Dam Building, Benthic Macroinvertebrate and Bioassessment of the Tinau River, Nepal

I. INTRODUCTION

Biological assessment of surface water was commenced more than a century ago as the idea of saprobity (the degree of pollution) developed by Kolkwitz and Marsson in 1908-1909 (Rosenberg and Resh, 1993) mainly by analysing the differences of organisms living in polluted water from organisms living in clean water (Sharma and Moog, 1996). The use of macroinvertebrates in biological assessment has been developed in Australia, North America and Europe (Dudgeon, 1999; Rosenberg and Resh, 1993; Whiles et al., 2000) due to the simplicity of sampling methods, the availability of information on pollution tolerance (Zamora-Munoz et al., 1995), and the greater degree of accuracy than methods based upon physical and chemical parameters of water quality (Sangpradub et al., 1997). Dudgeon (1999) accepts that there is a much to be addressed in this field in tropical Asia, as there is less information about benthic macroinvertebrates in this region. To study the biological monitoring process we require application of the site-specific biological criteria assessment process (Sharma and Moog, 1996; Rosenberg and Resh, 1993). The data generated by using different assessment methods are not directly comparable (Houston et al., 2002), but the techniques currently in use in one part can be adapted to other parts with necessary modifications (Royer et al., 2001). Seegert (2000) further emphasizes on three basic areas, viz., field collections, metricdevelopment and data analyses for choosing improved bio-criteria to gain better reliability.

Some authors consider that physical habitat is a primary factor influencing the structure and composition of stream faunal communities (Lammert and Allan, 1999; Downes et al., 2000) in which macroinvertebrate communities form one of the important components in the lotic environment for processing and cycling of a potentially key energy and nutrient sources (Stockley et al., 1998). Abundance, distribution and production of lotic invertebrate fauna are controlled by interactive conditions inherent to each microhabitat in the substratum (Thonney et al., 1987) that can directly or indirectly affect the suitability of the aquatic environment for insects

(Resh and Rosenberg, 1984). Importance of local microhabitat variables in predicting biotic integrity mainly for the macroinvertebrate shows the importance of the substratum for biological condition (Lammert and Allan, 1999; Nerbonne and Vondracek, 2001).

Modification of natural flow regimes alters the abundance and composition of biological conditions (Strange et al., 1999). Ogbeibu and Oribhabor (2002) found that there is an alteration in the faunal characteristics downstream to a dam. Dams alter the physical features of the riverine system that may change the biological conditions, the study of which is one of the main objectives of the present study. We also discuss the approaches of multi-habitat versus single habitat for an evaluation of biological conditions. Plafkin et al. (1989), based on their pilot study, advocate that the single habitat approach can be a representative sample for the evaluation. In the present study, however, we incorporated the multi-habitat approach of evaluation for biological condition of the river. We followed the one-time-event strategy for sampling macroinvertebrates, which has been applied in many studies (see Rosenberg and Resh, 1993).

Ruse (1996) alerts river managers who use biological data frequently to make judgements on water quality without considering the effects of physical and seasonal variations on the biota. However, the seasons (months) of collection of samples are less important for the macroinvertebrate (Ruse, 1996) than other factors like pollution, in calculating the biological indices (Zamora-Munoz et al., 1995).

1.1 Hypotheses

The following two hypotheses were assumed for the present investigation.

1. There is no change in the biological condition (based on macroinvertebrate composition) of river water due to the construction of the dam.
2. There is no difference in the quality of river water (based on the NEPBIOS/ASPT method) at different stations above and below the dam.

1.2 Objectives

Nepal harbours many hill streams that do not dry up throughout the year. These rivers provide an excellent source of drinking water in addition to the hydropower generation and irrigation. And there are very few studies about the environmental and sociological impacts of dams in Nepal. Bioassessment of rivers by using macroinvertebrate proves itself a very good method for preliminary assessment, I believe. Therefore, the present study aims to focus on the following main objectives to relate with two hypotheses mentioned above:

1. to assess the macroinvertebrate assemblage composition for analysing biological condition of the river water
2. to relate biological conditions of the river water to substrate composition and the dam building, and
3. to examine the river water quality by using Nepalese Biotic Scores/Average Score Per Taxon (NEPBIOS/ASPT) method.

1.3 Justification of the Study

Study of macroinvertebrate composition for the analysis of biological condition of the river water is being practised for many years (Dudgeon, 1999; Barbour et al., 2002; Plafkin et al., 1989; Rosenberg and Resh, 1993; Sharma and Moog, 1996; Whiles et al., 2000) considering its practicality and as a cheap method for the preliminary study (Sangpradub et al., 1997; Zamora-Munoz et al., 1995). I have adopted widely used protocols and methods recommended by the Environmental Protection Agency (EPA/US). Use of the site-specific methods, as recommended by many scientists (Rosenberg and Resh, 1993; Sharma and Moog, 1996), was followed for the present study by adopting Nepalese Biotic Score (NEPBIOS) method for analysing biological condition which has been recommended for further application and development (Sharma and Moog, 2000). I mainly focused my studies to investigate impacts of dam on the biological condition of benthic macroinvertebrates which otherwise would not have been there. Any change in the microhabitat caused by the dam has been considered for the present study to relate with the macroinvertebrate composition and finally with the water quality.

II. METHODS

2.1 Study Area

The present study was carried out in the Tinau River, originating from the watershed of Mahabharat range of Palpa district in Nepal and running south through the low land (terai region) to pass into Indian territory. The study was conducted in a 4 km stretch of the river including a dam for hydropower generation. The construction of the dam started in 1965/66 (Bikram Sambat 2022) and was completed after 11 years. The dam is 65 meter long, 8 m in height and 4 meter wide. The river has many feeder streams along its way and it can be considered as a third order stream. We observed that not more than 10% of river water was diverted to the tunnel, which is true for most part of the year. Four sampling stations were chosen for the present study as: Station 1 (upstream reference), Station 2 (reservoir), Station 3 (just below the dam) and Station 4 (downstream) (Figure 1). Stations 2 and 3 are mainly considered as disturbed sites due to their proximity to the dam. The main features of these study stations are described below (details in the Annex 1).

Station-1 (reference site) is located about 1.5 km upstream of the dam called Dovan (242 m above sea level). It was selected far above the dam as a reference site where I consider that there is no impact of the dam on aquatic fauna. It receives another feeder stream called Dovan River just above the sampling site. The substratum is composed of all of the categories except silt and is dominated by rocks (>80%). The average width and depth were 24.0 m and 0.71 m (max. depth 1.1 m) respectively with an average velocity of 0.60 m/s (max. 1.075 m/s). Right bank of the river has more depth but low current of water. The depth of the river varies considerably across the river. Left bank is rocky, eroding and steep with herbs, shrubs and trees; whereas right bank is rocky, stable and steep covered with trees (forest). The main human activities at this site are washing, bathing and fishing. The main effluents flowing into the river include agricultural and forest runoff.

Station-2 (also mentioned as D1 site) is located in the reservoir. Water is diverted towards the gate of a tunnel on the right bank of the river. It has a very small impoundment area. The substratum is composed of all of the categories, from silt to boulders, but dominated by boulders (> 40%). The average width and depth were

30.0 m and 0.54 m (max. depth 1.0 m) with average velocity of 0.67 m/s (max. 1.4 m/s). Left bank is rocky, eroding and steep covered with herbs, shrubs and trees whereas the right bank is rocky, stable and steep covered with trees (forest). The main human activities here are fishing, swimming and hammering (for fishing and making slabs).

Station-3 (also mentioned as D2 site) is located immediately below the dam. The substratum is mainly composed of rocks (~90%) with almost no gravel or and silt. The average width is 20 m but the average depth could not be measured due to the high velocity of water and difficult terrain. The river at this site is torrential due to high slope gradient and was measured to 2.25 m/s. The bank vegetation is similar to the station 2. The main human activities include fishing.

Station-4 (also mentioned as dwn site) is located about 2.5 km downstream from the dam site. The substratum is composed of all categories except silt, mainly dominated by rocks (>70%). The average flow of river water was 0.62 m/s with the maximum record of 1.01 m/s. Both banks are rocky, eroding and steep. Left bank is covered with herbs, shrubs and trees whereas right bank is full of trees (forest). The main human activities at this site include washing, bathing, fishing and hammering.

2.2 Physicochemical Characteristics of the River

Sampling was conducted in October 2002, following the protocols of Sharma (1996) developed for the streams of Nepal, and Plafkin et al. (1989). Depth and width of the river were measured in all possible stations with the help of the measuring-rod; and velocity was recorded at 0.6 of total depth using a "bray stroke" BFM 001 and BFM 002 Model 001 2 B Valeport flow meter. The substrate composition was estimated visually from boulders to the silt (see Annex 1 for detail). Substrate composition was also estimated at microhabitat level for each quantitative sample taken with the surber sampler. Some of the important physicochemical characteristics of the river are given in Table 1.

Table 1: Physicochemical characteristics of the sampling sites in the Tinau River.

Parameters↓ /Sites→	Station 1	Station 2	Station 3	Station 4
Altitude (m)	242.4	240	230	180
Average width (m)	24	30	20	20
Depth (m)				
Average	0.71	0.54	NA[1]	0.54
Maximum	1.1	1	NA	0.75
Substrate (%)				
Rocks	80	5	90	70
Boulder	5	40	5	10
Cobble	5	10	2.5	8
Pebbles	2	10	1	3
Gravel	3	15	-	5
Sand	5	18	1.5	4
Silt	-	2	-	-
Chemistry				
pH	8.12	7.65	8.8	7.76
Conductivity (µS/cm)	289	289	285	289
Temperature (°C)	23.7	25.1	23.8	20.4

2.3 Surber Sampling (Quantitative Sampling)

A Surber sampler covering $0.1 m^2$ area with 100 µm mesh size in the net was used for sampling macroinvertebrates. From each site 5 replicate samples were taken. As far as possible, samples were taken from the similar habitat types in all the sites to reduce the variability attributable to factors like current, speed and substrate type. Samples were taken by fixing the sampler in the riverbed in such a way that the position would not be changed keeping the open wall towards the flow and the wall with the attached collecting net behind floating freely. The river bottom inside the sampler was being dug with the help of a scalpel for a depth of about ten centimetres, and thoroughly stirred, so that the zoo-benthos would be dislodged properly and collected in the net along with the water flow.

[1] Information not available.

2.4 Qualitative Sampling

Supportive qualitative sampling was done by a hand net, D-net and by handpicking the zoo-benthos from different substrata in similar habitats. The substrate was disturbed in front of the D-net to collect the benthos. Artificial substrates, woods and other detritus were also looked upon for macroinvertebrates. The stones were also turned and observed.

2.5 Preservation and Further Investigation

The samples were preserved in 4% formaldehyde solution and transported to the laboratory for further investigation. In the laboratory, samples were rinsed thoroughly with pure water to remove preservative through a sieve (100 µm mesh size). Samples were then poured in a white-bottomed tray of the appropriate size for good visualisation. The sorted macroinvertebrates were then identified to family level after Dudgeon (1999), Merritt and Cummins (1998), and Ghetti (1998).

2.6 Field Data Collection

In general, the following data and information were collected based on field observation, estimates, and measurements in each sampling site:

- Geographic latitude and longitude, and altitude (by GPS, topographic-maps and altimeter).
- Geological features (direct observation, topographic maps and secondary information).
- Channel morphology: river type, channel type, stream order, channel width and depth, plant cover, habitat diversity, substrate composition, biotic substrate, bank structure and eco-morphology class (observation, estimates, measurements and secondary information).
- Flow characteristics: velocity, flow type (measurements and observation).
- Water characteristics: odour, colour, optical diagnosis, temperature, conductivity, pH, reductive features, iron occurrence and water quality class

(estimates, measurements and observation). Portable field equipments were used to measure pH, conductivity and temperatures.

- Natural disturbances: landslides, erosion and occurrence of last flood (observation and estimates).

2.7 Bio-classification of River Water

Bio-classification of the river water was done on the basis of the protocols and techniques given by Plafkin et al. (1989). Bio-classification of different sites of Tinau River were calculated in the terms of total taxa richness; Family Biotic Index (FBI modified); ratio of scrapers/filterers and collectors; ratio of EPT and Chironomidae abundances; percent contribution of dominant-family; EPT index; and community loss index. Two different scoring methods, viz., Nepalese Biotic Scores (NEPBIOS) method (Sharma, 1996) and the method adopted by Environmental Protection Agency, US (scores given by Hilsenhoff, 1988) (Plafkin et al., 1989; Barbour et al., 1999) were used separately to calculate family biotic index (FBI), which were then converted into the percent comparison and bioassessment scores. Total scores obtained were then used to categorize different sites. Finally, the Hilsenhoff family biotic scores (FBI) are used to convert the water quality classes to the equivalent saprobic water quality classes applicable to the Nepalese streams (Sharma and Moog, 1996).

2.8 Water Quality Assessment: Use of NEPBIOS/ASPT

NEPBIOS (Nepalese Biotic Scores) method, principally an extension of the BWMP/ASPT (Biological Monitoring Working Party/ Average Score Per Taxon) method, involves the determination of average score per taxon (ASPT) of the indicator species. Division of sum of the total individual NEPBIOS by the number of taxa scored in a sample gives NEPBIOS/ASPT that can be transformed to describe the water quality. The result can be presented in coloured maps so that non-biologists can also understand and apply it in the management of surface water (Sharma, 2000). An attempt has been done to evaluate the river water quality on the basis of this method.

III. RESULTS

3.1 Macroinvertebrate Assemblages

A total of 2120 benthic macroinvertebrates (mainly aquatic insects), representing 10 orders and 22 families, were recorded in the present study (see Table 2).

Table 2: Macroinvertebrate composition collected at different stations of Tinau River by two different methods, viz., qualitative (Qlt) and quantitative (Qnt), shown in different columns.

	Station 1		Station 2		Station 3		Station 4		Total	
	Qlt	Qnt	Qlt	Qnt	Qlt	Qnt	Qlt	Qnt	Qlt	Qnt
Diptera										
Chironomidae	46	105	6	668	34	58	42	87	128	918
Ceratopogonidae	2	9	-	4	-	2	-	3	2	18
Tabanidae	-	4	-	-	2	-	-	3	2	7
Tipulidae	1	-	-	-	2	1	-	1	3	2
Ephemeroptera										
Ephemerellidae	4	18		1	3	13	12	3	19	35
Baetidae	17	145	3	34	4	35	24	41	48	255
Heptageniidae	2	62	-	10	3	34	47	20	52	126
Leptophlebidae	12	47	10	40	29	60	20	24	71	171
Caenidae	1	1	4	24	8	4	-	1	13	30
Plecoptera										
Perlidae	-	1	2	3	2	2	1	1	5	7
Perlodidae	-	1	-	-	-	-	-	1	-	2
Chloroperlidae	-	1	-	-	-	-	-	-	-	1
Tricoptera										
Hydropsychidae	6	26	6	45	5	3	36	12	53	86
Coleoptera										
Psephenidae	1	1	-	4	-	-	3	2	4	7
Elmidae	-	11	-	2	-	25	-	-	-	38
Hydrophilidae	-	1	-	-	-	-	-	-	-	1
Megaloptera										
Corydalidae	-	-	-	-	-	-	2	-	2	-
Hemiptera										
Corixidae	-	-	-	1	-	-	-	-	-	2
Odonata	-	-	-	-	-	-	1	-	1	-
Crustacea										
Gammaridae	-	-	-	9	-	-	-	-	-	9
Potamidae	-	-	1	-	1	-	-	-	2	-
Oligochaeta	-	-	-	1	-	-	-	-	-	1
Total	92	407	32	845	93	237	188	199	405	1715

Dipterans had the highest abundance with approximately 51 % of the total count, representing an average density of 473 specimens/m^2. They were present in a high number in the reservoir (station 2) where they had an average density of 1344 specimens/m^2.

Chironomidae alone (pollution tolerant family) has app. 49.0 % of the total count. In the reservoir, Chironomidae had an average density of 1336 individuals/m^2.

The next most dominant taxon was the Ephemeroptera (mayflies) comprising 36 % of total count having average density of 309 specimens/m^2 followed by Trichoptera (caddis flies) with 5 % of the total count and average density of 43 individuals/m^2.

The highest macroinvertebrate density of 1672 individuals/m^2 (mainly due to high number of chironomidae) was recorded in station 2, followed by the station 1 (866 individuals/m^2), station 3 (474 individuals/m^2) and station 4 (398 individuals/m^2). Chironomidae was highly responsible to increase the total count of the macroinvertebrate ($r = 0.86$; $p = 0.000$), Hydropsychidae was the second responsible family, and other dominant families were poorly correlated with the total count (Table: 3).

Table 3: Correlation of major dominant families to the total count of benthic macroinvertebrate.

Families	Total macroinvertebrate count
Chironomidae	$r = 0.86$, $p = 0.000$
Baetidae	$r = 0.42$, $p = 0.062$
Leptophlebidae	$r = 0.32$, $p = 0.173$
Heptageniidae	$r = 0.26$, $p = 0.271$
Hydropsychidae	$r = 0.55$, $p = 0.012$

3.2 Macroinvertebrate and the Substrate Composition

The number of benthic fauna is highest in mixture of gravel and sand dominated substrate and lowest in rocky substrate (Figure 2). The lowest counts were recorded from either a large (rocky) or a small (sand) category of the substrate kind.

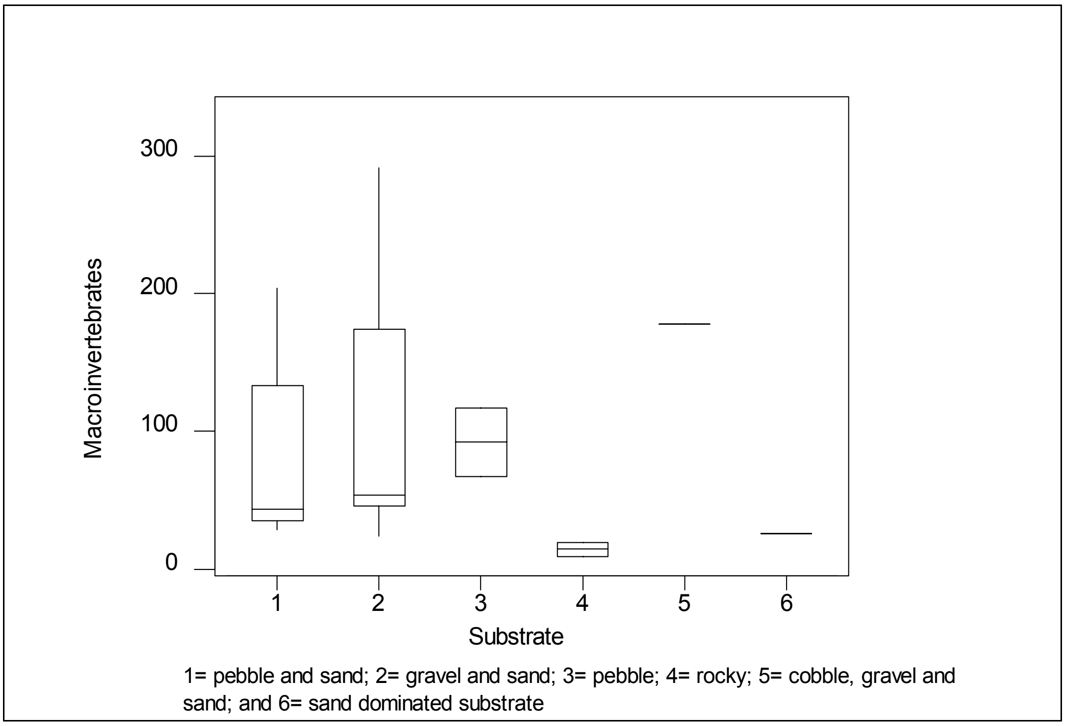
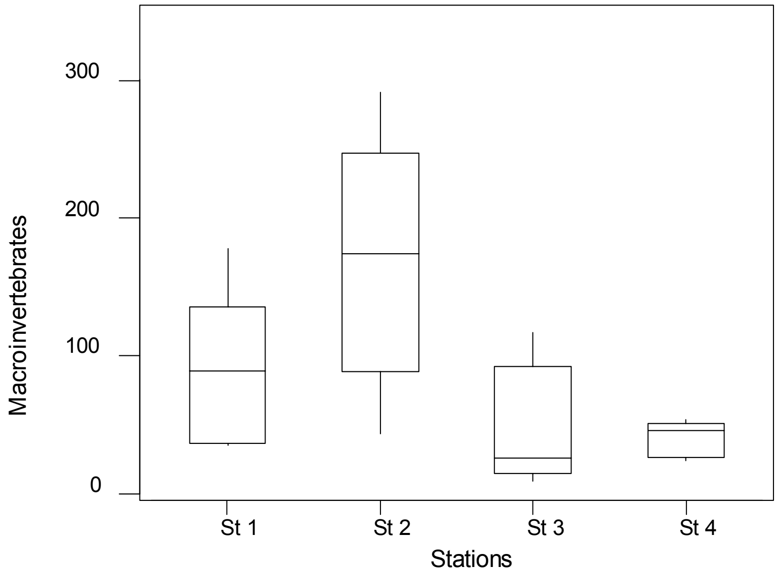


Figure 2: Macroinvertebrate count at different substrate composition

Macroinvertebrates show a different kind of relationships with the sites above and below the dam. Large number of these fauna were recorded from the station 1 (reference site) and station 2 (reservoir) which were set above the dam; and small number were recorded from the station 3 and the station 4 which were set below the dam (Figure 3). There is significant difference among these sites (F = 5.04; d.f. = 3, 16; p = 0.012).

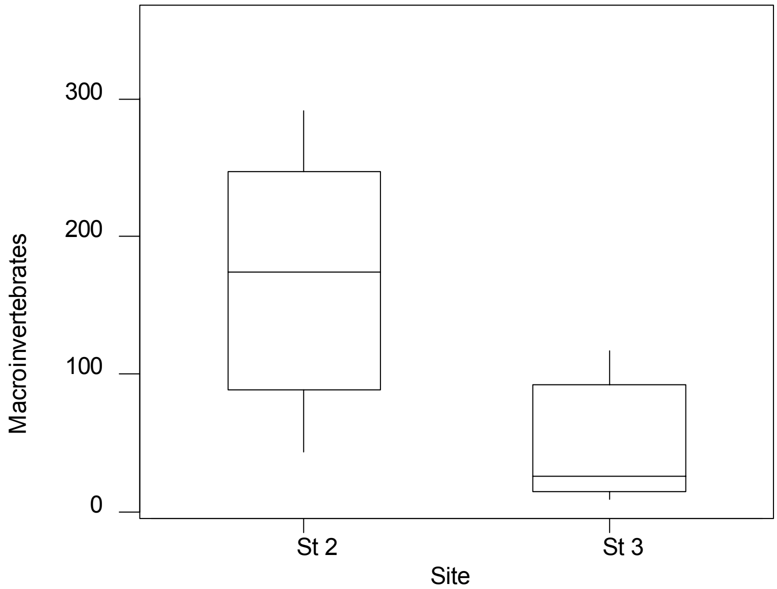
There is also a difference in the pattern of total count of macroinvertebrate between the sites immediately above and below the dam (Figure 4). The number of macroinvertebrates is much higher above the dam in comparison to below. The difference is significant (F = 7.14, d.f. = 1, 8; p = 0.028).

Chironomidae, the most dominant family, was found mainly associated with the gravel-sand-dominated substratum followed by pebble-sand dominated substratum (Figure 5). It was mainly associated with the sandy bottom mixed with other substrate types (a main characteristic of the reservoir). The second most abundant family, the Baetidae, was associated mainly with the gravel-sand and cobble-gravel-sand dominated substratum (F = 10.73; d. f. = 5, 14; p = 0.000) (Figure 6).



St 1= Station 1 (reference); St 2= Station 2 (reservoir); St 3= Station 3 (just below the dam); and St 4= Station 4 (downstream).

Figure 3: Macroinvertebrate count at different stations



St 2= Station 2 (Reservoir); and St 3= Station 3 (just below the dam)

Figure 4: Macroinvertebrate count just above and below the dam

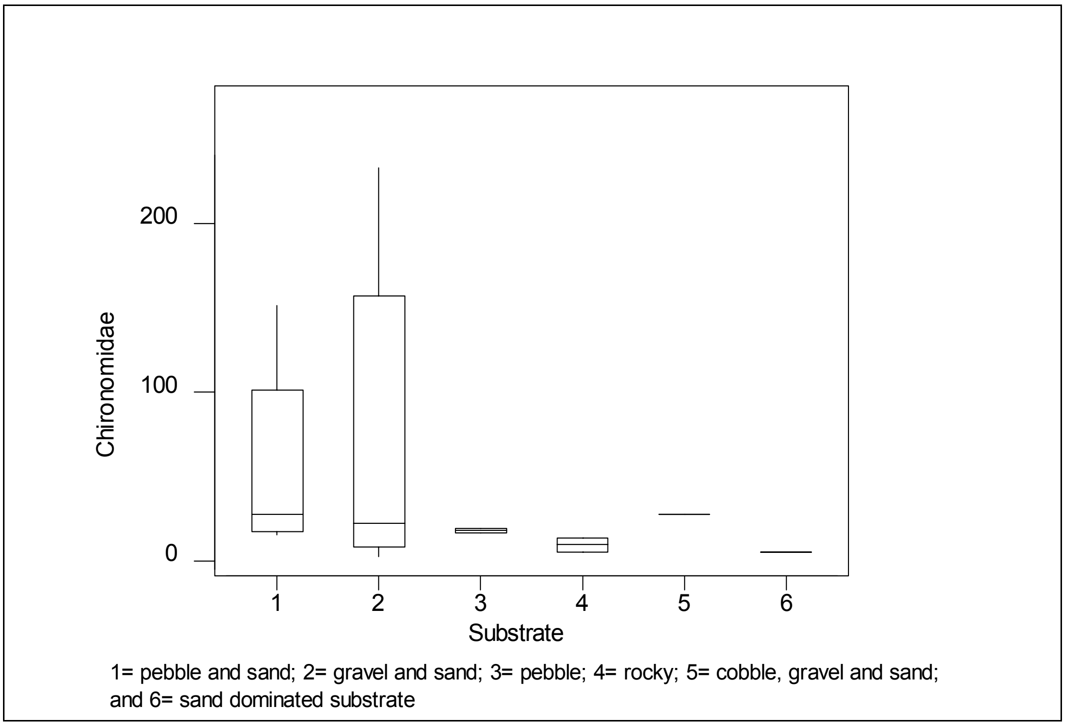


Figure 5: Distribution of Chironomidae family in different types of substrate composition

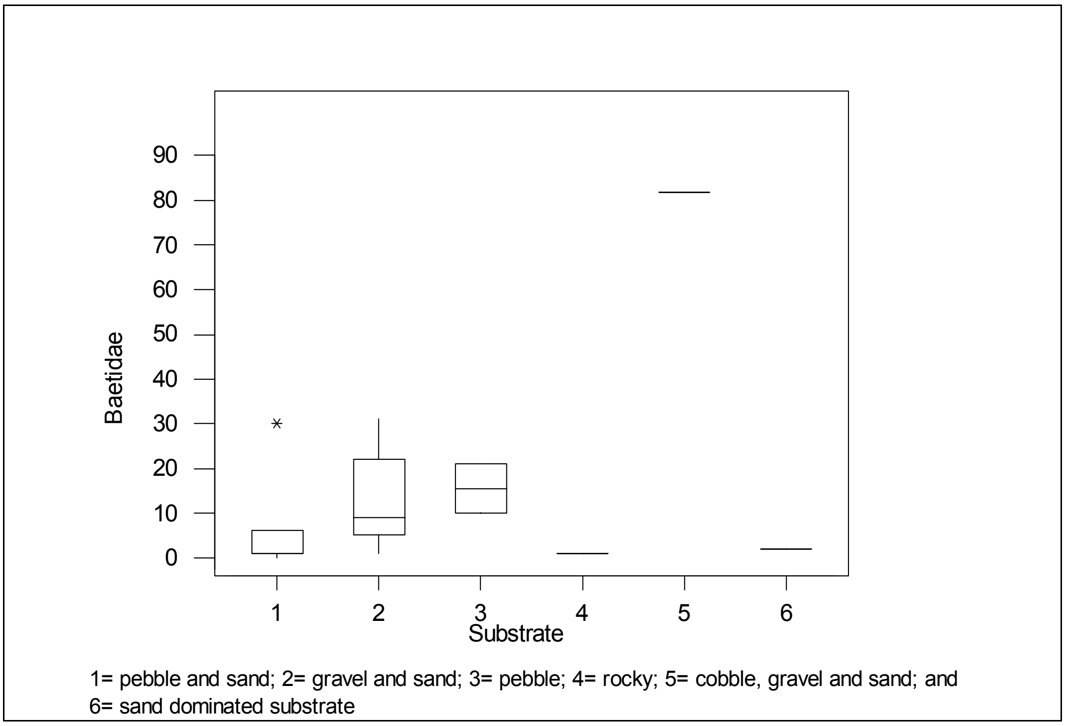
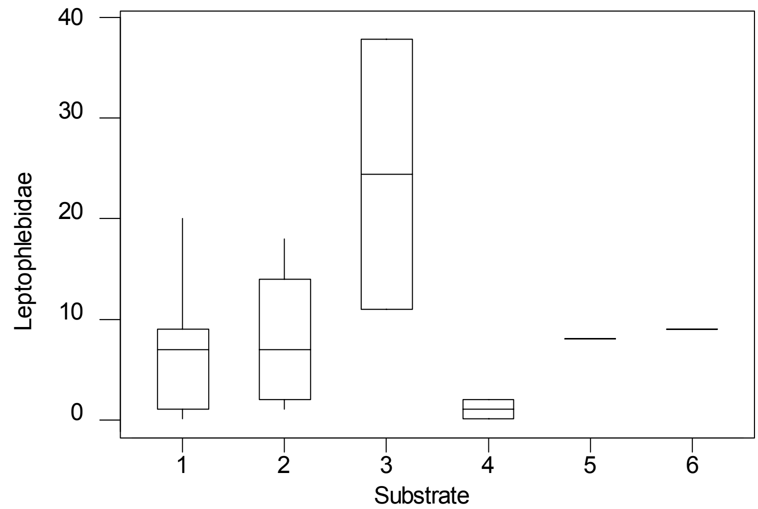


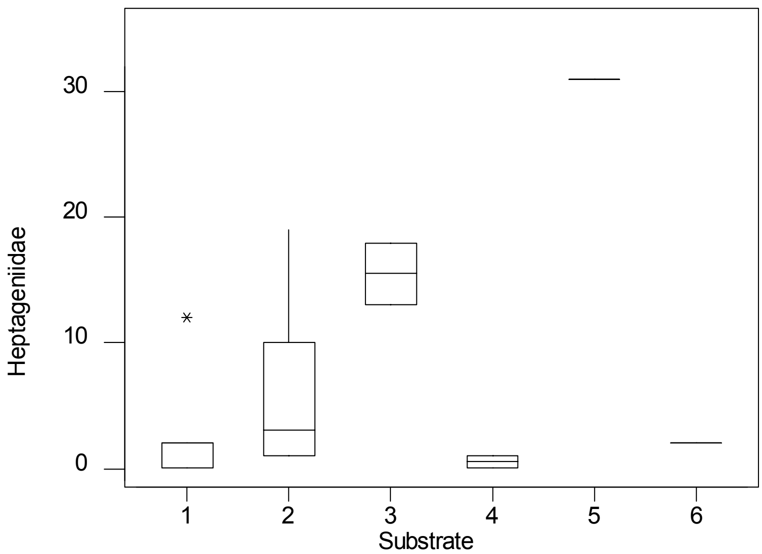
Figure 6: Distribution of Baetidae in different types of substrate

Similarly, the third dominant family, the Leptophlebidae, was most closely associated with the pebble-dominated substrata (Figure 7). Heptageniidae showed a variance with the substrate composition (F = 7.13; d. f. =5, 14; p = 0.002), which has highly associated with the gravel-sand and pebbles (Figure 8).



1= pebble and sand; 2= gravel and sand; 3= pebble; 4= rocky; 5= cobble, gravel and sand; and 6= sand dominated substrate

Figure 7: Distribution of Leptophlebidae family in different types of substratum



1= pebble and sand; 2= gravel and sand; 3= pebble; 4= rocky; 5= cobble, gravel and sand; and 6= sand dominated substrate

Figure 8: Distribution of Heptageniidae family in different substrate composition.

3.3 Bio-classification of River Water

The biological condition of the river water calculated by using Nepalese Biological Score (NEPBIOS) method ranged from 18 to 38 in different sites of a possible 40 points (mean ± SD: 32.00 ± 9.38). According to the results obtained from the bio-classification, the sites were ranked as: **station 1 (reference) > station 3 and station 4 > station 2 (reservoir)**. This indicated that the reference site was very good in terms of biological conditions and was categorised as non-impaired site. Station 3 (just below the dam) and station 4 (downstream) gained same scores and fell below the reference site, which were also categorised as non-impaired sites. Station 2 or reservoir (just above the dam) has got moderately impaired category regarding biological conditions (Table 4).

Table 4: Metric values, percent comparison, and bioassessment scores for benthic macroinvertebrate results: Family level identification data. FBI was calculated using the scores of NEPBIOS (1996).

Metrics	Metric value				Percent comparison				Bioassessment scores			
	Ref	D1	D2	Dwn	Ref	D1	D2	Dwn	Ref	D1	D2	Dwn
Taxa richness	16	14	13	15	100	88	81	94	6	6	6	6
FBI*	5.8	3.8	5.9	5.5	100	66	102	95	6	2	6	6
Scrapers/Filt. Coll.***	0.65	0.18	0.64	0.56	100	28	98	86	6	2	6	6
EPT/Chiron. abd.	2.28	0.27	2.23	1.88	100	12	98	82	6	0	6	6
% Contribution of dominant taxon	31	77	28	33	31	77	28	33	2	0	4	2
EPT index	9	7	7	8	100	78	78	89	6	2	2	4
Community loss index	0	0.36	0.31	0.2	--	--	--	--	6	6	6	6
Total score									38	18	36	36
Biological condition****									None	Mod	None	None

*Family Biotic index using the scores assigned by NEPBIOS (1996). It increases with the increase in quality of water.

*** Classification of functional groups like scrapers and filter collectors is done after Dudgeon (1999).

**** Biological condition categories are based on the % comparison to Reference score (>83% = non-impaired, 54-79% = slightly impaired, 21-50% = moderately impaired, and <17% = severely impaired) Plafkin et al. (1989) (detail biological condition categories are given in the Annex 2).

The family biotic index increase as the quality of water increase in NEPBIOS method which is just opposite in case of Hilsenhoff scoring method adopted by Environment Protection Agency (EPA), US. The family biotic index for different sites obtained by using the scores assigned by Hilsenhoff was different from NEPBIOS method (Compare FBI in Table 4 and Table 5). Analysis of Variance between the scores obtained by these two methods was done on the basis of percent comparison of FBI. The scores obtained were significantly different among the four different sites ($F = 17.64$; d.f. = 3, 4; $p = 0.009$). Comparatively a vast different result was obtained in assigning biological conditions to the station 2 by these two methods (Table 4 and 5). The station 2 (reservoir) was categorised as slightly impaired site when FBI was calculated by using the scores assigned by Hilsenhoff. This result (Table 5) was obtained only due to the differences in FBI scores by two different methods because all other metrics were same as in the table 4.

Table 5: Change in the total scores and biological conditions of different sites when Hilsenhoff (1988) scoring method was used. All other metrics remained the same as in table 4.

Metrics	Metric value				Percent comparison				Bioassessment scores			
	Ref	D1	D2	Dwn	Ref	D1	D2	Dwn	Ref	D1	D2	Dwn
FBI**	4.3	5.5	4.0	4.3	100	78	107	100	6	4	6	6
Total score									38	20	36	36
Biological condition****									None	Slight	None	None

** Family Biotic index using the scores of Hilsenhoff (1988). It decreases with the increase in quality of water.

**** Biological condition categories are based on the % comparison to Reference score (>83% = non-impaired, 54-79% = slightly impaired, 21-50% = moderately impaired, and <17% = severely impaired) Plafkin et al. (1989).

3.4 Water Quality Assessment Using NEPBIOS/ASPT

The water quality classes obtained for the Tinau River was II (good water quality with green colour) by using NEPBIOS scores method. Water quality classes obtained had no variations among the different sites for present study (Table 6).

Table 6: Water quality classes at different stations calculated on the basis of NEPBIOS method.

Stations	NEPBIOS Scores	NEPBIOS/ASPT (NEPBIOS Score/ number of taxon scored)	Water Quality Classes (NEPBIOS/ASPT)	Water Quality Classes using Hilsenhoff FBI
Station 1	107	6.69	II	II
Station 2	89	6.36	II	II-III
Station 3	83	6.38	II	I-II
Station 4	97	6.47	II	II

However, The saprobic water quality classes, converted on the basis of Hilsenhoff FBI, for the Tinau River were II (green), II-III (greenish yellow), I-II (bluish green) and II (green) for station 1 (reference), station 2 (reservoir), station 3 (just below the dam) and station 4 (downstream) respectively.

DISCUSSION

Quantifying the impact on freshwaters by using the presence of indicator species is described as a promising approach (Sangpradub, 1997). In the present study, the most impacted site (reservoir) was dominated by the dipterans, whereas less or non-impacted sites were more dominated by mayflies. The change in the physical features of the stream (habitat) was evident in the reservoir due to the reduction in the rocky composition on the substrata, which was the direct effect of the dam building. It was also evident that Chironomidae family was highly responsible for increasing the total count of macroinvertebrate in all sites (Table 3).

Galdean et al. (2000) have found a relationship between Chironomidae and the sandy substratum. However, the present study did not show significant variations of Chironomidae with the substrate composition. But there existed a significant variation of two of the dominant families, Baetidae ($F = 10.73$; d. f. = 5, 14; $p = 0.000$) and Heptageniidae ($F = 7.13$; d. f. =5, 14; $p = 0.002$), with the substrate composition. This finding indicates that the dominant-substrata in a microhabitat type have an influence on some of the macroinvertebrate types, partially agreeing with the findings of Lammert and Allan (1999).

Development of comparative studies in the bio-monitoring processes has provided good prospects for applying site-specific biological criteria to the management of ecosystems which is important due to change in the composition of fauna geographically (Rosenberg and Resh, 1993; Aanes and Baekken, 1995). Nepalese Biotic Score (NEPBIOS) method (Sharma, 1996) has, therefore, been incorporated to calculate the scores for different taxa for assessing water quality in addition to the biotic scores assigned by Hilsenhoff-1988 (Plafkin, 1989). Bio-classification results from Tinau River (Table 4 and 5) showed that the water quality is good in terms of biological conditions in the station 1 (reference), station 3 (just below the dam) and station 4 (downstream) having less or no effects of the dam on macroinvertebrates. The most disturbed site was the site within the reservoir, which can be categorised as moderately impaired according to the present study.

Though assessment information could be shared among some agencies using different techniques, not only the different assessment methods used (Houston et al., 2002) but also different scoring systems may considerably affect the results in calculating the final scores for biological water quality assessment. There was no significant difference in using biotic scores assigned by Hilsenhoff and Nepalese Biotic Scores (NEPBIOS). Though there is no significant difference in the calculation of total scores for biological conditions (F = 0.007; d.f. = 1, 6; p = 0.93), the final categorization of one of the sites (station 2) has been differed considerably. This finding, to some extent, agrees with the study of Sharma and Moog (1996) and Rosenberg and Resh (1993) showing the importance of site-specific biological criteria for the judgement. It also depends on how one interprets the result and what is the extent of the effects of that interpretation. The difference of slightly impaired and moderately impaired conditions, the result for the station 2 in present study by two different methods, is a vast difference that may guide a manager differently.

Generally, the total number of families (total taxa richness as well as EPT taxa richness) increases with the increase in water quality (Plafkin et al. 1989). Lydy et al. (2000) have described the use of EPT taxa richness (in %) as the most descriptive tool in analysing the biological data to ensure the most effective investigation of water quality. In the present study, both of the disturbed sites (reservoir and just below the dam) consisted of lower taxa richness (both total and EPT taxa) than the station 1 (reference) and station 4 (downstream) reflecting the decrease in water quality. But station 3 has gained a good score in terms of total biological condition (table 4 and 5). This result may be the case specific because the total diverted water quantity did not exceeded 10% of the total flow in the river so that the water level to downstream of the dam was not much reduced. In this regard, Station 2 (reservoir) can be considered as the moderately impaired site mainly due to the change in the substrate composition caused by the establishment of the dam.

The Water quality was assigned as class II (see the Annex 3 for the detail classification) by NEPBIOS/ASPT method that is attributed with good water quality with green colour (Table 6). But this method did not differentiate the variations in water quality at different sites. But the scores obtained by NEPBIOS method, when converted to the saprobic water quality classes using Hilsenhoff FBI, gave different classes to the different sites.

All of the above findings could not be generalised as impacts of the dam on macroinvertebrates because I already have described some of the anthropogenic activities like washing, bathing, hammering and fishing etc. in the study area, though to a less extent. The watershed of the river section studied consists of human settlement areas as well as agricultural fields that may have some of the impacts on the biological integrity of the river. There is also a motorway along the east coast of the river throughout the length of the study reach that might have some impacts on the biota as studied by Sriyaraj and Shutes (2001). However, I can conclude that dam buildings have profound impacts on the macroinvertebrates within the reservoir as indicated by this study.

NEPBIOS/ASPT scoring method is suitable to classify a river water quality classes broadly. When these scores are converted to the water quality classes using Hilsenhoff FBI, it appears a promising method.

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Annex 1: Results of the field protocols (after Sharma, 1996) describing eco-morphology different stations in the Tinau River.

Parameters↓/Sites→	**Station 1**	**Station 2**	**Station 3**	**Station 4**
Locality	Dovan	Reservoir	Below the dam	Chidiya khola
Date	24 Oct, 2002	24 Oct, 2002	25 Oct, 2002	24 Oct, 2002
Weather condition	Sunny	Normal	Sunny	Normal
Altitude (m)	242.4	240	230	180
Water level	High	High	High	High
Water uses	Washing, bathing and fishing	Hydropower, fishing and swimming	Hydropower, fishing, washing and bathing	Swimming, washing and fishing
Effluents (inflows into the river)	Agricultural and forest runoff	Forest runoff	Forest runoff	Forest runoff
Rocks (>40cm)	80	5	90	70
Boulders (20-40cm)	5	40	5	10
Cobbles (6.3-20cm)	5	10	2.5	8
Pebbles (2- 6.3 cm)	2	10	1	3
Gravels (0.2- 2 cm)	3	15	-	5
Sand (0.063- 0.2 cm)	5	18	1.5	4
Silt (< 0.063 cm)	-	2	-	-
Mean width (m)	24	30	20	20
Max depth (cm)	110	100	NA	75
Mean Depth (cm)	71.15	54.05	NA	54.58
Land use pattern	Agricultural fields, forest	Forest	Forest	Forest
Embankments	Natural	Natural	Natural	Natural
Bank vegetation (left side)	Herbs, shrubs and trees	Shrubs, trees and herbs	Herbs and shrubs (bushes)	Shrubs and herbs
Bank vegetation (right side)	Trees	Trees	Trees	Trees
Bank structure (left)	Rocky, eroding, steep	Rocky, eroding, steep	Rocky, eroding, steep	Rocky, eroding, steep
Bank structure (right)	Rocky, stable, steep	Rocky, stable, steep	Rocky, stable, steep	Rocky, eroding, steep
Plant cover (%)	0	0	0	0
Flow type	Rapids	Riffles, runs and pools	Rapids	Riffles, runs and rapids

Current velocity	High	High	Very high	High
Natural influences	Landslides	Rocky debris through landslides	Rocky debris through landslides	Landslides
Human impacts	Poisoning	Damming	Damming	-
Odour	None	None	None	None
Colour	Bluish green	Bluish green	Light green	Bluish green
Optical diagnosis	None	None	None	Washing and bathing waste
Water temp. (^oC)	23.7	25.1	23.8	20.4
Peculiar	None	None	None	None
Conductivity µS/cm	289	289	285	289
PH	8.12	7.65	8.8	7.76
Reductive features	None	None	None	None
Geological features	Siwalik fragile	Siwalik fragile	Siwalik fragile	Siwalik
Aquatic vegetation (%)	0	0	0	0
Detritus cover (%)	0	0	0	0

Annex 2: Biological condition categories and attributes given In Plafkin et al. (1989).

% Comparison to Reference Score [a]	Biological Condition Category	Attributes
> 83 %	Non-impaired	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
54- 79 %	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerance forms. Percent contribution of tolerant forms increase.
21- 50 %	Moderately impaired	Fewer species due to loss of most intolerant forms. Reduction in EPT index.
< 17 %	Severely impaired	Few species present. If high densities of organisms, then dominated by one or two taxa.

(a) Percentage values obtained that are intermediate to the above ranges will require subjective judgement as to the correct placement. Use of the habitat assessment and physiochemical data may be necessary to aid in the decision process.

Annex 3: Conversion table for the NEPBIOS/ASPT scores to the water quality classes assigned by Sharma (2000).

NEPBIOS/ASPT Value obtained	**Water quality Classes**	**Attribute to the water class**	**Mapping colour**	Uses
8.00- 10.00	I	Excellent	Blue	Recommended for drinking.
7.00- 7.99	I-II			
5.50- 6.99	II	Good	Green	Drinking possible after treatment.
4.00- 5.49	II-III			
2.50- 3.99	III	Fair	Yellow	Hazardous.
1.01- 2.49	III-V			
1.00	IV	Bad	Red	Unsuitable for any human use except as a receptacle for sewage.