.79 respectively. Comparing the differences between the means, all means are found to be significantly different. The insect consuming larvae significantly than others is Odonata. In the same way, to find out the instar of the larvae at which insects consume them in significant amount Turkey's HSD is calculated for 4, 3 and 2 means and they are 79.77, 70.66 and 56.34 respectively. Comparing the differences in the means with these values, it is found that insects consume larvae at 4th instar significantly more than the larvae at other stages. Out of the three larvae for managing or even controlling the mosquito larvae, Lutzia larvae might be the most efficient candidate for releasing in wild to control for they can survive and well adapted to the any habitats whether polluted or non-polluted but the Odonata and Hemiptera prefer somewhat non polluted aquatic habitats having moderate amount of dissolved oxygen. The main focus of the study is to select a bio-agent that has no habitat boundary or constrain and nature of aquatic habitat. Hence the efficient candidate for controlling the mosquitoes of a particular habitat will be to utilize natures' best weapon against the mosquitoes that is *Lutzia tigripes.*

Hazarika and Goswami (2012) found that *Diplonychus rusticus Fabricius* (Hemiptera, Belostomatidae) is one of the common aquatic insects inhabiting the freshwater habitats of Assam, India. An experimental approach has been used to study the predatory efficiency and feeding behavior of this aquatic bug in relation to individual density of 7 prey individuals of different size, namely fish species- *Catla catla* and *Puntius sp*., mosquito larvae- *Culex quinquefasciatus* (Diptera), Chironomus larvae- Tendipes sp. (Diptera), mayfly- Baetis sp. (Ephemeroptera), small aquatic beetle- *Amhiops pedestris* Sharp (Coleoptera) and Damsel fly nymph- *Ischnura sp* (Odonata) by separate feeding in aquaria in laboratory condition. The mean rank of consumption is calculated against each of the prey organism. Of the small size class the most consumed taxa is recorded as living spawn of *Catla catla* followed by the *Baetis sp*. Within the medium size class the most used taxa is the living forms of mosquito larvae which is closely followed by the living spawn of *Catla catla*. The results of the present laboratory experiments indicate the possible use of the aquatic bug as a biological control agent of mosquito vector under agro-climatic conditions of Assam, India. On the other hand, it shows significant negative role in the nurseries and rearing ponds of fish aquaculture system.

Hadicke *et al*. (2017) demonstrated that food webs are of crucial importance for understanding any ecosystem. The accuracy of food web and ecosystem models rests on the reliability of the information on the feeding habits of the species involved. Water boatmen (Corixoidea) is the most diverse super-family of water bugs (Heteroptera: Nepomorpha), frequently the most abundant group of insects in a variety of freshwater habitats worldwide. In spite of their high biomass, the importance of water boatmen in aquatic ecosystems is frequently underestimated. The diet and feeding habits of Corixoidea are unclear as published data are frequently contradictory. We summarise information on the feeding habits of this taxon, which exemplify the diffi culties in evaluating published data on feeding habits in an invertebrate taxon. It is concluded that Corixoidea are, unlike other true bugs, capable of digesting solid food, but their feeding habits are still insuffi ciently known. The dominant feeding strategy in this taxon is zoophagy, but several species consume other foods, particularly algae and detritus. Only members of the subfamily Cymatiainae seem to be exclusively predators. In other subfamilies, the diet of different species and different sexes or populations of a single species may vary depending on the food available or is still unknown. We conclude, that a multi-method approach is needed to elucidate the feeding habits of aquatic insects and invertebrates in general.

Allo and Mekhlif (2019) observed that the presence of the predators can alter the prey niche in the community. We evaluated the influence of the predator, *Anisops sardea* on mosquito *Culex pipiens molestus* population by predation, and non-consumptive effect by life-cycle prolongation in predator presence and residual kairomones. The predation depends on prey density, individual *A. sardea* predated 16.0-19.7 and 24.7-29.3 3rd larvae/ day at the densities 50 and 100 larvae / liter respectively, with clearance rate 0.19 and 1.1 for those densities. The predatory impact along four days within 8 hours daytime ranged between 0.98-1.20. The non-contact presence of the predator folded the larval stadium from 11.9 in contract to 23.7 days while it increased to 16.0 days at residual kiromone, the pupal stadium in control 5.8 days, then increased to 7.8 days in the two treatments. Thus, release of notonectid *A. sardea* will effectively control *C. pipiens molestus* by predation and besides decrease number of generations through immature stages extension. *A. Sardea* can be actively used as essential factor in integrated vector control.

Brahma *et al*. (2013) showed that wetlands are common habitats of a range of predatory water bugs (Heteroptera) constituting a guild that exhibit similar dietary choice including mosquito. Differences in body size and micro habitat preference among the heteropteran guild members provide a fair possibility of intraguild predation that can influence the regulatory effect on the prey species. This proposition was tested under laboratory conditions, using varying density of *Ranatra filiformis* (IG predator) and *Anisops bouvieri* (IG prey) as predators against mosquito larvae as shared prey. Compared to single predator system, mosquito larvae were proportionately less vulnerable to predation in intraguild predation (IGP), at low density of shared prey. In IGP system, vulnerability of shared prey increased with increase in density accompanied by a decline in mortality of IG prey. The mean mortality of shared prey and IG prey increased with the density of IG predator. It was apparent that the mosquito prey vulnerability was enhanced with increase in density of mosquito and *R. filiformis* while reducing the mortality of *A. bouvieri* partly. The interaction between *R. filiformis* and *A. bouvieri* as a part of IGP system indicate about the possible mechanism of coexistence of predators and prey in the wetlands. The density dependent effects on reduction and enhancement of shared prey (mosquito) mortality indicate that appropriate ratio of *R. filiformis*, *A. bouvieri* and mosquito larvae will be required to make biological regulation of wetland mosquitoes feasible.

Chandra *et al*. (2008) found that problems associated with resistant mosquitoes and the effects on non-target species by chemicals, evoke a reason to find alternative methods to control mosquitoes, like the use of natural predators. In this regard, aquatic coleopterans have been explored less compared to other insect predators. In the present study, an evaluation of the role of the larvae of *Acilius sulcatus* Linnaeus 1758 (Coleoptera: Dytiscidae) as predator of mosquito immatures was made in the laboratory. Its efficacy under field condition was also determined to emphasize its potential as bio-control agent of mosquitoes. In the laboratory, the predation potential of the larvae of *A. sulcatus* was assessed using the larvae of *Culex quinquefasciatus* Say 1823 (Diptera: Culicidae) as prey at varying predator and prey densities and available space. Under field conditions, the effectiveness of the larvae of *A. sulcatus* was evaluated through augmentative release in ten cemented tanks hosting immatures of different mosquito species at varying density. The dip density changes in the mosquito immatures were used as indicator for the effectiveness of *A. sulcatus* larvae. Results: A single larva of *A. sulcatus* consumed on an average 34 IV instar larvae of *Cx. quinquefasciatus* in a 24 h period. It was observed that feeding rate of *A. sulcatus* did not differ between the light-on (6 a.m. – 6 p.m.), and dark (6 p.m. – 6 a.m.) phases, but decreased with the volume of water i.e., space availability. The prey consumption of the larvae of *A. sulcatus* differed significantly ($P < 0.05$) with different prey, predator and volume combinations, revealed through univariate ANOVA. The field study revealed a significant decrease ($p < 0.05$) in larval density of different species of mosquitoes after 30 days from the introduction of *A. sulcatus* larvae, while with the withdrawal, a significant increase ($p < 0.05$) in larval density was noted indicating the efficacy of *A. sulcatus* in regulating mosquito immatures. In the control tanks, mean larval density did not differ ($p > 0.05$) throughout the study period.The larvae of the dytiscid beetle *A. sulcatus* proved to be an efficient predator of mosquito immatures and may be useful in bio-control of medically important mosquitoes.

Saha *et al*. (2010) demonstrated that dropical aquatic environments host a large number of predatory insects including heteropteran water bugs *Anisops bouvieri* Kirkaldy, 1704

(Heteroptera: Notonectidae), *Diplonychus* (=Sphaerodema) *rusticusFabricius*, 1781 (Heteroptera: Belostomatidae), and *Diplonychus* (=Sphaerodema) *Annulatus Fabricius*, 1781 (Heteroptera: Belostomatidae) feeding on a range of organisms. In tropical and subtropical wetlands, ponds, and temporary pools these predators play a role in regulation of dipteran populations, particularly mosquitoes and chironomids. Their relative abilities to control mosquitoes depend in part on predator preference for mosquitoes in relation to other natural prey, and the predators' propensities to switch to mosquitoes as mosquito density increases. The prey electivity and switching dynamics of these predatory water bugs were evaluated in the laboratory under various prey densities, using two instars (II and IV) of chironomid and mosquito larvae as prey. Studies of electivity at relatively high densities (20 prey L-1) in small (5 L) vessels demonstrated that all predators showed opportunistic foraging as the mosquito:chironomid ratio changed, with some evidence that mosquito larvae were positively selected over chironomids. In particular, *Anisops* showed strong electivity for mosquitoes when presented with any ratio of large mosquito and chironomid prey in the high density experiment, although the preference was not expressed in lower density (2.5 prey L-1) treatments executed in 40 L vessels. In these lower density treatments, *D. rusticus* demonstrated higher electivity for mosquitoes when the mosquito:chironomid ratio was high, consistent with non-significant trends observed in the higher density experiment. The positive electivity of *D. rusticus* for mosquitoes was reinforced in an experiment executed over 16 days at varying prey ratios, in which *D. rusticus* mosquito electivity was high and consistent while *D. annulatus* showed slight avoidance of mosquito larvae, and *Anisops* remained largely opportunistic in foraging on prey in proportion with availability. *Anisops* and *D. rusticus* are potentially good bio-control agents for mosquito larvae, in that they preferentially consume mosquitoes under many circumstances but can readily forage on other prey when mosquito density is low.

Banerjee *et al*.(2010) observed that the aquatic bodies designated as mosquito larval habitats are diverse in size and species composition. The macro invertebrate predators in these habitats are elements that influence the abundance of mosquito species, providing a basis for biological control. Assessment of species assemblage in these habitats will indicate the possible variations in the resource exploitation and trophic interactions and, therefore, can help to frame biological control strategies more appropriately. In the present study, the species composition is being investigated in five different mosquito larval habitats at a spatial scale. A random sample of 80 each of the habitats, grouped as either small or large, was analyzed in respect to the macro invertebrate species assemblage. The species composition in the habitats was noted to be an increasing function of habitat size (species number =1.653+0.819 habitat size) and, thus, the diversity. The relative abundance of the mosquito immatures varied with the habitat, and the number of useful predator taxa was higher in the larger habitats. In the smaller habitats— plastic and earthen structures and sewage drains, the relative and absolute number of mosquito immatures per sampling unit were significantly higher than the pond and rice field habitats. This was evident in the cluster analysis where the smaller habitats were more related than the larger habitats. The principal component analysis on the species diversity yielded four and six components, respectively, for the smaller and larger habitats for explaining the observed variance of species abundance. The species composition in the habitats was consistent with the earlier findings and support that the abundance of co-existing macro invertebrate species regulates the relative load of mosquito immatures in the habitats. The findings of this study may be further tested to deduce the relative importance of the habitats in terms of the productivity of mosquito immatures at a temporal scale.

Pramanik *et al* . (2017) showed that the prey preference of *Toxorhynchites splendens* was evaluated using the larval stages of the mosquitoes *Culex quinquefasciatus*, *Aedesaegypti* and chironomid larvae to substantiate the predatory efficacy and thus use in the biological control of mosquitoes. The field collected larval stages of *T. splendens* were allowed to consume the mosquito larvae alone or in combination with chironomid larvae in equal proportions. The larval stages of *T. splendens* consumed mosquito significantly more than the chironomid larvae, irrespective of combinations. In paired combinations, the preference of the mosquito remained significantly higher in terms of the Manly's selectivity index. 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. However, the overall consumption of the mosquito prey may be reduced by the presence of the chironomid larvae. In extension to the earlier observations, the results are encouraging, favouring the use of *T. splendens* in vector management in Kolkata, India and similar regions, where mosquito borne diseases is a major public health concern.

Millado and Sumalde (2018) found that mosquito-borne diseases are a major burden in the Philippines for centuries due to the lack of effective and sustainable vector control measures. Sightings of the elephant mosquito, *Toxorhynchites splendens* in the country were recorded since the 1940's. It has not been mentioned, however, in any control programs to date. The prey consumption by this larval predator for *Aedes aegypti* (Linnaeus, 1762) (Diptera: Culicidae), *Ae. albopictus* (Skuse, 1894) (Diptera: Culicidae), and *Culex quinquefasciatus* Say (1823) (Diptera: Culicidae) was, therefore, studied under a "with choice" and "without choice" situation to initially assess its capability under local conditions. The average cumulative voracity of larval *Tx. splendens* was higher for *Ae. aegypti* than for *Ae. albopictus* at all densities, with 70% consumed by the fourth instar. An increase in predation relative to increase in density was observed for all *Toxorhynchites* instars. Consumption of males and females did not vary in both prey species. Percent preys consumed per number of preys offered declined as density increased suggesting a satiation point. When offered a mix of different instars of *Ae. aegypti* larvae, *Tx. splendens* first and second instar larvae consumed the younger instars, but fourth instar *Tx. splendens* preferred older larvae and pupa, and when offered a mix of larvae belonging to three different species, the majority of *Tx.splendens* instars preferred *Ae. aegypti* and *Ae. albopictus* over *Cx. quinquefasciatus*. Our results suggest that *Tx. splendens* has very good potential in controlling dengue-carrying mosquitoes under Philippine conditions.

Khan and Hossain (2013) found that the eggs of *Culex quinquefasciatus* Say (Diptera: Culicidae) were exposed to 40^{o} C for different exposure periods (viz. half an hour, one, two and four hours) and control (room temperature, 28±60C); the percentage of egg hatching ranged from 74.14 to 96.33 (F=215.593, P<0.05), larval mortalities were from 24.52 to 0.00% (F=73.287, P<0.05), pupal mortalities ranged from 10.2 to16.71% (F=34.056, P<0.05), mean larval periods ranged from 127.9 to 155.3 hours (F=124.002, P<0.05), mean pupal periods ranged from 30.5 to 36.1 hours (F=10.531, P<0.05), lengths of 2nd instar ranged from 3.82 to 4.67 mm (F=16.50, P<0.05), lengths of 3rd instar ranged from 6.195 to 7.195 mm (F=7.558, P<0.05), lengths of 4th instar ranged from 7.395 to 8.025 mm (F=3.961, P<0.05), mean diameter of the head capsule of 1st instar larvae was 0.316 to 0.384 mm (F=8.308, P<0.05), that of 2nd instar larvae was 0.395 to 0.468 mm (F=4.953, P<0.05), that of 3rd instar larvae was 0.652 to 0.71 mm (F=2.629, P>0.05), that of 4th instar larvae was 0.806 to 0.91 mm (F= 13.871, P<0.05), length of the cephalothorax of pupae ranged from 1.862 to 2.062 mm (F=0.662, P>0.05), body length of male adults ranged from 3.41 to 3.58 mm (F=0.59, P>0.05), and that of female ranged from 3.75 to 4.09 mm (F=1.98, P>0.05), mean egg- rafts laid per female ranged from 1.4 to 2.0 and mean numbers of eggs per raft were 230 to 260.

Shocket *et al*. (2018) demonstrated that thermal biology predicts that vector-borne disease transmission peaks at intermediate temperatures and declines at high and low temperatures. However, thermal optima and limits remain unknown for most vector-borne pathogens. We built a mechanistic model for the thermal response of Ross River virus, an important mosquito-borne pathogen in Australia, Pacific Islands, and potentially at risk of emerging worldwide. Transmission peaks at moderate temperatures (26.4˚C) and declines to zero at thermal limits (17.0 and 31.5˚C). The model accurately predicts that transmission is year-round endemic in the tropics but seasonal in temperate areas, resulting in the nationwide seasonal peak in human cases. Climate warming will likely increase transmission in temperate areas (where most Australians live) but decrease transmission in tropical areas where mean temperatures are already near the thermal optimum. These results illustrate the importance of nonlinear models for inferring the role of temperature in disease dynamics and predicting responses to climate change.

Ohba *et a*l. (2011) found that residents of Vietnam living in areas with water shortages and/or poor tap water maintain water storage containers, such as jars, in and around their domiciles in order to store water used in daily life. Although these water jars are known tobe important breeding sources of the *Aedes mosquito*, use of chemical larvicides in such containers is legally prohibited in Vietnam. In this study, we identified the dominant mosquito insect predators in water jars in and around residences located in Tan Chanh, Long An, southern Vietnam. Of 3,646 Heteroptera collected from such jars, Corixidae (*Micronecta spp*.) and Veliidae (*Microvelia spp*.) were revealed to be the dominant predators. Polymerase chain reaction (PCR) analysis revealed that 40% of *Micronecta* and 12% of Veliidae had *Aedes aegypti*-positive reactions, indicating that these two dominant Heteroptera are important predators of *Ae. aegypti*. Our results suggest that aquatic Heteroptera may be an important mosquito control agent in addition to the currently used copepods.

Ohba and Takagi (2010) demonstrated that the predatory ability of adult Japanese diving beetles on 4th instars of the Japanese encephalitis vector mosquito, *Culex tritaeniorhynchus*, was assessed under laboratory conditions. To determine the differences in the predatory ability among 14 beetle species inhabiting rice fields, the following species were introduced to 10 *Cx. tritaeniorhynchus* 4th instars in a plastic cup: 5 small-bodied species (,9 mm in body length) comprising *Hydroglyphus japonicus*, *Noterus japonicus*, *Laccophilus difficilis*, *Hyphydrus japonicus*, and *Agabus japonicus*; 7 medium-bodied species (9–20 mm in body length) comprising *Hydaticus rhantoides*, *Hydaticus grammicus*, *Rhantus suturalis*, *Eretes griseus*, *Hydaticus bowringii*, *Agabusconspicuous*, and*Graphoderus adamsii*; and 2 large-bodied species (.20 mm) comprising *Cybister brevis* and *C. japonicus*. The average 24-h predation rate was highest in medium-bodied species (.90%), followed by small-bodied species (31%) and large-bodied species (19%). The functional responses to *Cx. tritaeniorhynchus* larvae of 3 medium-bodied species (*H. grammicus*, *R. suturalis*, and*E. griseus*) were estimated. Eretes griseus exhibited the highest attach rate and shortest prey-handling time, suggesting that medium-bodied diving beetles, especially *E. griseus*, may be efficient predators of mosquito larvae in rice fields.

Lundkvist *et al*. (2003) observed that field experiments were performed in artificial ponds to evaluate how the density of predatory diving beetles (Dytiscidae) would affect the population levels of mosquito larvae (Culicidae). Mosquitoes colonizing the ponds were predominantly species of the genus Culex. In 2000, most of the dytiscids colonizing the ponds were small (*Hydroporus* spp.), and these predators had no impact on the size of larval mosquito populations, not even in ponds with added dytiscids. In 2001, larger beetles (*Ilybius*, *Rhantus*, and *Agabus spp*.) were more common, and there were significantly fewer mosquito larvae in ponds with the highest numbers of dytiscids. There was a negative correlation between numbers of diving beetles in the ponds and the mean body length of mosquito larvae. In neither year could dytiscid densities be maintained above a certain level owing to emigration. In laboratory tests, there were marked differences between three common dytiscid species in regard to preferences for *Daphnia* and *Culex* species as prey: *Colymbetes paykulli* Erichson chose mosquito larvae more often, whereas both *Ilybius ater* (De Geer) and *I. fuliginosus* (Fabricius) preferred Daphnia spp. All of the tested dytiscids consumed large numbers of prey. Since some dytiscid species can efficiently decrease populations of mosquito larvae, they are probably important in the natural control of these dipterans.

Kumul *et al*. (2018) found that a survey was carried out to identify the mosquitoes inhabiting human premises in the rural locality of Maxcanu, Yucata ´n, Mexico. Using the centers for disease control and prevention backpack aspirators, simple random sampling was carried out inside of 101 homes during the November 2013 rainy season. A total of 1,492 specimens were collected. Three subfamilies (Anophelinae, Culicinae, and Toxorhynchitinae) and 5 species were identified: *Anopheles albimanus, Aedes aegypti*,*Culex interrogator*, *Limatus durhamii*, and *Toxorhynchites theobaldi*. The most abundant species was *Cx. interrogator* (74%) followed by

Ae. aegypti (25%). The Chao 1 and Bootstrap species richness estimator indicated that it was possible to collect 90% of the expected species. This is the 1st time that the presence of *An. albimanus*, *Cx.* interrogator, *Li. durhamii*, and *Tx. theobaldi* has been recorded in Maxcanu.

The ability to regulate mosquito population through consumption is a basis for considering predatory insects as biocontrol agent against mosquitoes, evident from mosquito consumption by water bugs (Aditya *et al*., 2004; Saha *et al*., 2003, 2007a, 2007b, 2008, 2010 & 2012) dytiscid beetles (Lundkvist *et al*., 2003; Aditya *et al*., 2006; Schäfer *et al*., 2006), and odonate larvae (Saha *et al*., 2012 and 2014) of rice fields and allied wetlands.

CHAPTER III

MATERIALS AND METHODS

The study comprising two sets of experiments has been conducted during the period October 2018 to February 2019. In the first experiment, A survey of different insect species diversity of mosquito predators in Dhaka district (different upazila near by Dhaka city and selected different location or point in Dhaka city) and surrounding water logging area in Bangladesh was conducted and in the 2nd experiment**,** an assessment of predatorial capacity of different aquatic predators against *Culex annulirostris*, mosquito immature was done at the Dr. Wazed miah central laboratory, under the Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka.

Experiment 1. Survey of different insect species diversity of mosquito predators in Dhaka district and surrounding water logging area

A sequential description of the methodologies followed in conducting this research work has been presented in this chapter.

3.1.1 Field survey

Selected important water logging areas of Dhaka district (different upazila near by Dhaka city and selected different location or point in Dhaka city) in Bangladesh were surveyed to collect information about the predator of different insect species on mosquito. Local predators were surveyed and collected to identify the most prevalent species and to subsequently investigate their efficacy against mosquito immature. These sites were surveyed monthly different days intervals using long-handled nets with 15 cm diameter x 30 cm long muslin sleeves. Predators which selected for experiment were transported alive from the field to the laboratory in plastic boxes half-filled with water and some cases debris from the breeding sites. In the laboratory, predators were washed with clean water and sorted into small plastic trays (15 x 11 x 5 cm) half-filled with de-ionized water. Other predators were identified according to keys of Gooderham and Tsyrlin (2002) and left to acclimatize to laboratory conditions. All predators were starved for two days before tests were conducted.

3.1.2 Experimental period: Area or locations of around or in the Dhaka city and different upazila under Dhaka district there were selected and data collected during the period from October, 2018 to February, 2019.

3.1.3 Breeding site of mosquito

Generally, mosquito breeding sites around residences exist in tree holes, rock holes, and tires. The large-scale change of environment might have produced new breeding sites for vector mosquitoes and influenced mosquito ecology, including density and species composition. Mosquitoes bred occasionally in storage containers in village areas but not in temporary housing sites. Some efforts will decrease the density of container-breeding mosquito,*Ae. Albopictus*. In contrast to storage containers, vector mosquito larvae (*Cx. quinquefasciatus, Cx. Annilrostris* and *Ae. albopictus*) proliferated in wastewater pools fed from each household in temporary housing sites. Wastewater pools did not disappear because they had been made simply by excavation. In addition, further wastewater was supplied constantly to the pools by residents, creating a breeding site preferred by *Cx. quinquefasciatus*. Thus, wastewater pools provided the best breeding site for *Cx. Sp* and will continue to do so until removed from around temporary housing sites. In village areas, vector mosquito larvae (*Cx. Quinquefasciatus* and *Ae. albopictus*) bred in some storage containers in gardens, whereas few vector mosquito larvae appeared in waste water pools. Waste water pools in village areas were smaller than those in temporary housing sites .wastewater pools in temporary housing areas were breeding sites of *Cx. sp*, and *Ae. albopictus*, whereas storage containers in village areas were breeding sites of *Cx. Sp* and *Ae. albopictus*.

Eliminating wastewater pools in temporary housing areas and storage containers in village areas may be an effective approach to reducing the risk of mosquito-borne diseases.

3.1.4 Location of Giant water bug and water boatman

The various species and genera of water boatmen are most common in ponds and in quiet areas of lakes and streams, where vegetation gives them something to cling to as well as something to eat. Water boatmen are strong fliers and are attracted at night to artificial lights. They are quite clumsy out of water. Water boatman can be found in birdbaths and swimming pools, where the insect ends up after a night's flying excursion.

3.1.5 Location of water strider

All water striders live in fresh water except those of the genus *Halobates*, which are considered the only true saltwater-inhabiting insects. They have been seen many miles from land on tropical and subtropical ocean surfaces, feeding on the fluids of dead floating animals. They can move quite quickly to catch prey or escape predation. Pond skaters are predatory, and sense their prey by detecting surface ripples. Water striders occur in large to small groups on the surface of still water (ponds, lakes) and near the calm edges of flowing water (rivers, streams). Adults and nymphs both inhabit the same types of areas, and they tend to avoid fast running water. Their ability to skate on the surface comes from their tarsi (terminal leg segments) being clothed in fine hairs which prevent the tarsi from getting wet.

3.1.6 Foods of Giant water bug, water boatman and water strider

Almost all "true bugs" (in the order Hemiptera) have tube like mouthparts for sucking in their nourishment. Water boatmen are one of the few aquatic members of this order that are not predaceous and do not bite people. Instead, they suck juices from algae, plants and detritus. Only a few species eat other small aquatic creatures (such as mosquito larvae).They are excellent and active swimmers both on the surface and under water, feeding on insect larvae, including mosquito larvae, by capturing the prey in the water and then sucking out the haemolymph from the prey body. Water strider feed on the fluids of dead floating animals in the ponds and lakes.

Experiment 2: **An assessment of predatorial capacity of different aquatic predators against *Culex annulirostris*, mosquito immature**

The experiment was conducted in the Dr. Wazed miah central laboratory, under the Department of Entomology at Sher-e-Bangla Agricultural University (SAU), Dhaka Bangladesh during the period of October, 2018 to February, 2019 to study the growth and development and abundance of mosquito, *Culex annulirostris* and an assessment of predatorial capacity of different aquatic predators against them.

3.2.1 Collection of mosquito larvae

Collections were conducted around residences in both temporary housing and village areas. The presence or absence of mosquito larvae was confirmed in all aquatic habitats within each area. When mosquito larvae were found, the larvae were collected using a 500µm mesh dipnet (8 5 cm mouth opening) and pipette. When mosquito larvae were found in a large pool (>0.5 m diameter), the above mentioned dip net was pulled for 0.3 m along the water surface 5 times. The collected larvae were preserved in 70% ethanol until identification. All larvae, excluding damaged and/or 1st-3rd instar larvae, were identified. The breeding sites were classified into three categories: waste water pool (including ditch), storage container (buckets, kettles and pots), and others (natural small pools, tap water tanks, rivers and fish aquaria). Waste water was pooled from each household, the largest part of a wastewater pool being more than 50 cm and the shape circular, vertically long, and square. Although all wastewater pools in temporary housing sites had been made simply by excavation on the ground ad hoc, some of those in village areas were U-shaped concrete ditches. On the other hand, storage containers were made from column-shaped plastic, and the diameter was less than 50 cm. The mosquito-positive containers were not adequately covered with a lid in either temporary housing or village areas. The largest mosquito positive aquatic habitats were measured and classified into five categories 1st, 2nd, 3rd,4th instars and pupae.

3.2.2 Materials to be used: Aquatic insect predator's Giant water bug, *Belostoma indica* and *Diplonychus* sp. Water boatman, Corixid sp. and Water striders, *Aquarius adelaides* were used as a bio-control agent against mosquito, *Culex annulirostris* controlling.

Firstly Three aquatics predators such as Giant water bug, *Belostomata indica*; Diplonychus bug, *Diplonychus* sp and W*ater* striders, *Aquarius adelaides* were used to determination of mosquito consumption capacity for assessment of their predatorial capacity against mosquito *(C. annulirostris).*

Secondly, the experiment consists of six treatments to determination the mosquito's mortality for assessment of predatorial capacity of mosquito predators against mosquito (*C. annulirostris*). Six treatments, viz. Treatment (s) were T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High Density (40 Larvae); T_3= Water Boatman Adult + Low Density (20 Larvae); T_4= Water Boatman Adult + High Density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae).The experiment was laid out Completely Randomized Design (CRD) with five replications .

Design of the experiment: CRD (Completely randomized design) with 5 replications.

3.2.3 Determination of the percentage of mosquito consumption by aquatic predators in different hours

Collected aquatic insect predator's giant water bug, *Belostoma indica* and *Diplonychus* sp. and Water striders, *Aquarius adelaides from field* were made them malnourishment for more than 12 hours for the experiment. The 50 numbers of different instat (1st, 2nd, 3rd and 4th) of mosquito, *Culex annulirostris* and different aquatic insect predator's as prey were released in the metallic/plastic container separately with 500 ml of water with five replications. Each replication one predator was released and monitored for the predatorial capacity of different aquatic predators against mosquito. Temperature of laboratory was ranged from 24 to 27^{0} C during the study periods. This experiment was conducted separate days for each instars and each with five replications. A control experiment was done in each case. The experiment was commenced from 9am to 4pm for every one hour interval the consumption rate was recorded for each predator. The similar methodology was maintained for 2nd, 3rd and 4th instars respectively.

	
Plate 1: Giant water bug, *Belostoma indica* aquatic predator which used to experiment	**Plate 2: Water striders , *Aquarius adelaides* aquatic predator which used to experiment**

Plate 3: Set of the experiment to assess predatorial capacity of giant water bug on immatured Mosquito

3.2.4 Determine the percentage of mortality of different growth stages of Mosquito by aquatic predators at the different days after treatment

3.2.4.1 To determination the percentage of Mortality of different growth stages of Mosquito by aquatic predators following treatments were used:-

T_1=Water Boatman Nymph + Low density (20 Larvae)

T_2= Water Boatman Nymph + High Density (40 Larvae)

T_3= Water Boatman Adult + Low Density (20 Larvae)

T_4= Water Boatman Adult + High Density (40 Larvae)

T_5=Water Strider + Low Density (20 Larvae) and

T_6=Water Strider + High Density (40 Larvae).

3.2.4.2 Collection of Giant water bugs, water boatman and water strider

Water boatmen and water striders were collected from water storage clay jars from Pabna Cholon Beel. All samples were brought to, and used to establish laboratory cultures at, the Department of entomology, Faculty of agriculture, Sher-e-Bangla agricultural University. Laboratory cultures and experiments were performed at 25 ± 1 °C and an L: D period of 12:12. Adult female and male *of water boatman and water strider* were kept in a 1.2 l clay jar for stock cultures and fed on *Culex annulirostris* larvae. All clay jars used were covered with nylon meshes (1 mm mesh size).

3.2.4.3 Rearing of *C. annulirostris* mosquito larvae, water boatman and water strider

Freshly laid *mosquitoes* eggs attached on filter paper and dry, were obtained from the laboratory cultures of the Department of Entomology in Sher-e-Bangla Agricultural University and were reared in 10 plastic rectangular containers in the laboratory at Sher-e-Babgla Agricultural University to obtain different instars of mosquito larvae for use in the experiments. Excess larvae were not reared further but killed and in-house *Culex annulirostris* cultures were not established. Tap water, for rearing all stadia of *water boatman and water strider* and *Culex annulirostris larvae*, was dechlorinated by leaving to air in containers for 24 h. For *Culex annulirostris*, the dried eggs on filter paper were added to this water whereupon they hatched within 30 minutes and the larvae were fed daily with crushed wheat. After 3 – 4 days under these conditions, larvae molted to the 2nd 3rd, 4th instars and pupae and when observed under a stereo- microscope was within the different size which were then selected and used in the experiments.

Plate 4: Collected *C. annulirostris* mosquito larvae

Plate 5: Set of the experiment to assess percentage of Mosquito Mortality by water boat man (**A**) and water strider (**B**)

3.2.4.4 Water boatman nymphal instars and adult

Measurements of the body length, head capsule size and head length were made on individual water boatman nymphs and adults using a stereo microscope (32 x). Water boatman were put individually on the petri dish by using a dropper. After that, tissue paper was used to dry up the water surrounding the insect body. The characters were measured once for each individual by a stage micrometer attached under the microscope. To determine the size range of each of the water boatman nymphal instars, as well as adults, the data for the measured characters for the nymphal instars and adults were analyzed by scatter graph plots. The individuals were then ascribed to a given nymphal instar or adult category based upon the size distribution scatter plot analysis and the neach category was reanalyzed for size range and variation within and between each defined nymphal instar and adults.

3.2.4.5 Mosquito larvae consumption

Feeding tests were conducted to determine the ability of the nymphal stage plus adults, of water boatman to feed on different mosquito larvae as determined by predation efficiency. To broadly standardize the hunger level of water boatman and water strider (predator), and thus the potential hunting desire and, when prey is not limiting, the total consumption rate, the two size categories of water boatman and large and adults were selected randomly from stock cultures and kept separately without food for the same period of time, that is for 24 h prior to experimentation. Water boatman was housed at three different densities, nymphs or adults in plastic container jars filled with fresh tap water. After that, differents instar *Culex annulirostris* larvae at one of two different densities, *viz* 20 and 40 larvae, were put into each plastic container jar containing the water boatman and water strider at different densities to start the tests. After 24 h the number of living larvae and the cadaver remains in the jars was recorded. In all experiments three replicates were performed for each combination. The mortality numbers were adjusted and then used to calculate the percentage mortality of mosquito larvae in all experiments, and as a measure of predation levels.

3.2.4.6 Feeding mechanism of Giant water bug, water boatman and water strider*:*

The mouthparts of Corixoidea are uniquely modified their rostrum is very short, joined immovably to the head capsule, their fore tarsi ("palae") are modified and there agrinder is situated in their food pump. The morphological specialization of corixoid mouthparts indicate that these bugs are capable of ingesting and digesting solid food, in contrast with the rest of Hemiptera, which only can consume liquid food. Water boatmen are true aquatic hemipteran insects' with paddle-like legs that have all their developmental stages in water. They are excellent and active swimmers both on the surface and under water, feeding on insect larvae, including mosquito larvae, by capturing the prey in the water and then sucking out the haemolymph from the prey body. Their natural habitat being stagnant water or parts of streams with little current flow, broadly the same as *Culex annulirostris* larvae, and that they are potential predators of *Ae. aegypti* larvae , makes them potential alternative bio-control agents in mosquito control programs. The predation levels increases with increasing predator size(developmental stage). Overall, adult water boatman provided the highest 3rd instar mosquito larvae mortality in all tests with the shortest feeding times. This may be due to adults being more active and larger than nymphs, but it may also reflect the relatively large prey size used. Thus, whilst it remains important to evaluate the predation efficiency and feeding times of all developmental stages of water boatman upon all larval developmental stages of *C. anuulirostris*, it also remains of interest to evaluate if different developmental stages of water boatman preferentially feed upon different larval developmental stages of *C. annulirostris,* as well as other prey items, since *Ae. Aegypti* development in urban water resources is frequently derived from multiple females and is asynchronous. Adult water boatmen showed the highest predation rates (*C. annulirostris*) followed by small nymphs, in that order, with small nymphs revealing no detectable predation mosquito larvae in all tests. Whilst the newly hatched instar nymphs would also still have nutrients from the yolk available to them.

3.2.4.7 DATA TO BE RECORDED

The data will be recorded on the following parameters mortality of the prey and predatorial capacity of the predators with their abundance of different growth and developmental stages.

Determination of Percent (%) Mortality

$$\textbf{Mortality} = \frac{\textbf{No. of mosquito larvae killed}}{\textbf{No. of mosquito larvae supplied}} \textbf{*100}$$

3.2.4.7 Statistical analysis

Recorded data were put and compiled on MS excel spreadsheet. Later on, data were analyzed by using STATISTICS 10 software for analysis of variance. ANOVA was made by F variance test and the mean value comparisons were performed.

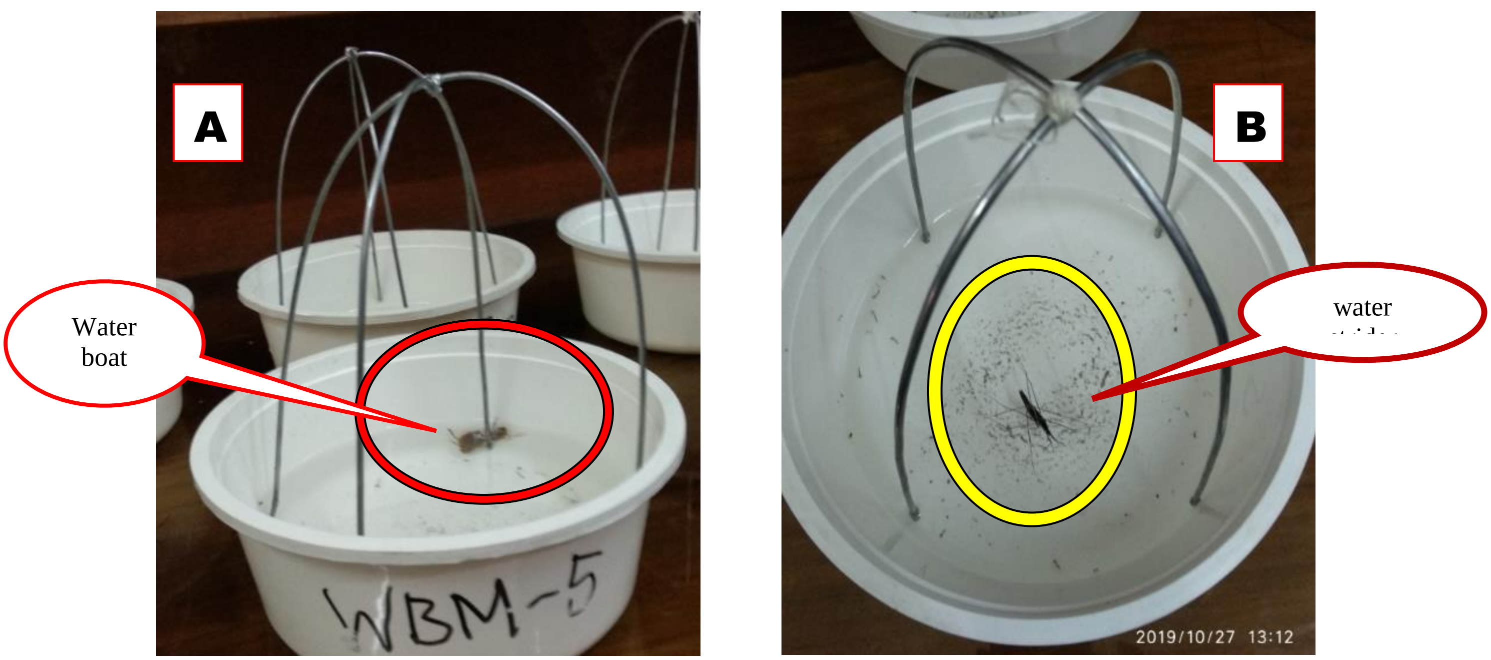


Plate 6: Photograph shows water boat man (**A**) and water strider (**B**) with Mosquito larvae

CHAPTER IV

RESULTS AND DISCUSSIONS

The present experiments were conducted to survey of mosquito predator in Dhaka districts and an assessment of their predatorial capacity against mosquito immature, *Culex annulirostris*. The analysis of variance (ANOVA) of the data has been presented in Appendix II-XIII. The results have been presented and discussed and possible interpretations were given experiment wise under the following parameters:-

Experiment 1. Survey of different insect species diversity of mosquito predators in Dhaka district and surrounding water logging area

In this chapter, the findings of the study were presented in accordance with the objectives of the study and possible interpretation of the recorded information also presented.

4.1 Common aquatic predacious insect of mosquitoes found in the rice field or water logged area during the study period

Under the present study, the aquatic predacious insect of mosquitoes found in the rice field or water logged area during the study period are presented in Table 1.

Table 1. List of the aquatic predacious insect and other of mosquitoes with stages of insect

Sl. No.	Common name of insect	Scientific name	Order, Family	Stage of insect
1.	Giant water bug	*Belostoma indica*	Hemiptera (Belostomatidae)	Adult
2.	Diplonychus bugs /Giant water bug	*Diplonychus rusticus* (Fabricius)	Hemiptera (Belostomatidae)	Larva
3.	Diplonychus bugs /Giant water bug	*Diplonychus eques*	Hemiptera (Belostomatidae)	Adult
4.	Corixids/ Water boatman	*Corixa* sp	Hemiptera (Corixidae)	Adult
5.	Back Swimmer bug	*Anisops sp*	Hemiptera (Notonectidae)	Adult
6.	Water striders	*Aquarius adelaides*	Hemiptera (Gerridae)	Adult
7.	Dragon fly	*Aeshna* sp	Odonata (Aeshnidae)	Larva, adult
8.	Damsel flies	*Coanagrion* sp	Odonata (Coanagrioniidae)	Larva, adult
9.	Water scavenger beetle	*Hydrophilus sp*	Coleoptera (Hydrophilidae)	Adult
10.	Frog (Anura)	*Hoplobatrachus tigerinus*	Anura (Ranidae)	Adult

From Table 1, it was observed that, nine different species of predators representing three orders such as Hemiptera, Odonata and Coleoptera were collected from the different survey sites under Dhaka district over a four month period.

The aquatic predacious insect of mosquitoes Giant water bug (*Belostoma indica*), Diplonychus bugs /Giant water bug (*Diplonychus sp*) belongs the family Belostomatidae ; Corixids / Water boatman (*Corixa sp*) belongs the family Corixidae; Back Swimmer bug (*Anisops sp*) belongs the family Notonectidae; and Water striders (*Aquarius adelaides*) belongs the family Gerridae under the order Hemiptera were found in the rice field or water logged area during the study period.

The predacious insect of mosquitoes Dragon fly (*Aeshna* sp) belongs the family Aeshnidae and Damsel flies (*Coanagrion sp*) belongs the family Coanagrioniidae under the order Odonata were found during the period of survey.

Aquatic predacious insect of mosquitoes, Water scavenger beetle (*Hydrophilus sp*) belongs the family Hydrophilidae under the order Coleoptera was found during the period of survey in the rice field or water logged area.

Aquatic predacious vertebrate of mosquitoes, Frog / Anura (*Hoplobatrachus tigerinus*) which belongs the family Ranidae under the order Anura was found during the period of survey in the rice field or water logged area.

	
Dragonfly in rice field	**Dragonfly in water logging lowland**
	
Giant water bug in low bottom pond	**Gray Treefrogs in rice field**
	
Diplonychus bugs, *Diplonychus eques*	**Back Swimmer bug, *Anisops sp***

Plate 7: Some mosquito predators during survey in different locations

	
Shekhertek, in Mohammadpur	**Kalshi, Mirpur**
	
Badda in Dhaka city	**Motijheel**
	
Hajipara in Khilkhet	**Shonir Akhra**

Plate 8: Some area/locations of Mosquito breeding places in Dhaka city

Plate 9:Survey of mosquito predators at the different locations in Dhaka district

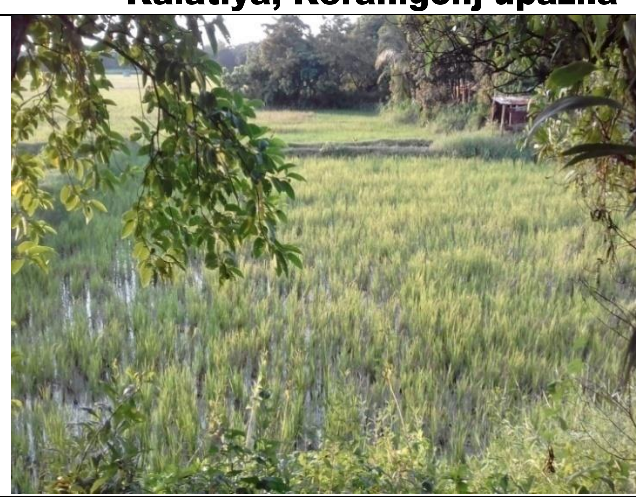
Galimpur, Nowabgonj Upazila

Agla, Nowabgonj Upazila

Konakhola, Keranigonj upazila

Kalatiya, Keranigonj upazila

Hazratpur, Savar upazila



Gangda, Savar upazila

4.2 Distribution of the predacious insect of mosquitoes in different locations or water logged area in Dhaka district

The distribution of the aquatic predacious insect of mosquitoes at different locations in Dhaka district is shown in Table 2. All predators were found in outside of the Dhaka city but one or some species of predators (a few number) were found in Dhaka city. Both *Anisops* sp. (backswimmers) and *Diplonychus* sp. were the most common predators followed by damselflies and dragonflies.

Table 2: Survey of the aquatic predacious insect of mosquitoes found in area or locations of around or in the Dhaka city and different upazila under Dhaka district ('+' predators were present; and '–' predators were absent)

Sl. No.	**Name of different locations or water logged area in Dhaka district**		Aquatic predacious insect of mosquitoes under the order			Frog (*Hoplobatrachus tigerinus*)
			Hemiptera	Odonata	Coleoptera	
01.	Nowabgonj Upazilla	i) Galimpur	+	+	+	+
		ii) Agla	+	+	+	+
02.	Savar Upazilla	i) Hazratpur	+	+	+	+
		ii) Gangda	+	+	+	+
03.	Karanigonj Upazilla	i) Konakhola	+	+	+	+
		ii) Kalatiya	+	+	+	+
04.	Dhaka city	i) Sher-e- Bangla Agril. University	+	+	+	+
		ii) Shekhertek, in Mohammadpur	–	–	–	–
		iii) Kalshi, Mirpur	–	–	–	–
		iv) Badda in Dhaka city	–	–	–	–
		v) Motijheel	+	+	–	+
		vi) Hajipara in Khilkhet	–	–	–	–
		vii) Shonir Akhra	+	+	–	+
		viii) Dhaka University area	+	+	–	+

Experiment 2: An assessment of predatorial capacity of different aquatic predators against *Culex annulirostris*, mosquito immature

An assessment of predatorial capacity of different aquatic predators against *Culex annulirostris*, mosquito immature during the period from October 2018 to February 2019. The results have been presented and discussed details under following heading and sub-heading:

4.3 Predatorial capacity of different aquatic predators against 1st instar of *C. annulirostris*, mosquito immature

Table 3. Predatorial capacity of different aquatic predators against 1st instar of *Culex annulirostris*, mosquito immature

Aquatic predators	**% of mosquito Consumption by aquatic predators in different hours**							**Total**
	9-10am	10-11am	11-12am	12 -1pm	1-2pm	2-3 pm	3 -4pm	
Giant water bug, *Belostoma indica*	85 a	10 c	5 a	0 b	0 b	0	0	100
Diplonychus bug, *Diplonychus* sp	81.8 ab	14 a	4.2 ab	0 b	0 b	0	0	100
Water striders, *Aquarius adelaides*	78.2 b	12 b	3 b	5.0 a	1.8 a	0	0	100
LSD $_{(0.05)}$	5.61	1.86	1.38	0.56	0.18	--	--	--
CV (%)	4.98	11.28	4.69	24.49	21.52	--	--	--

In case of first instar from table 3, it was revealed that, % of mosquito consumption by aquatic predators in similar of different species of (Giant water bug, *Belostoma indica*, Diplonychus bug, *Diplonychus* sp and *Water* striders, *Aquarius adelaides*).There was no significant difference between the percent of mosquito consumption by different aquatic predators. The mosquito larva capturing efficiency of different species of (Giant water bug, *B. indica*, Diplonychus bug, *D.* sp and Water striders, *A. adelaides*) in first five hours completely similar (100%). But in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica*, Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 85, 81.8 and 78.2% respectively.

From this finding it was concluded that, mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *B. indica*; the second highest Diplonychus bug, *D.* sp and the lowest in Water striders, *A. adelaides.* As a result, the trend of Predatorial capacity of different aquatic predators against 1st instar of *Culex annulirostris*, mosquito immature was Giant water bug > Diplonychus bug > Water striders.

Table 4. Predatorial capacity of different aquatic predators against 2nd instar of *Culex annulirostris*, mosquito immature

Aquatic predators	% of mosquito Consumption by aquatic predators in different hours							Total
	9-10am	10-11am	11-12am	12 -1pm	1-2pm	2-3 pm	3 -4pm	
Giant water bug, *Belostoma indica*	83.40 a	9.3 b	5.3 a	2 a	0 b	0	0	100
Diplonychus bug, *Diplonychus* sp	81.68 a	11 a	4.2 b	2.2 a	0.92 a	0	0	100
Water striders, *Aquarius adelaides*	62.20 b	5.0 c	1.8 c	0 b	0 b	0	0	69
LSD $_{(0.05)}$	3.10	1.42	0.31	0.33	0.03	--	--	--
CV (%)	2.98	12.29	5.94	17	5.95	--	--	--

From table 4, in case of second instar, it was revealed that, % of mosquito consumption by aquatic predators in difference of different species of (Giant water bug, *Belostoma indica*, Diplonychus bug, *Diplonychus* sp and *Water* striders, *Aquarius adelaides*).There was a significant difference between the percent of of mosquito consumption by different aquatic predators . The mosquito larva capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp in first five hours completely similar (100%). On the other hand, mosquito larva capturing efficiency of Water striders, *A. adelaides* in first five hours was not similar (69%). But in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 83.40, 81.68 and 62.20 % respectively.

From this finding it was concluded that, mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *B. indica*; the second highest Diplonychus bug, *D.* sp and the lowest in Water striders, *A. adelaides.* As a result, the trend of Predatorial capacity of different aquatic predators against 2nd instar of *Culex annulirostris*, mosquito immature was Giant water bug > Diplonychus bug > Water striders.

Table 5. Predatorial capacity of different aquatic predators against 3rd instar of *Culex annulirostris*, mosquito immature

Aquatic predators	% of mosquito Consumption by aquatic predators in different hours							Total
	9-10am	10-11am	11-12am	12 -1pm	1-2pm	2-3 pm	3 -4pm	
Giant water bug, *Belostoma indica*	74.31 a	11.3 a	2.3 a	1.7 a	1.0 a	0	0	90.61
Diplonychus bug, *Diplonychus* sp	71.68 b	8.6 b	2.2 a	0.25 b	0 b	0	0	82.73
Water striders, *Aquarius adelaides*	17.3 c	1.8 c	0 b	0 c	0 b	0	0	19.1
LSD $_{(0.05)}$	2.22	0.69	0.18	0.13	0.30	--	--	--
CV (%)	2.96	6.91	8.61	14.51	65.95	--	--	--

In the term of third (3rd) instar , it was revealed that, % of mosquito consumption by aquatic predators in difference of different species of (Giant water bug, *Belostoma indica,* Diplonychus bug, *Diplonychus* sp and *Water* striders, *Aquarius adelaides*).There was a significant difference between the percent of of mosquito consumption by different aquatic predators . The mosquito larva capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp and Water striders, *A. adelaides* in first five hours was not similar (90.61, 82.73 and 19.1%). It was observed that, the highest percent of mosquito consumption capacity (90.61%) in Giant water bug, *B. indica,* whereas the lowest percent of mosquito consumption capacity (19.1%) in *Water* striders, *Aquarius adelaides.* It also observed that, in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 74.31, 71.68 and 17.3% respectively (Table 5).

From Table 5 it was concluded that, mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *B. indica*; the second highest Diplonychus bug, *D.* sp and the lowest in Water striders, *A. adelaides.* As a result, the trend of predatorial capacity of different aquatic predators against 3rd instar of *Culex annulirostris*, mosquito immature was Giant water bug > Diplonychus bug > Water striders.

Table 6. Predatorial capacity of different aquatic predators against 4th instar of *Culex annulirostris*, mosquito immature

Aquatic predators	% of mosquito Consumption by aquatic predators in different hours							Total
	9-10am	10-11am	11-12am	12 -1pm	1-2pm	2-3 pm	3 -4pm	
Giant water bug, *Belostoma indica*	43.7 a	18.3 b	13.3 b	17.7 a	5.3 a	0	0	98.3
Diplonychus bug, *Diplonychus* sp	30.6 b	25.7 a	20.2 a	6.25 b	2.7 b	0	0	85.45
Water striders, *Aquarius adelaides*	7.3 c	1.8 c	0 c	0 c	0 c	0	0	9.1
LSD $_{(0.05)}$	1.67	0.78	0.76	0.82	0.52	--	--	--
CV (%)	4.44	4.23	5.09	7.41	8.35	--	--	--

In the term of forth (4th) instar, it was exposed that, % of mosquito consumption by aquatic predators in difference of different species of (Giant water bug, *Belostoma indica*, Diplonychus bug, *Diplonychus* sp and *Water* striders, *Aquarius adelaides*).There was a significant difference between the percent of mosquito consumption by different aquatic predators (P> 0.05). The mosquito larva capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp and Water striders, *A. adelaides* in first five hours was not similar (98.3, 85.45 and 9.1%). It was observed that, the highest percent of mosquito consumption capacity (98.3%) in Giant water bug, *B. indica* , whereas the lowest percent of mosquito consumption capacity (9.1%) in *Water* striders, *Aquarius adelaides.* It also observed that, in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica*, Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 43.7, 30.6 and 7.3% respectively (Table 6).

From Table 6 it was concluded that, mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *B. indica*; the second highest Diplonychus bug, *D.* sp and the lowest in Water striders, *A. adelaides.* As a result, the trend of predatorial capacity of different aquatic predators against 4th instar of *Culex annulirostris*, mosquito immature was Giant water bug > Diplonychus bug > Water striders.

Table 7. Predatorial capacity of different aquatic predators against pupae of *Culex annulirostris*, mosquito immature

Aquatic predators	% Consumption of mosquito by aquatic predators in different hours							Total
	9-10am	10-11am	11-12am	12 -1pm	1-2pm	2-3 pm	3 -4pm	
Giant water bug, *Belostoma indica*	41.3 a	28.3 a	8.7 b	5.7 a	3.3 a	0	0	87.3
Diplonychus bug, *Diplonychus* sp	40.7 a	25.7 b	20.2 a	6.15 a	2.7 b	0	0	95.45
Water striders, *Aquarius adelaides*	0 b	0 c	0 c	0 b	0 c	0	0	0.0
LSD $_{(0.05)}$	0.72	0.92	1.22	0.46	0.27	--	--	--
CV (%)	1.92	3.75	9.21	8.41	9.79	--	--	--

In the term of mosquito pupae , it was exposed that, % of mosquito consumption by aquatic predators in difference of different species of (Giant water bug, *Belostoma indica*, Diplonychus bug, *Diplonychus* sp and W*ater* striders, *Aquarius adelaides*).There was a significant difference between the percent of mosquito consumption by different aquatic predators (P> 0.05). The mosquito pupa capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp and Water striders, *A. adelaides* in first five hours was not similar (87.3, 95.45 and 0.0%). It was observed that, the highest percent of mosquito pupae consumption capacity (95.45%) in Diplonychus bug, *Diplonychus* sp; whereas the lowest percent of mosquito consumption capacity (87.3%) in Giant water bug, *B. indica.* On the other hand, there was no percentage of mosquito consumption capacity (0.0%) recorded in aquatic predator W*ater* striders, *Aquarius adelaides.* It also observed that, in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 41.3, 40.7 and 0.0 % respectively (Table 7).

From Table 7 it was concluded that, mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *B. indica*; the second highest Diplonychus bug, *D.* sp and the lowest in Water striders, *A. adelaides.* As a result, the trend of predatorial capacity of different aquatic predators against pupae of *Culex annulirostris*, mosquito immature was Giant water bug > Diplonychus bug > Water striders.

4. 4 The mortality of mosquito caused by different predators

4.4.1 Determination of % mortality of 1st instar larvae of mosquito

Statistically significant variation (p>0.05) was recorded for 1st instar larvae of mosquito due to different insect predator (Error! Reference source not found. **8**) at one hour interval in observation period. At first day in observation period, the highest percentage (%) of mortality (50.83) was found from T_4 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar (45.00) with T_3 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_2 (32.50) and T_1 (31.67).

On the other hand, the lowest percentage (%) of mortality was recorded in (6.67) T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (11.67).

At 2nd, 3rd ,4th day in observation period, the highest percentage (%) of mortality (51.67), (51.66) , (53.33) was found from T_4 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (46.6) , (48.33),(43.33),with T_3 [Water Boatman Adult + Low density (20 Larvae)] and followed by T2 (32.50) , (31.66), (32.26) and T_1 (26.66),(31.66) , (28.33).

On the other hand, the lowest percentage (%) of mortality was recorded in (6.66) (6.66**),** (5.00**),** T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (6.66) (12.50**),** (10.00**).**

At 5th ,6th ,7th day in observation period, the highest percentage (%) of mortality (50.83), (52.50) , (50.83) was found from T_4 [Water Boatman Nymph + Low density (20

Larvae)] which was statistically similar (45.00) , (46.66), (40.00) with T_3 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_2 (33.33) , (33.33), (33.33) and T_1 (33.33) , (32.50), (26.66).

On the other hand, the lowest percentage (%) of mortality was recorded in (8.33), (6.66**),** (8.33**),** T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (11.66), (11.66**),** (10.00) at the 5th, 6th, 7th days respectively.

Table 8: Determination of % mortality of 1st instar mosquito larvae at the different days after treatment

Treatment (s)	% Mortality of 1st instar mosquito larvae after different days						
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
T_1	31.67 b	26.66 d	31.66 b	28.33 c	33.33 b	32.50 c	26.66 d
T_2	32.50 b	32.50 c	31.66 b	33.26 c	33.33 b	33.33 c	33.33 c
T_3	45.00 a	46.67 b	48.33 a	43.33 b	45.00 a	46.66 b	40.00 b
T_4	50.83 a	51.67 a	51.66 a	53.33 a	50.83 a	52.50 a	50.83 a
T_5	6.67 c	6.66 e	6.66 c	5.00 d	8.33 c	6.66 d	8.33 e
T_6	11.67 c	6.66 e	12.50 c	10.00 d	11.66 c	11.66 d	10.00 e
CV (%)	12.06	9.26	10.96	12.92	12.40	10.20	10.45
LSD (0.05%)	6.37	4.68	5.93	6.63	6.71	5.54	5.24

[T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High density (40 Larvae); T_3= Water Boatman Adult + Low density (20 Larvae); T_4= Water Boatman Adult + High density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae)]

From the (**Table 8**) it was observed that among the different treatments, T4 [Water Boatman Nymph + Low Density (20 Larvae)] performed best in 1st instar larvae of mosquito. Whereas, T5 [Water Strider + Low Density (20 Larvae)] showed the lowest performance in 1st instar larvae of mosquito. As a result the order of rank of study survey of mosquito predator in Dhaka districts and an assessment of their predatorial capacity against mosquito immature, *Culex annulirostris* by number was $T_4 > T_3 > T_2 > T_1 > T_6 > T_5$.

4.1.2 Determination of % mortality of 2nd instar mosquito larvae at the different days after treatment

Statistically significant variation (p>0.05) was recorded for 2nd instar larvae of mosquito due to different insect predator (**Error! Reference source not found.** 9) at one hour interval in observation period. At first day in observation period, the highest percentage (%) of mortality (58.33) was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar (43.33) with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 (39.66) and T_2 (34.66).

On the other hand, the lowest percentage (%) of mortality was recorded in (5.00) T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (11.66).

At 2nd, 3rd ,4th day in observation period, the highest percentage (%) of mortality (58.33) , (59.16), (56.66) was found from T_3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (41.66) , (46.66), (46.66) with T4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (38.83) , (35.50), (33.83) and T_2 (36.33) , (34.66), (41.33).

On the other hand, the lowest percentage (%) of mortality was recorded in (6.66) (8.33**),** (6.66**),** T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (10.83) (10.83**),** (10.83**)** at the 2nd, 3rd,4th days respectively**.**

At 5th ,6th ,7th day in observation period, the highest percentage (%) of mortality (56.66), (58.33), (57.50) were found from T_3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (48.33) , (46.66), (48.33) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (41.33) , (41.33), (38.00) and T_2 (34.66) , (37.16), (36.33) respectively.

On the other hand, the lowest percentage (%) of mortality was recorded in (6.66), (5.00**)** **,** (6.66**),** T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (10.83),(12.50**)** **,** (10.83**)** at 5th ,6th ,7th days respectively**.**

From the (Table 9) it was observed that among the different treatments, T_3 [Water Boatman Nymph + Low Density (20 Larvae)] performed best in 1st instar larvae of mosquito. Whereas, T_5 [Water Strider + Low Density (20 Larvae)] showed the lowest performance in 1st instar larvae of mosquito. As a result the order of rank of study survey of mosquito predator in Dhaka districts and an assessment of their predatorial capacity against mosquito immature, *Culex annulirostris* by number was $T_3 > T_4 > T_1 > T_2 > T_6 > T_5$.

Table 9: Determination of % mortality of 2nd instar mosquito larvae at the different days after treatment

Treatment (s)	% Mortality of 2nd instar mosquito larvae after different days						
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
T_1	39.66 bc	36.33 b	34.66 c	41.33 b	41.33 c	41.33 bc	38.00 c
T_2	34.66 c	38.83 b	34.50 c	33.83 c	34.66 d	37.16 c	36.33 c
T_3	58.33 a	58.33 a	59.16 a	56.66 a	56.66 a	58.33 a	57.50 a
T_4	43.33 b	41.66 b	46.66 b	46.66 b	48.33 b	46.66 b	48.33 b
T_5	5.00 e	6.66 c	8.33 d	6.66 d	6.66 f	5.00 e	6.66 d
T_6	11.66 d	10.83 c	10.83 d	10.83 d	10.83 e	12.50 d	10.83 d
CV (%)	10.60	11.40	16.55	8.30	7.30	8.85	10.60
LSD (0.05%)	5.70	6.10	8.85	4.48	4.10	4.95	5.86

[T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High density (40 Larvae); T_3= Water Boatman Adult + Low density (20 Larvae); T_4= Water Boatman Adult + High density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae)]

4.4.3 Determination of % mortality of 3rd instar larvae of mosquito at the different days after treatment

Statistically significant variation ($p>0.05$) was recorded for 3rd instar larvae of mosquito due to different insect predator (Error! Reference source not found.

10) at one hour interval in observation period. At first day in observation period, the highest percentage (%) of mortality (78.33) was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae] which was statistically similar (66.66) with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 (41.66) and T_2 (37.50).

On the other hand, the lowest percentage (%) of mortality was recorded in (8.33) T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (8.33).

At 2nd, 3rd ,4th day in observation period, the highest percentage (%) of mortality (78.33), (83.33) , (83.33) was found from T_3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (67.50) , (70.83), (66.33) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (43.33) , (48.33), (47.50) and T_2 (39.16) , (36.66), (39.16) respectively.

On the other hand, the lowest percentage (%) of mortality was recorded in (6.67), (5.00 f**),** (6.66**),** T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 8.33), (10.83**),** (8.33**)** at the 2nd, 3rd, 4th days respectively.

At 5th ,6th ,7th day in observation period, the highest percentage (%) of mortality (80.00), (76.66) , (93.33) was found from T_3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (68.33) , (65.83), (64.16) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (50.00) , (43.33),(43.33) and T_2 (40.83) , (41.66), (41.66) at the 5th ,6th ,7th days respectively.

On the other hand, the lowest percentage (%) of mortality was recorded in (5.00) (8.33), (6.66), T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6 (10.83), (7.50), (10.83) at the 5th ,6th ,7th days respectively.

From the (Table 10) it was observed that among the different treatments, T_3 [Water Boatman Nymph + Low Density (20 Larvae)] performed best in 1st instar larvae of mosquito. Whereas, T_5 [Water Strider + Low Density (20 Larvae)] showed the lowest performance in 1st instar larvae of mosquito. As a result the order of rank of study survey of mosquito predator in Dhaka districts and an assessment of their predatorial capacity against mosquito immature, *Culex annulirostris* by number was $T_3 > T_4 > T_1 > T_2 > T_6 > T_5$.

Table 10: Determination of % mortality of 3rd instar mosquito larvae at the different days after treatment

Treatment (s)	% Mortality of 3rd instar mosquito larvae after different days						
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
T_1	41.66 c	43.33 c	48.33 c	47.50 c	50.00 c	43.33 c	43.33 c
T_2	37.50 c	39.16 c	36.66 d	39.16 d	40.83 d	41.66 c	41.66 c
T_3	78.33 a	78.33 a	83.33 a	83.33 a	80.00 a	76.66 a	93.33 a
T_4	66.66 b	67.50 b	70.83 b	66.33 b	68.33 b	65.83 b	64.16 b
T_5	8.33 d	6.66 d	5.00 f	6.66 e	5.00 e	8.33 d	6.66 d
T_6	8.33 d	8.33 d	10.83 e	8.33 e	10.83 e	7.50 d	10.183 d
CV (%)	9.74	7.82	7.07	8.37	8.99	9.96	7.07
LSD (0.05%)	6.95	5.64	5.34	6.25	6.79	7.18	5.44

[T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High density (40 Larvae); T_3= Water Boatman Adult + Low density (20 Larvae); T_4= Water Boatman Adult + High density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae)]

4.4.4 Determination of % mortality of 4th instar larvae of mosquito at the different days after treatment

Statistically significant variation ($p>0.05$) was recorded for 4th instar larvae of mosquito due to different insect predator (**Error! Reference source not found.** 11) at one hour interval in observation period. At first day in observation period, the highest percentage (%) of mortality (26.66) was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae] and (26.66) T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 (23.33) and T_2 (20.83).

On the other hand, the lowest percentage (%) of mortality was recorded in (3.33) T_6 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_5 (8.33).

At 2nd, 3rd ,4th day in observation period, the highest percentage (%) of mortality (23.33), (21.66), (26.66) was found from T_3 [Water Boatman Nymph + Low density

(20 Larvae)] which was statistically similar (19.16), (21.66), (22.50) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (23.33) , (21.66), (21.66) and T_2 (20.83) , (23.33), (21.66) respectively.

On the other hand, the lowest percentage (%) of mortality was recorded in (4.16) (3.33**),** (4.16**)** in T_6 [Water Strider + Low Density (20 Larvae)] which were statistically similar with T_5 (8.33) (6.66**),** (8.33**)**.

At 5th ,6th ,7th day in observation period, the highest percentage (%) of mortality (23.33), (23.33), (21.66) was found from T_3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (22.50), (23.33), (17.50) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_2 (21.66) , (21.66), (21.66) and T_1 (23.33), (21.66), (21.66).

On the other hand, the lowest percentage (%) of mortality was recorded in (5.00) (3.33), (4.16) in T_6 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_5 (6.66) (8.33) , (6.66) respectively.

From the (Table 11) it was observed that among the different treatments, T_3 [Water Boatman Nymph + Low Density (20 Larvae)] performed best in 1st instar larvae of mosquito. Whereas, T_6 [Water Strider + Low Density (20 Larvae)] showed the lowest performance in 1st instar larvae of mosquito. As a result the order of rank of study survey of mosquito predator in Dhaka districts and an assessment of their predatorial capacity against mosquito immature, *Culex annulirostris* by number was $T_3 > T_4 > T_1 > T_2 > T_5 > T_6$.

Table 11: Determination of % mortality of 4th instar mosquito larvae at the different days after treatment

Treatment (s)	% Mortality of 4th instar mosquito larvae after different days						
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
T_1	23.33 ab	23.33 a	21.66 a	21.66 b	23.33 a	21.66 a	21.66 a
T_2	20.83 b	20.83 ab	23.33 a	21.66 b	21.66 a	21.66 a	21.66 a
T_3	26.66 a	23.33 a	21.66 a	26.66 a	23.33 a	23.33 a	21.66 a
T_4	26.66 a	19.16 b	21.66 a	22.50 ab	22.50 a	23.33 a	17.50 a
T_5	8.33 c	8.33 c	6.66 b	8.33 c	6.66 b	8.33 b	6.66 b
T_6	3.33 d	4.16 d	3.33 b	4.16 c	5.00 b	3.33 c	4.16 b
CV (%)	12.54	13.81	13.93	13.88	15.04	13.47	15.62
LSD (0.05%)	4.06	4.06	4.06	4.32	4.56	4.06	4.32

[T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High density (40 Larvae); T_3= Water Boatman Adult + Low density (20 Larvae); T_4= Water Boatman Adult + High density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae)]

4.4.5 Determination of % mortality of mosquito pupae at the different days after treatment

Statistically significant variation (p>0.05) was recorded for the pupae of mosquito due to different insect predator (Error! Reference source not found. **12**) at one hour interval in observation period. At first day in observation period, the highest percentage (%) of mortality (26.66) was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar (25.00) with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 (23.33) and T_2 (21.66).

On the other hand, the lowest percentage (%) of mortality was recorded in (3.33) T_6 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_5 (6.66).

At 2^{nd}, 3^{rd} ,4^{th} day in observation period, the highest percentage (%) of mortality (23.33), (21.66), (26.66) was found from T_3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar(19.16) , (21.66), (22.50) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (23.33) , (21.66), (26.66) and T_2 (23.33) , 2(3.33), (21.66) respectively.

On the other hand, the lowest percentage (%) of mortality was recorded in (3.33), (3.33), (4.16), T_6 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_5 (8.33) (6.66), (10.00) at 2^{nd}, 3^{rd},4^{th} days respectively.

At 5^{th} ,6^{th} ,7^{th} day in observation period, the highest percentage (%) of mortality (23.33), (25.00) , (21.66) was found from T3 [Water Boatman Nymph + Low density (20 Larvae)] which was statistically similar (22.50) , (24.16), (19.16) with T_4 [Water Boatman Adult + Low density (20 Larvae)] and followed by T_1 (24.16) , (24.16), (21.66) and T_2 (23.33) , (21.66), (23.33) respectively.

On the other hand, the lowest percentage (%) of mortality was recorded in (5.00) (3.33), (4.16), T_6 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_5 (6.66) (6.66) , (6.66) respectively.

From the (Table 12) it was observed that among the different treatments, T_3 [Water Boatman Nymph + Low Density (20 Larvae)] performed best in 1^{st} instar larvae of mosquito. Whereas, T_6 [Water Strider + Low Density (20 Larvae)] showed the lowest performance in 1^{st} instar larvae of mosquito. As a result the order of rank of study survey of mosquito predator in Dhaka districts and an assessment of their predatorial capacity against mosquito immature, *Culex annulirostris* by number was $T_3 > T_4 > T_1 > T_2 > T_5 > T_6$.

Table 12: Determination of % mortality of mosquito pupae at the different days after treatment

Treatment (s)	% Mortality of mosquito pupae after different days						
	D1	D2	D3	D4	D5	D6	D7
T_1	23.33 a	23.33 a	21.66 a	26.66 a	24.16 a	24.16 a	21.66 a
T_2	21.66 a	23.33 a	23.33 a	21.66 b	23.33 a	21.66 a	23.33 a
T_3	26.66 a	23.33 a	21.66 a	26.66 a	23.33 a	25.00 a	21.66 a
T_4	25.00 a	19.16 a	21.66 a	22.50 ab	22.50 a	24.16 a	19.16 a
T_5	6.66 b	8.33 b	6.66 b	10.00 c	6.66 b	6.66 b	6.66 b
T_6	3.33 b	3.33 c	3.33 b	4.16 d	5.00 b	3.33 b	4.16 b
CV (%)	15.90	16.07	13.93	14.85	15.79	17.17	17.92
LSD (0.05%)	5.02	4.80	4.06	4.91	4.91	5.34	5.13

[T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High density (40 Larvae); T_3= Water Boatman Adult + Low density (20 Larvae); T_4= Water Boatman Adult + High density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae)]

4.5 The mortality of *mosquito* caused by different predators: From figure 1, it was observed that, predator's body mass (mg) increased due to increases the percent of mosquito's mortality. As the mosquito's population killed by individual predators, so the mortality of mosquito will increase.

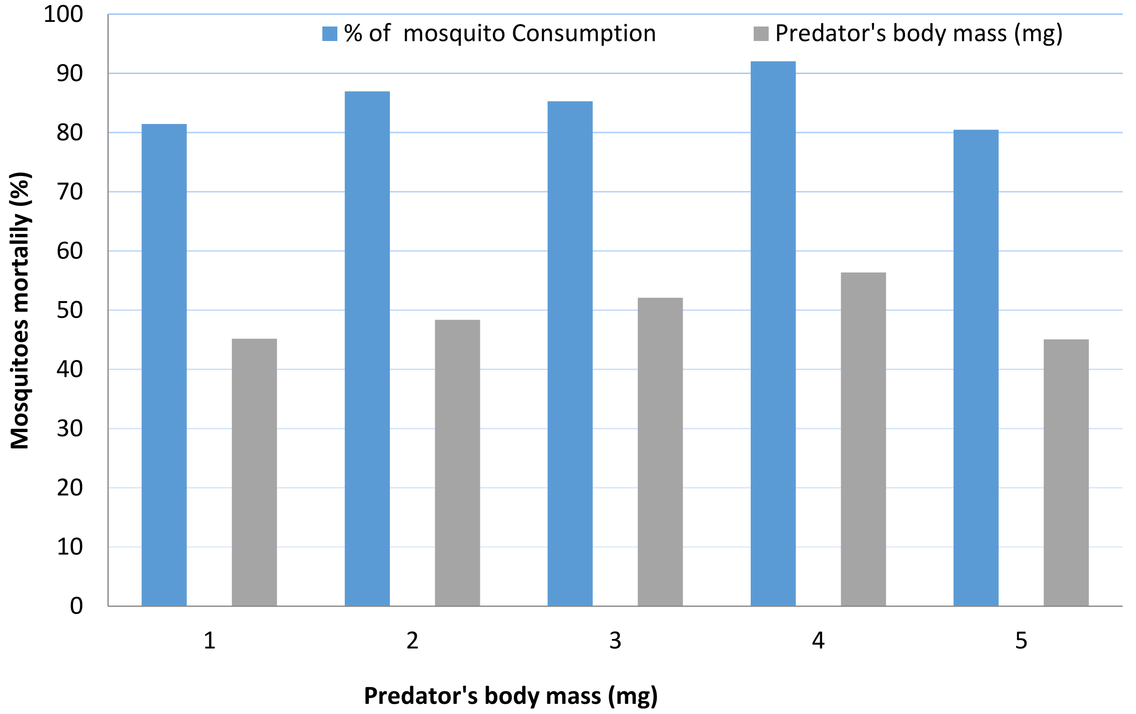


Figure 1: Predator's body mass (mg) and Mosquito mortality

4.6 Relationship between % of mosquito consumption and Predator's body mass (mg) among different observations

Correlation study was done to establish the relationship between % of mosquito Consumption and Predator's body mass (mg) among different observations. From the Figure 3, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = = 0.952x -31.79 gave a good fit to the data and the co-efficient of determination (R^2 = 0.841) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the Predator's body mass (mg) was strongly as well as positively correlated with % of mosquito Consumption. Predator's body mass (mg) was increased due to increase of the % of mosquito Consumption.

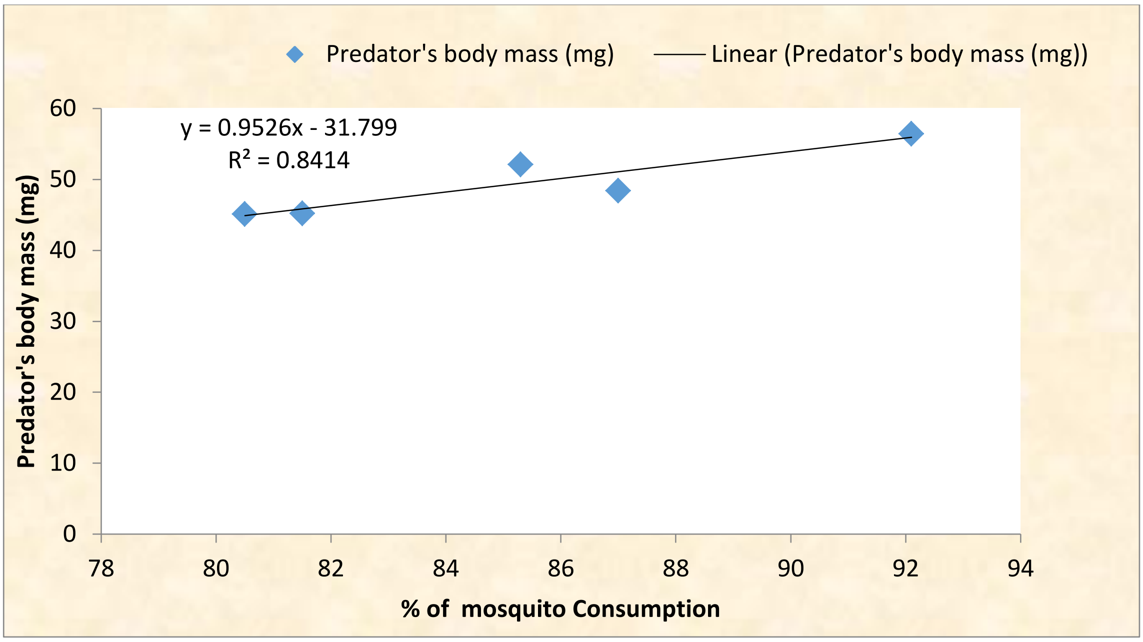


Figure 2: Relationship between % of mosquito Consumption and Predator's body mass (mg) among different observations

CHAPTER V

SUMMARY AND CONCLUSION

Different sets of experiments were conducted at Dr. Wazed miah central laboratory, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, and water logged area in Dhaka city and selected water logging areas of Dhaka district (different upazila nearby Dhaka city and selected different location or point in Dhaka city) in Bangladesh were surveyed to collect information about the predator of different insect species on mosquito during the period of October, 2018 to February, 2019 to find out the inspection of mosquito predators in Dhaka district and an assessment of their predatorial capacity against mosquito *(Culex annulirostris).* Firstly Three aquatics predators such as Giant water bug, *Belostomata indica*; Diplonychus bug, *Diplonychus* sp and W*ater* striders, *Aquarius adelaides* were used to determination of mosquito consumption capacity for assessment of their predatorial capacity against mosquito *(C. annulirostris).* Secondly, the experiment consists of six treatments to determination the mosquito's mortality for assessment of predatorial capacity of mosquito predators against mosquito (*C. annulirostris*). Six treatments, viz. Treatment T_1=Water Boatman Nymph + Low density (20 Larvae); T_2= Water Boatman Nymph + High Density (40 Larvae); T_3= Water Boatman Adult + Low Density (20 Larvae); T_4= Water Boatman Adult + High Density (40 Larvae); T_5=Water Strider + Low Density (20 Larvae); T_6=Water Strider + High Density (40 Larvae).The experiment was laid out Completely Randomized Design (CRD) with five replications .

In term of determination of mosquito consumption capacity, mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *Belostomata indica* ; the second highest and the lowest in Water striders, *A. adelaides.* Incase of *first instar*, mosquito larva capturing efficiency of different species of (Giant water bug, *B. indica*, Diplonychus bug, *D.* sp and Water striders, *A. adelaides*) in first five hours completely similar (100%). But in 1^{st} hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 85, 81.8 and 78.2% respectively.

In case of *2nd instar*, the mosquito larva capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp in first five hours completely similar (100%). On the other hand, mosquito larva capturing efficiency of Water striders, *A. adelaides* in first five hours was not similar (69%). But in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 83.40, 81.68 and 62.20 % respectively.)

In case of *3rd instar,* The mosquito larva capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp and Water striders, *A. adelaides* in first five hours was not similar (90.61, 82.73 and 19.1%). It was observed that, the highest percent of mosquito consumption capacity (90.61%) in Giant water bug, *B. indica,* whereas the lowest percent of mosquito consumption capacity (19.1%) in *Water* striders, *Aquarius adelaides.* It also observed that, in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 74.31, 71.68 and 17.3% respectively.

In case of *4th instar,* between the percent of mosquito consumption by different aquatic predators ($F= 0.010$, $P> 0.05$). The mosquito larva capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp and Water striders, *A. adelaides* in first five hours was not similar (98.3, 85.45 and 9.1%). It was observed that, the highest percent of mosquito consumption capacity (98.3%) in Giant water bug, *B. indica* , whereas the lowest percent of mosquito consumption capacity (9.1%) in *Water* striders, *Aquarius adelaides.* It also observed that, in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica,* Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 43.7, 30.6 and 7.3% respectively.

In case of mosquito pupae consumption capacity, the mosquito pupa capturing efficiency of aquatic predators, Giant water bug, *B. indica,* and Diplonychus bug, *D.* sp and Water striders, *A. adelaides* in first five hours was not similar (87.3, 95.45 and 0.0%). It was observed that, the highest percent of mosquito pupae consumption capacity (95.45%) in Diplonychus bug, *Diplonychus* sp; whereas the lowest percent of mosquito consumption capacity (87.3%) in Giant water bug, *B. indica.* On the other hand, there was no percent of mosquito consumption capacity (0.0%) recorded in aquatic predator W*ater* striders, *Aquarius adelaides.* It also observed that, in 1st hour (9-10am) % of mosquito consumption by Giant water bug, *B. indica*, Diplonychus bug, *D.* sp and Water striders, *A. adelaides* were 41.3, 40.7 and 0.0 % respectively.

In case of mortality results showed that, the significant variations were observed among different growth stage of mosquito larvae such as 1st instar , 2nd instar, 3rd instar , 4th instar and pupae and their percent (%) mortality .

Among six treatments, it was observed that treatment T_3 [Water Boatman Adult + Low Density (20 Larvae)] was the most effective treatment for reducing mosquito.

For 1st instar larvae of mosquito due to different insect predator at one hour interval in observation period, the highest percentage (%) of mortality was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 and T_2. On the other hand, the lowest percentage (%) of mortality was recorded in T_5 [Water Strider Low Density (20 Larvae)] which was statistically similar with T_6.

For 2nd instar larvae of mosquito due to different insect predator at one hour interval in observation period, the highest percentage (%) of mortality was found from T_3 (Water Boatman Nymph + Low Density (20 Larvae) which was statistically similar with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 and T_2. On the other hand, the lowest percentage (%) of mortality was recorded in T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6.

For 3rd instar larvae of mosquito due to different insect predator at one hour interval in observation period, the highest percentage (%) of mortality was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 and T_2. On the other hand, the lowest percentage (%) of mortality was recorded in T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6.

For 4th instar larvae of mosquito due to different insect predator at one hour interval in observation period, the highest percentage (%) of mortality was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar with T_4 [Water Boatman Adult + Low Density (20 Larvae)] and followed by T_1 and

T_2. On the other hand, the lowest percentage (%) of mortality was recorded in T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6.

For pupae of mosquito due to different insect predator at one hour interval in observation period, the highest percentage (%) of mortality was found from T_3 [Water Boatman Nymph + Low Density (20 Larvae)] which was statistically similar with T_4 [Water Boatman Adult Low Density (20 Larvae)] and followed by T_1 and T_2. On the other hand, the lowest percentage (%) of mortality was recorded in T_5 [Water Strider + Low Density (20 Larvae)] which was statistically similar with T_6.

From the results , it was found that the percentage of mortality was increased in 2nd instar than 1st instar larvae and the highest percentage of mortality was found in 3rd instar larvae because it was easier to catch the small size larvae. But percentage of mortality was decreased in 4th instar and 5th instar larvae due to the larger size of mosquito larvae.

CONCLUSION

From this result it was concluded that mosquito larva consumption rate and predatorial capacity was the highest in Giant water bug, *Belostomata indica*, the second highest Diplonychus bug, *Diplonychus* sp and the lowest in Water striders, *A. adelaides. But* the highest percentage of mosquito pupae consumption capacity was by Diplonychus bug, *D.* sp; the lowest percent of mosquito consumption capacity in Giant water bug, *B. indica* and no mosquito consumption recorded in aquatic predator W*ater* striders, *Aquarius adelaides. So,* Giant water bug, *B. indica* showed more predatorial efficiency than other two predators, *Diplonychus* sp and *Aquarius adelaides.* In considering the predatory potentiality, the highest percentage of mortality after different days, in case of 1st, 2nd, 3rd, 4th instar larvae and pupae of mosquito were observed from T_3 treatment; whereas the lowest percentage of mortality were recorded in T_5 treatment, but in case of 4th instar larvae and pupae of mosquito the lowest percentage of mortality were recorded in T_6 treatment. The % mortality rate decreased with the increase of prey size. But, the predatory capacity of adult was found to be higher than the nymph.

CHAPTER VI

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