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BIO-INDICATORS FOR ASSESSING NEPALESE RIVER HEALTH

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Background

Healthy rivers provide goods and services such as water, hydro-electric power generation, food, recreation, flood control, groundwater recharge, temperature regulation, nutrients and pollutants processing, carbon and nitrogen storage. They are essential for the life and well-being of human beings. The services provided by freshwater ecosystems alone accounts 20% of all Earth's ecosystems (Costanza et al. 1997). Freshwater ecosystems cover less than 1% of the Earth surface, however, support 10% of all known species in which 50% belong to insects group (Balian et al. 2008). Despite their high significances to the society and in maintaining biodiversity, rivers are highly threatened in human dominated landscape (Dudgeon 2007). Human activities such as irrigation, hydro-electricity generation, and waste disposal have deteriorated river ecosystems massively in many countries. Many large rivers across the globe have been extensively modified for water abstraction, hydropower generation and transportation (Nilsson et al. 2005) resulting river fragmentation. Currently, humans control and use about 40 - 50% of available freshwater and the extent is projected to increase to 70% by the year 2050 (Postel et al. 1996; Chapin Iii et al. 2000).

Climate change is a burning issue across the globe. Scientists believe that climate change may further exacerbate the effects of human inducded activities on river ecosystems and their bidiveristy. Freshwater ecosystems occurring in mountains and highlands are particularly sensitive to climate change as their hydrology, morphology and physico-chemical conditions are affected by changes in precipitation and thermal regime (Jacobsen et al. 2012; Berghuijs et al. 2014; Tachamo Shah et al. 2015). In the Himalaya of Nepal, the rate of warming is more rapid which is almost three times higher than the global average (Shrestha et al. 1999; Shrestha et al. 2012). These increasing warming trends, shifting of precipitation patterns and rapid glacier retreats have indicated that Himalaya including Nepal is likely to exhibit severe impacts in different sectors. To address climate vulnerabilities and identify adaptation measures Nepal prepared the National Adaptation Programme of Action (NAPA) (MOE-Nepal 2010). NAPA has identified "Water resources and energy" as one of the sensitive sectors. To integrate the adaptation measures, Local Adaptation Plans for Action (LAPA) was formulated in 2011 (GoN-Nepal 2011). These plans, however, have not considered climate change impacts on freshwater ecosystems and likely consequence on water quality and biodiversity.

In this regard, macro-invertibrates based on bio-monitoring of freshwater ecosystems could be a milestone in the country like Nepal where institutional capacity is weak to address wider ranges of stressors including climate challenges.

Bio-monitoring is the use of organisms' responses to evaluate any changes in the ecosystem. Its primary goal is to assess the relative impacts of degradation on biotic assemblages (Morse et al. 2007). Use of the biotic assemblages as bio-indicators in monitoring of the freshwater systems has a long history and many advantages over direct chemical analysis of water. Aquatic organisms used in bio-monitoring live continuously in water and respond to a vast array of pollutants and changes in habitat, thereby integrating responses to long-term conditions in the river system. Chemical analysis in contrast provides a snapshot of the conditions at the specific time of sampling. Among many other aquatic organisms, stream benthic macro-invertebrates (larvae) have been widely applied in bio-monitoring across the world (Barbour et al. 1999; European Union 2000) because they (i) have relatively larger body size making them easier to identify, (ii) are taxonomically and ecologically highly diverse (iii) occur in high abundances making them useful for statistical analyses, (iv) live from few months to years allowing them to integrate long term pollution exposures, (v) have less mobility than fish preventing them to escape from occasional pollutions, and vi) many taxa are highly sensitive to changes in water quality, flow regimes and habitat changes. Today, bio-assessment has become a legal instrument for water resource management in many developed countries like the United States (Barbour et al. 1999), Canada , Australia (Halse et al. 2002), New Zealand (Stark et al. 2001) and European Union countries through WFD (European Commission 2000).

2. Methods

Study Area

The study was carried out in headwaters of Ganga river system, namely Koshi, Bagmati, Langtang, Gandaki and Karnali in Nepal Himalaya. The sampling sites were distributed at altitudinal ranges from less than 100 m to above 4500 m asl (Figure 1).

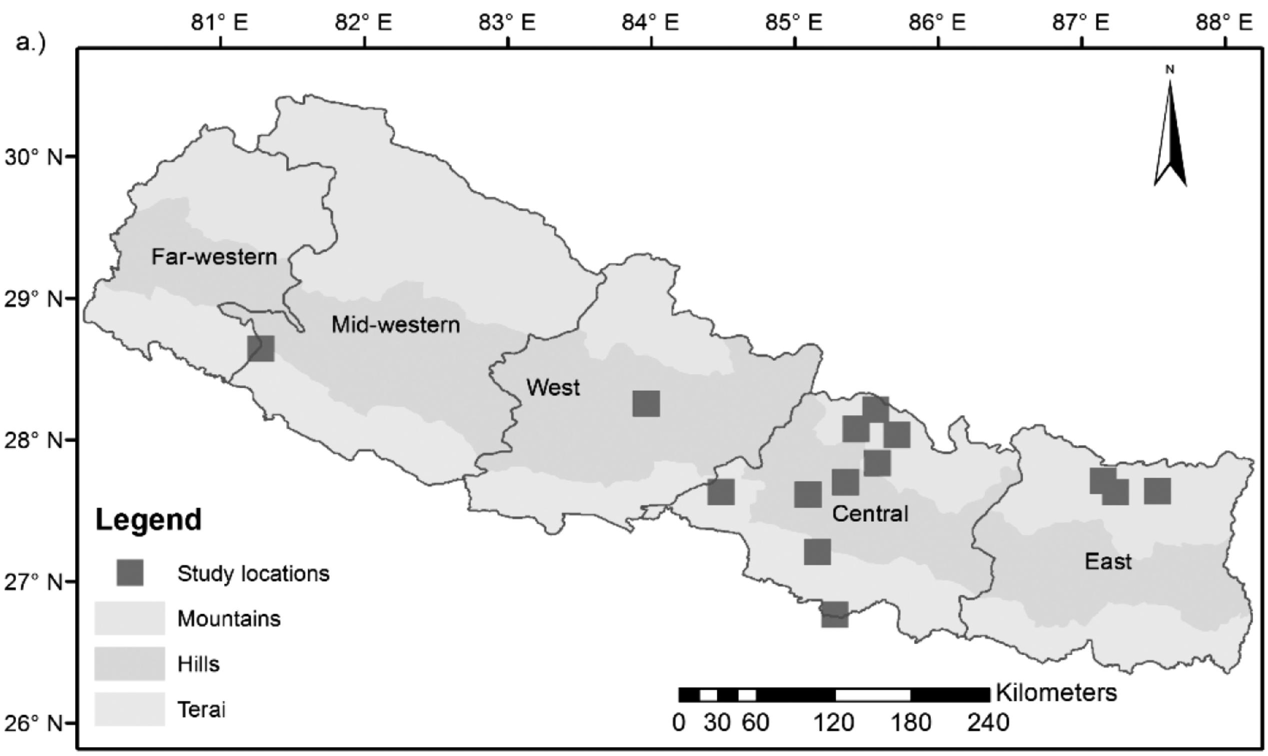

Figure 1: *Sampling sites are distributed in different ecological zones in rivers of Arun, Indrawati, Bagmati, Trisuli, Kali-Gandaki, and Karnali Rivers.*

Benthic Macro-invertebrates Sampling

Multi-habitat sampling approach (modified after Moog 2007; Tachamo Shah et al. 2015) was used to collect benthic macro-invertebrates. In each sampling site, 50-100 m stream stretch was selected and habitat coverage was estimated at 10% interval and noted on habitat protocol (Barbour et al. 1999) for the distribution of sub-samples at each site. Macro-invertebrates samples were collected by using a standard hand net (frame of 25 cm and 25 cm) of 500μm mesh size from 10 micro-habitats in each river stretch (Figure 2). Micro-habitats less than 10% coverage were not considered for sampling macro-invertebrates. Altogether 10 sampling zaps were taken (total sampling area is 0.625 cm^2) and combined to one composite sample for a site.

Taxonomic Identification: Benthic macro-invertebrates were sorted from samples in laboratory. Each group of the benthic macro-invertebrates was identified upto possible taxonomic level under stereomicroscope by using available identification keys (Dudgeon 1999; Nesemann et al. 2007; Nesemann et al. 2011). Examples of some benthic macro-invertebrates are presented in Figure 3.

Figure 2: *Sampling of stream benthic macro-invertebrates using hand net (frame of 25 cm and 25 cm) having 500 μm mesh size in Langtang.*

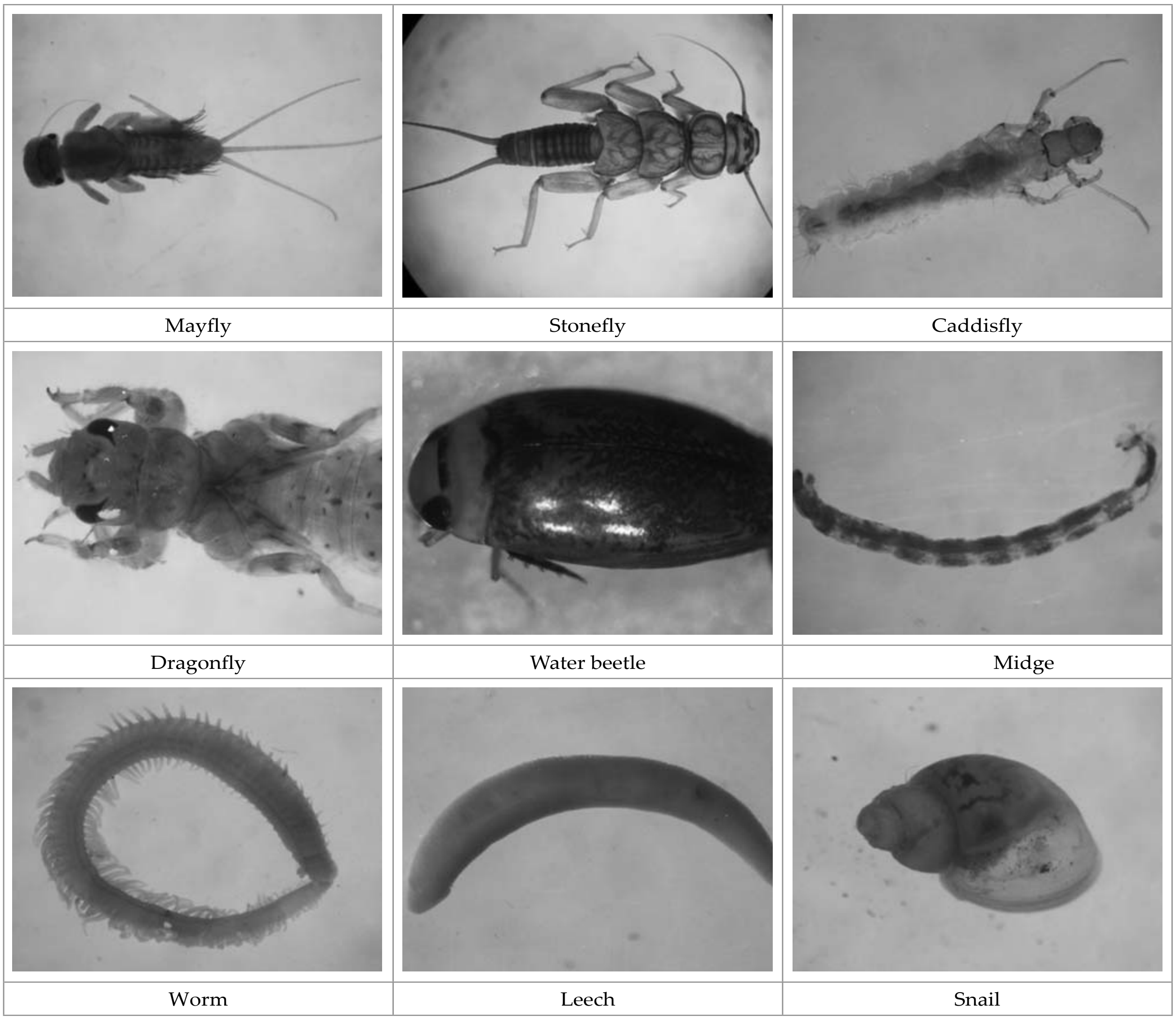

Figure 3: *Benthic invertebrates with common names (@ RDTS)*

Results

Biotic Index: Currently, NEBBIOS-original (Sharma 1996), HHHbios and GRSbios Indices are in use for assessment of river ecosystem in Nepal. Shah and Shah (2012) identified that GRSbios outperformed among the indices. The main differences between GRSbios and others are the number of taxa included in the list and taxa tolerance score at species or generic level and family or order level for non-insecta, respectively, making the GRSbios more efficient even for low altitude sites as the effects of disturbances or pollution are first realized at species level. The biotic index classified the study river systems into five river quality classes (RQC) ranging from 1-5 (Table 1). Class 1 represents none to slight pollution while Class 5 denotes severe pollution.

Disturbance Zonation: A study by Shah and Shah (2013) found that the degree of pollution in Himalayan rivers vary considerably between seasons. An increased pollution level during pre-monsoon season could be expected for the rivers having anthropogenic influences because the impacts remain constant throughout the year but the river flow decreases considerably intensifying the concentration of pollutants. The synchronized effects of stressors together with lower river discharge have adversely impacted sensitive species while enhanced the abundance of pollution tolerant species. Today, rivers are deteriorating in an alarming rate and restoration has become challenging both in terms of techniques and resources and is particularly difficult for a country having limited resources. The disturbance zone classification in this context might be a milestone in river management. The classification of disturbance zones provides information to river managers on accurate ecological health and prioritizes the river sections/zones where they can implement stressor specific restoration measures in time and cost effectively.

Climate Sensitive Zone

Climate Sensitive Zone (CSZ) is based on a maximum turnover of taxonomic richness across altitudinal bands in the Central Himalaya. CSZ was observed at an altitudinal band of 2900 – 3300 m asl (Tachamo Shah et al. 2015). The study listed a total of 33 indicator taxa that are likely to respond to changing climatic variables (Figure 4). Monitoring the indicator taxa in term of community assemblages, abundance and ecological behaviors in the climate sensitive zone would likely to detect effects of climate change in the freshwater ecosystems and their biodiversity. Similarly an extension of the CSZ across the Himalaya would be beneficial for benchmarking biodiversity changes with respect to climate change and results can be employed to formulate a mitigation policy and plans to combat the adverse impact to the river ecosystems and biodiversity.

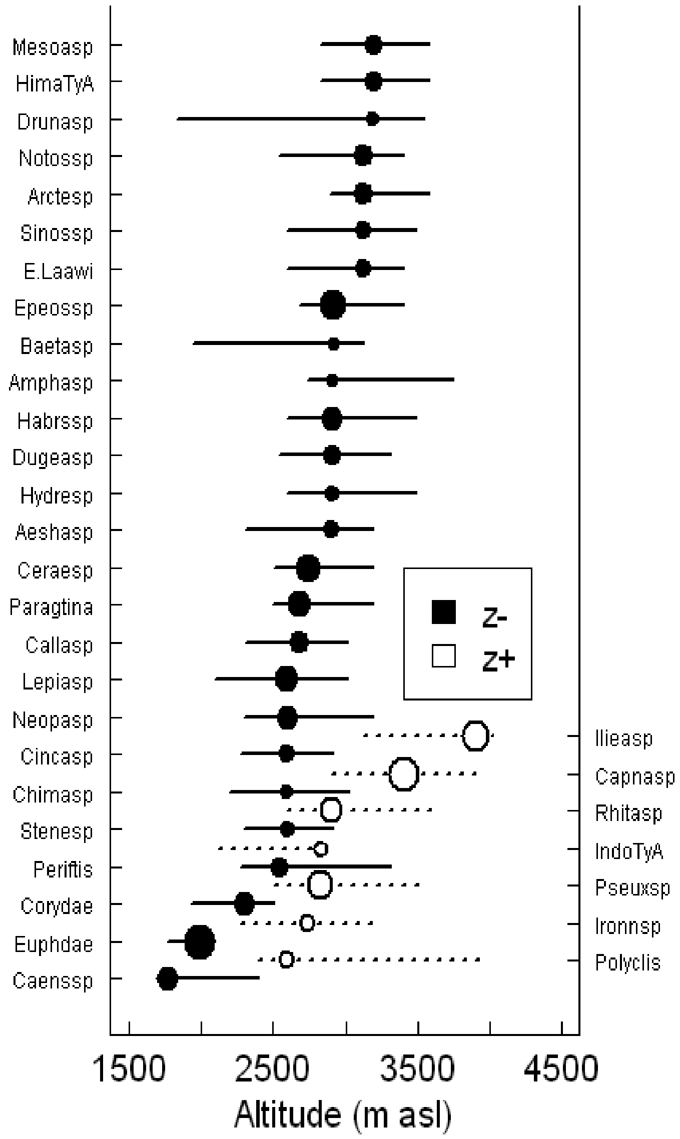

Figure 4: *Indicator taxa that respond to changes in altitude. Left axis presents a list of macroinvertebrates that respond to lower elevations while right axis presents macroinvertebrates occurring in higher elevations.*

Summary

The Himalayan rivers are the headwaters of major river systems in South Asia (e.g., Ganges, Indus, Brahmaputra) which support a population of 1.3 billion people in the Hindu Kush Himalayan region. Being mostly headwaters, the Nepalese rivers are the habitat for many endemic freshwater species and crucial in maintaining discharge to the areas downstream. However, many rivers have been degraded forcing majority of people live under water stress. Water resources are again sensitive to climate change. Hence, assessing and conserving these Himalayan river networks is a prerequisite for preserving regional biodiversity and sustaining life downstream. Benthic macroinvertebrates based bio-monitoring provides a means to sustain the water resources development and protect biodiversity in the region.

Table 1: Name of the Study Streams/Rivers with their River Quality Classes

SN	River system		Region	River Quality Class (Biotic Index)
1	Koshi	Barun and its tributaries	Eastern Nepal	1
		Larke, Yangri and upstream of Indrawati and Handi Khola		1-2
		Downstream of Handi Khola and Indrawati		3
2	Bagmati	Bagmati upstream of Shivapuri dam and Nagmati	Central Nepal	1-2
		Middle stretch Bagmati (Sundarijal buspark – BP chwok)		3
		Downstream of Bagmati (Gokarneshwor to Chovar)		4-5
3	Langtang	Langtang and its tributaries		1-2
4	Kali-Gandaki	Kali-Gandaki (Lete-Seti Dovan)	Western Nepal	1-2
		Kali-Gandaki downstream of Kaligandaki HP I to Ridhi		3-4
5	Karnali	Lower Karnali (Chisapani-Kothiyaghat)	Far Western Nepal	2-3

The traditional bio-monitoring approaches consider taxonomic resolution at family, genus and species level. For accurate determination of ecosystem status, the finer taxonomic resolution is important. However, the taxonomic identification at finer resolutions is difficult to achieve. In this context, molecular tools in bio-monitoring would likely to precisely measure river health. For this, the country has to go long run to achieve the goal as it needs trained human resources and modern laboratories. Nevertheless, this should be the next step.

Many of the headwaters are still in good ecological status with RQC 1 and 2 while downstream river stretches have been heavily deteriorated with RQC 4-5 due to wide ranges of human interventions on river ecosystems.

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