Chapter - VII

MACROINVERTEBRATES POPULATION IN THE SELECTED WETLANDS

7.1. Introduction

The freshwater bodies including wetlands harbour organisms that generate oxygen in the surrounding environment which is utilized by members of all trophic levels and these aquatic assets also provide habitats to a large number of diverse aquatic organisms [150]. One such aquatic fauna is macroinvertebrates, though may be tiny and spineless, but when it comes to represent a wetland function and cycling of nutrients, they always play a major role. Most macroinvertebrates are too small to noticeably stir the water's surface, but are large enough to see with the naked eye. They include small worms, snails, slugs, leeches, crabs, shrimps and insect larvae. Besides playing a star role in many important wetland functions, macroinvertebrates are sometimes employed as a tool for characterizing aquatic habitats and learning about aquatic habitat water quality.

It is estimated that about 3% of the total macroinvertebrates are aquatic, spending at least a part of their life cycles in the water which include nearly 25,000–30,000 species [151]. Aquatic macroinvertebrates play a vital role in the ecosystem and in the circulation and recirculation of nutrients in aquatic ecosystem by accelerating the breakdown of decaying organic matter into simpler inorganic forms [79]. These organisms may be sensitive to changes in the environment such as pollution, habitat fragmentation and other stresses that degrade the ecological diversity. Therefore, aquatic macroinvertebrates have been identified as an excellent tool for bio-monitoring as they respond rapidly to the environmental changes. However, the water and soil quality have a pronounced influenced in the diversity of macroinvertebrate because of their spontaneous ability to encounter such changes. With this background, macroinvertebrate population was studied in the selected wetlands of the basin with an aim to assess the ecological status and health of the wetlands and correlate among the wetlands together with the variety and abundance of macroinvertebrates encountered during the study period.

7.2. Data Collection and Analysis

Identification of the aquatic insects were done and categorized into groups varying from pollution tolerant to extremely sensitive group of insects, to create a biotic stress indicator for the region. Dip nets and Sieves were used to collect groups or individuals of macroinvertebrates. The samples were counted manually and preserved immediately in 4% formalin. They were examined and identified, using the Aquatic Insects of India Field Guide [6] and Water Bug Detective Guide [24]. The sampling was done for four seasons for two years i.e. 2013 and 2014. Detail sampling techniques and procedures have been discussed already in ***Chapter III, Section 3.3.9.***

7.3. Results and Discussion

The observation and the results generated from the study are discussed and presented at ***Table 7.2***. However prior to the detail discussion, the taxonomic classification and significant features of the macroinvertebrates encountered during the study are discussed as below.

7.3.1. Taxonomic Characteristics of the Macroinvertebrates

A total of 150-200 individuals were collected from each of the wetlands and 21 families of macroinvertebrates were encountered collectively in the wetlands. The macroinvertebrates were classified on the basis of their relative pollution tolerance capabilities, such as – ‘Pollution Intolerant’, ‘Somewhat Pollution Tolerant’ and ‘Very Tolerant’ as presented in ***Table 7.1***.

Pollution intolerant insects fall in the group of *Ephemeroptera*, *Trichoptera* and *Plecoptera*. Somewhat tolerant are *Odonata, Coleoptera, Lepidoptera, Aranea and Decapoda* like *Penaeidae* and ‘Very Tolerant’ falls in the group of *Hemiptera, Hygrophila, Oligochaetes*, *Hirudinea,* etc. which is presented in Table 7.1. ‘Pollution Intolerant’ group of aquatic insects demand for a specific habitat quality like higher DO (>5 mg/l), neutral pH value in the range of 6.5 – 7.5 and stable temperature. Most of the ‘Somewhat Tolerant’ group basically require emergent or submerging vegetation, such as cattails for resting and for laying their eggs and they prefer for standing water. However, some of the pollution intolerant insects are also found on the macrophytes. The ‘Very Tolerant’ group can withstand lower DO, lower or higher pH and warmer temperature.

Table 7.1. Macroinvertebrates showing the relative Pollution Index

Pollution Index	Family
Pollution Intolerant	Hydropsychidae
	Ephemeridae
	Baetiscidae
	Caenidae
Somewhat Tolerant	Gomphidae
	Aeshnidae
	Libelluloidea
	Lestidae
	Elmidae
	Gyrinidae
	Dytiscidae
	Penaeidae
	Pyralidae
	Pisauridae
Very Tolerant	Potamonidae
	Lymnaeidae
	Hirudinidae
	Belastomatidae
	Nepidae
	Gerridae
	Olegochaetes

The taxonomic classification and detail features of the encountered and examined aquatic insects in the study are illustrated as follows.

1. Trichoptera (Caddisflies)

The order *Trichoptera* (*caddisflies*) has four life stages - egg, larva, pupa, and adult. In most of the families, the female deposits eggs in or above water and the larva undergoes five stages, or instars, before fastening its case to a solid substrate when entering the pupal stage. Generally, the pupa emerges as an adult after two or three weeks [152].

The family *Hydropsychidae* of *Trichoptera* group was encountered during the study period in the study area and the photograph is presented at ***Plate 7.1***.

(a) Hydropsychidae

It belongs to the most sensitive group of aquatic insects. The photoplates of *Hydropsychidae* is presented at ***Plate 7.1*** and the distinguishing features of *Hydropsychidae* family are

(i) Anal claws hook-shaped

(ii) No portable case

(iii) Thoracic segments covered by sclerites

(iv) Branched gills in rows on abdomen

(v) Anal claw with prominent brush of hairs at base [152]

Plate 7.1: *Hydropsychidae*

2. *Ephemeroptera (Mayfly)*

The order *Ephemeroptera*, mayfly has four life stages - egg, larva, sub-imago, and imago (adult). The female lays eggs in water and most species of larvae hatch from a week to several months later. All larvae are aquatic and undergo more instars (periods between molts) than any other insect order. Larvae spend from 3 months to 2 or more years in the water before emerging from the water as subimagos. Mayflies are the only insects with a subimago instar, which possesses fully functional wings along with an immature reproductive system. Within approximately 24 hours, the subimago sheds its skin (molts) and becomes an imago [153].

Mayfly larvae live in a wide variety of aquatic habitats. Some kinds live in both standing and running water; other kinds live in only one or the other. Both their presence and abundance are excellent indicators of the quality or “health” of aquatic environments. Three families of *Ephemeroptera*, namely – *Ephemeridae*, *Baeticidae* and *Caenidae* were spotted during the study and the photographs are presented at ***Plate 7.2***. General features of these three aquatic insects are discussed below –

(a) Ephemeridae

This is one of the larger mayfly larva found worldwide. Larvae burrow in the silt of rivers, streams, ponds, or lakes where they build U-shaped burrows less than six inches. They are generally particle feeders and feed on microorganisms in the sediment. Size of the common burrowers at maturity is 12-32 mm [154]. Some of the basic features of *Ephemeridae* are as mentioned below –

- *(i)* The tusks lack spines or the spines are located on the outside edge of the tusk.
- *(ii)* Gills are forked with fringed margins and are dorsal.
- *(iii)* Their legs are fossorial and are used for digging a burrow into the river sediments.
- *(iv)* Also known as the burrowing mayfly, it burrows u-shape paths in the silt.
- *(v)* Wing pads are free and separate [154]

(b) ***Baetidae***

The small minnow mayflies which are usually small, streamlined larvae that measure 3-12 mm when mature. Different species emerge at different times of the year, from August to May, and so there can be several generations of *Baetidae* nymphs living in the water simultaneously. *Baetidae* nymphs occur in almost all freshwater habitats, including the fast flowing riffle zone of rivers to the slack waters of rivers, wetlands, billabongs and farm dams, but they are most diverse in cool and flowing waters [155]. The nymphs are usually found near or on aquatic macrophytes. *Baetidae* nymphs scrape algae and fine detritus from submerged rocks, wood and macrophytes. Nymphs are strong swimmers and move with a rapid up and down motion of their abdomen [155]. Significant features of *Baetidae* are as follows –

- *(i)* One of the most apparent features of this group is the long antennae. They are usually two or three times longer than the head's width.
- *(ii)* Their hind wing pads are sometime absent or minute.
- *(iii)* Oval or heart-shaped gills are present on abdominal segments (but these gills often are broken off during collecting).
- *(iv)* Posterior abdominal segments usually lack spines pointing backwards, but rarely have moderately developed spines.
- *(v)* Their head is vertically oriented and either 2 or 3 tails are present [156]

(c) ***Caenidae***

Caenidae nymphs occur in slow flowing silty areas of stony streams, rivers, billabongs and lakes. They typically dwell in leaf packs, on logs or macrophytes. Nymphs feed on fine particulate detritus. The operculate gills (gill covers) are thought to protect the other delicate posterior gills from becoming clogged by fine sediment [57]. They are sprawling nymphs and poor swimmers that mostly crawl along the riverbed. The body is covered in a layer of fine hairs which can give them a "fuzzy" appearance when fine algae or detritus is trapped. *Caenidae* species typically have one or two generations per year with adults emerging in spring and summer [157]. *Caenidae* nymphs are more pollution tolerant than other families of *Ephemeroptera.* General features of *Caenidae* are –

(i) The most obvious feature of the Square-gills is their square shaped operculate gills on abdominal segment two.

(ii) The inner edges of these gills meet or almost meet medially.

(iii) They have a robust thorax with the notum fused between fore wing pads for at least half length of pads.

(iv) They do not have long setae on forelegs [158].

(a)

(b)

(c)

Plate 7.2: (a). *Caenidae* (b). *Baetidae* and (c). *Ephemeridae*

3. Odonata

The order *Odonata* ("toothed ones") includes some of the most ancient and beautiful insects that ever roamed earth, as well as some of the largest flying invertebrates ever to have lived. Many characteristics distinguish *Odonata* from other groups of insects – minute antennae, extremely large eyes (filling most of the head), two pairs of transparent membranous wings with many small veins, a long slender abdomen, an aquatic larval stage (nymph) with posterior tracheal gills, and a prehensile labium (extendible jaws underneath the head). *Odonata* consists of three groups – *Anisoptera* (which includes dragonflies), *Zygoptera* (which includes damselflies), and *Anisozygoptera* (a relict group represented by only two living species) [159]. Though they share some of the common features, there are some noticeable differences as well. For example, dragonfly eggs are round and about 0.5 mm long, whereas damselfly eggs are cylindrical and longer, about 1 mm long. Similarly, the nymphs (larvae) of the two groups differ. A larval damselfly abdomen is longer and narrower with three fin-like gills projecting from the end. Dragonfly nymphs are shorter and bulkier, and the gills are located inside the abdomen. Four families of *Odonata* were encountered during the study**.** General features and their habitat ecology are discussed below –

(a) Gomphidae

Gomphidae or Clubtail larvae are burrowing predators which lie in wait for their prey and the photograph is presented at ***Plate 7.3***. They are found in a variety of aquatic habitats including rivers and ponds. They overwinter as eggs. The size of clubtail nymphs at maturity is 23-40 mm and sometimes up to 65 mm [160]. Distinguishing characteristics of *Gomphidae* are as follows -

(i) The club-tails have a four segmented antennae with the third segment large and the fourth segment small.

(ii) The ligula is lacking a median cleft.

(iii) The prementum and palpal lobes of the labium are flat or nearly so.

(iv) They have two segmented tarsus on the midleg [160].

(b) Libelluloidea

They are found in a variety of still water environments including ponds and the still edges of streams and rivers. They are predators that feed on small animals the photograph of this insect is shown at ***Plate 7.3***. They overwinter as eggs. The size of the Common Skimmers at maturity is 8-28 mm [161]. Distinguishing features of *Libelluloidea* are -

(i) The prementum and palpal lobes of the labium of the common skimmers is in a spoon-shape mask that covers the lower half of the "face".

(ii) Their crenulations are separated by shallow notches not deep notches as in *Corduliidae*.

(iii) The lateral spines of segment eight are as long as or longer than the midlength of segment nine.

(iv) They have cerci that are not more than 1/2 as long as the paraprocts [161]

(a) **(b)**

Plate 7.3: *(a). Gomphidae* and *(b). Libelluloidea*

(c) Aeshnidae

The darner nymphs are found in slow moving rivers and streams as well as ponds and marshes. They are predators that climb through the vegetation stalking their prey, which includes a wide variety of small animals, including fish. They overwinter as eggs. The size of the darner nymphs at maturity is 31-50 mm, although sometimes more than that [162]. General features of *Aeshnidae* are mentioned below –

(i) The darners have 6 or 7 segmented antennae that are slender and bristle like.

(ii) Their ligula contains a median cleft.

(iii) The fore and middle tarsi are three segmented.

(iv) Their prementum widens towards the distal half [162]

(d)Lestidae

Spread-winged damselfly larvae are climbers that are found on submerged vegetation in a wide variety of environments including streams and almost any small standing water environment. They are predators that feed on small animals. They overwinter as eggs. The size of the Spread-winged Damselflies at maturity is 20-29 mm excluding caudal lamellae [163]. Distinguishing characteristics of *Lestidae* are as follows -

(i) The spread-winged damselflies have antennae segments which are about the same length.

(ii) They have a prementum which has a narrow stalk at the base and expands at the palpal lobes.

(iii) Lateral tracheal branches of the caudal lamellae are nearly at a right angle to the central tracheal trunk [163].

4.Coleoptera

The *Coleoptera* or Beetles are the most numerous, in terms of species on this planet. They belong to a diverse and interesting Order with many Families that are aquatic. There are also several Families with only aquatic adults, one Family with only aquatic larvae. Beetles undergo complete metamorphosis. This means they have distinct egg, larval, pupal, and adult stages. The larvae and adult bear no resemblance to each other. Interestingly, the intervening pupal stage is terrestrial. When the aquatic larvae is ready to pupate and undergo metamorphosis into an adult, it will crawl onto shore and either burrow into the soil or find a protective area to pupate. When the adult emerges, it will re-enter in water. Adult beetles are characterized by the hard outer covering, called elytra, that covers their backs [164]. The elytra are actually the front pair of wings which have been modified into protective plates. Adult beetles have chewing mouthparts and six distinct legs. Larval beetles are very diverse from one group to the next. Some are elongate with gills; others are caterpillar like - although all have distinct segmented legs [164]. During the study period, three families of *coleoptera* were spotted. Distinguishing features and habitat ecology of these families are discussed below -

(a) Elmidae

Riffle Beetles are commonly found in gravel and rocky bottoms in riffles of rivers and streams while some are found in lakes with considerable wave action. The photograph of this aquatic insect is presented at ***Plate 7.4***. Most of them feed on periphyton, but some are detrovites. They use well developed plastrons, and some don't need to resurface in well oxygenated water. The size of the Riffle Beetles at maturity is 1-8 mm [165]. Distinguishing characteristics are –

- *(i)* The riffle beetles usually have filiform antennae that are much longer that the head.
- *(ii)* Their tarsi are distinctly five segmented.
- *(iii)* They are underwater crawlers and do not swim, therefore they have no swimming hairs on their hind legs.
- *(iv)* They have 5-6 abdominal segments [165]

(b) Gyrinidae

The Whirligig Beetles belong to *Gyrinidae* family and are found in a variety of aquatic habitats, generally on the surface of quiet waters. It is thought that the two pair of eyes is an adaptation for seeing both what is above them in the air and what is below them in the water. They are predators of small organisms and scavengers of floating material [166]. They secrete a substance that makes them unpleasant to fish and other predators. The size of the Whirligig Beetles at maturity is 3-15 mm. Distinguishing characteristics are –

(i) The whirligig beetles are easily identified by having both a dorsal and ventral pairs of eyes.

(ii) They are oval shaped beetles that are strong swimmers and will often twirl about rapidly in circles on or near the surface.

(iii) They have short, clubbed antennae [166]

(a)

(b)

Plate 7.4: (a). *Elmidae* and (b). *Gyrinidae*

(c)Dytiscidae

The Diving Beetles are a large and fairly common group. They are found in almost every kind of aquatic habitat, although less common in swift currents of streams and rivers. They are predators which feed on a variety of small animals, including small fish. The size of the Predaceous Diving Beetles at maturity is 1-40 mm; however the range is usually 3-25 mm [167]. Distinguishing characteristics are –

(i) The predaceous diving beetles are swimmers and so have swimming hairs on their hind legs.

(ii) Their antennae are usually long and not clubbed.

(iii) The ventral side of their thorax usually has distinct notoplural sutures.

(iv) The medial portion of the hind coxae extend posteriorly to divide abdominal sternite one into lateral sclerites [167]

5. *Lepidoptera*

The *Lepidpotera*, which includes the butterflies and moths, are not normally thought of as being aquatic insects [168]. However, there are a few groups with aquatic larvae (caterpillars) and most of them feed on aquatic vegetation. In this study, only one family of this order *Lepidoptera* was encountered. General features and habitat ecology are discussed below –

(a) Pyralidae

Overwintering is done as larva. They live in lentic habitats with a few exceptions and are herbivores. The size of the Aquatic *Pyralidae* moths at maturity is 3-35 mm [169]. Distinguishing characteristics are –

(i) The aquatic *Pyralidae* moths have pro-legs.

(ii) The pro-legs on abdominal segments 3-6 and 10 have crochets.

(iii) They lack both an anal fork and an anal horn on the terminal abdominal segment.

6. *Aranaea*

The *Araneae* are the true spiders and almost all spiders have only five segments in the abdomen. Spiders are one of the most easily recognisable orders among the invertebrates and differ from other arachnids in having abdominal glands that produce silk. Spiders come in a variety of shapes, colours and sizes. They can range in size from minute to spiders less than 0.5 millimetres and up to a huge size with a 20 centimetre leg-span [170]. Most species of spider are active at night and all are predatory, feeding on a wide range of other invertebrates. Spiders are found in all terrestrial habitats and some have even adapted to a semi-aquatic lifestyle. They are common inhabitants of almost every kind of habitat. In the present study, *Pisauridae* family of the order *Araneae* was encountered and the photograph is presented at ***Plate 7.5***. This family of spiders are called water or fishing spiders. Some spiders in this family wait for prey at the water's edge. Their front legs rest on the surface, sensing vibrations [170]. They can grab tadpoles or fish swimming past, or race across the water to seize insects that falls in. Some *Pisauridae* form underwater retreats in large air bubbles, others make their webs in green leaves of shrubs [170]. Basic information and features of this family are discussed below -

(i) The eyes are arranged in three rows, with the first row composed of four eyes in a transverse row.

(ii) They have elongated bodies with different markings.

(iii) They are large spiders with long legs. The first two pairs often are held together at an angle when resting and when sensing prey.

Plate 7.5: *Pisauridae*

7. Decapoda

It belongs to the class *Malacostraca* which is divided into five orders with over 10,000 species, the largest being *Decapoda*. This order also contains the biggest and most familiar crustaceans, such as shrimp, lobsters, crayfish, and crabs. *Decapodas* are primarily marine animals and are most abundant in warm, shallow tropical waters; but they are exploited commercially throughout the world. Approximately 10 percent of known *Decapoda* species occur in freshwater or terrestrial habitats. Survival in freshwater depends upon an organism's ability to keep its blood concentration at a level higher than the medium and to reduce the permeability of its body surface. Terrestrial *decapods* must usually return to the sea to spawn, while most freshwater *decapods* spend their entire life cycle in fresh water, commonly hatching their young as miniature adults. *Decapodas* have three distinct body regions, each made up of segments, or somites - the head, thorax, and abdomen [171]. A pair of appendages is attached to each somite. The first two pairs, the first and second antennae, consist of a segmented stalk and flagella. A head shield, or carapace, covers the cephalothorax and extends over the gills, which are attached to the body wall of the thorax. The eyes, which may be absent in some deep-sea species, are usually well-developed with a pigmented, multifaceted cornea.

The *Peneidae* shrimps and *Potamonidae* crabs were spotted during the study period. Basic information and habitat ecology are discussed below.

(a) Penaeidae:

This family of shrimps contains some of the most valuable commercial species of shrimps and the photograph is shown at ***Plate 7.6***. They are small to medium sized animals with well developed and foliaceous prosartema. The cervical groove seldom reaches beyond half the distance between the hepatic spine and dorsum of the carapace. Maxilliped III has no epipodite and the exopodites are long, usually reaching to or beyond merus of endopodite [172]. Appendix masculina does not contain an appendix internal.

Plate 7.6: *Penaeidae*

(b) Potamonidae

They have wide range of distribution all over India and basically small and medium sized crabs. Most freshwater crabs are nocturnal scavengers or opportunistic predators, and some species have economic and ecological importance. Their habitats are varied-ponds, ditches, rice fields, irrigation channels, manmade reservoirs, slow flowing and torrential streams [173]. Some are found in the water, while some inhabit burrows close to the water. Some of the identification keys of *Potamonida*e are discussed below -

(i) The carapace is fairly broad, convex with an uneven surface.

(ii) The lateral epibranchial tooth is very minute.

(iii) The antero-lateral borders of carapace are cut into four claw like spines.

(iv) In the adult female, the chelipeds are almost equal and are rather slender and shorter than the legs.

8. Hygrophila

Hygrophila species occur in a wide variety of freshwater habitats from stagnant pools to fast flowing creeks and rivers. They are found amongst macrophytes and algae, in soft sediments or on woody debris. *Hygrophila* snails are scrapers feeding on algae, macrophytes and diatoms [174]. *Hygrophila* eggs are usually laid in a gelatinous mass. Young hatch as miniature forms of the adult. They reproduce once or twice per year. The life span is about seven to twelve months. They have a diversity of shell forms and do not have an operculum. All species have an enclosed, air-breathing lung, although several species have also evolved external respiratory gills. The eyes are located at the base of a single pair of non-retractable sensory tentacles attached to the head. During the study the *Lymnaeidae* Family of this Order was recorded and the photograph of this Family is presented at ***Plate 7.7.***

(a) Lymnaeidae:

Nearly all *Lymnaeidae* species occur in slow flowing or still waters, where they are found in mud or on plants in shallow water. *Lymnaeidae* species thrive in eutrophic conditions. *Lymnaeidae* species are scrapers feeding on algae. *Lymnaeidae* snails can hang suspended upside down on the surface film by their very wide, muscular foot with the pneumostome open to the air [174]. This may allow them to live in waters with low dissolved oxygen. *Lymnaeidae* species are hermaphrodites capable of self-fertilisation but typically eggs are fertilised in both parents during copulation. Eggs are laid in a gelatinous mass. Young hatch as miniature forms of the adult. Most *Lymnaeidae* snails are short lived. General information describing the features are discussed below –

(i) True molluscan gill is lost and is replaced by various types of secondary gills in some groups.

(ii) Positions of eyes relative to tentacles are variable, usually at inner bases or at middle of bases.

(iii) Hermaphroditic (simultaneous or protandric)

(iv) Operculum is typically absent, present in 2 basal families (one estuarine).

(v) Mantle cavity is modified as pulmonary cavity.

(vi) Head and snout are spread laterally.

(vii) Radula has many tooth rows (most teeth rather similar).

*(viii)*Eyes are on inner side of tentacle bases.

(ix) Shell coiled, dextral, ovate, spire are short to moderate.

(x) Mantle edge is simple, no pseudo branch [174].

Plate 7.7: *Lymnaeidae*

9. Hirudinea

Leeches are worms that live off of blood or hunt small aquatic animals. Most leeches are fresh water and completely terrestrial, whereas some are marine. Leeches prey on small invertebrates or they feed on the body fluids of vertebrates [175]. They have a tough, moveable body and two suction pads, one in front and one in back. Small teeth are located in the front suction pad, which are used to make wounds. Their major characteristics are –

(i) The segments at either end have been modified to form attachment suckers around the mouth and another (usually much smaller) at the posterior end.

(ii) The sucker around the mouth is usually the smaller.

(iii) Their body functions as a single hydrostatic skeleton as the internal divisions or septa have been lost.

(iv) They do not have Chaetae.

The Family *Hirudinidae* of the order *Hirudinea* has been encountered during the study and the photograph of this Family is shown at ***Plate 7.8***.

(a) Hirudinidae

It is one of the largest groups of *Hirudinea* and has an elongated body. This is a variable family of leeches [175]. Most of them are freshwater leeches. *Hirundinidae* are either predators or blood suckers. Some of the identification keys are presented below -

(i) They are found in the range of smallest to the largest group of leeches.

(ii) Body coloration varies from light to dark.

(iii) Some of them have ribbon like and wormlike with patterns of line on the back.

(iv) Size found in the range of 1-10 inches.

Plate 7.8: *Hirudinidae*

10.Hemiptera

This is called true bugs where the life cycle of water bugs exhibits incomplete metamorphosis. This means that there is not much change between the larval and adult versions of the bug. The larvae are often called as nymphs. The adult stage is usually the overwintering stage. Some overwintering *Hemiptera* go into a dormant stage while others may be active. Most adults have wings and many are capable fliers. Water bugs can be found submerged in the water, skating on its surface, or along the margins and shores. Many water bugs are predacious and have modified front legs for capturing and grasping prey. Some identification keys of water bugs are the forewings of water bugs overlapped in the back half. In addition, the posterior portion of the wings is often membranous. The water bugs can be broken down into two main groups, the *Cryptocerata* which have small, hidden antennae and the *Gymnocerata* which have longer, easily visible antennae [176]. In the present study three families of *Hemiptera* were encountered and recorded from the wetlands and their photographs are presented at ***Plate 7.9***. The detailed features and habitat ecology of the observed families are discussed below.

(a) Belastomatidae:

This is one of the widely found water bugs throughout. They are very tolerant to pollution and basically prefer stagnant water bodies. The giant water bugs are medium to large, oval, and somewhat flattened bugs. They are predators feeding on insects, tadpoles, small fish, and other small animals [177]. They often conceal themselves in the debris and vegetation of ponds, pools of streams, and slow ditches. During dispersal flights at night they are often attracted to lights. They can inflict a painful "bite" so care in handling is advised. The size of the Giant Water Bugs at maturity is 20-65 mm. Some identification features of *Belastometidae* are as follows –

(i) They have raptorial forelegs for grasping prey.

(ii) The antennae are found under the eyes and are shorter than head.

(iii) Typical of many bugs, they have a three or four segmented cylindrical beak.

(iv) The apex of abdomen has a pair of air straps to aid in respiration [177].

(b) Nepidae

The Water Scorpions or *Nepidae* was encountered in the study. They are predators which are usually found in debris or vegetation in shallow areas. They are poor swimmers so they suspend themselves upside down with their breathing tube sticking out of the water waiting for prey to swim by. The size of the water scorpions at maturity is 15-45 mm [178]. Some of the distinguishing features of *Nepidae* are -

(i) Water scorpions have a distinctive long body shape.

(ii) Their antennae are found under their eyes and are shorter than the head.

(iii) They have a three or four segmented cylindrical beak and raptorial forelegs.

(iv) Their abdomen ends in a long cylindrical breathing tube, composed of two filaments [178].

(c) Gerridae

They are found skating across the surface of the water in all kinds of aquatic habitats. They are mainly predators and eat a variety of aquatic and terrestrial insects. Cannibalism is also common. The size of the Water Striders at maturity is 3-20 mm [179]. Some of the identification keys are illustrated below

(i) The water striders can be identified by their long legs.

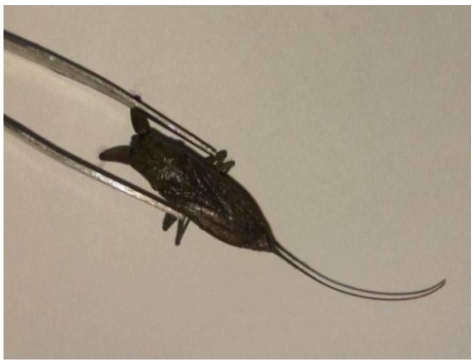
(ii) Their antennae are longer than their head.

(iii) The claws of the front legs are positioned before tip of the leg.

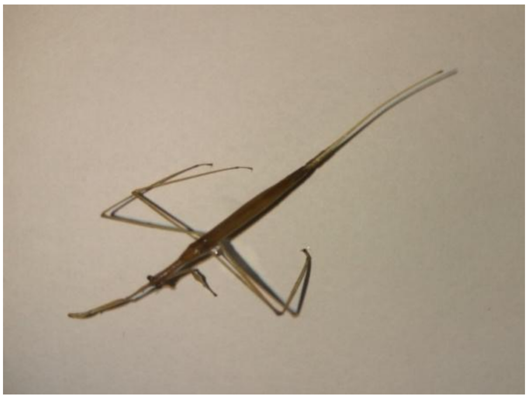
(iv) The hind femur extends past the terminal end of abdomen.

(v) The middle legs attach closer to back legs than front legs [179].

(a)



(b)



(c)

Plate 7.9: (a) *Belastometidae*, (b) *Nepidae* and (c) *Gerridae*

11.Olegochaetes

These include about 3500 species of earthworms and freshwater worms. The members of this group range in length from about 0.5 mm–3 m. Most are burrowers in soil, while some of them inhabit in well, fresh water, swamp etc. They can withstand any kind of environment. *Olegochaetes* in particular, the earthworm are ecologically important in their roles of turning over and aerating the soil. The earthworm is secondarily important as fish bait and food. Many species have a clitellum, a thickened region that secretes cocoons for enclosing eggs, which suggests a close relationship with leeches (Class *Hirudinea*) [180]. The photograph of *Olegochaetes* is shown at ***Plate 7.10*** and some distinguishing features are –

(i) The body is divided into segments and they lack parapodia with a few exceptions which have relatively few and inconspiscious setae or bristles on the body.

(ii) All species are simultaneous hermaphrodites i.e., the functional reproductive organs of both sexes occur in the same individual. Development and growth are direct, with no larval stages.

(iii) They use the capillaries of the body walls for respiratory exchange [180].

Plate 7.10: *Olegochaetes*

7.3.2. Macroinvertebrates population

The percentage distribution of macroinvertebrates in all the wetlands is presented in ***Fig 7.1***. Some species are common to all the wetlands. The percentage of common macroinvertebrates was 14%. Among the uncommon macroinvertebrates, the maximum contribution to total macroinvertebrates was found in the waterlogged wetland, Kilakili with 25%, as this wetland is a running water body integrated with sandy bottom and floating hydrophytes, algae and submergents though less compared to the other wetlands. Hence, it has majority of the features for the aquatic insects to sustain. Bordoibam Beelmukh wetland that falls in the riverine category has been seen with significant numbers of macroinvertebrate with 23% of the total population and it has managed to attract some sensitive insects as well indicating a desirable aquatic habitat to a certain extent. Lake/Pond (Borbeel) was represented with 21% of the total population. It is a stagnant wetland, basically used by the local people for fishing and other domestic usage. As the wetland has stagnant water, the aquatic plants and other hydrophytes remain decomposed and trapped in the bottom which results in the deposition of rich organic nutrients. Moreover, higher is the organic content, lower is the oxygen level. Low content of DO is a sign of organic pollution due to inorganic reductants like - ammonia, nitrates and other such oxidizable substances [181]. All these factors extensively shape up as an unsuitable habitat for the sensitive aquatic insects. The wetland with minimum presence of macroinvertebrates was recorded in the oxbow wetland, Bukrong with 17%. Least contribution of macroinvertebrates population in this wetland may probably be due to the large loads of clay particles which disturbs the littoral zone of the wetland.

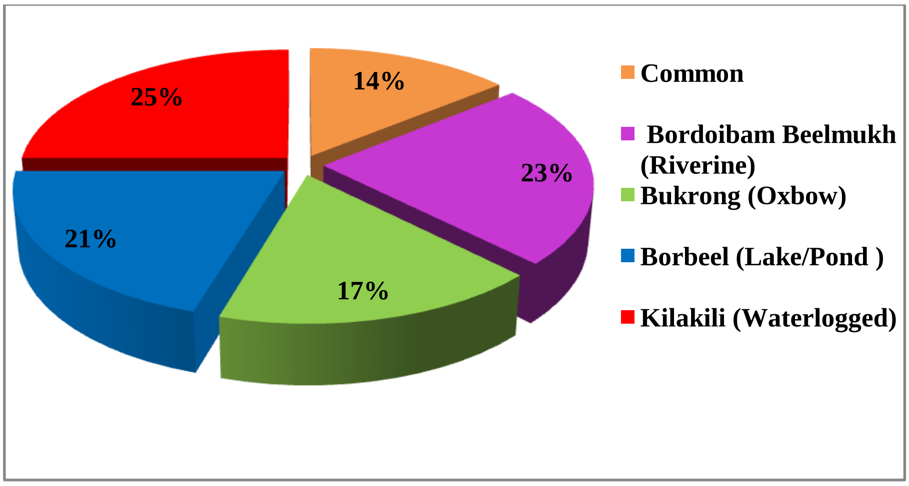


Fig 7.1: The percentage of Macroinvertebrates distribution in the wetlands

The common macroinvertebrates were mostly contributed by the families of *Aeshnidae, Libelluloidae, Lymnaeidae, Belastometidae* and *Nepidae*. They belong to the 'somewhat tolerant' and 'very tolerant' group. To spawn and rest on the floating emergents or submergent, *Odonata* like - *Aeshnidae* and *Libelluloidae* desire standing aquatic habitats. *Lymnaeidae, Belastometidae* and *Nepidae* can withstand any kind of environment and have adapted themselves to survive even on low oxygen level, hence apprehended to be prevalent in all the wetlands. Moreover, the maximum presence of scrapers and predators make these wetlands rich in organic debris and small insects, fishes, tadpoles etc.

The order *Hemiptera* was found to be the dominated macroinvertebrates in all the wetlands. Most of the sensitive macroinvertebrates were observed in the Kilakili (waterlogged) wetland signifying a pleasing aquatic habitat. Majority of the sensitive aquatic insects demand a running water body and they are seen to be less in stagnant water body like the Borbeel wetland. The detail tabular form of macroinvertebrates distribution in the wetlands is presented in ***Table 7.2.***

Macroinvertebrates maintain various levels of interaction between the community and its environment. Hence, it could generate a convenient result in connection to the study. The study revealed the changes in the community abundance and distribution throughout the years. The present study provided information on the diversity and community structure of the macroinvertebrates in the wetlands in lieu of their morphological feature. Significant heterogeneity was observed in the waterlogged wetland Kilakili and recorded with the maximum individuals of sensitive insects like *Hydropsychidae, Ephemeridae, Baetidae* and *Caenidae* along with maximum aggregation of aquatic insects. The sensitive insects were restricted to only two wetlands namely riverine (Bordoibam Beelmukh) and waterlogged (Kilakili) category. *Ephemeroptera, Trichoptera* group of the benthic insects prefer viciously flowing and pollution free water body and like to spend most of the time in the sandy bottom of the water and their presence reflect the desirable status of the habitat. Moreover, *Caenidae* is addressed as the most rugged group based on their relative pollution tolerance among the sensitive insects. The ratio and number of these macro-invertebrates change with the stream food resources and human impacts and therefore, it can be used as a tool for assessing the ecological status of the biotic community and water quality. The presence of those sensitive insects indicated the waterlogged category, Kilakili as a desirable habitat. The observation of few sensitive aquatic insects indicated the riverine (Bordoibam Beelmukh) wetland to be a sustainable habitat to certain extent. Generally, macroinvertebrates demand peculiar criteria for survival in lieu of their resistance to pollution. Most of the sensitive species are adapted to running water bodies and this type of habitats can be viewed as erotional [6]. They are less attracted to standing waters like ponds or lakes, which can be viewed as depositional habitat [6]. Moreover, the clay soil bottom of the Bukrong wetland has established as a stressful habitat for the insects. However, there are other pollution tolerant or moderately tolerant species, which are attracted to stagnant water of ponds/lakes and oxbow wetlands. The scraper snails and the predators that prefer to feed on the debris and shallow aquatic plants felt appealing to this habitat

Table 7.2. Macroinvertebrates distribution in the four selected wetlands

Pollution Index	Family	Bordoibam Beelmukh (Riverine)				Bukrong (Oxbow)				Borbeel (Lake/Pond)				Kilakili (Waterlogged)			
Pollution Intolerant	Hydropsychidae	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
	Ephemeridae	3	4	2	-	-	-	-	-	-	-	-	-	3	4	3	-
	Baetidae	-	-	-	-	-	-	-	-	-	-	-	-	3	4	3	-
	Caenidae	2	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-
Somewhat Tolerant	Gomphidae	-	-	-	-	-	-	-	-	-	-	-	-	5	18	12	9
	Aeshnidae	9	11	12	11	10	8	9	9	7	9	6	10	7	22	6	9
	Libelluloidae	6	6	4	7	7	4	8	6	7	4	8	10	9	10	6	5
	Lestidae	-	-	-	-	-	-		-	-	-	-	-	5	11	4	6
	Elmidae	1	12	-	2	8	10	6	5	-	-	-	-	-	-	-	6
	Gyrinidae	10	14	12	13	-	12	-	7	10	12	8	7	7	22	8	8
	Dytiscidae	6	-	5	8	-	-	-	-	7	8	9	7	-	-	-	-
	Penaeidae	-	4	2	2	10	6	8	-	7	6	-	-	10	16	12	3
	Pyralidae	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pisauridae	-	-	-	-	-	-	-	-	8	-	6	-	-	-	-	-
Very Tolerant	Potamonidae	7	5	5	5	-	-	-	-	-	-	-	2	-	-	-	-
	Lymnaeidae	9	30	10	16	12	9	12	14	7	12	10	11	7	28	18	16
	Hirudinidae	3	3	4	6	3	5	13	5	2	6	2	5	-	12	-	-
	Belastomatidae	24	20	24	22	18	14	16	22	14	16	14	20	24	22	22	14
	Nepidae	28	59	34	32	23	26	18	21	18	23	12	18	19	24	16	25
	Gerridae	-	-	-	7	-	-	-	6	-	-	-	5	13	26	20	14
	Oligochaetes	3	-	-	3	-	-	-	-	2	-	-	2	2	-	-	-

The Bordoibam Beelmukh (riverine) wetland is connected with three tributaries of the river Subansiri and this interconnecting network feature helped in creating a well aerated and oxygenated water body. DO was found to have close relationship with the organic matter where the oxygen level depletes with the increasing amount of organic matter. This may be due to the bacteria using the available oxygen present in the wetland during the decomposition process of organic matter. This eventually have an impact on the pollution intolerant aquatic insects. Though the riverine wetland is integrated with rich organic matter, yet the width, volume, depth, aquatic vegetation and the well aerated water quality reconstructed it as a favourable ground for few sensitive aquatic insects as some of the pollution intolerance group like *Caenidae* and *Baetidae* prefer to scrape on the algae, detritus and sit on the macrophytes. However, the Kilakili wetland has a better mechanism of habitat quality with appreciable level of dissolved oxygen and lesser organic content and the maximum presence of the pollution intolerant group of insects made the hypothesis more convincing. Borbeel (lake/pond) and Bukrong (oxbow) wetlands were deprived of the sensitive individuals as Borbeel is a standing water body practically no flow was observed, however Bukrong has a minimal flow which was virtually unnoticeable except during monsoon. The depth and the discharge were found to be very less for the solubility of oxygen and to get re-aerated. Moreover, the decomposed organic matter produce detritus and as water move slowly through this stagnant wetland, the detritus gets arrested in the bottom due to poor dilution and hence deposition of this material tend to degenerate the habitat quality. However, it was observed to be an abode for the pollution tolerant group of insects.

Coleptera like *Dytiscidae* and *Gyrinidae* also demand for a unique aquatic habitat. Noticeable rate of flow was required for their sustenance and generally found less in organic debris as they feed on small insects, fishes etc. *Odonata* like *Aeshnidae, Libelluloidae, Lestidae* nymphs prefer stagnant water with floating emergent or submerged vegetation to lay their eggs on the leaves or for resting. The Bordoibam Beelmukh (riverine) and Kilakili (waterlogged) wetlands have been incorporated with these significant qualities of water bodies as most of these moderately pollution tolerant group of insects were prevalent in these two wetlands, thus shaping up as favourable ground for this genre of aquatic insects. *Pyralidae* or aquatic moths also feed on the aquatic plants and favour for lentic habitats. However, *Odonata* was one of the most common groups found in all the wetlands. Algae, macrophytes and diatoms work as a food for the scraper *Lymnaeidae* snails. The presence of these insects revealed that the wetlands have mesmerising floating or submerged aquatic plants and phytoplanktons with significant productivity. Fishing spider or *Pisauridae* are basically active at night and hence observed only in the Borbeel wetland during premonsoon and autumn. The *Hemiptera* which are predators is the most dominant group that feeds on the small insects and tadpole are basically found in debris and shallow vegetation and observed in all the wetlands all throughout the period.

7.3.2.1. Seasonal Variation of Macroinvertebrates Population

The highly sensitive insects of the wetlands cannot withstand adverse environmental conditions and hence reflect the effects of seasonal variations of different environmental parameters as well as the extent of pollution and eutrophication. The consequences of the changes in the seasonal meteorology are highly acknowledged by them and were observed to a certain degree during the study. Thus, the study on their seasonal diversity and density can give an insight into the background and context corresponding to the changes in the environmental settings. The results generated from this study are discussed as follows ***(Refer Table 7.2).***

Macroinvertebrate population seemed to be significantly diverse all throughout the year. Monsoon season showed peak abundance in terms of diversity and abundance coupled with observance of considerate number of sensitive group of insects. However, the rest of the three seasons conferred a slight drop in the density of population, along with the disappearance of some of the sensitive aquatic insects finding it ill suited habitat to survive. The presence of *Ephemeroptera, Trichoptera* during monsoon season reflected the desirable habitat feature for the insects. Pollution intolerant group of insects like *Hydropsychidae* that belongs to *Trichotera* group was seen during this season only. However, *Ephemeridae, Caenidae* and *Baetidae* were also observed during pre-monsoon and autumn, though in lesser count. The higher flow regime and volume of oxygen framed the hydrological settings as an ideal abode for the sensitive insects during monsoon. Post-monsoon period seem to be unsuitable for the sensitive insects as none of them were observed. Moreover, the macroinvertebrates population was also recorded very less in this season in all the wetlands. However, the death and decay of the aquatic vegetation made the habitat inconvenient for the insects that feed and reside on the aquatic plants. Moreover, the stagnant aquatic habitat during post-monsoon also affected the aquatic beetles, mayflies and caddisflies.

The presence of the pollution intolerant insects imprinted the waterlogged wetland, Kilakili to be a covetable habitat all throughout the season except post-monsoon. The highest number of individuals was observed in the Kilakili wetland except in post-monsoon season. During post-monsoon, the macroinvertebrate population of Bordoibam Beelmukh wetland surpassed the Kilakili wetland, as the deposition of organic detritus can enthral many scrapers and this detritus material was found in larger load in the Bordoibam Beelmukh (riverine) wetland. Generally pollution tolerant scrapers and predators like *Hemiptera, Pulmonates, Hirudinea, Oligochaetes* etc. preferred to remain in this habitat.

The dead logs and sticks from the trees generally fall in the wetlands, and gets decompose. This decomposed product happens to be food for some of the aquatic insects and fishes present in the wetlands. Maximum number of aquatic insects like *Hemiptera*, snails, beetles feeding on the dead logs was observed during the stagnant period (postmonsoon) of the wetland. *Olegochaetes* was not observed during monsoon as the higher flow regime might have created the aquatic habitat stressful for them. However, this season (monsoon) attracted the pollution intolerant group and the insects that live and feed on the aquatic vegetation. The existence of *Oligochaetes* in the pre-monsoon and post-monsoon period indicated the presence of excessive nutrients during that period, further depleting the oxygen level. Soft clay soil, decaying leaves and organic matter is suitable for this habitat. Hence *Oligochaetes* was not recorded during the monsoon period. *Ephemeroptera* and *Trichoptera* group of the benthic invertebrates was found to be absent during the post-monsoon period. Hence the presence of these groups can imply the periodic variation of the habitats. The wetland with minimum presence of macroinvertebrates during this phase was recorded in the Borbeel (Lake/Pond) and Bukrong (oxbow) wetlands which are shallow and have stagnant water. These wetlands have almost failed to correlate with the macroinvertebrates to build up their habitat.

7.3.3. Macroinvertebrates Population in Relation to Water and Soil Quality

The three main components of a true wetland are the wetland hydrology, hydric soil and aquatic flora and fauna. Hydrological characteristics of a wetland are the driving force for a wetland formation as it explains the distribution and effect of water. The wetland soils are saturated with water for a long period of time and hence anaerobic in condition. This characteristic inhibits the microbial decomposition of organic matter and forms detritus and humus. The aquatic plants are acclimatized to this anaerobic hydric soil and the aquatic fauna or benthic macroinvertebrates are adapted to the wetland hydrological settings and hydric soil.

Macroinvertebrate species exhibit a wide variation of response to pollutants and have been extensively monitored in lotic water bodies to evaluate water quality and complement physico-chemical surveys [182, 183]. The composition of aquatic insects has developed morphological and physiological adaptations to survive in particular oxygen concentration. Running water is well oxygenated than the standing water. This is one important factor that determines the distribution of groups like mayflies *(Ephemeroptera)*, stoneflies *(Plecoptera)* and caddiesflies *(Trichoptera).* These groups require a dissolved oxygen level of more than 5 mg/l and basically sustain in running water. Generally, sensitive aquatic insects are connected to wide and oxygenated water body with composed substrate. The water current and the physical properties of a wetland indicate the physical nature of the substrate. The organic detritus adds complication to the substrata and this factor can strongly influence the organism's response to the substrate [6]. So, an attempt has been made to discuss and formulate relationships of macroinvertebrates with water and soil components and the role of water and soil quality to establish the habitat for macroinvertebrates assemblages in a water body. Some of the criteria parameters were selected for the findings viz: Flow regime, Dissolved Oxygen and Organic Matter to calibrate against the macroinvertebrates. These parameters were chosen to measure whether the physical habitat or nutrient enrichment help in structuring macroinvertebrates communities.

To explore the relationships between macroinvertebrate population with the water and soil quality parameters the method of regression analysis was applied. The best fitting curves obtained by using the method of 'Least Squares' are presented in ***Fig.7.2.*** Macroinvertebrates and Dissolved Oxygen showed a moderately strong relationship with an R^2 value of 0.583, which has been represented as the most significant relationship among the variables. This relationship indicated that a particular set of aquatic insects tend to be comfortable or flourish with the higher value of DO. They prefer for a well oxygenated water body with Dissolved Oxygen requirement of above 5mg/l. Hence Dissolved Oxygen has one of the strongest role to uphold the entire ecosystem to keep the food chain functioning. Negative correlation with organic matter content with an R^2 value of 0.448 reflected that population of aquatic insects tend to decrease with the increasing value of organic matter. Dissolved Oxygen has a negative correlation with Organic Matter, as the later tends to get lesser with the increasing value of Organic Matter. To decompose the dead aquatic plants and algae, bacteria uses up the available oxygen and eventually lower the Dissolved Oxygen level. However, this also influences the macroinvertebrates population as dissolved oxygen level less than 5mg/l put the aquatic life at stress. Moreover, a firm substrate and flow regime were also observed to be reconstructing the habitat to create chaos for the aquatic insects. Considering this factor, relationship was analysed with the flow regime, however it indicted an R^2 value of 0.277 which is assumed to have very weak relationship among each other. The minimal value presented by the relationship of flow regime and macroinvertebrates indicated that all the benthic insects did not prefer for a pristine flowing water body. The sensitive aquatic insects were observed only in the sites where noticeable flow was observed and did not imply to appear on the occasions where the flow was negligible. Hence a favourable result generated from these parameters can be the reflection of a healthy aquatic ecosystem

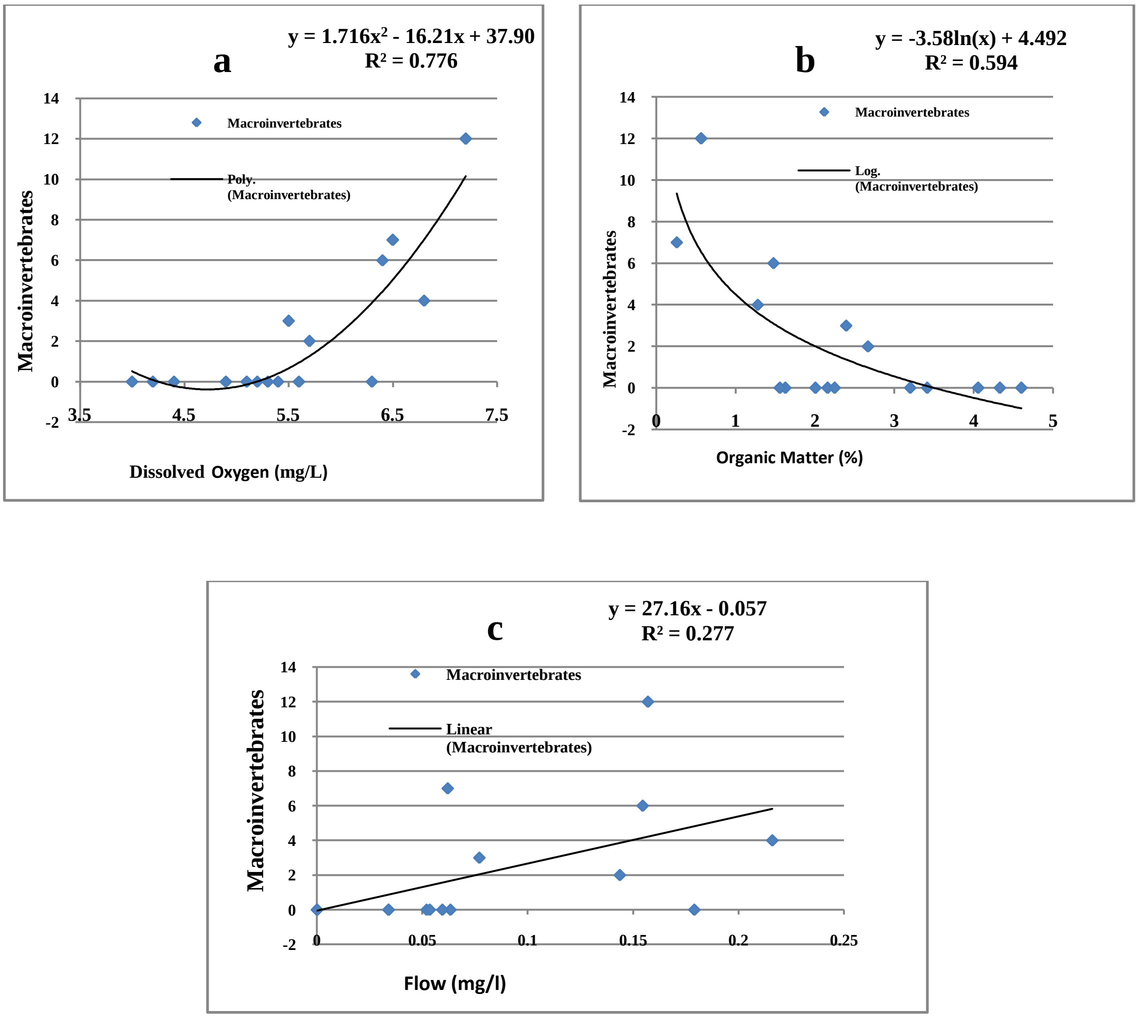


Fig 7.2: Variation of Macroinvertebrate Population with (a) DO and (b) OM and (c) Water Flow

7.4. Conclusion

The study on the diversity and community structure of benthic macroinvertebrates in the four selected wetlands revealed that there were changes in their abundance and structure on the basis of wetlands types and also periodic changes with the season. Maximum diversity and population of macroinvertebrates were observed in the wetlands with diverse hydrophytes and macrophytes and maximum DO level. This may perhaps be due to the availability of the aquatic plants for shelter and desirable condition of water quality. Density of the aquatic insects was found to be the maximum at the Bordoibam Beelmukh (riverine) and Kilakili (waterlogged) wetland. The high diversity and presence of some sensitive insects in the wetlands indicated that the wetlands had good life support status for fishes, birds and other aquatic organisms. The peak density of the macroinvertebrates during summer reflected an ideal habitat condition. This may be due to the availability of macrophytes and organic enrichment during this season which favours the establishment of majority of macroinvertebrates. Moreover, the maximum oxygen generation during this season also created favourable site for the sensitive benthic macroinvertebrates. Hence the diversity and structure varied in terms of significant wetland ecology viz: nature of substrates, physiochemical conditions, availability of macrophytes, detritus contents and varying seasonal changes. However, it appeared that specific seasonal abundance was observed mostly in the population distribution of *Ephemeroptera* and *Trichoptera* larvaes. Further, the information on the composition and distribution of the seasonal benthic invertebrates can be used to design conservation strategies as the wetlands were observed with numerous socioeconomic and ecological values.

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