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Review

Macroinvertebrates (oligochaetes) as indicators of pollution: A review

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Macroinvertebrates formed an important constituent of an aquatic ecosystem and had functional importance in assessing the trophic status as the abundance of benthic fauna mainly depends on physical and chemical properties of the substratum and thus the benthic communities respond to changes in the quality of water and available habitat. This review discussed the occurrence, composition and distribution of macroinvertebrates of lakes and wetlands, and some environmental factors which regulated their occurrence and distribution. Also, analysis of the benthic community helped in the determination of trophic status of lakes because of their sensitivity to pollution and is, therefore, an important criterion in the ecological classification of lakes.

Key words: Macroinvertebrates, substratum, lake, wetlands, trophic status, habitat.

INTRODUCTION

The benthic macroinvertebrates are associated with bottom or any solid liquid interface, those that are retained by a sieve or mesh with pore size of 0.2 to 0.5 mm which includes a heterogeneous assemblage of organisms belonging to various phyla like Arthropoda, Annelida, Mollusca and others. The benthos occupies an important position in the lake ecosystem, serving as a link between primary producers, decomposers and higher trophic levels (Pandit, 1980). They also play an important role in the decomposer food chain which in turn affects the cycling of minerals (Gardner et al., 1981). Macroinvertebrates are used as indicators of pollution as invertebrate community change in response to changes in physicochemical factors and available habitats (Sharma and Chowdhary, 2011). The importance of macroinvertebrates as bioassessment tools is widely recognised because of their limited mobility, comparatively long life cycles and differential sensitivity to pollution of various types and they reflect the impact of cultural eutrophication on aquatic habitats quite satisfactorily. According to Jumppanen (1976) the first signs of eutrophication and pollution in a lake are reflected in the benthic flora and fauna as the suspended waste immediately sink to the bottom to decompose and thus cause a change in the benthic organisms. The lakes and wetlands having soft bottom sediments are characterised by annelids either as dominant group or an important contributor to the macrobenthic fauna. Of the fresh water annelids, the oligochaetes display the greatest diversity and have the greatest indicator value.

MACROINVERTEBRATES AS BIOINDICATORS

Liebmann (1942) claims the microscopic benthic organisms being the most useful as true indicators of pollution and investigators like Richardson (1921, 1929), Gaufin and Tarzwell (1952, 1956), Heut (1949), Brinkhurst (1966) and Wilhm and Dorris (1966), among many others have relied almost entirely on them though their suitability and again diminished because of their rapid rate of reproduction and the difficulty of sampling

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and correctly identifying the species (Liebmann, 1951). Except in case of macroinvertebrates which are generally regarded as most suitable indicators of pollution, the presence of a particular species does indicate the suitability of the environment for its growth and development but the absence of any species does not necessarily indicate the unsuitability of the environment, instead the absence of an entire group of species with same ecological needs indicate adverse environmental conditions (Kaul and Pandit, 1981). According to Jumppanen (1976) also the first signs of eutrophication and pollution in some Finnish lakes are usually seen in the benthic fauna as the suspended wastes immediately sink to the bottom to decompose and thus causing a change in the benthic organisms. Thus, certain species of sponges, for example, respond to various types of poisonous pollutants even in very mild cases, while others (tubificids, sludge worms, maggots and chironomids) can tolerate even the most gross organic pollution and high levels of toxic pollution. Hence, the species analysis of benthic community enables the determination of trophic type of lakes and is, therefore, an important criterion in the ecological classification of lakes (Thut, 1965; Seather and McLean, 1972; Bazzanti, 1975). As the emergence of species like *Tubifex* sp. and *Chironomus* sp. in Nilnag lake indicated the eutrophic status of the lake (Yaqoob et al., 2007). Benthoses of the Shallabugh wetland were represented by Arthopoda (10), Annelida (7) and Mollusca (6). The abundance of some specific pollution indicator species, especially annelids such as *Limnodrilus* sp, *Tubifex tubifex* and *Branchiura sowerbyii*, is depictive of transition in trophic status of the wetland from meso- to eutrophy (Siraj et al., 2010). Dar et al. (2010) reported a few species of annelids like *Tubifex tubifex*, *Limnodrilus* sp. and *Erpobdella octoculata* to be dominant in terms of taxa and abundance. However, Mollusca were poorly represented and Insecta although represented by one taxa namely *Chironomus* sp. was abundant throughout the study period revealing the eutrophic status of Hokera wetland as the organisms recorded mostly occur in eutrophic waters. Lang (1985) studied the eutrophication of lake Geneva and recorded species like *Potamothrix hammoniu*, *P. Heuscheri* and *Tubifex tubifex* to be numerically dominant ones as compared to *P. veidovskyi* (mesotrophic), *Stylodrillus heringianus* (oligotrophic) in the community structure indicating a meso- eutrophic status of lake. Awal and Svozil (2010) identified 481 to 629 organisms in three constructed wetlands in South East metropolitan Melbourne comprising of 16 taxa. There was no significant differences between the wetlands on the basis of one way analysis of variance (ANOVA) for species richness (P> 0.05, F= 0.19) and Shannon-weiner index (P. 0.05, F=2.54) but the data collected was compared with the earlier published data which depicted differences in species richness and diversity. Hence, macroinvertebrates were used as a universal measure of wetland ecosystem integrity and consequently the management and conservation of constructed wetlands. Kaul and Pandit (1982) while describing the biotic factors and food chain structure in different wetlands of Kashmir observed the macrozoobenthos to be limited in number of species. They also observed summer predominance of annelids and molluscan predominance in winter. *Tubifex tubifex* and *Glossiphonia weberi* exhibited highest energy content during summer, where as *Chironomus plumosus* and *Viviparus bengalensis* revealed highest values during winter (Gupta and Pant, 1983b). The diversity of benthic macroinvertebrates was much lower in Lake Carl Blackwell. Nineteen genera of benthic macroinvertebrates were found, but nine genera were the maximum being found at one time and station with density ranging from 2310 ind./m^2 in fall to 1625 ind./m^2 in spring of which greatest density (91.5%) was contributed by *Chaoborus* of the assemblage (Howick and Wilhm, 1984). The faunal diversity was minimum at Perumathura where the substratum was highly unstable, but the density was maximum at Murukampuzha where the substratum was relatively stable. There was also the varying pattern of regional and seasonal variations in different groups of benthic organisms (Nair et al., 1984). Singh and Ahmad (1989) compared the benthic fauna of lotic and lentic water bodies and observed oligochaetes/insects to be the chief component of lentic waters while as the polychaetes were the major contributors of lotic system. Oligochaetes were the groups with higher similarity whereas the polychaetes were altogether absent in lentic systems.

FACTORS AFFECTING LAKE MACROINVERTEBRATES

The environmental factors that affect the structure of macrozoobenthic community should be considered while scaling the ecological status (Trayanova et al., 2007). Pearson et al. (1986) described long term changes in the benthic community of two areas Loch Linn and Loch Eil, Scotland. They held the view that the changes in population of benthic community over a period of twenty years were related to and dependent upon changing organic inputs which in turn determined the carrying capacity of sedimentary benthos, while as the species composition was dependent upon climatic fluctuations like long term temperature changes. A low species diversity index was observed at thermal effluent site due to deteriorated water quality at that site and hence, the community structure at the effluent site was reported to be under stress (Singh, 1988). The nature of the sediment influenced the population dynamics of the oligochaetes of the lake as dominant oligochaetes of Dal lake, Kashmir includes *Limnodrilus hoffmeister*, *Tubifex tubifex*, *Branchura sowerbyii*, *Aelosoma* sp. and *Nais* sp. which thrive in sediments rich in organic nutrients (Mir and Yousuf, 2003). Among 24 taxa of benthic macroinverebrates in Lake Uluabat, Bursa, Turkey, Insecta and Oligochaeta were the most abundant groups, dominated by species characteristic to nutrient rich waters, including *Pristina aequiseta*, *Nais communis*, *Tubifex tubifex*, *Limnodrilus hoffmeisteri*, *Potamothrix hammoniensis* and *Tanypus punctipennis*. Most of the variance (63.5%) in relationships between species and environmental variables as explained by the first two axes of a canonical correspondence analysis (CCA) and placed most Oligochaeta and Chironomidae near the vectors of high nutrients and chlorophyll-a concentrations, while the sensitive Crustacea and some Oligochaeta (Lumbricidae) species on sectors of the plot with the smallest weight of those variables (Celik et al., 2010). Eighteen taxa of macrozoobenthic organisms, belonging to Annelida, Mollusca and Arthropoda, were recorded during the course of a yearlong study in the Dal lake, Kashmir and marked variations were found in the spatial distribution of various taxa, which was influenced by the texture of the sediment as well as by the macrophytic community structure (Mir and Yousuf, 2002). The macrozoobenthic community was found to be influenced by the type of substrate, the organic matter, the abundance of macrophytes as well as the concentration of calcium (Qadri and Yousuf, 2004). During the survey, 5 macrozoobenthic taxa belonging to Annelida, Mollusca and Arthropoda were recorded among which Annelida formed the most dominant group being represented by two oligochaetes that is, *Tubifex tubifex* and *Branchiura sowerbyii*, which have been designated as an indicators of pollution (Oliver, 1971; Milbrink, 1980; Bazzanti, 1983). The water quality, sediment characteristics and general ecology indicated the association of distribution, diversity and population density with habitat ecology, substratum diversity, altitude and climatic conditions of the concerned area (Roy and Nandi, 2008). Gong et al. (2000) made comparative studies on macrozoobenthos in two shallow mesotrophic lakes (Biandantang and Houhu) and found macrozoobenthos more diverse in Lake Biandantang where macrophytes were abundant than in Lake Houhu where macrophytes were scarce. In shallow lakes, submerged macrophytes are essential for the maintenance of biodiversity of macrozoobenthos because the macrophytes increase habit heterogeneity and availability of suitable food, and may also decrease predation by fish on the macrozoobenthos (Gong et al., 2000). The epiphytic oligochaetes were more diverse and more abundant in the *naiko* than those in littoral Lake Biwa, probably because of higher temperatures, denser aquatic vegetation, and higher primary production (Othaka and Nishino, 2006). Organic matter, ammonium and phosphates were positively correlated with the mean oligochaete abundance, but not with the granulometry. The canonical correspondence analysis (41.2% cumulative variance) indicated that the oligochaetes distributed along both an eutrophication-pollution gradient and a turbidity-conductivity gradient (Armendariz et al., 2011). Increasing temperatures due to climate change were found to influence abundance and timing of species in numerous ways (Burgmer et al., 2007). Whereas many studies have investigated climate-induced effects on the phenology and abundance of single species, less is known about climate-driven shifts in the diversity and composition of entire community. They analysed time series of entire community of macrozoobenthos in lakes and streams in Northern Europe but, no direct linear effects of temperature and climate indices (North Atlantic Oscillation index) on species composition and diversity was found. However, multivariate statistics showed that trends in average temperature have had profound impacts on species composition in lakes and future climate shifts may thus induce strong variance in community composition (Burgmer et al., 2007). Amakye (2001) while monitoring the seasonal as well as depth wise distribution of macroinvertebrates in the sediments of lake Volta at Yeji area observed the highest density of macroinvertebrates between the shore and depths of 8-10 m and their abundance in July. It was also found that Chironominae were abundant while Orthocladinae and Ephemeroptera were scare in the sediments compared to the formative years of the lake. The observed changes in the composition and diversity of benthos were attributed to increasing anthropogenic influences on the lake which was depicted by the changing chemistry of the lake water. In temporary or permanent wetlands, the total macroinvertebrate biomass and densities were positively related to coarse particulate organic matter abundance (living and nonliving plant matter; CPOM) and negatively related to turbidity. Density of ecologically sensitive EOT (Ephemeroptera, Odonata and Trichoptera) taxa was also positively related to CPOM and negatively related to turbidity. Total taxa richness was negatively related to turbidity, and percent of total macroinvertebrate density consisting of EOT (% EOT) was positively related to CPOM (Stewart and Downing, 2008). Stepwise multiple regression analysis demonstrated that the water depth, conductivity and chlorophyll "*a*" were the key factors affecting macrozoobenthic abundance in the lakes (Yongde and Hongzhu, 2007). The diversity and distribution patterns of certain species were clearly related to water quality (Latha and Thanga (2010). Leech community composition was best described by an ordination incorporating alkalinity, primary productivity and lake area. In general, highest species richness occurred in small eutrophic lakes where as lowest richness was recorded in medium to large lakes with low productivity. Contrary to results for some other taxa, lake pH was not a dominant variable describing only a small amount of variance in the species-environment relationship (Grantham and Hann, 1994). The oligochaete community of the acidified lakes was poorer compared to the neutral ones. Taxa richness, total biomass of the oligochaetes, their relative density and relative biomass in macroinvertebrate communities were lower in the strongly acidified lakes. Changes of major taxa proportions in the total density and biomass of the oligochaetes were recorded with lowering of pH (Ilyashuk, 1999). The oligochaetes were separated into three functional feeding groups, as gatherers (S) that are selectively ingested mainly on the sediment surface and other substrates, gatherers (T) that are selectively ingested mainly in the sediments, and predators. Total density of gatherers (T) as well as their relative density in the oligochaete assemblage and macroinvertebrate community was lower in the acidified lakes (Ilyashuk, 1999). In an eutrophic subarctic lake, the largest populations of animals were found in the deepest part of the lake. However, in the anoxic part of the lake, species were in low number due to the low oxygen levels in water and high organic content of the sediments of the lake (Moore, 1981). Further, the anoxic zone of Nainital lake was found to be devoid of macrobenthos (Gupta and Pant, 1983a). Efitre et al. (2001) quantified the spatial and temporal distribution of macroinvertebrates in Nabugabo lake, Uganda with a focus on habitat associations and they found the total absence of bivalves and crustaceans and less abundance (1.8%) of gastropods. The dominant taxa, however, were ephemeropterans (77.7%), dipterans (11.1%) and smaller contributions were made by annelids (5.4%), odonates (2.8%) and tricopterans (1.3%) to the benthic assemblage. Further, the study revealed that abundance of macroinvertebrates was due to the habitat effects as water lily habitat reflected low level of oxygen near the sediments. Gong and Xie (2001) reported 33 taxa belonging to Mollusca, Oligochaeta and Arthropoda in lake Donghu-China and observed low species diversity in highly eutrophic areas measured in terms of species number, diversity index and k-dominant curves. Abundance of *Limnodrilus hoffmeisteri* was positively correlated to the degree of eutrophication due to its ability to tolerate low dissolved oxygen as the worms exhibit very marked physiological tolerance for oxygen depletion related to excess decomposable organic matter present in the environment, but they do decrease in number when condition are at their worst. Few other organisms can survive under these circumstances, so that worms, which have a very efficient oxygen uptake mechanism, may take up the entire benthic community (Zajic, 1971).

CONCLUSION

From the preceding review, it is evident that macroinvertebrates occupies an important position in the lake ecosystem serving as a link between primary producers and higher trophic levels. They also play an important role in the decomposer food chain which in turn affects the cycling of minerals macroinvertebrate community change in response to changes in physicochemical factors and available habitats and hence, are used as bioassessment tools because of their limited mobility, comparatively long life cycle, differential sensitivity to various types of pollution and reflectance of cultural eutrophication and health status of aquatic habitats, thus can be used as robust bioindicators. In addition, it may be said that the occurrence, composition and distribution of macroinvertebrates in lakes and wetlands is governed by numerous environmental factors that affect the structure of macrozoobenthic community and their distribution pattern should be considered while evaluating the ecological status.

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