Benthic macroinvertebrates: Bioindicator for assessing ecological status of lake

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Abstract:

Aquatic macroinvertebrate communities can act as good indicators of the prevailing hydrological regime and water quality in aquatic systems. As benthic invertebrates respond sensitively not only to pollution, but also to a number of other human impacts (hydrological, climatological, morphological, navigational, recreational, and others), they could potentially be used for a holistic indication system for lake ecosystem health. Several studies on macroinvertebrates, focused on community composition or association with the plant community, have been carried out on large water bodies throughout the world. However, only a handful of studies are available in Indian context. The current lack of knowledge is one of the limiting factors for developing such a nationwide guideline and thus compromising the basis for setting the environmental objectives for assessment of lake ecosystem functioning.

Keywords: macroinvertebrate, biological indicator, lake ecology, aquatic food chain.

Introduction

Macroinvertebrates are the most diverse and abundant organisms in freshwater aquatic systems and are a key component of aquatic ecosystem function (Kratzer, 2002). Macroinvertebrates distribution and community is strongly dependent on the composition and structure of vegetation and macroinvertebrates are recognized as an essential food source for juvenile fish and amphibians in aquatic systems (Takhelmayum and Gupta, 2011). Diversity and density of the macrobenthos is dependent on chance settlement of pelagic larval forms of different species, affinity to suitable substratum and also the degree of stress effect caused by various environmental as well as anthropogenic factors. Hence, any environmental changes in lakes, for example in nutrient concentrations, would be reflected by changes in the structure of the benthic invertebrate community (Carvalho et al. 2002). This means that benthic invertebrates may potentially indicate eutrophication, as planktonic communities, but in addition several other modes of lake degradation. In consequence, the more holistic assessment based on benthic invertebrates is expected to result in different categorization for lakes subjected to multiple impacts.

Advantages of using macroinvertebrates as bioindicator

Macroinvertebrates are studied in waterbodies because they are useful biological indicators of change in the aquatic systems. The main advantages of using macroinvertebrates is that (i) visible to unaided eyes, (ii) they relatively sedentary and therefore easy to deal with, (iii) have varying sensitivities to changes in water quality (Sharma et al., 2006), (iv) some have life span of up to a year or greater and (v) they are easily collected and identified. Recent extensive reviews of the current state-of the- art of ecological water quality assessment systems in Europe have revealed that, while practical (and WFD-compliant) assessment tools using macroinvertebrate parameters are already in use to assess the ecological quality of rivers, in many European countries there are currently no working macroinvertebrate assessment systems for lakes (Cardoso et al. 2005, Nõges et al. 2005). In India, there were few initiatives to assess water quality based on benthic macroinvertebrate fauna. Most of the works were found to be based either on efficiency of marobenthos as bioindicator of water quality in different streams of southern (Latha and Thanga, 2010; Kani and Murugesan, 2014) and northern parts (Sharma et al., 2008; Sharma and Chowdhary, 2011) of India or abundance of mosquito larva (Banerjee et al., 2010). There were hardly any data available for ecological characterisation of water bodies using macroinvertebrate as bioindicator in West Bengal with the exception of Basu et al., 2013 working in East Calcutta Wetlands.

Importance of Macrophyte cover around lakes

The Macrophyte cover in and around the waterbody generally has a strong impact on the macroinvertebrate diversity and abundance (Dalu et al., 2012). Macrophytes can also provide protection from predation, mainly by fish (Crowder and Cooper, 1982; Gilinsky, 1984; Hanson, 1990; Diehl, 1992; Svensson et al., 1999). Hence, lakes with fish may contain different invertebrate communities than those without (Hinden et al., 2005). Although fish species vary in their foraging habit for macroinvertebrates among plants (Persson, 1987; Kornijów et al., 2005), submerged plants and reed beds can also act as a cover and source of food for, particularly, small fish (Diehl and Kornijów, 1998; Okun and Mehner, 2005). While macrophyte cover generally supports greater diversity and abundance of invertebrates than open silty areas or those dominated by gravel and stones (Watkins et al., 1983), and removal of submerged vegetation generally reduces macroinvertebrate taxa richness (Rabe & Gibson, 1984; Tolonen et al., 2003), this is not always the case (Kuflikowski, 1974).

Macroinvertebrates: an integral part of aquatic foodchain

Macroinvertebrates are an important part of the aquatic food chain and can be characterised by what the animal feeds on and how it acquires it. The categories are referred to as functional feeding groups and help describe the role each macroinvertebrate plays in an aquatic system.

(i) **Shredders** feed on organic material, such as leaves and woody material, and help to convert this matter into finer particles. They require vegetation growing along a waterbody, so that plant material falls into the stagnant or slow flowing water is not swept away. Such animals include amphipods, isopods, freshwater crayfish (marron, gilgies, koonacs) and some caddisfly larvae

(ii) **Collectors/Filter feeders** feed on fine organic particles that has been produced by shredders, microorganisms and various other physical processes. Examples include mayfly nymph, mussels, water fleas, some fly larvae and worms.

(iii) **Scrapers** graze algae and other organic matter that is attached to rocks and plants. Such animals include snails, limpets and mayfly larvae.

(iv) **Predators** feed on live prey and are found where smaller collectors and shredders exist. Examples include, dragonfly and damselfly larvae, adult beetles and beetle larvae, some midge larvae and some stonefly larvae.

High standing biomass of invertebrate grazers among plant beds implicate them as major conduits of energy along trophic pathways, prompting suggestions that grazers on epiphytes are important symbionts for macrophytes by cleaning epiphytes from stems and leaves (Phillips et al., 1978; Underwood, 1991; Daldorph and Thomas, 1995). Changes in standing biomass of filtering molluscs can also relect and effect shifts in lake trophic state (Lewandowski, 1991; Dobrowolski, 1994; Krzyzanek and Kaska, 1995; Dusoge et al., 1999). Patterns of abundance and prevalence of oligochaetes and chironomids are often very notable within plant beds (Soszka, 1975; Gerrish and Bristow, 1979; Kornijow, 1989a,b; Van den Berg, 1997). Overall, littoral macroinvertebrate communities may have an important role in sequestration and recycling of minerals (Kolodziejczyk, 1984a,b; Underwood, 1991; Schindler and Scheuerell, 2002).

An indicator of environmental modifications

Environmental modifications can alter macroinvertebrate communities. Poor catchment management can exaggerate the turbidity of water. In highly turbid water, the light penetration is reduced affecting photosynthesis of plants and also increases the temperature of the water. The suspended solids may clog respiratory surfaces or interfere with feeding appendages. Filter feeders receive reduced nutritional value and expend more energy to collect food. High levels of suspended solids may begin to settle and change the composition of the bed of the waterbody. This can affect movement, feeding, habitat and reproduction of some macroinvertebrates.

High levels of nutrients in the form of nitrogen and phosphorus from fertilisers and wastewater can activate excessive algal growth (algal blooms). The death and decay of these algae can produce toxins and stagnant conditions. In these conditions, macroinvertebrate community diversity is usually reduced but there is generally an increase in the abundance of a few tolerant opportunistic species. These macroinvertebrates are able to take advantage of the altered conditions and exploit the excess of food supply.

Some animals can act as pollution indicator species because they respond to specific changes in the water conditions since response to pollutants vary enormously. For example, most species of mayfly nymph are found to be quite sensitive to sediment or organic pollutants, but some are quite tolerant. Red midge larvae (Chironomids) are very tolerant to low levels of dissolved oxygen (Harikumar et al., 2014). The larvae of dragonflies and damselflies can be quite tolerant to salinity fluctuations, but are harmed by other pollutants. Toxic materials can enter waterbodies from industrial and agricultural wastewater and can include such substances as pesticides and heavy metals. The effect of pollutants to the macroinvertebrate communities may be short-term (acute) if the pollutant exists in the water at high concentrations or long-term effect (chronic) where toxins can accumulate and become concentrated in food chains. As a result, the macroinvertebrate communities could be affected by decreased reproduction, impaired behavioural responses, disease or eventually death. The presence of such toxicants generally tends to reduce the overall diversity of macroinvertebrates (Paerl et al., 2007; Sultana and Kala, 2012; Sharma and Rawat, 2009). Therefore, aquatic macroinvertebrate assemblages and communities can be used as an efficient indicator of the prevailing hydrological regime and water quality in aquatic systems. For this purpose, the water framework directive (WFD) with some modifications could be referred as noted below:

Table 1: Assessing ecological status of lakes using benthic invertebrate fauna as bioindicator in accordance with Directive 2000/60/EC, commonly known as the Water Framework Directive (WFD), Europe. (modified after Solimini et al., 2006).

Sl No.	Features of macroinvertebrate community	Good status	Moderate status	Poor status
1.	Taxonomic composition and abundance	undisturbed	differ moderately	disturbed
2.	Ratio of sensitive taxa to tolerent taxa	no signs of alteration	lower and typespecific community are absent.	substantially lower and typespecific community are absent.
3.	Diversity of invertebrate taxa	no sign of alteration	significantly lower	substantially and significantly lower

For this kind of study, the good or high status or the reference state has to be identified. The Reference state is, subsequently, the benchmark used to calculate Ecological Quality Ratios. The identification of the reference status for a specific lake type based on benthic invertebrates is complicated by the facts that the composition of benthic invertebrate communities exhibits natural variation due to season, lake depth, meso-scale habitat structure, and also due to biotic effects (competition and predation). Clear seasonal changes in community structure can be observed which are primarily due to the life cycles of aquatic insects, but may be influenced by seasonal changes in habitat conditions, too. As most univoltine insects emerge in summer, these are hardly present in summer samples of benthic invertebrates, and the early larval stages present in autumnal samples can often not be determined taxonomically. Therefore, the reference states are to contain type specific biological communities that have been subject to very minor anthropogenic disturbance. However, the same phenology applies to benthic macroinvertebrates in streams and rivers, which have been very successfully used as bioindicators for more than a century.

Benthic invertebrates play an essential role in key processes within lake ecosystems, like, food chain dynamics, productivity, nutrient cycling and decomposition (Reice and Wohlenberg 1993). Benthic invertebrates form an important link between primary producers, detrital deposits and higher trophic levels in aquatic food webs (Brinkhurst 1974, Stoffels et al 2005). Despite their key role in aquatic ecosystems, macroinvertebrates are a neglected element in the development of an assessment system in lakes. Factors that may be largely responsible for this include their complex biotic structure, high temporal variability and the high substrate heterogeneity found in lakes. A solution needs to be found to understand natural variability so that anthropogenic impact may be identified and extracted from other sources of variation.

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