

## Major Stressors Influencing the River Ecosystems of Far and Mid Western Development Regions of Nepal

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### Abstract

Maintaining healthy river ecosystem is essential both from aquatic biodiversity conservation perspective as well as for the socio-cultural and economic development of nations all over the world. Many rivers in Nepal have largely been modified with the purpose of supplying drinking water, irrigating agricultural lands, producing hydro-electricity, and operating water mills. During the process, rivers are channelized and the river bed materials are removed. Such activities of river bed excavation have changed both the natural flow regimes and morphological characteristics of rivers. Studies on the impacts caused by such stressors on river ecosystems are lacking in the context of Nepalese river systems. Therefore we have assessed how these stressors might change the faunal composition of benthic macroinvertebrates in headwaters of the Western region of Nepal. The study was conducted in the headwaters of rivers of Mahakali and Karnali rivers. Habitat specific benthic macroinvertebrates were sampled from 33 sites seasonally in the year 2016 and 2017. Physical characteristics of rivers including river bed composition, water abstractions and other local stressors including waste dumping and washing-bathing were noted in the field. The study showed that macroinvertebrates community structures were significantly different in the habitat modified sites compared to reference sites. In general, abstracted sites coupled with river bed removals were found to be colonized by fewer taxa with high dominance of pool preference biota such as genera of Mayflies (*Torleya spp.*, *Caenis spp.*, *Choroterpes spp.*) and families of true flies (Chironomidae and Ceratopogoniidae). Macroinvertebrates' abundance was significantly lower in the habitat modified sites. This study envisages that maintaining river's habitats with minimal flows all round year could preserve ecological integrity of river systems.



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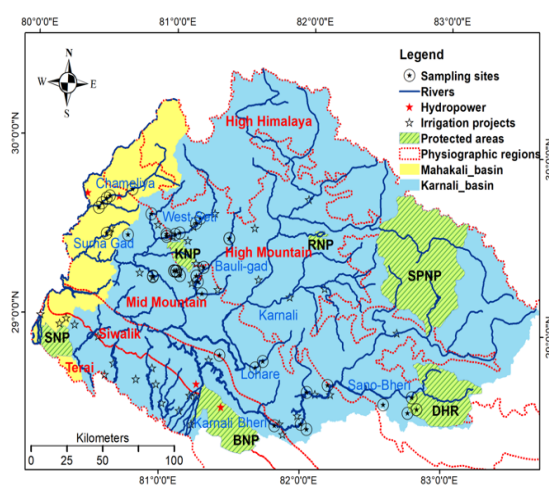
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## Introduction

Nepal, being a mountainous country, possesses diverse climatic zones ranging from subtropical to alpine climates supporting diverse types of rivers for huge biodiversity. Many headwater streams and rivers are still intact from urban development. However, recent water resource development such as water diversion and operation of hydropower dam and irrigation channels along with extraction of river-bed materials have deteriorated morphology and hydrology of rivers and streams and their biota. The types and frequency of disturbances, nevertheless, vary along the river course from source to mouth and increase from source to mouth which have displaced many sensitive organisms from disturbed river stretches (Shah and Shah 2013). Loss of biodiversity is one of the major threats in human dominated river basin (Shah and Shah 2012; Shah and Shah 2013). In the built up areas, the river ecosystems are impacted by solid wastes and discharge of sewerage (Shah and Shah 2013) whilst in agricultural dominated catchment, river ecosystems are highly influenced by water diversions projects. Water abstractions in irrigation projects, operation of water mills and hydropower and tapping of water from source have reduced water volume and discharge in the rivers of Mahakali and Karnali river basins which might have adverse impact to the river ecosystems.

River flow and geomorphology are basic natural parameters to river biodiversity and functioning of ecosystems as channel features including river bed materials provide habitats for the biota and influence water quality, exchange of materials and source of energy (Degani *et al.*, 1993; Elozegi *et al.*, 2010; Roll *et al.*, 2012). River flow in a river exerts physical force on biota while physical habitats provide shelters to biotic community (Benn and Arthington, 2002). The flow modification affects physical habitat in a river by the development of bars, benches and islands, retention of organic matter, presence of pool habitat, availability of woody debris, substrate composition and sediment transport (Lloyd *et al.*, 2005). Among others, benthic macroinvertebrates have important ecological roles to maintain aquatic ecosystem (Wagenhoff *et al.*, 2012). Ephemeroptera, Plecoptera and Trichoptera orders are found to have a very strong negative response to stress (Clarke *et al.*, 2010). The response to reduced flow is increased in active drift by some taxa such as *Baetis spp.*, *Epeorus spp.*, *Simuliidae*, *Brachycentrus spp.* and decreased active drift by others such as *Paraleptophlebia spp.*, some *Ephemerella spp.*, *Lepidostoma spp.* (Poff and Ward 1991). The hydropsychid caddisfly larvae have tendency to aggregate in high-velocity water where feeding rates are higher than in low-velocity water (Dewson *et al.*, 2007). Even small impoundments



**Fig. 1: Distribution of sampling sites in tributaries of major river systems of Nepal. Protected areas are kept in short form where SNP: Suklaphata National Park; KNP: Khaptad National Park; RNP: Rara National Park; BNP: Bardia National Park; SPNP: Shey-Phoksundo National Park**

are found to have a negative effect on sensitive macro invertebrate taxa such as the plecopterans which reduces macro invertebrate richness at the downstream reaches, whereas high abundances of tolerant taxa, such as dipterans at the downstream sites (Mbaka and Mwaniki, 2015). In the downstream of water abstraction, high sediment levels retard macroinvertebrates and fish communities (Sullivan and Watzin, 2008) as sediment load hinders the growth of periphyton which reduces the availability of algae to grazers and decreases the densities of scrapers, shredders and predators (Ndaruga *et al.*, 2004). The shredders and collector-gatherers; both groups use leaves as a substrate for adherence and refuge and scrapers and shredders are found where fine and coarse organic matter are more abundant (Fierro *et al.*, 2015).

## Materials and Method

### Study Area and Sampling Sites

The study was conducted in headwaters of Mahakali and Karnali basins in far western and mid western regions of Nepal (Figure 1). Mahakali and Karnali rivers are glaciers and snow fed rivers. Only about 35.4% of Mahakali basin drains in Nepal territory (Mool *et al.*, 2001) while about 55% of Karnali river basin falls in Nepal (WSHP, 2007).

A total of 33 river stretches in Mahakali and Karnali river basins were selected for sampling of benthic macroinvertebrates during post-monsoon, baseflow and pre-monsoon seasons, respectively in the years 2016 and 2017. Rivers without water diversions and intact habitats were considered as references (Figure 2, Left) while sites downstream of water

abstraction and with habitat modification were regarded as disturbed sites (Figure 2, Right).

## Biological Data Set

### Sampling, Processing and Identification of Benthic Macroinvertebrates

About 50-100 m river stretch was selected at each sampling sites. A total of 10 sub-samples were collected following relative coverage area of substrates (Sharma and Tachamo Shah 2017). The habitat coverage was estimated at 10% interval and made one sub-sample for at least of 10% coverage of habitat. Increase in specific habitat coverage increases the number of sub-samples for that particular habitat. For instance, cobble distribution coverage was 50% in a river stretch led to 5 sub-samples only from 5 cobble habitats.

A standard hand net of 25 cm × 25 cm metallic frame with mesh 500 µm was used for benthic sampling. The net was placed against water flow and habitat/substrates of 25 cm and 25 cm were rigorously scrolled for a minute. The drifted macroinvertebrates then passed through the sampling net and finally transferred to a sampling container. Prior to sampling, depth and velocity were noted. Velocity was measured at 0.6 times of total water depth from water surface by using Global Flow Probe.

## Data Analysis

Non-metric multidimensional scaling (NMDS, Bray-Curtis Similarity) was applied to assess the impact major stressors on composition and diversity of benthic macroinvertebrates. NMDS technique explores any similarities or dissimilarities



**Fig. 2: Sequential photographs showing natural site without water abstraction and habitat modification in Karnali tributary (left) and downstream of water abstraction and habitat removal in the same river (right)**

in community data as it does not require any assumptions of multivariate normality and yields good results even when large numbers of data sets have zero values (Clarke, 1993). NMDS was conducted on benthic macroinvertebrates abundance data for seasonal variations and major stressors using Sørensen's distance measure in the R software. Prior to NMDS analysis, benthic macroinvertebrates abundance data were transformed to log (x+1).

**Results and Discussion**

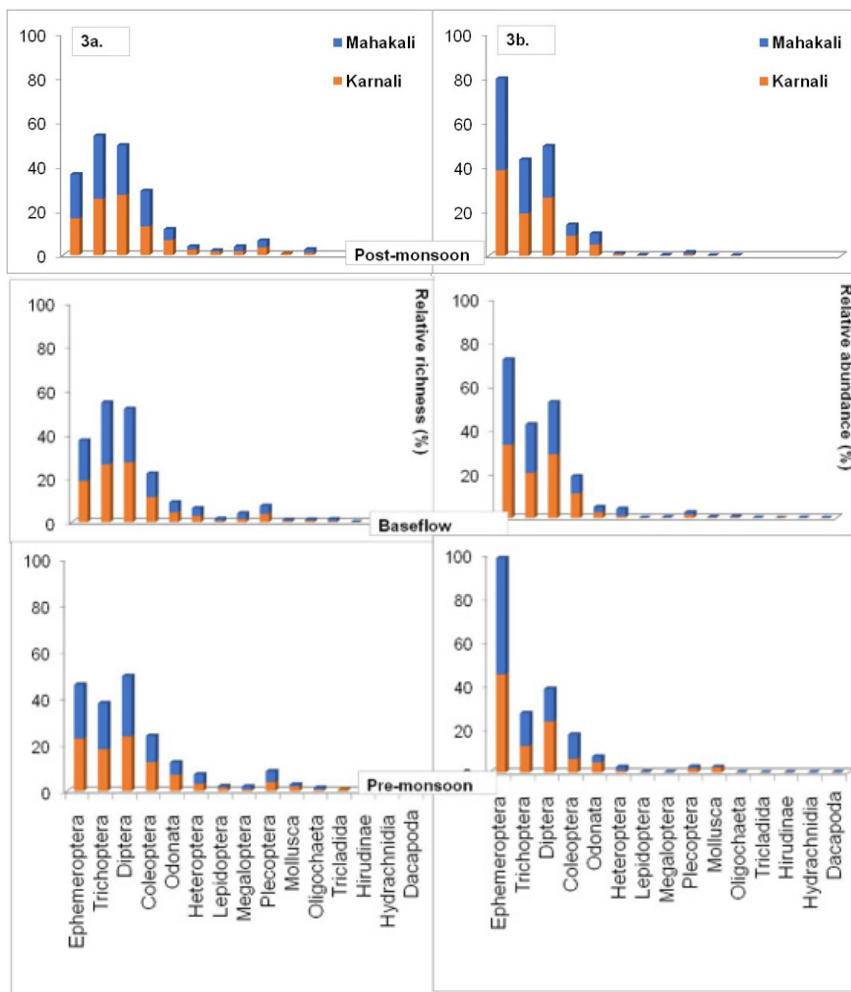
**Faunal composition**

A total of 139 taxa belonging to 15 order/classes were recorded from the study sites. Three taxonomic groups namely mayflies (ephemeroptera), caddisflies (trichoptera) and true flies (diptera) contributed over

80% of relative abundance in Mahakali and Karnali basins (Figure 3a). These three taxonomic groups contributed about 70% of taxonomic richness in two basins (Figure 3b). Ephemeroptera and trichoptera were the most diverse groups among others. In general, ephemeropterans were the most dominant group in the studied basins.

**Benthic MacroInvertebrates Responses to Water Abstraction**

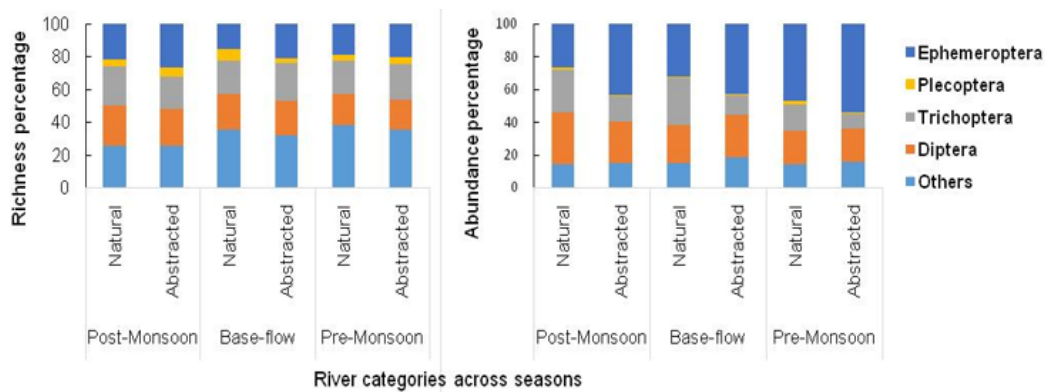
A total of 68, 79 and 76 families of macroinvertebrates were recorded for post-monsoon, baseflow and pre-monsoon seasons, respectively. Taxonomic richness and abundances did not differ among seasons for natural sites while % Ephemeroptera, % Trichoptera and % Diptera varied between natural



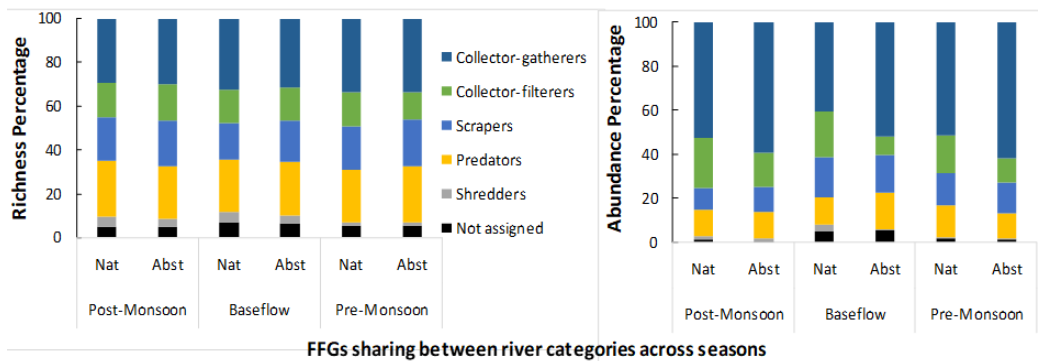
**Fig. 3: Taxonomic composition according to macroinvertebrates order in study river basins**

and abstracted sites in seasons (Figure 4). With abstraction, abundance of Ephemeroptera increased by 6% in pre-monsoon, 10% in baseflow and 17% in post-monsoon seasons which was found contrast for Trichoptera abundance and declined upto 17% for dries period of the year (baseflow). Water abstraction upstream of the rivers have dramatically reduced mean total density of individuals in abstracted sites (McIntosh *et al.*, 2002). In general, EPT compositions dominate rivers with high flow (Holt *et al.*, 2014). Our results partly contradicted to the findings of Holt *et al.*, (2014) as plecoptera did not show significant variation between abstraction categories while ephemeroptera increased their richness and abundance in abstracted rivers compared to natural sites. However, Trichoptera abundance

was found to be reduced in abstractions sites. In general, loss of macroinvertebrates abundance in the downstream sections is mainly attributed to loss of microhabitats and riffle or rapid sections. Loss of habitats creates intra-specific and inter-specific competitions for habitats and food resources (Lake 2000; McIntosh *et al.*, 2002; Dewson *et al.*, 2007). Findings of Sabater *et al.*, (2018) suggest that flow alterations induced by water abstraction and channelization have shown minor effects on benthic macro invertebrates compared to flow alteration by operation of dams (Sabater *et al.*, 2018). Since this study was conducted in streams that were mainly affected by water diversions for irrigation, operations of micro-hydropower and water mills, changes in water quality was only partly attributed in this study.



**Fig. 4: EPT and Diptera composition between river categories across seasons. Left: macroinvertebrates richness share between river categories and right: macroinvertebrates abundance between river categories across seasons**



**Fig. 5: Functional feeding groups between river categories across seasons. Left: FFGs richness between river categories across seasons. Right: FFGs abundance between river categories across seasons**

Many of Trichopteran are rheophilic in nature so reduce in flow regimes might have declined their richness and abundance in the abstracted sites of this study (*sensu* Castella *et al.*, 1995; Fenoglio *et al.*, 2007). Nevertheless, overall richness macroinvertebrates did not changed as appearance of lentic taxa mainly Coleoptera, Odonata and Lepidoptera in abstracted sites.

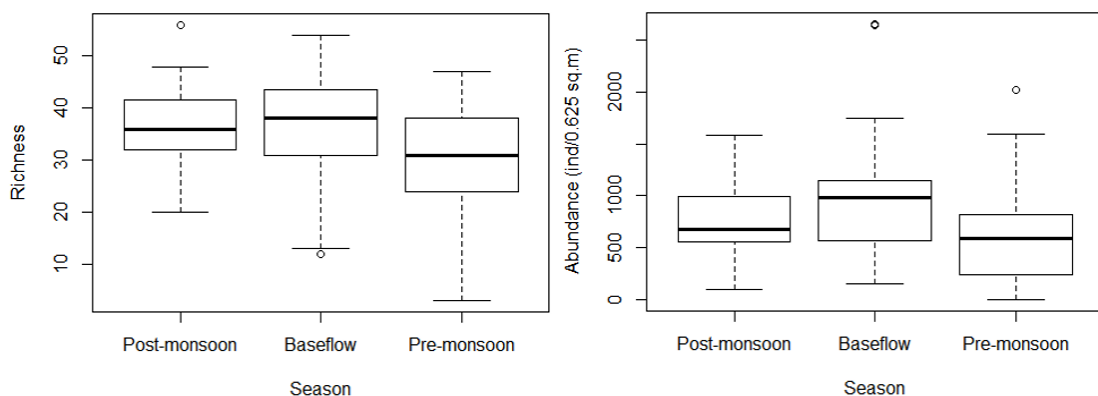
In total, collector-gatherers, scrapers and predators were the first diverse functional feeding groups in benthic macroinvertebrates samples, comprising 32%, 25% and ~ 20% in both river category in a year. Water abstractions did not affect functional feeding groups in macroinvertebrates richness (Figure 8 left) while impacted their abundances (Figure 8 right). In case of abundance, collector-gatherers contributed nearly 50% of macro invertebrates composition followed by ~ 16% collector-filterer, 14% scrapers and 13% predators (Figure 8 right) Collector-gatherers were found to be positively affected by water abstractions while collector-filterers were negatively influenced with water abstraction. Scrapers and Predators were the most stable feeding groups in terms of richness and abundance in these river systems.

Both richness and abundance increased from post-monsoon to base flow season and again reduced during pre-monsoon season (Figure 6). Richness and abundance were found high for the base flow season. Both the metrics were significantly different across the seasons (richness;  $F = 7.634$ ,

$df = 2$ ,  $p$ -value = 0.02; abundance;  $F = 8.9887$ ,  $df = 2$ ,  $p$ -value = 0.01).

In headwater streams, energy influx is mainly driven from input of allochthonous organic matters from riparian zones (Vannote *et al.*, 1980). With reduced wetted river width, the relationship between riparian vegetation and river channel reduces, which leads to unfavorable conditions for shredders and collector-gathers. Abstracted sites had lower proportion of collector gathers and shredders compared to natural sites while predators remained unaffected (McKay and King 2006). Changes in trophic strategies might be due to reduction in relative abundance of Trichoptera, which are one of the most sensitive to changing hydraulic condition (McKay and King, 2006). Low diversity of shredders has been documented as an effect of low discharge in rivers in New Zealand (Dewson *et al.*, 2007). Though some studies illustrate small effects of water diversion and channelization compared to operation of dams on river ecosystems, the consequences of water diversion in river networks in most temperate, semi-arid and arid regions could have severe effects (Boulton 2003; Boix *et al.*, 2008; Sabater *et al.*, 2018).

The high sediment levels in streams have retarding effect on macroinvertebrates and fish communities (Sullivan and Watzin, 2008) as sediment load hinders the growth of periphyton which reduces the availability of algae to grazers and decreases the densities of scrapers, shredders and predators (Ndaruga *et al.*, 2004). The shredders and



**Fig. 6: Richness of macroinvertebrates (Left) in different seasons and Abundance of macroinvertebrates (Right)**

collector-gatherers; both groups use leaves as a substrate for adherence and refuge and scrapers and shredders are found where fine and coarse organic matter are more abundant (Fierro *et al.*, 2015).

### Conclusion

Nepal is considered rich in terms of its water resources yet there are many areas suffering from water stressed situation. This is due to huge variation in temporal variability in water availability due to the types of rivers. Rivers in Nepal may be broadly classified into three categories such as snow fed perennial rivers with high hydropower potential are the major rivers, rivers originating in the middle mountains have high variations in the flows during monsoon and dry months, and ephemeral rivers originating in the Siwalik regions which bring flash flood during rainy season and dry during other time of the year. Water abstraction is common in all kinds of rivers for either hydropower generation, or irrigation and drinking water supply. It is observed that such water abstraction coupled with habitat modification

have altered the benthic community structure. Water abstraction with less morphological disturbance had low impact on benthic macroinvertebrate community. Among other metrics abundance of macroinvertebrates seems to be sensitive to reduced flow under habitat modification. There is very little attention given in Nepal in protecting the aquatic life, which are so important as indicators of watershed conditions. It is therefore recommended that in order to maintain the ecological status of rivers, minimum flow be maintained and there must be some legal instrument limiting the amount of water abstraction.

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### Conflict of Interest

There is no conflict of interest for this manuscript.

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