ASSESSING WATER QUALITY FOR ECOSYSTEM HEALTH OF THE BABAI RIVER IN ROYAL BARDIA NATIONAL PARK, NEPAL.

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ABSTRACT
Water quality of the Babai River was assessed through surveying the aquatic invertebrate populations. Study was carried out at Royal Bardia National Park to observe the effect of irrigation dam on water quality through observing the aquatic benthic macro invertebrate's composition and abundance. The Nepalese Biotic Score (NEPBIOS) method has been used for the biological water quality assessment. Different metrics like Shannon-Wiener Generic Diversity, Diversity Index, Community loss, taxa richness, EPT index, Chironomidae taxa, were also used for assessing the level of impact caused by dam on the aquatic ecosystem health. Considerable variability in macro invertebrate assemblages was found among different sites. Many of the data obtained suggested further analysis but provisional interpretation suggests that all four sites investigated showed signs of pollution. Even the reference site, which was to act as a control, had a high-loading of organic content, perhaps due to soil and debris from the previous year's monsoon and the presence of poison resulting in large-scale death of aquatic life.

Key words: Benthic macro invertebrates, water quality, impact, river ecosystem

INTRODUCTION
The Babai Valley was incorporated into the Royal Bardiya National Park (RBNP) in 1983. RBNP is the largest national park in the Terai lowland physiographic region of Nepal and it is one of the most attractive and biologically diverse areas (Giri *et al*., 1999). It is situated between latitude 28° 17' to 18° 40'N and longitude 81° 12' to 81° 43'E. Figure 1 shows the location of Babai Valley within Nepal and Figure 2 illustrates the sites surveyed.

The topography of RBNP is quite varied, with the presence of Churia ridge, the Bhabar foothills, the alluvial Terai flat land, riverine flood plains and the Babai Valley. It has an altitudinal range of 110m - 1441m above sea-level (Upreti, 1994). The Babai River is a warm water system, with the source of the river in the Dang Valley, which is rare in a country where most rivers are snow-fed. The river runs through a valley of mixed Sal (*Shorea robusta*) forest containing a rich diversity of flora and fauna.

Benthic macro-invertebrates are invertebrates (or animals without a backbone) that live on the bottom of streams during all or part of their life cycle. 'Benthic' means bottom dwelling, and 'macro' indicates that these organisms can be seen with the naked eyes. Although benthic macro-invertebrates often go unnoticed because of their size and habitat, they are an extremely important part of river ecosystems, and serve as a link in the food web between decomposing leaves and algae, and fish and other vertebrates.

Assessing ecosystem health requires performing abiotic as well as biotic investigations, for which, four sampling sites were chosen, one to act as a reference site, two were located in what was thought to be disturbed sites close to the dam and two further downstream to investigate river recovery. The reference site of Chepang Ghat, site 1, was located 25-30km upstream of the dam, 300m above sea level. The site was selected far above the dam so that there was no potential impact from the dam on aquatic fauna. The riverbed substratum was dominated by boulders (>70%) with the rest being cobbles and sand. The water depth varied considerably across the Babai River. The northern bank of the river was deeper and with high water velocity. Boulders and muddy sand with tall grasses dominated both north and south right banks. There were minimal human activities at this site as it was located inside RBNP. The main drainage flowing into the river was feeder streams and runoff from the forest.

Site 2 was located at the reservoir. The sampling site was approximately 1km upstream from the dam. The effect of the dam was clearly seen at this site, as the river had no movement. It was thought that the reservoir would remain flooded for much of the year. Water was diverted towards the gate of a tunnel on the left bank of the river. The riverbed was composed of mixed substrates, from silt to boulders, although it was dominated by boulders (>40%). The left and right banks were muddy and covered with grasses. In the upstream area, the banks were covered with forest vegetation and at the sampling point the riverbanks were covered with cobbles and muddy-sand. Site 3, was located 500m below the dam. The riverbed was largely composed of cobbles and sand with almost no rocks and boulders. The bank vegetation is similar to site 2 but there were more grasses. In the stream, an island had formed due to sedimentation. Site 4 was located 2.5km downstream from the dam. The riverbed was mainly dominated by boulders (>70%) but was of mixed substrate. The left bank was covered with herbs, shrubs and trees, whereas there was forest on right bank. Despite being within RBNP, considerable activity was observed in the study area with large vehicles collecting boulders from the river.

The main aim of this study was determining the impact of the irrigation dam on water quality of the Babai River using macro invertebrate populations as indicators with the following objectives:

- To determine quantitatively the spatial variability of benthic macro invertebrates at different sites in the Babai river,
- To assess water quality analysing the basic physico-chemical and biological parameters using benthic macroinvertebrates as biological indicators,
- To apply multi-metrics method of impair assessment based on benthic macro invertebrates different faunal assemblages.

MATERIAL AND METHODS

Benthic macro invertebrates samples were collected in March 2003, following protocols developed for the streams of Nepal (Plafkin *et al.*, 1989; Sharma, 1996). Substrate composition was also estimated at microhabitat level for each quantitative sample taken with the Surber sampler. In this method, a Surber Sampler net of $0.1m^2$ surface area with 100µm mesh size was used to collect benthic macro invertebrates. Samples were taken by fixing the Surber in the riverbed to collect animals flowing downstream. The riverbed was then disturbed to a depth of 10 cm using a metal implement such as a shovel, scalpel or iron peg. The substrate was thoroughly stirred, so that the animals were dislodged and collected in the net. Any boulders, cobbles, or stones found inside the Surber were washed and brushed so that animals attached to them would be dislodged and collected in the net. Whilst doing this, the number (or amount, as a percentage) of the substrate was recorded so this information could be used to correlate the composition and abundance of animals with the substrate microhabitat. After completing the disturbance process, the collecting net was detached from the sampler. Whatever had been collected in the net was concentrated to the bottom of the net and then carefully transferred to a white plastic tray. Any remaining animals still attached to the net were picked off individually and transferred in the tray. To increase precision, five samples were taken at each site. All samples were taken from different habitats in order to give a representative picture of the site as much as possible. All samples were transferred to labelled broad-necked bottles and tightly closed after the addition of 4% formaldehyde as a preservative.

Kick sampling was also undertaken to provide a qualitative description of the study areas. This method disturbs the animals living in or on the bottom of the river and allows the current to sweep them into the net. Riffle areas were selected for this method. These are shallow, fast-moving sections of the river, with a depth of 10-30cm, and stones that are cobble-sized (6.4cm or larger). The kick sampling net was placed at the downstream edge of the riffle so that the current flows through it. The bottom of the sampler should fit tightly against the streambed. Rocks were sometimes employed to hold the net down, so that no organisms could escape. To collect the sample, the stream-bed was disturbed for a distance of 1m upstream of the kick sampling net by vigorously physically kicking up mud and stones around the foot for a couple of minutes. The water current would then sweep dislodged invertebrates into the net. If any large stones were turned over, they would be put back in their original positions after sampling had been completed. A forward scooping motion was used to lift the net from the water to remove the net without allowing any insects to escape from the surface. The net's contents were then gently emptied into a white tray for identification and counting. In between sampling, the net was rinsed out thoroughly, so that any debris was removed.

Samples were preserved for 15 days to fix them in formalin (formaldehyde). After preservation, the samples were washed thoroughly with tap water to remove the formalin completely. The washing was done using a sieve with 100µm mesh. Small quantities of the sample were placed onto a white enamelled tray and observed with naked eye under a bright light. Organisms were picked up using forceps and sorted into families, placed in corresponding Petri dishes and, when necessary, further examined under a compound microscope.

The classification scheme proposed by Moog (1994) is adapted for ecological integrity classification and Sharma (1996) for river water quality classification.

Table 1: Seven-class scheme of river water quality classification and its ecological integrity for the streams of Nepal (Adopted from Sharma, 1996; Moog, 1994)

Classes	Ecological integrity/Water quality
I	Undisturbed/none to slight pollution
I-II	Slightly disturbed/slightly polluted
II	Moderately disturbed/moderately polluted
II-III	Significantly disturbed/Critically polluted
III	Heavily disturbed/Heavily polluted
III-IV	Very heavily disturbed/Very Heavily Polluted
IV	Completely disturbed/Extremely polluted

RESULTS AND DISCUSSION

The important physicochemical characteristics at each river site are shown in Table 2, chemical characteristics in Table 3 and aquatic invertebrate species identification and further water quality interpretations are detailed in Table 4.

Physico-chemical characteristics:

The following water quality parameters were tested in all sites, temperature, oxygen, pH, phosphate, general hardness, carbonate hardness, and nitrate. At some sites, ammonia and nitrite levels were also tested. Apart from temperature, all parameters were tested using Salifert test kits.

The water quality tests showed slight variations from site to site (Table 3). Generally there were no detectable levels of phosphate or nitrate. Temperature ranged from 20-25 deg Celsius, pH averaged about 7.5, but in one site was as low as 6.3 (a tributary stream). The water was quite hard in most sample sites with a GH of 12-20 and a correspondingly high dKH value. The exception was in one tributary that had significantly lower hardness values. Oxygen levels varied considerably. In some tributaries there was little to no detectable oxygen. In others, the value was as high as 8mg/l. Water quality values were generally good for the parameters tested (Table 3). It was interesting to note that nitrate and phosphate levels were undetected despite the obvious heavy agricultural use of land above Chepang. Evidence of blue-green algae blooms (cyanobacteria) however, indicate the presence of some organic pollution entering the system. Oxygen values were extremely variable at different sites, which was surprising. In some tributary streams a thriving population of small fishes and invertebrates was found despite no detectable oxygen being measured. Such low oxygen values can be attributed to eutrophication and little flow along with high temperatures and little photosynthesis. It was interesting to note the variety of species adapted to living in such oxygen deficient environments.

Taxa richness of aquatic macro invertebrates and biomass:

A total of 16 families were recorded from site 1 (reference site), 14 families were recorded from site 2 (disturbed site), 12 families from site 3 (disturbed site), and 20 families from site 4 (recovery site). The total carbon contents weight of macro invertebrates, per order, was measured and the results illustrated in Figure 3.

Site 1 (reference):

At this site, 16 macro invertebrate families of 6 orders were recorded. Five of the 16 families were of Ephemeroptera order, 3 families of Trichoptera, and 4 families of Diptera and 1 family. Biomass (g/m2) each from orders Plecoptera, Odonata and Coleoptera. Caenidae (order Ephemeroptera), and Chironomidae (order Diptera) were the most abundant aquatic invertebrates.

Ephemeroptera had the highest biomass followed by Coleoptera, Trichoptera and Diptera. The total biomass of this site was less than for sites 2 and 3.
The water quality index, NEPBIOS/ASPT (Nepalese Biotic Score/ Average Score Per Taxon), at this site produced a figure of 5.83. This indicated that the Saprobic Water Quality Class of this site is moderately polluted and is categorised as class II.

Site 2 (disturbed):
At this site just above the dam, 14 macroinvertebrate families from 6 orders were found. Six of the 14 families belonged to order Ephemeroptera, 2 to Odonata, 1 to Oligochaeta, 3 to Diptera, 1 to Trichoptera, and 1 to Mollusca. Families Baetidae, Caenidae, and Ephemeridae of order Ephemeroptera, Tubificidae of Oligochaeta and Ceratopogonidae and Chironomidae of Diptera were the most abundantly found aquatic invertebrates at this site. The Ephemeroptera showed the highest biomass followed by Diptera, Trichoptera and Oligochaeta respectively. The total biomass of this site was higher than site 3, disturbed site and site 1, the reference site.

The water quality index, NEPBIOS/ASPT (Nepalese Biotic Score/ Average Score Per Taxon), at this site produced a figure of 5.55. This indicated that the Saprobic Water Quality Class of this site is moderately polluted and is categorised as class II.

Site 3 (disturbed):
At this site, just below the dam, 12 macro invertebrate families from 5 orders were recorded. This reduced number of families suggested that the dam construction might be affecting the number of families of aquatic invertebrates at this site. Baetidae, Caenidae, Leptophlebiidae, and Ephemeridae of order Ephemeroptera, and Ceratopogonidae and Chironomidae of Diptera are the most abundantly found species. Ephemeroptera had the highest biomass, then followed Trichoptera and Diptera. The total biomass of this site is less than that for site 2 above the dam. The water quality index, NEPBIOS/ASPT (Nepalese Biotic Score/ Average Score Per Taxon), at this site produced a figure of 5.50. This indicated that the Saprobic Water Quality Class of this site is moderately polluted and is categorised as class II.

Site 4 (recovery):
At this site, 20 macroinvertebrate families from 7 orders were recorded. This increase in the number of families found, suggested much more favourable conditions that those found at site 1, the so-called reference site. Six families of Ephemeroptera, 1 family of Plecoptera, 3 families of Trichoptera, 5 families of Diptera, and 2 families of Odonata, and 1 family each of the orders Coleoptera, Oligochaeta and Mollusca were recorded. Baetidae, Leptophlebiidae, Caenidae, and Ephemeridae of the order Ephemeroptera, and Ceratopogonidae, Limoniidae and Chironomidae of Diptera were the most abundant invertebrates. Ephemeroptera had the highest biomass followed by Trichoptera and Diptera.
The total biomass of this site was, however, less than that found in site 2.

The water quality index, NEPBIOS/ASPT (Nepalese Biotic Score/ Average Score Per Taxon), at this site produced a figure of 6.36. This indicated that the Saprobic Water Quality Class of this site is moderately polluted and is categorised as class II. Aquatic invertebrate species identification and further water quality interpretations are detailed in Table 4. The results obtained with the application of Multi-metrics approach for describing ecological conditions of the Babai River is tabulated in Table 5.

The multi-metrics approach uses a number of single metrics to assess environmental degradation. The major assumption is that a single metrics increases or decreases with an increase in disturbance (Table 5). NEPBIOS (Sharma, 1996) is considered one of such metrics effective in pre-classification of streams polluted due to organic load. The indicator value of NEPBIOS should increase with the decrease in organic load. In this study as water quality classification of the Babai River based on NEPBIOS has not shown clear distinction, the cause of impairment in such a case should be something different but not organic pollution. Similarly, Total number of families (total Number of Taxa as well as EPT Count) increases with the increase in water quality (Plafkin et al. 1989).

The metrics calculated during the present study has indicated, in most of the cases, an increase in metrics at Recovery Site than at Reference indicating that the Reference site, which was to act as control, was more polluted than the site downstream. Many criteria are suggested for recognising reference sites. But in many cases it is difficult to apply specific criteria. The Babai River is poisoned by fish poachers through application of pesticides (Thiodin or Metacid) at different places. Finding a reference site in the mainstream Babai River for this reason is difficult. However, result has clearly indicated an improvement in the water quality as the river flows through the protected forests, in this case which was considered as Recovery Site in reality could be considered as a Reference Site for the comparison of the level of impairment. Alternatively, a similar stream with identical land features, absence of dams, diversion, and discharges, flowing through similar eco-regions could also be selected for comparison of the results obtained.

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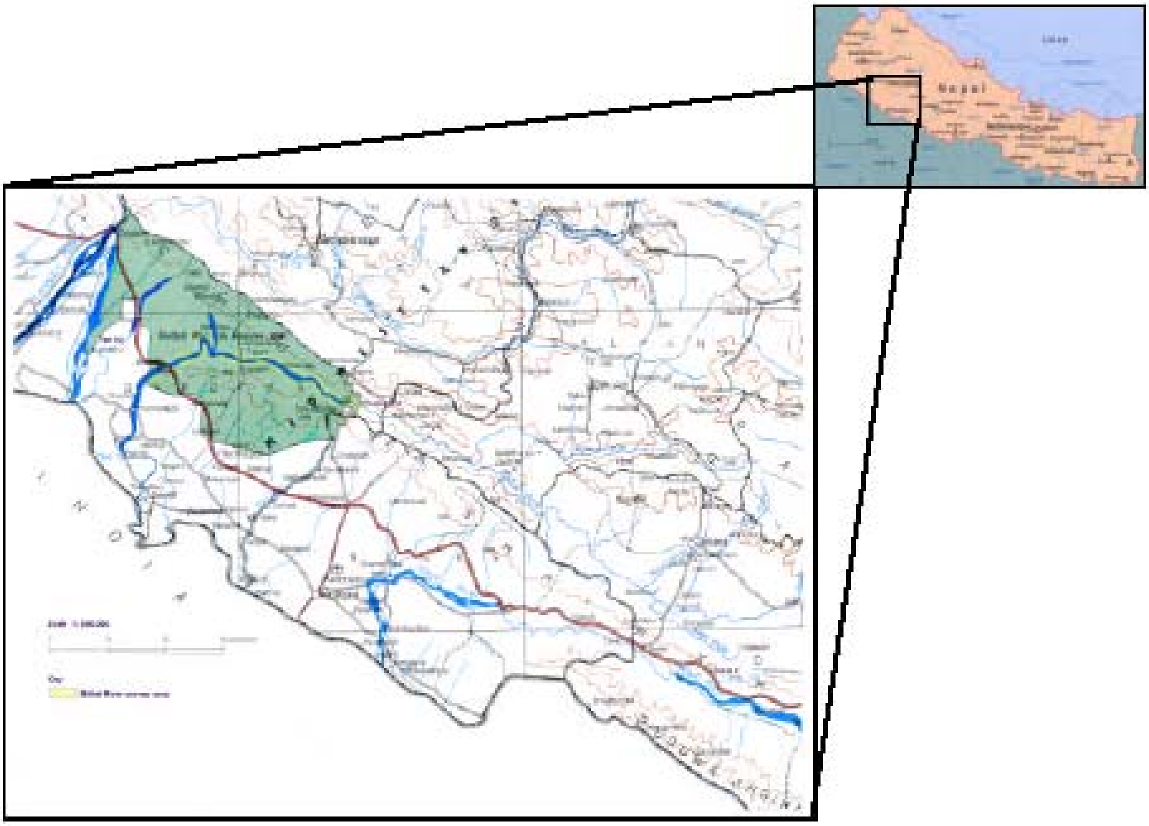

Figure 1: Location of Royal Bardiya National Park (RBNP) in Mid-western Nepal.
Nepal map : Magellan Geographix, 1999 ©,
Regional map : adapted from Topographical Survey Branch map H.M.G., Kathmandu, Nepal, 1997

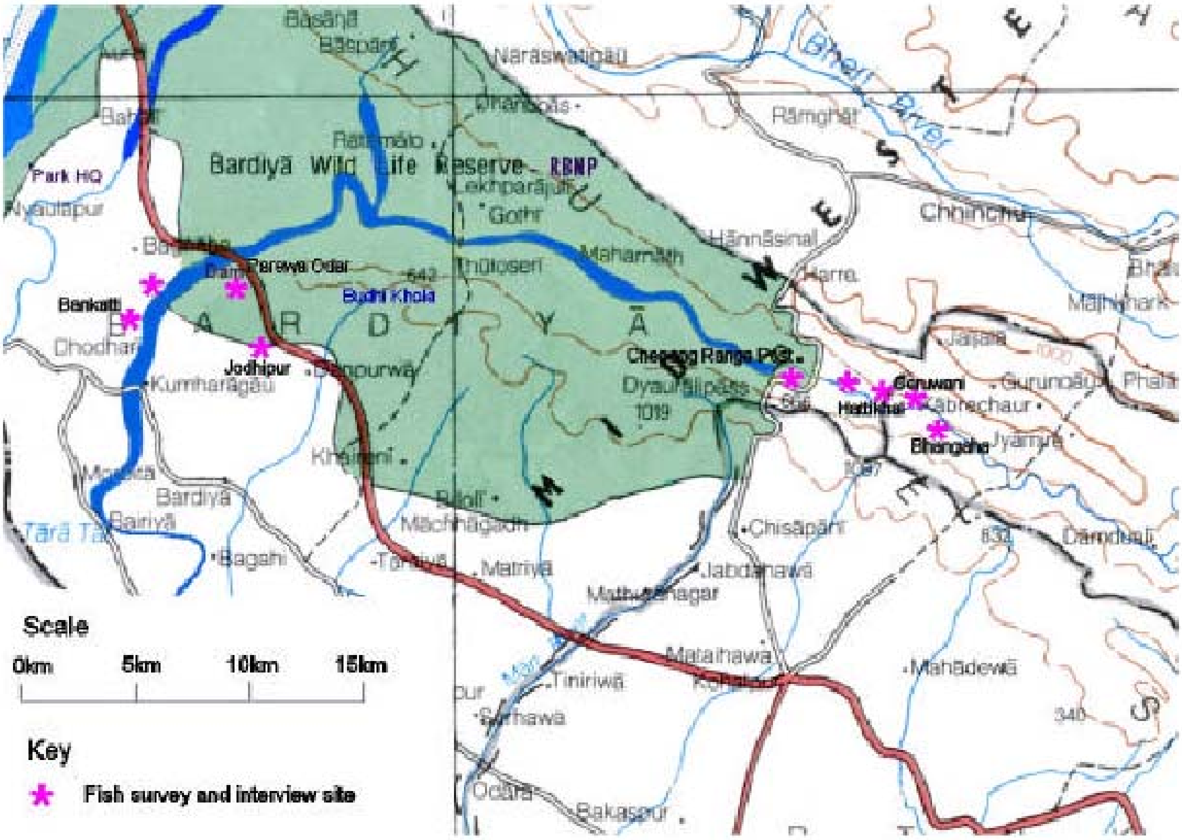

Figure 2: Location of sites investigated in Royal Bardiya National Park (RBNP) in Mid-western Nepal.

Table 2: Physical characteristics of the sampling sites in the Babai River

Parameters	Site 1 Reference site	Site 2 Disturbed site	Site 3 Disturbed site	Site 4 Recovery site
Altitude (m above sea level)	300	187	185	184
Max. river width (m)	24	30	20	20
Substrate (%):				
Rocks	1	-	1	1
Boulder	30	20	60	30
Cobbles	60	30	30	20
Pebbles	2	5	1	40
Gravel	2	2	-	3
Sand	5	40	5	4
Silt	-	3	3	2
Chemistry:				
Conductivity (µS/cm)	69	77.7	77.0	75.8
Temperature (^{o}C)	19.2	19.2	21.8	22.8

Table 3: Chemical characteristics of the sampling sites in the Babai River

Water Quality Parameter	Sites below dam	Sites upriver of dam	Above Chepang Bridge	Irrigation Canal
pH	7.5	7.5	7.5	7.8
Oxygen (mg/L)	5	8	6	7
CO_2 (mg/L)	15	25	15	15
Phosphate (mg/L)	0.00	0.00	0.08	0.00
Nitrate (mg/L)	0	0	0	0
GH (dGH)	13	11	8	11
KH (dKH)	9	9	8	10
Calcium (mg/L)	0 - 5	0 - 5	0 - 5	0 - 5
Iron (mg/L)	0	0	0	0
Bivalent Iron (mg/L)	0.00	0.00	0.05?	0.00

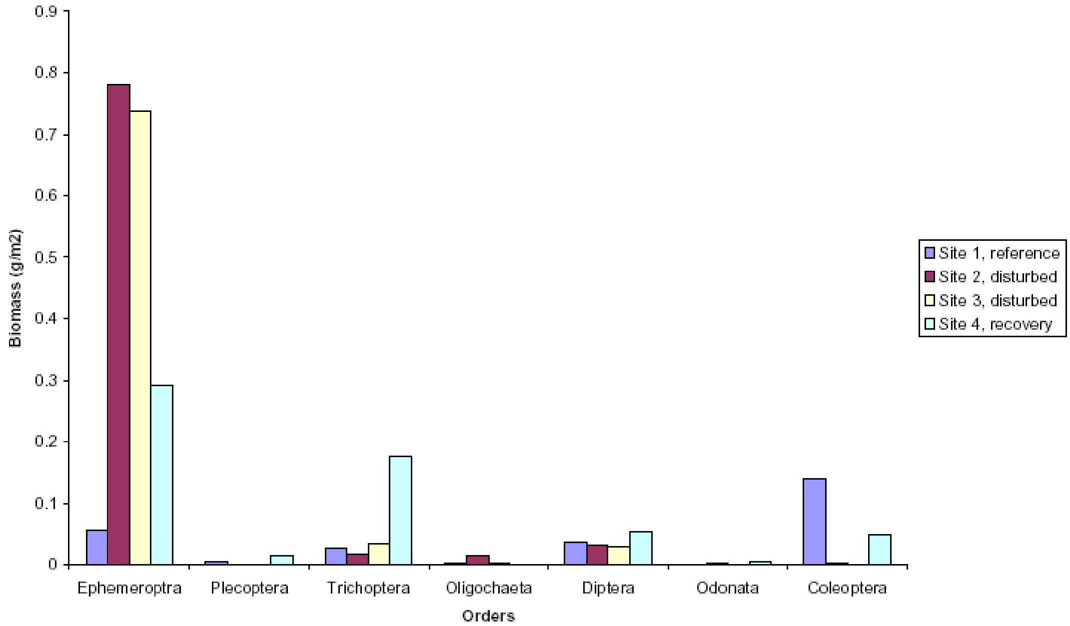

Figure 3: Order-wise Comparison of Aquatic Invertebrates Biomass at each site

Table 4: Species List of Aquatic Invertebrates as indicators of water quality
Rel. Ab. Stands for Relative Abundance of the macroinvertebrates observed :
(1=very rare, 2=rare, 3=common, 4=abundant, 5=highly abundant)
Impairment assessment is based on qualitative sampling of the macoinvertebrates.

Site and Date	Scientific name	Number	Comments
Site 1 **Reference Site** **Babai River,** 750 m upriver of the bridge at Chepang Ghat 08 Mar. 03	Baetidae	3	Saprobity level (water quality = Beta to Alpha mesosaprobic) of Babai river at this stretch was detected as between II-III (Critically Polluted). A reference site in principle should represent the best available condition within the reachable stretch of the river. A Reference site should be representative of a group of minimally disturbed site. The river bed at this site was dominated by deposits of soil and debris brought to river by last year's monsoon, which was reported as disastrous that has posed a great threat to the ecosystem health of the river. The other disturbance to this river at the site investigated was releasing poison into river causing large scale death of aquatic life.
	Caenidae	5	
	Ceratopogonidae	4	
	Chironomidae	5	
	Ecnomidae	2	
	Elminthidae	4	
	Ephemeridae	2	
	Gomphidae	2	
	Heptageniidae	2	
	Hydropsychidae	3	
	Leptophlebiidae	4	
	Limoniidae	2	
	Perlidae	3	
	Philopotamidae	3	
	Tabanidae	1	
Site 2 **Disturbed site** Babai River, 100m upriver of the bridge at Chepang Ghat 07-Mar-03	Athericidae	1	Saprobity level (water quality = Beta to Alpha mesosaprobic). Critically polluted with high organic matter and nutrient contents, oxygen contents fluctuating, causing injuries or killing sensitive fish species. Remarkable putrification in fine sediment in lentic zone, and black spots of sulphide deposit beneath the stones. Faunal diversity, especially the insect faunal diversity, is poor. Algal diversity is also reduced indicating release of insecticides/ pesticides that would have led to killing of flora/fauna.
	Baetidae	1	
	Chironomidae	3	
	Corduliidae	1	
	Ecnomidae	1	
	Ephemeridae	3	
	Heptageniidae	2	
	Leptophlebiidae	2	

Site 3 **Disturbed site** Babai River, 500m down the river bridge a Chepang Ghat 06-Mar-03	Athericidae	1	Water quality as in site 1 or 2, but the increase in insect diversity clearly indicates tendency of improvement in quality from Beta to Alpha mesosaprobic (water quality II-III) to Alpha mesosaprobic (water quality class II). The above list further indicates recovery state of the river with comparatively very high diversity / species richness of tolerant species, but the sensitive species of the insect orders Ephemeroptera, Plecoptera and Trichoptera) Perlidae, are less abundant.
	Atyidae	1	
	Baetidae	1	
	Chironomidae (Red)	3	
	Chironomidae (Green)	1	
	Corydalidae	3	
	Dryopidae	1	
	Ecnomidae	3	
	Elmidae	2	
	Ephemerellidae	1	
	Ephemeridae	1	
	Gyrinidae	1	
	Helodidae	2	
	Heptageniidae	3	
	Leptophlebiidae	2	
	Limoniidae	3	
	Perlodidae	2	
	Simuliidae	2	
Site 4 **Recovery site** Babai River, Mulghat, 2.5km downriver of the bridge. 07-Mar-03	Athericidae	2	Water quality in site 4 is predicted as of Beta mesosaprobic (water quality, class II), moderately polluted, high organic matter and nutrients, oversaturation of oxygen and subsequent depletion is possible. Oxygen depletion in very fine sediment observed in lentic zone, low biodiversity is an indication of severe anthropogenic impact, but the faunal composition shifted to sensitive form indicating improvement in water quality.
	Baetidae	3	
	Caenidae	5	
	Ceratopogonidae	4	
	Chironomidae	5	
	Ecnomidae	4	
	Elminthidae	4	
	Ephemerellidae	3	
	Ephemeridae	4	
	Gomphidae	2	
	Heptageniidae	3	
	Hydropsychidae	5	
	Leptophlebiidae	5	
	Libellulidae	1	
	Limoniidae	4	
	Perlidae	3	
	Philopotamidae	5	

Table 5: Use of Multi-metrics Approach for describing Ecological Conditions of the Babai River at four different sites (see text for explanation).

Metrices used	**Ref.**	**D1**	**D2**	**Rec.**
NEPBIOS	5.83	5.5	5.55	6.36
Number of Taxa	17	15	12	20
Number of Individuals	317	986	1052	755
EPT Count	111	433	762	349
Ephemeroptera Count	75	421	721	159
Plecoptera Count	7	0	0	14
Trichoptera Count	29	12	41	176
EPT/Total Count	0.350158	0.439148	0.724335	0.462252
Chironomidae Count	119	381	168	325
EPT abundance/Chironomidae abundance	0.932773	1.136483	4.535714	1.073846
Relative Chironomidae Abundance	0.075079	0.077282	0.031939	0.086093
Ephemeroptera biomass	0.0569	0.7804	0.7375	0.2926
Plecoptera biomass	0.0056	0	0	0.0132
Trichoptera biomass	0.0274	0.0163	0.0333	0.176
EPT biomass	0.0899	0.7967	0.7708	0.4818
%Ephemeroptera	23.66	42.7	68.54	21.06
%Plecoptera	2.21	0	0	1.85
%Trichoptera	9.15	1.22	3.9	23.31
%EPT	35.02	43.92	72.44	46.22
%Ephemeroptera biomass	21.0274	92.0066	91.6635	49.5009
%Plecoptera biomass	2.0695	0	0	2.2331
%Trichoptera biomass	10.1257	1.9217	4.1361	29.775
%EPT biomass	33.2226	93.9283	95.7996	81.509