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Benthic invertebrate species influences nutrient cycling and energy flow in fresh water ecosystems

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Abstract
Nepal is a land-locked country situated in the central part of the Himalayas stretching between 260 22' and 300 27' N latitudes and 800 40' and 880 12' E longitudes with an altitudinal range from 60m in the south to 8,848m (Mt. Everest, the world's highest mountain peak) in the north. The country is bordered by India in the east, west and south, and the People's Republic of China in the north. The country is about 885 km long (east-west) with an average breadth of 193 km (north-south). About 500 million people in South Asia depend directly on the abundant water from the mountainous rivers of the Himalaya. The rivers provide water for irrigation, drinking, household, municipal water use, industrial activities, and more than in other regions of the world dominate the religious and cultural life of the society. In spite of the integral role of water for the economic well-being of the area, rivers are under tremendous pressures; additionally monitoring of rivers and sustainable water uses are underdeveloped. In the Himalayan countries, approximately 20% of all deaths among children under five years of age is caused by water borne diseases.

Keywords: Benthic invertebrates, rivers, ecosystems, nutrient cycling, Nepal

1. Introduction

Nepal is rich in freshwater resources with 6000 rivers and rivulets. Most of the big and perennial rivers in Nepal have originated from melting of snow [1]. They flow from high mountains with greater velocity and have enormous energy to clean the shores with mechanical process [1] and others are spring-fed which flow through the mid hills of Nepal. River water fulfills the major demands (drinking, cleaning, irrigation, and hydropower) of people in both the rural and urban localities. The water quality for drinking purpose is concerned widespread among the public in Nepal. However, very little attention is given to quality of water in river. But mostly the poor and migrated laborer communities are directly dependent on rivers as a source for their livelihood [2]. Despite various benefits of river and stream water, the continuous and improper use is degrading their integrity of water quality. There are a number of anthropogenic stressors which affect the rivers/streams globally such as eutrophication [3], agricultural intensification [4], thermal effluent discharge [5], water abstraction [6], organic pollution [7], and river bed extraction [8] have profound impacts on river morphology and its biodiversity. Benthic Invertebrates are organisms that live in or on the bottom sediments of rivers, streams, and lakes. The benthic invertebrate species is strongly affected by its environment, including sediment composition and quality, water quality, and hydrological factors that influence the physical habitat. Because the benthic community is so dependent on its surroundings, it serves as a biological indicator that reflects the overall condition of the aquatic environment [9].

Macroinvertebrates, in stream water monitors the environmental quality [10]. Any changes (biological, chemical, or physical) that occur in the aquatic ecosystem have direct impact on the resident organisms [11]. So, these resident organisms are an important component of freshwater ecosystems and are capable of detecting the effects of sporadic and cumulative pollution of their habitat [12]. These are also sensitive to changes in conditions such as, precipitation, temperature, and the associated flow regimes; hence they provide good indication of environmental change [13]. Small invertebrates are functionally important in many terrestrial and aquatic ecosystems [14]. In freshwater sediments, benthic invertebrates are diverse and abundant, but they are often patchily distributed and relatively difficult to sample, especially when they live in deep subsurface sediments [15]. Thus, the species richness and functional importance of fresh-water benthic invertebrates generally go unnoticed until unexpected changes occur in ecosystems.

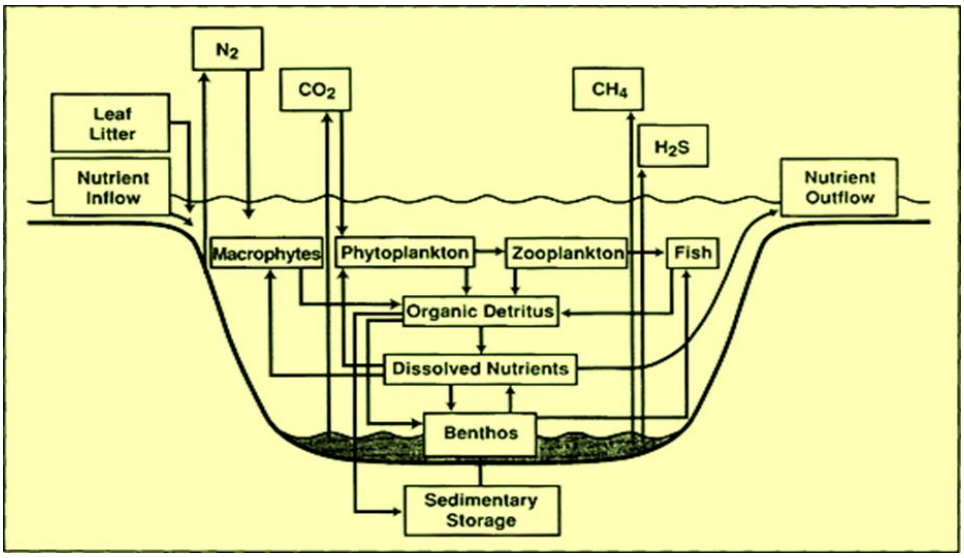

Fig 1: Showing benthic position through schematic diagram in an ecosystem

In addition, benthic species can themselves constitute a disturbance, such as when they transmit diseases. For example, certain benthic invertebrate species (e.g., Tubifex tubifex) serve as parasite-transmitting vectors; if these invertebrates increase in abundance in stream sediments, they may spread a lethal disease to trout, causing trout populations to decline [16]. Fish kills may also occur because of increased accumulation of nutrients, which cause formation of toxic algal blooms, Deoxygenation of deeper, density-stratified waters, and high con-centrations of ammonia or hydrogen sulfide [17]. The bottom muds of lakes and streams may at first glance appear to be uniform and, therefore, unlikely habitats for high biodiversity. However, physical, chemical, and biological processes create significant horizontal and vertical heterogeneities in the substrata that provide a physical template for distinct niches [18]. These sedimentary processes include changes in direction and rates of flows, differential deposition of sediment grain sizes and dead organ-isms, growth and death of roots, burrowing and sediment reworking, and fecal production by benthic consumers.

2. Diversity of benthic freshwater communities

The benthic zone is the ecological region at the lowest level of a body of water such as an ocean, lake, or stream, including the sediment surface and some sub-surface layers. Organisms living in this zone are called Benthosand include microorganisms (e.g., bacteria and fungi) as well as larger invertebrates, such as crustaceans and polychaetes. Freshwater benthic species evolved from many phyla over millions of years and represent a rich fauna. Hutchinson [18] concluded that "the Diptera are by far the most diverse order of insects in fresh water; they are in fact the most diversified of any major taxon of freshwater organisms." He estimated that more than 20,000 Dipteran species breed in fresh water worldwide, approximately four times the number of Coleoptera.

Others estimate that there are large numbers of benthic species of protozoa, crustacea, and other groups [19]. Moreover, systematists estimate that only a small percentage of certain taxa (e.g., freshwater nematodes) have been described. Diverse forms are continuously discovered, especially in deep groundwaters, in which regional endemics reflect iso-lation and evolutionary adaptations to specific conditions [20]. Many species still remain undescribed, both taxonomically and ecologically [21]. Protecting diverse benthic communities will require more thorough understanding of long-term functional relationships among these species in an ecosystem context.

3. Importance of individual species in ecosystem processes

According to the Encyclopedia of Earth, species diversity is a measurement of an ecosystem's species richness and species evenness. If an ecosystem has poor species diversity, it may not function properly or efficiently. A diverse species assemblage also contributes to ecosystem diversity. Species richness is the number of different species an ecosystem [22]. Environments that can support large numbers of species, such as tropical areas, tend to have greater species richness. The Encyclopedia of Earth defines species evenness as "the variation in the abundance of individuals per species within a community." If a community has a large disparity between the numbers of individual within each species it has low evenness [23]. If the number of individuals within a species is fairly constant throughout the community it has a high evenness. If community A has 10 individuals divided between two species, but species 1 represents nine individuals, while species 2 has only one, then community A has a low evenness and lower species diversity. If community B has ten individuals divided between two species, with species 1 having four individuals and species 2 having six, then community B has high evenness and higher species diversity. The more even the number of animals per species within an ecosystem, the greater the species diversity. It is evident from studies of terrestrial species that the number of species is not necessarily related to rates of ecosystem production [24]. Instead, each species is adapted to function under variable conditions, with different species being of different relative importance to particular ecological processes [25]. Recently, Palmer *et al.* [26] proposed that particular benthic species are especially important for determining how organic matter is processed in freshwater ecosystems. Based on current information about the separation of niches among benthic species, it is conclude that different species of sediment-dwelling macro-invertebrates are unlikely to be interchangeable components in many complex ecosystem processes [27].

4. Diversity and species redundancy in ecosystems

For decades, ecologists have questioned how much overlap in resource use can persist over time among competing species. Recently, this question has been rephrased to ask if, and under what conditions, the functional roles of each species are necessary for ecosystem processes to persist. This "redundancy hypothesis" predicts that not all species are equally necessary at any one time for ecosystem processes to continue [28]. If some species were "redundant" in terms of their functional relations, then their loss would not result in observable changes in energy flow or nutrient cycling. The concept of "parallel redundancy" used in engineering analysis for system reliability is likely to be applicable for comparing species' roles in ecosystem studies [29]. The redundancy hypothesis can be broken down into three sub hypotheses. The "functional group hypothesis" predicts that as long as one species from each functional group is present, ecosystem processes will continue. The "trophic level hypothesis" predicts that as long as the biomass or turnover of organisms at each trophic level remains relatively uniform and is independent of species composition, energy flow and ecosystem processes will persist. Finally, the "keystone species hypothesis" predicts that not all species are of equal functional importance; rather, only a few are truly necessary for ecosystem processes, even though these species may not be abundant [30].

Linkage of niche theory to trophic dynamics led to the "rivet hypothesis" [31], which postulates that each species has the potential to perform an essential role in the persistence of the community and the ecosystem and that some species may remain as the sole representatives of a particular functional group [31]. Although it is clear that at some level each species is unique, overlap in resource use among species is not unusual, especially in freshwater food webs.

5. Species redundancy in freshwater sediments

There is insufficient information about how individual Zoo benthic species interact with one another under the dynamic range of natural conditions in fresh-water sediments. Nevertheless, from detailed field observations it appears that redundancy in many freshwater benthic ecosystems is low. For example, numerous zoo benthic species occupy particular microhabitats along stream channels or at various depths in [18] and at various times of year [21]. These spatial and temporal distributions suggest that benthic species have different preferences for particular ranges of temperature, pH, current velocity, and types of substrata.

6. Roles of benthic species in ecological processes

Benthic species perform a variety of functions in freshwater food webs. Dead organic matter is one of the main sources of energy for benthic species in shallow-water habitats [32]. Benthic invertebrates are estimated to process 20-73% of riparian leaf-litter inputs to headwater streams. Second, benthic invertebrates release bound nutrients into solution by their feeding activities, excretion, and burrowing into sediments (Figures 1). Bacteria, fungi, algae, and aquatic angiosperms can quickly take up these dissolved nutrients, accelerating microbial and plant growth [33]. Finally, benthic organisms accelerate nutrient transfer to overlying open waters of lakes [34] as well as to adjacent riparian zones of streams [35].

7. Additions of benthic species to food webs

Food-web structure is a fundamental feature of marine ecosystems as it gives insight into how energy and contaminants are transferred from low trophic positions to upper trophic-level consumers [36]. It further provides insight in the relationships between biodiversity and ecosystem functioning [37], and how trophic cascades may alter ecosystems [38]. Knowledge of food web characteristics, such as key species, food chain length, or primary food sources, can be used to understand differences in ecosystem resilience in response to natural and anthropogenic disturbances [39], and is therefore essential to sustainably manage ecosystems and their harvestable resources in a changing environment.

Knowledge of seasonal changes in species assemblages, diversity and food-web structure is especially important for understanding the ecosystems [40]. However, it is important to ask about the effects on ecosystem processes, because native species are generally well adapted to local conditions, movements of additional species into fresh-water assemblages can sometimes alter energy flow and change nutrients [41]. Successful invaders often have biotic attributes that predispose them to have major impacts on highly variable ecosystems. Identifying these invasive characteristics may be useful for better understanding how resident, native benthic species function in an ecosystem context.

8. Losses of benthic species in food webs

Loss of some species will likely alter or degrade critical ecosystem processes because of the unavailability of replacement species. Once species are lost, the costs for maintaining natural ecosystems with engineering processes would be prohibitively expensive [42]. If at least one species were to remain in each functional group and the rate of processing by that species were sufficiently high, then, in theory at least, ecosystem processes should continue. Consequently, ecosystems composed of a bare minimum of species in a fluctuating environment probably could not continue to function over time merely by compensating for the losses of some species with increased densities, biomass, or processing rates of the few remaining species [43].

9. Freshwater ecosystem processing by crustaceans

Several studies have shown that crustaceans play important roles in stream and lake food webs. We out-line these studies as examples to stimulate additional field studies and to emphasize the need for more effective conceptualization of cross-linkages among different benthic species. Herbivorous benthic species have distinct functional morphologies, feeding preferences, and behaviors, resulting in major differences in their grazing rates [44]. Grazing crayfish generally do not consume all types of rooted macro phytes as widely as they con-sume most algae in stream food webs [45].

10. Conclusions

Benthic invertebrate species function in different ways that are important to maintaining ecosystem functions such as energy flow in food webs. Many benthic species convert live plant and dead organic material into prey items for larger consumers in complex food webs. In the process of maintaining energy flow, these benthic species simultaneously provide essential ecosystem services, such as nutrient cycling and aeration of sediments thus, it is increasingly important to protect the biodiversity of benthic communities to lower the risk of unexpected and unwanted consequences. Freshwater ecologists understand that benthic species provide important ecosystem services, but an adequate model for evaluating these services is lacking.

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