CHAPTER - 1
GENERAL INTRODUCTION

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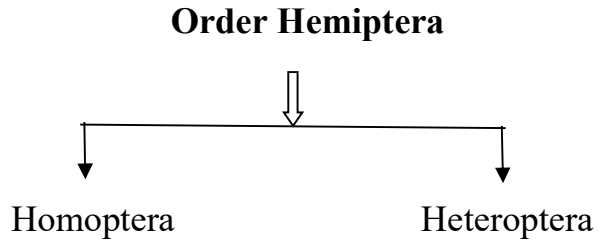
1.1 Classification of Class Insecta

Entomology is a branch of science which deals with the study of insects. It is subdivided in to two sections. One is basic entomology and the other one is applied entomology. The basic entomology deals with the taxonomic as well as the morphometric studies. The applied entomology deals with the well-being of destructive as well as beneficial insects. The insects are originated in the lower Devonian period. Insects are more abundant, unique and a specialized group of invertebrates coming under the major animal Phylum Arthropoda (Arthro - joint or segment, poda - foot or appendage). The distinguishing character of Class Insecta includes the body of an insect is divided into three distinct parts i.e., head, thorax, and abdomen. Head has a pair of antennae. Thorax has three pairs of walking legs (Hexapoda) and one or two pairs of wings (Pterygota). A long abdomen bearing distally the genital appendages. Class Insecta is divided into two Subclasses according to the presence or absence of wings - Apterygota and Pterygota. The entire body organization is evolved so widely, that the Class Insecta again divided into thirty orders based on the structure of wings, mouthparts, and metamorphosis. This study is discussing about the Order Hemiptera.

1.2 Introduction to Order Hemiptera

The Order Hemiptera belongs to the Subclass Pterygota and Division Exopterygota. They are commonly called as “bugs” and usually possess two pairs of wings and undergo incomplete metamorphosis. The most distinguished feature of this order is the "beak," a piercing mouthpart which is well adapted for sucking sap from the plants or blood from the animals. Scutellum is present between the bases of wings. Hemiptera are primarily living in the terrestrial habitats but, some species are secondarily adapted to semi-aquatic and aquatic life. The aquatic and semi-aquatic hemipterans are

commonly called as "water bugs". Majority of this insect order are plant sap feeders but, some are voracious predators and ectoparasites in nature. Few species act as vectors for a various kind of disease-causing pathogen in plants as well as animals. Based on the speciality of wings, this Order Hemiptera again divided in to two Suborders. One group is Suborder Homoptera, in which the forewings are modified into elytra and the beak is used to feed on the fluids of plant tissue. The other one is Suborder Heteroptera, in which the forewings are modified into hemelytra and this order consists of members which are predatory, parasites or detritivores and aquatic Hemiptera belongs to this group.



1.3 Suborder: Heteroptera

The Suborder Heteroptera are a set of about 40,000 species of insects in the Order Hemiptera, also called "true bugs", that name more usually refers to the Hemiptera as a whole, and "typical bugs" might be used as a more unambiguous alternative since among the Hemiptera. The heteropterans are most consistently and generally termed "bugs". "Heteroptera" is Greek for "different wings": the majority species have forewings with both membranous and hardened portions (called hemelytra). The name "Heteroptera" is used in two very different ways in modern classifications; in Linnean nomenclature, it commonly appears as a suborder within the Order Hemiptera, where it can be paraphyletic or monophyletic depending on its delimitation. The Suborder Heteroptera is divided into three divisions based on their habitat preferences and ecological niche, that is terrestrial (Geocorisae or Gymnocerata), semi-aquatic (Amphibicorisae) and aquatic heteropterans (Hydrocorisae or Cryptocerata).

1.3.1 Systematic account of water bugs

The water bugs are classified in to three infraorders such as, Gerromorpha, Nepomorpha, and Leptopodomorpha (Chandra *et al.*, 2017b; Basu & Subramanian, 2017). Nepomorphans are the exclusively aquatic bugs, living under the water. Gerromorphans are semi-aquatic bugs, living on the surface of water, whereas Leptopodomorphans are the shore inhabitants, residing the littoral or intertidal zones (Chandra *et al.*, 2017b). These three Infraorders again subdivided in to 18 families (Thirumalai, 1999c, 2002a, 2007). Each family differs in their morphology as well as habitat preferences. Some of these are fully aquatic and others are semi-aquatic in nature. Among these 18 families, the Family Gerridae, Vellidae, Hydrometridae, Hebridae, Mesoveliidae under the Infraorder Gerromorpha. The Infraorder Nepomorpha consists of Family Aphelocheiridae, Nepidae, Naucoridae, Notonectidae, Corixidae, Micronectidae, Pleidae, Helotrephidae, Ochteridae, Gelastochoridae, and Belostomatidae. The remaining two families such as Leptopodidae and Saldidae are included in the Infraorder Leptopodomorpha.

Classification of water bugs of Indian Sub-region (Basu & Subramanian, 2017)

Infraorder Gerromorpha

Superfamily Gerroidea

Family GERRIDAE

Subfamily Rhagadotarsinae

Subfamily Trepobatinae

Subfamily Gerrinae

Subfamily Eotrechinae

Subfamily Cylindrostethinae

Subfamily Ptilomerinae

Subfamily Halobatinae

Family VELIIDAE

Subfamily Microveliinae

Subfamily Rhagoveliinae

Subfamily Haloveliinae

Subfamily Veliinae

Subfamily Perittopinae

Superfamily Mesovelioidea

Family MESOVELIIDAE

Subfamily Mesoveliinae

Superfamily Hydrometroidea

Family HYDROMETRIDAE

Subfamily Hydrometrinae

Superfamily Hebroidea

Family HEBRIDAE

Subfamily Hebrinae

Subfamily Hyrcaninae

Infraorder Nepomorpha

Superfamily Nepoidea

Family NEPIDAE

Subfamily Nepinae

Subfamily Ranatrinae

Family BELOSTOMATIDAE

Subfamily Belostomatinae

Subfamily Lethocerinae

Superfamily Ochteroidea

Family GELASTOCORIDAE

Subfamily Nerthrinae

Family OCHTERIDAE

Superfamily Corixoidea

Family CORIXIDAE

Subfamily Corixinae

Subfamily Cymatinae

Family MICRONECTIDAE

Subfamily Micronectinae

Superfamily Naucoroidea

Family APHELOCHEIRIDAE

Subfamily Aphelocheirinae

Family NAUCORIDAE

Subfamily Cheirochelinae

Subfamily Laccocorinae

Subfamily Naucorinae

Superfamily Notonectoidea

Family NOTONECTIDAE

Subfamily Anisopinae

Subfamily Notonectinae

Superfamily Pleoidea

Family PLEIDAE

Family HELOTREPHIDAE

Subfamily Fischerotrephinae

Subfamily Helotrephinae

Infraorder Leptopodomorpha

Family LEPTOPODIDAE

Family SALDIDAE

1.3.2 General morphology

The body of water bugs are divided in to three parts viz., head, thorax, and abdomen. Head consists of a pair of compound eyes, two ocelli (which is absent in most families), a pair of antennae, large sensory bristles (Trichobothria), and the mouth parts merged to form the rostrum or beak. Thorax contains three segments such as pro, meso, and metathorax. The exoskeleton consists of three sclerites such as the dorsal (notum), lateral (pleurite) and ventral (sternum). The notum consists of three segments such as pronotum, mesonotum and metanotum. The other two sclerites are famed in the same manner. There is a triangular shaped sclerites called scutellum on the anterior part of the pronotum. Each thoracic segments constitutes three pairs of legs. Mesothorax and metathorax consists of two pairs of wings. In Heteroptera, some species consists of highly adapted forelegs (raptorial legs). The forewings are leathery in basal portion and membranous in distally (called Hemelytra). The abdomen consists of two sclerites such as abdominal tergites and sternites. The genitalia are situated on the nineth segment of the abdomen.

1.3.3 Life cycle

The water bugs are hemimetabolous insect. The developmental stage completes from egg to nymph to adult **(**Plate 1: Fig. 4a-4c). They produce one or more generations per year. The life cycle of water bugs depends on the temperature of aquatic ecosystems and the availability of food resources (Chandra *et al.*, 2017a). The aquatic heteropteran bugs shows sexual dimorphism. The adult males are usually smaller in size than females. They mate almost throughout the year. The water bugs stridulate to attract their mates (Basu & Subramanian, 2017). The life cycle of water bugs completing their life cycle fully on or under the water surface (Chen *et al.*, 2005). The females release their eggs on water and the eggs are glued to the substratum or the aquatic vegetation with the flattened side or basal adhesive disc. The eggs are usually oval, or spindle shaped in appearance (Fig. 4a). The female Belostomatid bug lay eggs on the dorsal side of the male bug and this male bug guard their eggs until hatching. The nymphal stage completes through the five instars. The nymphs are morphologically resembling the adult bugs (Fig. 4b & 4c),

but without the development of reproductive structures. Some species of water such as Mesovelia, Microvelia and Rhagovelia bugs are completes their nymphal stage only through four instars. The life cycle of the water bugs may complete from 2 to 3 months (Leong, 1962; Chandra *et al.*, 2017a). The adult water bugs can be easily distinguished by the division of the insect body.

1.3.4 Adaptations to aquatic life

The Suborder Heteroptera has a diverse group of bug species, which are adapted to various habitats like terrestrial, fully aquatic, and semi-aquatic. Terrestrial bugs are often associated with plants. The aquatic and semi aquatic bug species are mainly inhabited in the freshwater although some species are inhabited in brackish water as well as marine ecosystems. So, these bugs are commonly called as "water bugs". The water bugs belonging to the Infraorder Nepomorpha are commonly live under the water, but the Infraorder Gerromorpha are present only on the water surface. All the members of the water bugs migrate to new aquatic habitats and some species are attracted to light (Chandra *et al.*, 2017b; Basu & Subramanian, 2017). In the case of Infraorder Leptodomorpha are found near the aquatic ecosystems. That's why they commonly called "shore bugs".

The water bugs have various kinds of adaptations to live in the aquatic ecosystems. The Family Gerridae is fully living on the water surface, and they have the adaptations with long to very long middle legs for rowing (Chen *et al.*, 2005); sub-apical claws and other tarsal modifications; receptors for detecting surface disturbances (Andersen, 1982). Most of the aquatic bugs have hairy structures on the appendages for swimming. The families of Nepidae and Belostomatidae are living completely under water thus, they consist of a specialized breathing system i.e., pair of breathing tubes, called as respiratory siphon or respiratory tube, present on the last abdominal tergites, which is take oxygen from the atmosphere for respiration.

1.3.5 Predatory behaviour

The most of the aquatic heteropteran species shows exclusively predatory nature and they feed on small to medium sized, living, or dead insects and other invertebrates of the aquatic ecosystem. They are the most important component in the food web of aquatic fauna. It is also observed that in the starvation these bugs show cannibalistic behaviour, the stronger predators feed upon the weaker ones. They have various morphological adaptations especially the forelegs are well specialized (raptorial) to capture and holding the prey.

The aquatic bugs are not fast swimmers rather than slow movers in water although they are the ambush attackers. They hide in the aquatic vegetation and quietly wait for the chance of any prey of suitable size come close to them. They attack the prey with the help of their raptorial forelegs and pierce the rostral beak into the body of the prey and inject the saliva to immobilize it (Ranjini & Kakkassery, 2019). Their beak is well developed for biting and killing the captured prey and they use a solid to liquid feeding method by sucking nutrient solid or semi-solid body parts of their prey (Bal & Biswas, 2013).

1.4 Economic importance of water bugs

Among the various groups of aquatic insects, water bugs are beneficial to humans in many ways (Chen *et al.*, 2005). They are important as fish food, key stone predators, bioindicators, and biocontrol agents. The larval forms of water bugs used as live feed for fishery farm industry. The adult water bugs can be used as bioindicators as well as biological control agents. Many species of water bugs are very good predators, they contribute to the control of aquatic vectors especially different kinds of mosquito larvae, and water snails such as *Lymnaea* and *Indoplanorbis* (intermediate host of liver fluke), which are harmful to mankind as well as domestic animals. They are very important as bioindicator species that characterize the health of aquatic habitat. They respond to the stress of aquatic habitat either by changing their abundance or presence/absence of these water bugs.

1.5 Significance of the present study

Aquatic Heteroptera have significant ecological roles and economic importance, which has probably been underestimated. Around the world, freshwater habitats are being exposed to increased levels of anthropogenic activities (Saunders *et al.,* 2002) which leads to severe water pollution and finally affects the survival of different aquatic diversity. Aquatic biodiversity is one of the most important characteristics of an aquatic ecosystem for sustaining the ecological stability (Vinson & Hawkins, 1998). The study of different groups of the freshwater habitats aims at frequent monitoring the health of the aquatic ecosystems (Sivaramakrishnan, *et al.,* 1996). The water bugs are the abundant groups in the aquatic ecosystems. The present taxa of water bugs from the selected habitats of Kerala provided baseline data for future research studies. There are no specialized tools such as taxonomic key presently available for the identification of this group from this region. In this context, the taxonomic key provided more useful for the upcoming researchers and future references.

Most of the aquatic insects with their life stages are predatory in nature (Rajan, 2016). The water bugs are one of the prominent groups in freshwater habitats. Water bugs are important generalist predators in freshwater habitat, and they maintain the prey – predator balance (Saha *et al*., 2010; Gilbert & Burns, 1999). This quality favours the water bugs are used as biological control agents. Nowadays, the mosquito borne diseases such as Malaria, Filariasis, Dengue fever and Chikungunya are more prevalent in Kerala due to different kinds of anthropogenic activities, unplanned urbanization, and loss of biological control agents. Although, the filarial vector, *Culex* mosquitoes especially *Culex quinquefasciatus* Say, 1823, they are commonly called as 'Sothern house mosquito' found dominant in this tropical region. The usage of the chemicals or the pesticides against mosquitoes including larvae, will be eluted to aquatic habitats, which accumulates and magnify through the food chain and finally reaches to human beings. So, in this situation, it is very urgent to find out and conserve the natural biological agents by using to decrease the population of this *Culex* mosquitoes. It is very easy to control the larval forms of this mosquitoes rather than adult forms. Some species under the families of

water bugs such as Belostomatidae and Nepidae are very good predators and their abundance is crucial to the existence of animal communities in an aquatic ecosystem (Murdoch *et al.*, 1984). Water bugs are often included in the lists of biological control agents, no doubt because they prey upon mosquito larvae. The observations and results of this study provided information and knowledge to the Science.

1.6 Objectives of the proposed work

The major objectives of the study include,

- To study the taxonomy of the aquatic heteropterans from selected habitats of Kerala.
- To generate the taxonomic key of explored water bugs.
- To assess the efficacy of selected species of this group as biocontrol agents on mosquito larvae of *Culex quinquefasciatus* Say.

PLATE – 1

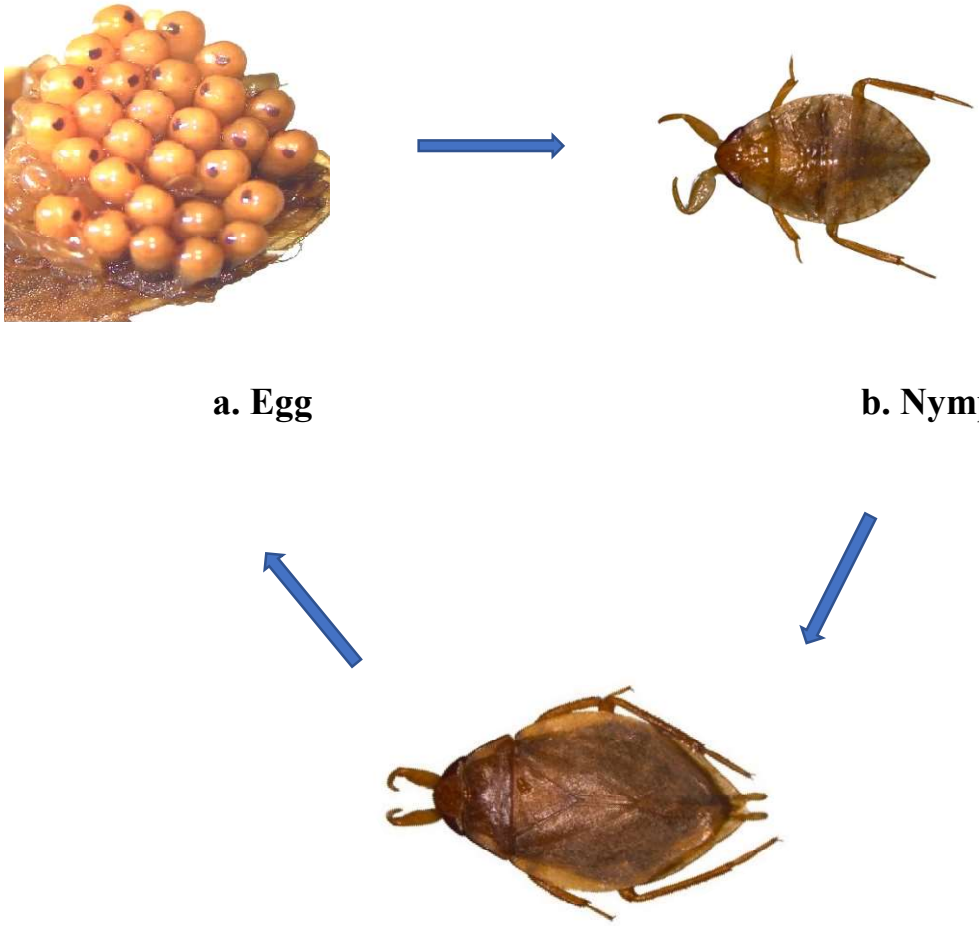


Figure 4. (a-c): Life cycle stages of *Diplonychus molestus* Dufour, 1863.