IOSR Journal Of Pharmacy And Biological Sciences (IOSR-JPBS)
e-ISSN:2278-3008, p-ISSN:2319-7676. Volume 14, Issue 1 Ver. I (Jan–Feb 2019), PP 31-37
www.Iosrjournals.Org

Diversity and habitat selection of aquatic beetles (Coleoptera).

[1]Shailendra Sharma, [2]Gurudutt Sharma, *[1]Faisal Ahmad Pir
[1]P.G.Department of Zoology, Adarsh Institute of Management & Science, Dhamnod. (Devi Ahilya University, Indore) (M.P.) India.
**[1,2]P.G.Department of Zoology, P.M.B.Gujarati Science College, Indore. (M.P.)*
Corresponding Author: Faisal Ahmad Pir

***Abstract**: In this study the diversity and habitat selection of aquatic Coleoptera has been assessed. The order Coleoptera includes more species than any order, constitutes 25 % of known life forms. Most of the species are terrestrial but some of them are aquatic however there is doubt whether a particular species is terrestrial or aquatic that is why Jach and Bhalke (2008) classify them as true water beetles, facultative water beetles,Phytophilous water beetles etc. depending upon the time they spend in or out of the water. More than 350000 species of beetles has been described so far out of which 12000 species are known from aquatic habitat. The order has been divided into 4 suborders three of which have aquatic representatives, Myxophaga (90% aquatic), Adephaga (18% aquatic), and Polyphaga (1.25% aquatic).Polyphaga contains most families (15) of which the family Hydrophilidae represents highest number of species (2,652). Aquatic beetles areknown to have diverse habitat selection and so is their adaptability. They are found to live in almost all kinds of aquatic habitats, such as rivers, springs, lakes, ditches, puddles, phytotelmata, seepages, and ground water but did not live in oceans however they can cope with a salinity up to 250%.*

***Key words:** Aquatic, Beetles, Coleoptera, Diversity, Habitat*

Date of Submission: 22-12-2018 Date of acceptance: 07-01-2019

I. Introduction

Biological diversity means the variability among the living organisms from all sources including terrestrial, marine, and other aquatic ecosystems (Harper and Hawksworth, 1994). This includes diversity within species, between species, and of ecosystems. Biological diversity refers to the entire body of organisms, their ecological complexity within the environment, and all the ecological processes in relation to these systems (Primack, 1999). Approximately30 million species are found worldwide, of which about 1.4 million have been briefly described; of these, about 750,000 are insects. Insects comprise more than 75% of all described animal species and exhibit not only a rich variety of form, color, and shape, but also a range of ecological adaptations unexcelled by any other group (Balaram, 2005). Among insects, the order Coleoptera includes more species than any other order, constituting almost 25% of all known life-forms (Thakur, 2003). The word "Coleoptera" is from the Greek keleos, meaning "sheath," and pteron, meaning "wing," thus "sheathed wing." The reason for the name is that most beetles have two pairs of wings, the front pair, and the "elytra," being hardened and thickened into a sheath-like or shell-like protection for the rear pair and for the rear part of the beetle's body. Beetles are holometabolous insects, normally with adecticous, exarate pupae. Adults are characterized by a strongly sclerotized body with the forewings hardened into elytra, which serve to protect the more delicate hind wings, as well as the dorsal surface of the hind two thoracic segments (pterothorax) and abdomen. Other derived characteristics of adult beetles are: presence of a gula; antenna primarily with 11 articles; hind wings folded under elytra; thorax broadly connected with abdomen, so that the primary functional units of body are head, prothorax, pterothorax-abdomen, rather than the more typical head, thorax, abdomen of many other insect orders; genitalia retracted into abdomen (Jach and Balke, 2008).

More than 350 000 species of beetles have been described, with many new descriptions appearing every day. The final species count may be several times that number once tropical areas of Earth are fully explored. Indeed beetles occur in just about every habitat from the driest deserts to the intertidal zones of the oceans. While the vast majority of beetles are terrestrial, about 12 000 species are known from aquatic habitats worldwide (Sharma et al 2012). Beetles have a wide variety of associations with aquatic habitats, so it is often difficult to draw the line between aquatic and terrestrial (White, 2009). For the purposes here, aquatic Coleoptera is defined as species that spend at least a portion of their life cycles in water or that are restricted to living on aquatic plants or the riparian margins of lakes and rivers (Ponomarenko and prokin, 2015). According to Crowson (1981) water has been ‘‘invaded’’ at least 10 times independently during the evolution of Coleoptera, but this process in fact seems to have happened more than 20 times, and the water's edge has been

‘‘approached’’ even more often. Water beetles do therefore not represent a single monophyletic clade. Accordingly, their behavioural and morphological adaptations to the aquatic environment are exceptionally diverse. The smallest water beetles are less than 1 mm, the largest ones are about 5 cm long. In the ‘‘great three’’aquatic insect orders (Ephemeroptera, Plecoptera and Trichoptera) there is usually a fully submerged, long-lived larval stage and a shorter-lived, fully terrestrial adult stage. This type of life cycle is comparatively scarce in beetles (e.g., Scirtidae, Psephenidae). The life histories of water-associated beetles are in fact extremely many fold, differing greatly between families. Aquatic beetles are found to live in almost all kinds of aquatic habitats, such as rivers, springs, lakes, ditches, puddles, phytotelmata, seepages, and groundwater (Yule & Yong, 2004). They are known to survive trapped in ice. Salinity is also not a limiting factor for some species of water beetle. However, beetles do not inhabit the oceans, although numerous species live at their shores, where they can be found in hypersaline rock pools of the supralittoral, i.e., the spray (or splash) zone slightly above the intertidal zone. In contrast to other insects, water beetles prefer small, richly vegetated ditches. In larger lakes, they prefer the swampy margins, as for instance the reed belt of the Central Europe, where water beetle biomass is probably higher than anywhere on earth (Biswas et al 1995).

Biologists have been studying the effects of human activities on aquatic systems and organisms for decades but their findings have been translated into methods suitable for monitoring the quality of water bodies relatively recently (biological assessment). Biological assessments to determine the environmental quality of water bodies is based on surveys and other direct measurements of biological organisms (macroinvertebrates, fish, and plants) (Barbour et al. 2008). Moreover, it is carried out to determine the biological integrity of surface water that supports and maintains a balanced, integrated and adaptive community of organisms having diverse species composition and functional organization compared to natural terrestrial habitat (Rosenberg and Resh, 1993, Barbour, 2008). It has been recognized as a vital component for an integrated assessment of water quality. Use of aquatic insects as biomonitor provides important insights into changes in water and habitat quality (Rosenberg &Resh, 1993). These changes are valuable in demonstrating the effects of anthropogenic disturbances in the aquatic ecosystems. Numerous taxa of aquatic insects groups have been used as biological parameter to know the ecological status of aquatic systems.Of these aquatic beetles provides all the requirements needed for the assessment that is, large diversity, various adaptations (tolerance and sensitivity), long life, and use of different types of habitats. All these qualities suit them perfectly to use as biological indicators (Sharma, et al.2013).

Species diversity

More than 750000 species of insects are roaming on the earth, comprising more than 75% of all described animal species. Majority of the described species are terrestrial of which 3 – 5 % are aquatic and are taxonomically diverse (Daly et al., 1999). The order coleoptera of class insecta contains more species than any order. About 400,000 species have been described until today, some biodiversity experts estimate that millions of species may actually roam the earth. (Jach and Balke. 2008). While the vast majority of beetles are terrestrial, about 12 000 species are known from aquatic habitats worldwide (Arnett, 2000). Counting the described species, the Palearctic Region houses the highest number of water beetles species. Although comprehensive water beetle surveys are still lacking for large parts of the Neotropical and Afrotropical Realms, it is estimated that the Palearctic region contains 3,350 described species out 3,900 total estimated, the Neotropical region (2,510 out of 3,900), and the Afrotropical Region contains (2,700out of 3,750 total estimation, followed by the Oriental (2,200out of 3,580 and the Australian/Pacific Realm (1,340out of 2,100 estimated species. Undoubtedly, the Nearctic (1,420 out of 1,550 species is by far the poorest region in terms of water beetle diversity. Within the Palearctic Region, the Mediterranean countries and Anatolia are to be regarded as biodiversity hot spots, at least for certain families. In the comparatively well-explored Oriental Region, Borneo was found to be a hot spot of paramount significance for many water beetle families. (Balian, et al 2008).

The order Coleoptera is comprised of four suborders, three of which have aquatic representatives: Myxophaga (77 described species, 90% aquatic), Adephaga(30,000 described species, 18% aquatic), and Polyphaga (370,000 described species,1.25% aquatic).While truly terrestrial species are an exception in the Myxophaga, eight of the 11 extant families of Adephaga are regarded as predominantly aquatic (Gyrinidae, Haliplidae, Meruidae, Noteridae, Amphizoidae, Aspidytidae, Hygrobiidae, Dytiscidae), and only 13 of the 150 recognized families of the large suborder Polyphaga are regarded as ‘‘predominantly aquatic’’ (Helophoridae, Epimetopidae, Hydrochidae, Spercheidae, Hydrophilidae, Hydraenidae, Scirtidae, Elmidae, Dryopidae, Lutrochidae, Psephenidae, Cneoglossidae, Eulichadidae). Larvae of the scirtoid family Decliniidae are still unknown and it cannot be excluded that they are aquatic like scirtid larvae. In addition to these 25 typically aquatic families, another 12 families (1 adephagan and 11 polyphagan) have at least one representative living in or in very close association with freshwater habitat, but the most of their members are terrestrial: Carabidae (Adephaga), Leiodidae, Staphylinidae, Scarabaeidae, Ptilodactylidae, Lampyridae, Nitidulidae, Monotomidae, Chrysomelidae, Nanophyidae, Erirhinidae, Curculionidae (Polyphaga). Larvae of some species of Limnichidae

are also aquatic but detailed ecological studies are yet to disclose. Nosodendridae, a small family known to occur in tree sap, are not included in this assessment. However, it should be kept in mind,that further research might reveal, that some nosodendrids are well able to live in phytotelmata like the nitidulidAmphicrossusjaponicusReitter .Typical Shore Beetles (Jach, 1998) are found in numerous families, e.g., Carabidae(Adephaga), Lepiceridae (Myxophaga), Helophoridae, Hydrophilidae, Georissidae, Histeridae, Ptiliidae, Leiodidae (Cholevinae), Staphylinidae, Micropeplidae, Scarabaeidae,Elateridae, Limnichidae, Heteroceridae, Lampyridae, Latridiidae, etc. (Polyphaga)(Jach,. 1998).

At least 50% of the species of each of the 25 families in this group are aquatic. All the typical water beetle families are included here. Ecologically, they are mostly True Water Beetles, like PredaceousDiving Beetles (Dytiscidae), Whirligig Beetles (Gyrinidae), Water Scavenger Beetles (Hydrophilidae) and Riffle Beetles (Elmidae), or, to a lesser percentage, False Water Beetles, e.g., Water Penny Beetles (Psephenidae).

The aquatic families representing the above mentioned suborders are described briefly as:

Adephaga

1. Gyrinidae: About 750 described species in 13 genera. Gyrinids occur on all continents. Adults and larvae of all species are strictly aquatic. The majority of the species lives in running water (Beutel&Roughley, 2005; Mazzoldi, 1995).
2. Haliplidae. About 200 described species in five genera are found on all continents, but they are more diverse in the northern temperate regions. Larvae and adults of all species are truly aquatic. They live mainly in stagnant water, some species prefer lotic habitats. This family is remarkably well explored (Vondel 2005).
3. Meruidae:Monogeneric family described from Venezuela in 2005. The single known species lives at the gravelly margins (interstitial) of mountain streams (Beutel et al. 2006; Spangler & Steiner 2005).
4. Noteridae: About 250 species in three subfamilies and 14 genera have been described so far. The family occurs on all continents. Adults and larvae are aquatic; Noterus pupates under water in air-filled cocoons. Noteridae are commonly found in stagnant water between roots of water plants. The monogenericPhreatodytinae (six species, all restricted to Japanese groundwater habitats) are considered as distinct family (Nilsson (2005a).
5. Amphizoidae:Monogeneric family with five described species, known only from North America and China. Larvae and adults of all species are aquatic living in rather fast flowing rivers (Nilsson, 2005b).
6. . Aspidytidae:Monogeneric family with two species from South Africa and China. Larvae and adults live in seepages; pupae unknown. (Balke et al. (2003; Nilsson (2005c).
7. Hygrobiidae:Monogeneric family with six described species, occurring in Europe, China and Australia. Larvae and adults of all species are aquatic lives instagnant water. (Nilsson (2005d).
8. Dytiscidae: With almost 4,000 described species in 175 genera, this is the most speciose water beetle family; it occurs on all continents. A total of 10 subfamilies (Agabinae: 388 spp., Colymbetinae: 130 spp., Copelatinae: 568 spp., Coptotominae: 5 spp., Dytiscinae: 377 spp., Hydrodytinae: 4 spp., Hydroporinae: 2,012 spp., Laccophilinae: 400 spp., Lancetinae: 8 spp., Matinae: 8 spp.) are presently recognized. Larvae and adults of almost all species are aquatic (Larson et al. (2000); Nilsson, 2001).

Myxophaga

1. . Lepiceridae:Monogeneric family with two New World species. Lepicerusinaequalis and L. bufo both usually found on sand banks very close to streams but assumed thay they might get submerged under water (Reichardt1976).
2. Torridincolidae: About 31 tiny species in seven genera occurring in South America (three genera), Africa including Madagascar (three genera) and Palearctic Asia (one genus). An undescribed species is known from the Philippines. The species are found in mountain streams (Jach, 1998b; Spangler, 1980b).
3. Hydroscaphidae: About 21 tiny species in three genera occurring on all continents except Australia. One species, Hydroscaphanatans, is recorded from two biogeographical regions. Adults and larvae of all species are aquatic preferring seepages (hygropetric habitats), hot springs, or the interstitial of gravel banks of streams and rivers (Jach1995a; Lobl, 2003a).
4. Sphaeriusidae:Monogeneric family with 23 tiny species occurring on all continents. Several species are reportedly terrestrial (humicolous); other species (e.g., the type species SphaeriusacaroidesWaltl) occur at the margins of running and/or stagnant water, often in wet sand very close to the water surface(Beutel&Raffaini, 2003; Hall, 2003; Lobl, 1995).

Polyphaga

1. Helophoridae:Monogeneric family with about 185 species, more or less confined to the Holarctic Realm. Adults of most species are considered truly aquatic (about 75% living in stagnant water, R. Angus, pers. comm.); several species are usually encountered slightly above the water line and therefore seem to be facultatively aquatic or riparian (Angus, 1992; Hansen1999).
2. Epimetopidae: About 29 species in three genera occurring in the New World (Epimetopus), Africa (Eupotemus) and Asia (Eumetopus). Adults of all species are probably aquatic (sandy margins of lentic habitats), ecology of larvae unknown (Hansen (1999), Ja¨ch (2002; Skale& Ja¨ch 2003).
3. Hydrochidae:Monogeneric family with about 180 species; hydrochids occur on all continents. All species are truly aquatic, living in well-vegetated stagnant water and/or at the edges of very slowly flowing water (Hansen 1999; Short &Hebauer2005).
4. Spercheidae:Monogeneric family with 18 species. The genus occurs on all continents. Larvae and adults generally live in stagnant water (Hansen, 1999; Short&Hebauer2005).
5. Hydrophilidae: About 2,652 species in 174 genera. Hydrophilids occur on all continents. They comprise four subfamilies: (1) Horelophinae: monotypical, New Zealand, adults obviously riparian or hygropetric; (2) Horelophopsinae: monogeneric, two species, New Guinea (Yapen Island) and Japan (Ryukyu Archipelago), the Japanese species is obviously aquatic, the ecology of the Yapen species is not exactly known;(Jach and Stankle, 2008).
6. Hydrophilinae: 1,740 species in 66 genera, on all continents, adults and larvae of most species are living in stagnant water, running water, in phytotelmata or seepages, numerous species are reportedly riparian or terrestrial (humicolous) (Jach & Balke, 2008).
7. Sphaeridiinae: 909 species in 106 genera, most of which are terrestrial; only seven genera include aquatic representatives. In total, about 70% of Hydrophilidae are aquatic (Hansen 1999; Short &Hebauer 2005).
8. Hydraenidae: About 1,420 species in about 40 genera. Hydraenids are encountered on all continents and inhabit even some Subantarctic Islands, where only few insects are able to cope with the hostile climatic conditions. While adults of most species are aquatic (stagnant water, running water, seepages), many are riparian or strictly terrestrial and a few species are known to live exclusively in hypersaline marine rock pools. Hydraenid larvae are usually riparian or terrestrial, only the first instar of some species is aquatic (Hansen, 1998; Jach et al. 2000).
9. Scirtida: About 900 species in 30 genera. Scirtids occur on all continents. Larvae are usually aquatic, although there are reports about scirtid larvae found in wet soil and on rotten logs. Imagos are generally terrestrial, but adults of Hydrocyphon are occasionally collected under water; pupae of Hydrocyphon are also reported to be aquatic. Scirtid larvae are found in running water (about 20%), in stagnant water, phytotelmata, and in groundwater (Klausnitzer, 2004; Lawrence, 2005; Yoshitomi &Sato, 2005).
10. Elmidae: About 1,330 species in 146 genera. Elmids occur on all continents. Two subfamilies are presently recognized: Larainae (26 genera, 130 species), and Elminae (120 genera, 1,200 species). Adults and larvae of all species are considered to be aquatic, however, adults of many Larainae species often can be encountered below or a little above the water line or in spray zones of water falls and cascades. Members of this family are generally living in lotic habitats, very few species are encountered at lake shores or in ponds (Brown 1981; Kodada& Jach (2005).
11. Dryopidae: About 300 species in 33 genera. Dryopids occur in all biogeographical regions, but they are absent from the Australian continent. Larvae are generally riparian or terrestrial; adults of about 75% of the species are regarded as aquatic (lotic and lentic habitats), the remaining ones are riparian or terrestrial (Brown (1981; Kodada&Jach2005).
12. Lutrochidae: About 15 species, all confined to the New World. Larvae and adults are reported to be aquatic in lotic habitats (riparian gravel, emergent rocks or submerged wood). (Brown&Murvosh, 1970; Ideet al. 2005).
13. Psephenidae: About 272 species in 35 genera. Psephenids occur on all continents. They are comprised of four subfamilies: Eubrianacinae, Eubriinae, Psepheninae, Psephenoidinae. Larvae are alwaysaquatic, almost exclusively occurring in running water; with few exceptions, adults and pupae are strictly terrestrial (Brown, 1981; Lee et al. 2005).
14. Eulichadidae: About 21 species in two genera occurring in North America and Asia. Larvae live in streams, but adults are strictly terrestrial. (Jach1995).

Habitat selection

Habitat selection theory suggests that, if habitats are hierarchical in suitability, colonization of less suitable habitats occurs only as density increases in preferred sites. Even the least suitable sites are occupied at saturation densities, because the fitness in a poor site exceeds that of a good site where resources are already monopolized (Fretwell& Lucas 1970). This density dependent process restricts the ability of field patterns alone

to establish primary habitat preferences or determine the ultimate processes leading to observed species distributions (Morris2003). There are many different kinds of aquatic insects and almost every type of freshwater environment will have some kind of aquatic insect living in it. One of the most fascinating characteristics of the aquatic insect population is their diverse pattern of distribution in aquatic habitat coupled with their adaptability (Lewis and Gripenberg, 2008). These aquatic insects are sufficiently flexible to withstand the often severe and sometimes unpredictable environments. One of the vital factors that govern the population dynamics of the aquatic insect is the substratum upon which the drama of its ecology is acted out (Merritt; Cummins and Berg, 2008). It is the medium upon which they move, rest, find shelter and seeks food. . Aquatic beetles had clear habitat preferences for fresh water system occupying the complete range of wetland habitats from headwaters, where they can be the dominant life form, to saltmarshes and rock pools. (Fairchild et al.2000). Beetles are found in almost all kind of aquatic habitats except oceans but are capable also to cope with salinity. Theirbehavioral and morphological adaptations to the aquatic environment are exceptionally diverse, so is their pattern of habituation. Keeping this in mind the objective is to evaluate the different patterns of habitat selection aquatic beetles do as the order is more specious and show drastic variability in their size (smaller less than 2mm),however the ecology of the most species has not been studied till date due their small size and lack of experts of the field and requires strict work to reveal out their ecological behavior so that effective steps can be taken out for their protection and other problems created by humans which directly or indirectly effects them. The ecology and the habitat preference of a few has been studied so for which is briefly described as

1. Dytiscidae: this family occurs on all continents. Most of the species are aquatic but a few are known to be terrestrial. Larvae and adults of almost all species are aquatic; they live in a wide variety of freshwater habitats: stagnant water, running water, groundwater (as deep as 30 m underground), seepages, phytotelmata. These generally inhabits bottom macrophytes and are predacious in nature.The legs are modified in such a way that they facilitate in swimming. They bear two rows of swimming hair on the edge of flattened tibia and tarsi of the middle and hind legs. (Khan and Ghosh, 2001).
2. Gyrinidae: the members of Gyrinidae (whirling beetles) occurs on all continents. Adults and larvae of all species are strictly aquatic found in fresh water ponds, lakes, open flowing streams etc. while majority of the species lives in running water. When the Gyrinid beetles swim on the surface of the water, the dorsal portion of the eye is in air and the ventral portion in water.Adults are found on the surface of the water, but they can also dive, if necessary. When they dive, an air bubble is trapped under the elytra for respiration underwater. The fore legs are relatively long and adapted for grasping prey and the middle and hind legs are short with hairs. They swim in circular, gyrating, and whirling manner, which is why they are called whirlig beetles (Lehmkuhl, 1979).
3. Haliplidae: the members of the family Haliplidae (Crawling beetles) are found on all continents, but are more diverse in the northern temperate regions. Larvae and adults of all species are truly aquatic. They live mainly in stagnant water, some species prefer lotic habitats. Haliplids are not particularly strong swimmers and, with a few exceptions, adults and larvae are found together on vegetation along the margins of ponds and slow streams. Both larvae and adults are herbivorous, scraping periphyton and detritus (fine organic matter) from the stems and leaves of aquatic plants. When mature, pupae leave the water to construct chambers in moist mud at the water's edge (Vondel 2005).
4. Amphizoidae:The members of this family lives in North America and China. Larvae and adults of all species are aquatic. Both larvae and adults live in fast-flowing mountain and foothill streams where they feed primarily on stonefly (Plecoptera) naiads. They may be abundant on driftwood and floating trash or along undercut banks among roots and accumulations of Pine needles. Both larvae and adults live in fast-flowing mountain and foothill streams where they feed primarily on stonefly (Plecoptera) naiads.Amphizoids live at the interface between aquatic and terrestrial environments and seem at home in both. Larvae remain just out of the water on twigs or other wood. They enter the water to seize prey, but quickly return to the twig to eat the victim. (Nilsson, 2005).
5. Noteridae: The family occurs on all continents. Adults and larvae are aquatic. The most usual habitat is on plants along weedy margins of lakes and streams. Both the larvae and adults are predators, primarily on chironomid (Diptera) larvae and other small insects. Some species construct cocoons on the exposed roots of aquatic plants. Larvae pierce the root at the point of cocoon attachment, and escaping air from the root is caught in the developing cocoon (Nelson, 2005a).

II. Conclusion

Conservation of natural resources and biodiversity has become urgent issues in recent years for attaining an environmentally sustainable future. The impact ofanthropogenic activities on fresh water system is so adverse that the diversity of species inhibiting them are decreasing at an alarming rate. The handling of this situation is becoming more difficult due to lack of sufficient knowledge regarding their habitat selection.

Aquatic Coleoptera falls on the same class due to their diverse nature in habitat selection, different size and lack of effective research of the said field. Therefore effective work should be done mostly on their diversity, habitat selection, status (endangered, rare andthreatened) etc. so that the gap in diversity will be filled and effective measures will be recommended for conservation strategies.

References

[1]. Angus, R.B., 1988. A New sibling species of Helophorus F. (Coleop- tera: Hydrophilidae), revealed by chromosome analysis and hybri- disation experiments. Aquatic Insects 10, 171-184
[2]. Arnett, Ross H. (2000). American Beetles: Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia. CRC Press.1:8-10.
[3]. Balaram, P. (2005). Insect of tropical streams. Curr. Sci., 89: 914.
[4]. Balian, E.V.,C. Lévêque, H. Segers, K. Martens fresh water animal diversity assessment, Hydrobiologia 595 419- 442
[5]. Balke, M., I. Ribera & R. G. Beutel, 2005. The systematic position of Aspidytidae, the diversification of Dytiscoidea (Coleoptera, Adephaga) and the phylogenetic signal of third codon positions. Journal for zoological systematics and evolutionary research 43: 223–242.
[6]. Barbour M. T., J. B. Stribling& Piet F.M. Verdonschot, 2008, the multihabitat approach of USEPA's rapid bioassessment protocols: Benthic macroinvertebratesLimnetica, 25 (3): 839-850.
[7]. Barbour MT, Gerritsen J, Snyder BD, Stribling JB. 2006. Rapid BioassessmentProtocols for Use in Streams and Wadable Rivers: Periphyton, BenthicMacroinvertebrates and Fish. Washington, DC: US EPA. 202 pp.
[8]. Beutel, R. G. & G. B. Raffaini, 2003. First record of Sphaeriusidae for Argentina (Coleoptera: Myxophaga). KoleopterologischeRundschau 73: 1–6.
[9]. Beutel, R. G. & R. E. Roughley, 2005. 7.1. Gyrinidae, Latreille, 1810. In Beutel, R. G. & R. A. B. Leschen (eds), Handbook of Zoology, Vol. IV (Part 38), Coleoptera, Beetles, Vol. I: Morphology and Systematics (Archostemata, Adephaga, Myxophaga, Polyphagapartim). Walter de Gruyter, Berlin: 55–64
[10]. Biswas, S., Mukhoupadhyay, P. and Saha, S.K. (1995 b). Insecta :Coeloptera : Adephaga, family dystiscidae. In: State faunaSeries 5: Fauna of West Bengal, Z. S. I., Calcutta, 5: 77-120.
[11]. Brown, H. P. & C. M. Murvosh, 1970. Lutrochusarizonicus new species, with notes on ecology and behavior (Coleoptera, Dryopoidea, Limnichidae). Annals of the Entomological Society of America 63(4): 1030–1035.
[12]. Brown, H. P., 1981a. A distributional survey of the world genera of aquatic dryopoid beetles (Coleoptera: Dryopidae, Elmidae, and Psephenidaesens.lat.). Pan-Pacific Entomologist 57(1): 133–148.
[13]. Crowson, R. A., 1981. The biology of Coleoptera. Academic Press, London: 802 pp.
[14]. Daly, H. V. 1998).introduction to insect biology and diversity, oxford university press, New York 215-225.
[15]. Fairchild G.W.A M Faulds&J.F.Mattat.2000.beetle assemblage in ponds:effect of habitat and site age.Fresh water biology, 44, 523-534
[16]. Gerdes, G., J. Spira& C. Dimentman, 1985. 15. The fauna of the GavishSabkha and the Solar Lake – a comparative study. In Friedman, G. M. & W. E. Krumbein (eds), Ecological Studies. Vol. 53: Hypersaline Ecosystems. Springer Verlag, Berlin: 322–345.
[17]. Hall,W. E. 2003. Sphaeriusidae (Coleoptera). In M. A. Ja¨ch,&L. Ji (eds), Water Beetles of China, Vol. III. Wien: Zoologisch-BotanischeGesellschaft& Wiener Coleopterologenverein: 37–41.
[18]. Hammond, P. M. 1994 Practical approaches to the estimation of the extent of biodiversity in speciose groups. Phil. Trans.R. Soc. Lond. B **345**, 119–136.
[19]. Hansen, M. 1998. Hydraenidae (Coleoptera). In Hansen, M. (ed.), World Catalogue of Insects, Vol. I. Stenstrup: Apollo Books: 168 pp.
[20]. Hansen, M. 1999. Hydrophiloidea (Coleoptera). In Hansen, M. (ed.), World Catalogue of Insects, Vol. II. Stenstrup: Apollo Books: 416 pp.
[21]. Harper, J.L, & D.L. Hawksworth, 1994. Biodiversity: measurement and estimation. Phil. Trans. R. Soc. Lond. B 1994 345, 5-12
[22]. Ide, S., C. Costa & S. A. Vanin, 2005. 18.4. LutrochidaeKasap&Crowson, 1975. In Beutel, R. G. & R. A. B. Leschen (eds), Handbook of Zoology, Vol. IV (Part 38), Coleoptera, Beetles, Vol. I: Morphology and Systematics (Archostemata, Adephaga, Myxophaga, Polyphagapartim). Walter de Gruyter, Berlin: 508–512.
[23]. Jach, M. A., M. Balke, 2008.Global diversity of water beetles (Coleoptera) in freshwater Hydrobiologia, 595:419–442 pp.
[24]. Jach, M. A., 1995a. Hydroscaphidae (Coleoptera). In Ja¨ch, M.A. & L. Ji (eds), Water Beetles of China, Vol. I. Zoologisch-BotanischeGesellschaft in O¨ sterreich and Wiener Coleopterologenverein, Wien: 33–34.
[25]. Jach, M. A., 1998b. Torridincolidae: I. First record of Torridincolidae from China (Coleoptera). In Ja¨ch, M. A. & L. Ji (eds), Water Beetles of China, Vol. II. Zoologisch- BotanischeGesellschaft in O¨ sterreich and Wiener Coleopterologenverein, Wien: 51–52.
[26]. Jach, M. A., 2002. First record of Epimetopidae in Laos (Coleoptera: Epimetopidae). KoleopterologischeRundschau 72: 161–164.
[27]. Jach, M. A., R. G. Beutel, J. A. Dı´az& J. Kodada, 2000. Subgeneric classification, description of head structures, and world check list of HydraenaKugelann (Insecta: Coleoptera: Hydraenidae). Annalen des Naturhistorischen Museums in Wien 102B: 177–258.
[28]. Khan, R.A. and Ghosh, L.K., 2001. Faunal Diversity of Aquatic insects in Freshwater Wetlands of South eastern West Bengal, Occasional Paper No. 194, Records of Zoological Survey of India
[29]. Kodada, J. & M. A. Ja¨ch, 2005a. 18.2. Elmidae Curtis, 1830. In Beutel, R. G., & R. A. B. Leschen (eds), Handbook of Zoology, Vol. IV (Part 38), Coleoptera, Beetles, Vol. 1 Morphology and Systematics (Archostemata, Adephaga, Myxophaga, Polyphagapartim). Walter de Gruyter, Berlin: 471–496.
[30]. Kodada, J. & M. A. Jach, 2005b. 18.3. DryopidaeBilberg, 1820 (1817). In Beutel, R. G. & R. A. B. Leschen (eds), Handbook of Zoology, Vol. IV (Part 38), Coleoptera,Beetles, Vol. 1: Morphology and Systematics (Archostemata,Adephaga, Myxophaga, Polyphagapartim). Walter de Gruyter, Berlin: 496–508.
[31]. Larson, D. J., Y. Alarie& R. E. Roughley, 2000. Predaceous diving beetles (Coleoptera: Dytiscidae) of the Nearctic region, with emphasis on the fauna of Canada and Alaska. NRC Research Press, Ottawa: 982 pp.
[32]. Lawrence, J. F., 2005. 15.4. Scirtidae Fleming, 1821. In Beutel, R. G. & R. A. B. Leschen (eds), Handbook of Zoology, Vol. IV (Part 38), Coleoptera, Beetles, Vol. 1: Morphology and Systematics (Archostemata, Adephaga, Myxophaga, Polyphagapartim). Walter de Gruyter, Berlin: 443–450.
[33]. Lee, C.-F., M. A. Ja¨ch & R. G. Beutel, 2005. 18.7. PsephenidaeLacordaire, 1854. In Beutel, R. G. & R. A. B. Leschen (eds), Handbook of Zoology, Vol. IV (Part 38), Coleoptera, Beetles, Vol.: Morphology and Systematics (Archostemata, Adephaga, Myxophaga, Polyphagapartim). Walter de Gruyter, Berlin: 521–533.
[34]. Lobl, I, 2003a. Family HydroscaphidaeLeConte, 1874. In Lo¨ bl, I. & A. Smetana (eds), Catalogue of Palaearctic Coleoptera, Vol. 1, p. 35. Stenstrup: Apollo Books: 25.

[35]. Lobl, I., 1995. New species of terrestrial Microsporus from the Himalaya (Coleoptera: Microsporidae). EntomologischeBla¨tter 91(3): 129–138.
[36]. Mazzoldi, P., 1995. Gyrinidae: Catalogue of Chinese Gyrinidae. In Ja¨ch, M. A. & L. Ji (eds), Water Beetles of China, Vol. I. Zoologisch-BotanischeGesellschaft and Wiener Coleopterologenverein, Wien: 155–172.
[37]. Merritt, R.W., Cummins, K.W. and Berg, M.B. (2008). An introduction to the Aquatic insect of North America. 4th Ed.: 1158.
[38]. Morris D.W. Toward an ecological synthesis: a case for habitat selection. Oecologia. 2003; 136:1–13.
[39]. Nilsson, A. N. 2005a. Family Noteridae (Coleoptera, Adephaga). In Nilsson, A. N., Vondel& B. J. van 2005 (eds), Amphizoidae, Aspidytidae, Haliplidae, Noteridae and Paelobiidae (Coleoptera, Adephaga). World Catalogue of Insects, Vol. 7. Apollo Books, Stenstrup: 87–158.
[40]. Nilsson, A. N. 2005b. Family Amphizoidae (Coleoptera,Adephaga). In Nilsson, A. N. &Vondel, B. J. van 2005 (eds), Amphizoidae, Aspidytidae, Haliplidae, Noteridae and Paelobiidae (Coleoptera, Adephaga). World Catalogue of Insects, Vol. 7. Apollo Books, Stenstrup: 15–18.
[41]. Nilsson, A. N. 2005c. Family Aspidytidae (Coleoptera, Adephaga). In Nilsson, A. N. &Vondel, B. J. van 2005 (eds), Amphizoidae, Aspidytidae, Haliplidae, Noteridae and Paelobiidae (Coleoptera, Adephaga). World Catalogueof Insects, Vol. 7. Apollo Books, Stenstrup: 19.
[42]. Nilsson, A. N. 2005d. Family Paelobiidae (Coleoptera, Adephaga). In Nilsson, A. N. & van B. J. Vondel, 2005(eds), Amphizoidae, Aspidytidae, Haliplidae, Noteridae and Paelobiidae (Coleoptera, Adephaga). World Catalogue of Insects, Vol. 7. Apollo Books, Stenstrup: 154–163.
[43]. Novotny, V., Basset, Y., Miller, S. E., Weiblen, G. D., Bremer, B. &Drozd, P. 2002 Low host specificity of herbivorous insects in a tropical forest. Nature **416**, 841–844.
[44]. Ponomarenkoa A. G. and A. A. Prokin, 2015 Review of Paleontological Data on the Evolution of Aquatic Beetles (Coleoptera) Paleontological Journal, 2015, Vol. 49, No. 13, pp. 1383–1412.
[45]. Primack, 1993; Essentials of conservation biology. Saunderland,mass-saunder 213-215
[46]. Reichardt, H., 1976b. Revision of the Lepiceridae (Coleoptera, Myxophaga). Pape´isAvulsos de Zoologia 30(3): 35–42.
[47]. Rosenberg, D.M., and Resh,V.H. 1993. Freshwater Biomonitoring and benthic Invertebrates. Chapman and hall, New York.488 pp.
[48]. Sharma R K and N Agrawal 2012. Faunal diversity of aquatic insects in Surha Tal of District - Ballia (U. P.), India. J. Appl. & Nat. Sci. 4 (1): 60-64.
[49]. Sharma S., P. Pandey & V Dave (2013) Role of aquatic beetles for water quality assessment. International Journal of Recent Scientific Research Vol. 4, Issue, 11, pp.1673-1676.
[50]. Short, A. E. Z. & F. Hebauer, 2005. World Catalogue of Hydrophiloidea – additions and corrections, (1999–2005) (Coleoptera). KoleopterologischeRundschau 76: 315–359.
[51]. Skale, A. & M. A. Ja¨ch, 2003. A new species of Eumetopus Balfour-Browne, 1949 from Nepal (Insecta: Coleoptera: Epimetopidae). In Hartmann, M., & H. Baumbach (eds), Biodiversita¨t und Naturausstattungim Himalaya. Verein der Freunde&Fo¨rderer des Naturkundemuseums Erfurt e.V., Erfurt: 195–196.
[52]. Spangler, P. J. & W. E. Steiner, 2005. A new aquatic beetle family,Meruidae, from Venezuela. Systematic Entomology 30(3): 339–357.
[53]. Thakur, S. 2003. Survey of Coleoptera and Hemiptera inhabiting water bodies around Trikuta Hills, Jammu. M.Phil. Dissertation, University of Jammu, Jammu.
[54]. Vondel 2005).Vondel, B.J. van, 2005. Family Haliplidae (Coleoptera, Adephaga). In Nilsson, A. N. &Vondel, B. J. van (eds), Amphizoidae, Aspidytidae, Haliplidae, Noteridae and Paelobiidae (Coleoptera, Adephaga). World Catalogue of Insects, Vol. 7. Apollo Books, Stenstrup: 20–86.
[55]. White, D.S. 2009. Coleoptera (Beetles) in Aquatic Ecosystems, American press Elsevier inc.141-156
[56]. Yule, C. M. and Yong H. S. (2004). Freshwater Invertebrates of the Malaysian Region, Academy of Sciences Malaysia, Kuala Lumpur Malaysia.

Shailendra Sharma" Diversity and habitat selection of aquatic beetles (Coleoptera)."IOSR Journal of Pharmacy and Biological Sciences (IOSR-JPBS) 14.1 (2019): 31-37.