Diatom Communities in Himalayan Hill Streams

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Abstract

We sampled diatoms in over 130 rivers in Nepal to assess effects by natural and anthropogenic factors. We found marked differences between altitudes and regions which reflect habitat structure, stream chemistry, and biotic interactions with grazing invertebrates. Effects from different forms of pollution were clearly detectable and emphasise the potential value of diatoms as cost-effective bioindicators with particular value in remote areas where opportunities for chemical monitoring are limited.

Introduction

Diatoms (*Bacillariophyceae*) are the most common and diverse primary producers in rivers (Round 1991). Increasingly they are being recognised as bioindicators of environ-mental change and pollution (Leland 1995, Lobo et al. 1995). In integrating effects by short- and long-term chemical change, they are likely to be particularly useful in remote locations, such as the Himalayas, where other monitoring methods are limited (Ormerod et al. 1994, Jüttner et al., submitted).

Nepal is rich in biodiversity due to its geographical position and physico-chemical heterogeneity, but its natural ecosystems have experienced large changes in past decades (Jha 1992). Increased cultivation, deforestation, and sewage have affected rivers, presenting a major challenge to sustainable development (Ormerod and Jüttner, 1996 in press). In this situation, river ecosystems provide a valuable monitor of whether sustainable catchment management is achieved. Such multi-scaled monitoring using biota has been advocated to determine normal ecosystem functions, and to detect adverse changes which deplete basic natural resources (O'Neill et al. 1996).

As part of an ongoing study about natural and anthropogenic influences on mountain rivers of the Hindu Kush - Himalayas (see also Ormerod et al., this volume), we are developing diatom communities as indicators of the physico-chemical environment (pollution, habitat structure, land use changes) and biotic character (biodiversity and function) of rivers along altitudinal gradients. Here, we outline progress so far.

Methods

Field work involved expeditions in 1992 - 1995 to over 130 sites in the Langtang River system, the Likhu *Khola*, and the Kathmandu Valley in Central Nepal, to the

Simikot and Dunai region in the far west, and to the Arun Valley in the far east (Fig. 1). Physico-chemical data were collected at the same time as diatom samples. River habitat surveys (RHS) (Ormerod et al. 1996 in press) were carried out to assess habitat character within the river channel and banks. Concentrations of anions and cations were determined by ion chromatography and inductively coupled plasma spectrometry, respectively. Diatoms were scraped from at least five stones in riffles at each location and preserved in five per cent formaldehyde. Using standard methods, 400-500 valvae were identified to species or sub-species (Krammer and Lange-Bertalot 1986-1991). Percentage abundances for each were derived, and species' richness, diversity, and evenness calculated after Shannon and Weaver (1949). To assess patterns in community composition, we used two-way indicator species analysis (TWINSPAN), which identifies site groups from affinities in their diatom floras. We also used either detrended correspondence analysis DECORANA or principal components' analysis (PCA) to arrange sites into an objective order in which those with similar communities have similar scores along axes. Analysis of variance (oneway-ANOVA; hierarchical ANOVA, general linear model) or a non-parametric test (Kruskal-Wallis) were used to evaluate differences between site groups in altitude, habitat character, and chemistry, with the latter complex data again reduced by PCA. Discriminant analysis was used to identify environmental variables which best differentiated between the site groups.

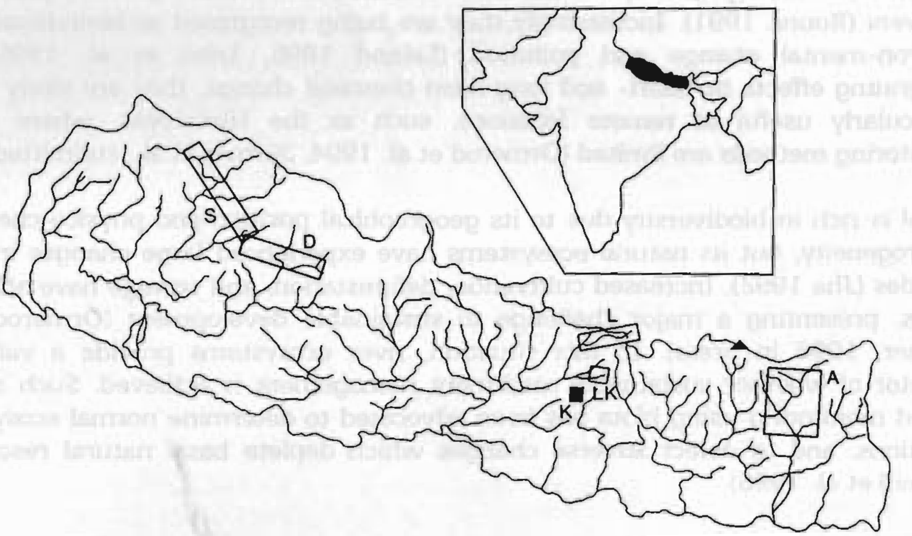

Figure 1: Map of the Study Sites in Nepal (S: Simikot, D: Dunai, L: Langtang, LK: Likhu *Khola*, K: Kathmandu Valley, A: Arun)

Results and Discussion

Downslope Change

Altitudinal changes were shown strongly, representing changes in a range of environmental factors. In the Langtang and Likhu *Khola* system, there was an increase in species' richness with decreasing altitude (Fig. 2). This reflects nutrient enrichment in the lower altitude streams situated in the Likhu *Khola*, where catchments are extensively cultivated and the rivers have higher ionic contents than semi-natural sites at similar altitudes (Jüttner et al., submitted). Species-rich communities in the terraced streams of the Likhu *Khola* were clearly separated by TWINSPAN from the higher altitude forest, scrub, and tundra streams in Langtang (Figs. 2, 3). In contrast, our 1994 data set, involving 76 mainly semi-natural sites from the Simikot, Dunai, and Arun regions, showed a reversed trend, with species' richness increasing with altitude (Table 1). Species' richness, diversity, and evenness increased along the first principal component of the habitat survey (RHS PC1), reflecting an altitudinal shift from large streams with laminar flow and boulders to small, pebbly streams with features related to trees (woody debris, shade, roots, Table 1).

Table 1: Environmental Factors Significantly Correlated with Diatom Species' Richness (S), Diversity (H'), Evenness (E) from 76 sites in the Simikot, Dunai, and Arun regions, Nepal. (Spearman rank correlation P = * < 0.001, ** < 0.01, * < 0.05)**

	S	H'	E
Altitude	0.42***	0.41***	0.31**
Slope	0.28*	0.29*	0.25*
RHS PC 1	0.53***	0.52***	0.41***
RHS PC 3		- 0.25*	- 0.27*
RHS PC 4	0.24*	0.24*	
Chemistry PC 2	0.29*		
Chemistry PC 3	0.28*	0.23*	
Chemistry PC 4	- 0.30**	- 0.30**	- 0.23*
Macroinvertebrate DECORANA score	- 0.28*	- 0.32**	- 0.26*
Macroinvertebrate Grazers %		- 0.31**	- 0.31**
Macroinvertebrate grazers total		- 0.26*	- 0.24*

Note: RHS PCs are trends in habitat structure (see Ormerod et al. 1996, in press), chemistry PC 2 describes an increase in Na^+, Si, Cl^-, F^- and a decline in NO_3^{2-}, chemistry PC 3 an increase in Fe, and chemistry PC 4 an increase in NO_3^{2-} and a decline in PO_4^{3-}.

Regional Pattern

There was a strong regional difference between communities in the Simikot region, Dunai region, and Arun Valley (Fig. 4). Discriminant analysis showed that altitude, water chemistry (a decline in pH, conductivity, sulphate, and base cations and an increase in iron), and habitat structure (RHS PC 1) were environmental factors that might influence this pattern (Fig. 5).

Effects by Pollution

To assess effects by pollution at similar altitudes, we used a replicated survey (five sites per group) to compare the composition and diversity of diatom communities in semi-natural sites (Arun Valley), rivers enriched by agricultural runoff (Likhu *Khola*), or grossly polluted by sewage (Kathmandu Valley). Species' richness and diversity were significantly higher in agricultural streams than in either organically polluted or semi-natural streams (Fig. 6), showing that simplistic indices cannot differentiate between polluted and unpolluted sites. However, PCA showed characteristic communities at each site type (Fig. 7). Species' characteristics of agriculturally enriched or organically polluted sites were highly significantly correlated ($P < 0.01$) with the first two principal components (Table 2). Together, these patterns emphasise the indicator potential of diatoms in Nepal. To assess whether effects of water pollution were consistent between different habitats, riffles, vegetation surfaces, and pools were sampled in the Likhu *Khola* and in the Kathmandu Valley. Principal components' analysis did not differentiate between habitats, indicating that community differences between rivers with contrasting water quality were stronger. This suggests that, for monitoring purposes, samples from riffles are sufficient. However, pool and vegetation samples increased the total species recorded by 15-26 per cent, so that assessments of biodiversity may need a more extensive sampling procedure.

Table 2: Principal Components Derived from Diatom Communities at 15 Sites in Three Groups of Nepalese Rivers in the Kathmandu Valley, Likhu *Khola* and Arun Valley (Species whose relative abundance correlated significantly ($p<0.01$) with PC 1 and 2 are listed in rank order.)

PC 1 (22.6% of variance)	PC 2 (18.1 % of variance)
Achnanthes lanceolata v. rostrata (Oestr.) Hustedt	Navicula cryptocephala Kützing
Navicula vandamii Schoenman and Archibald	Navicula atomus (Kütz.) Grunow
Navicula sp.	Nitzschia palea (Kütz.) W. Smith
Navicula schroeteri Meister	Gomphonema parvulum Kützing
Navicula cryptotenella Lang-Bertalot	Nitzschia perminuta (Grunow) M. Peragallo
Navicula decussis Oestrup	Navicula subrotundata Hustedt
Nitschia gracilis Hantzsch	Navicula cryptocephala v.2
Cocconeis placentual Ehrenbert	Navicula viridula (Kütz.) Ehrenberg

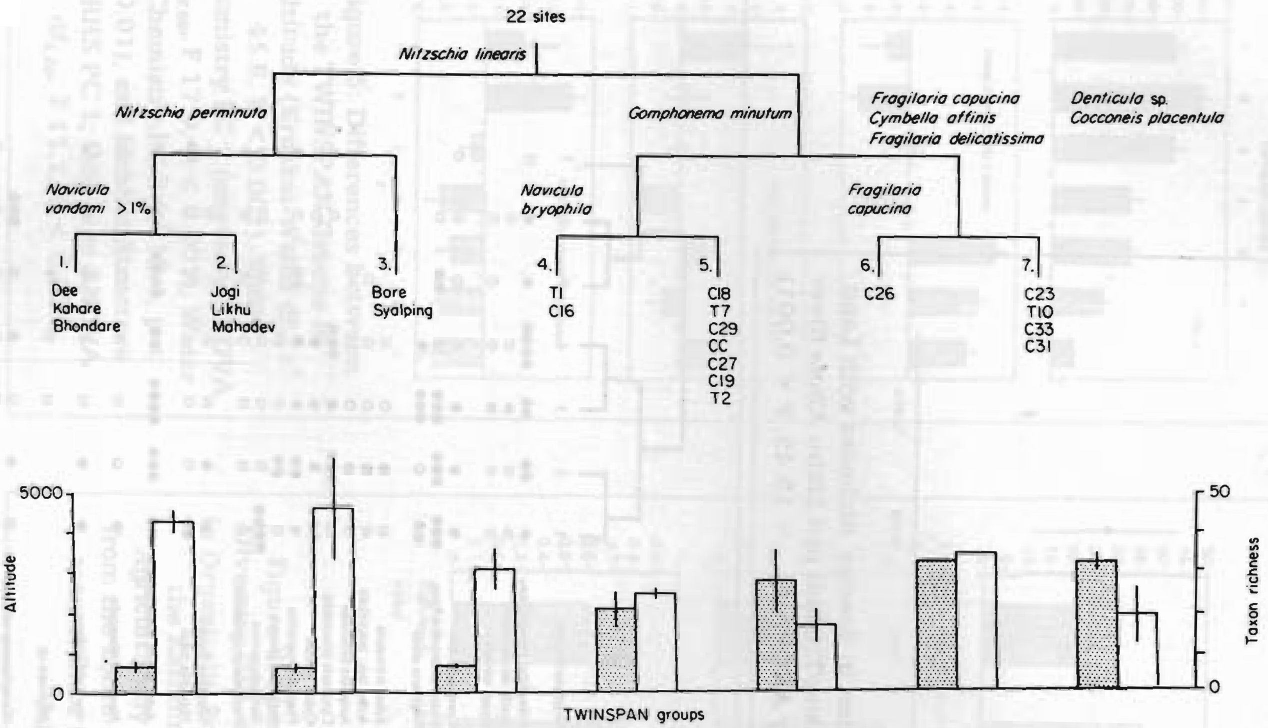

Figure 2: TWINSPAN Classification of Twenty-two Streams in the Langtang/Trishuli and Likhu *Khola* River Systems (group 1-3: rivers in the Likhu *Khola* catchment, T and C sites in the Langtang catchment) with Indicator Species for Each Division Mean altitude (one-way ANOVA: $F_{6,15}$ = 15.91, P < 0.001; shaded) and Species' Richness ($F_{6,15}$ = 10.6, P < 0.001; unshaded) Are Shown for Each Site Group

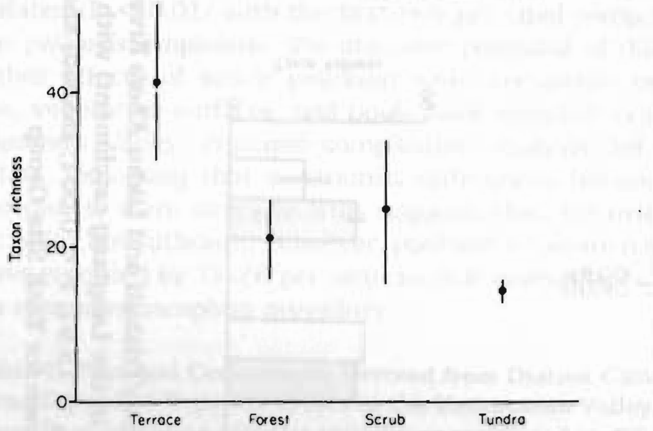

Figure 3: Variation in Species' Richness with Land Use in the Langtang/Trishuli and Likhu *Khola* River System (one-way ANOVA $F_{3,18} = 15.45$, $P < 0.001$)

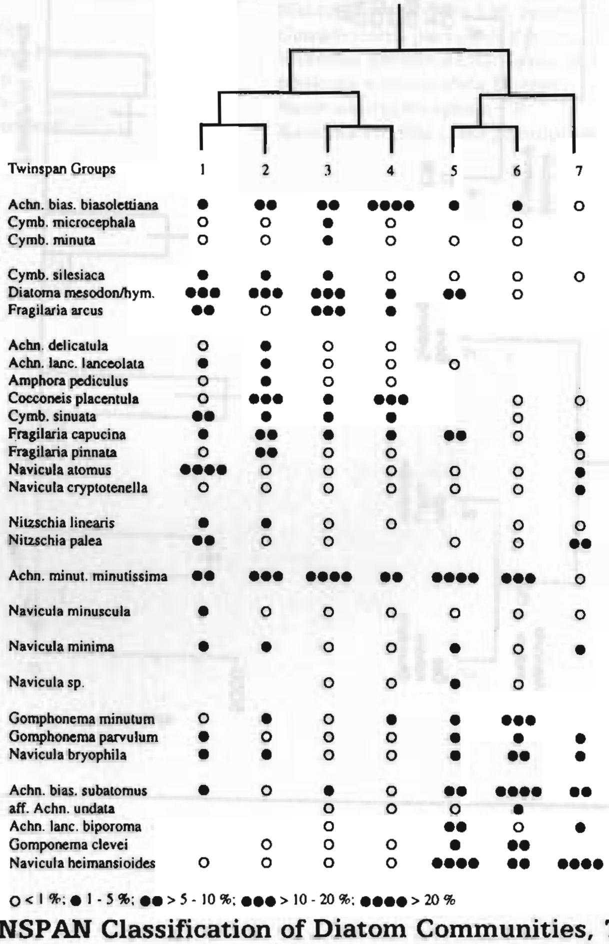

Figure 4: TWINSPAN Classification of Diatom Communities, 76 Sites from the Simikot (S), Dunai (D) and Arun Region (A) (TWINSPAN groups contain sites from regions as follow, 1-S,D; 2-S,D; 3-S,D,A; 4-S,D,A; 5-A; 6-A; 7-A.)

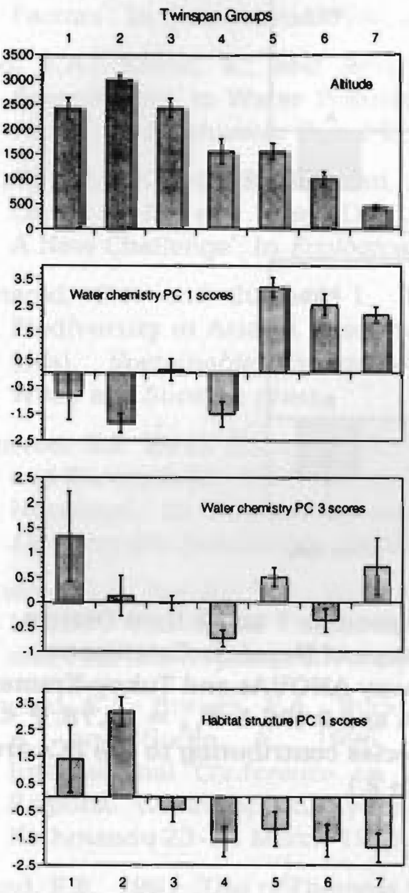

Figure 5: Differences between the TWINSPAN Groups in Altitude (Kruskal-Wallis df_6, c^2 45.8, P < 0.001), Water Chemistry PC 1 (one-way ANOVA $df_{6,69}$, F 17.9, P < 0.001), Water Chemistry PC 3 (c^2 18.4, p < 0.01), and Habitat Structure (RHS PC 1; One-way ANOVA $df_{6,69}$, F 11.1, P < 0.001)

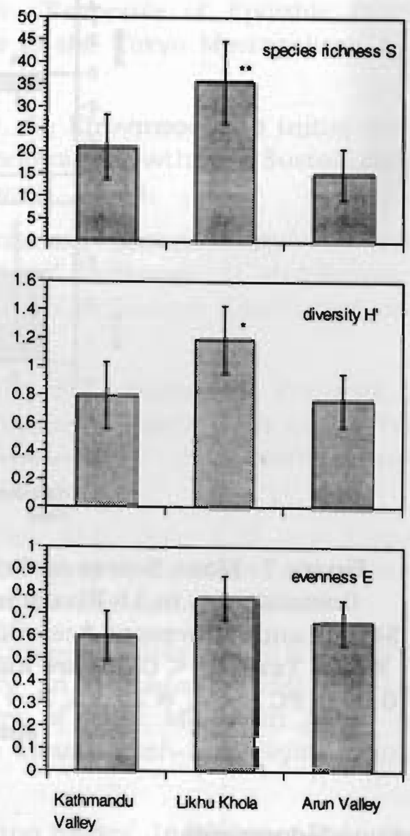

Figure 6: Species' Richness, Diversity (H'), and Evenness (E) in Organically Polluted Sites from the Kathmandu Valley, Agriculturally Enriched Sites from the Likhu *Khola* and Semi-natural Sites from the Arun Valley

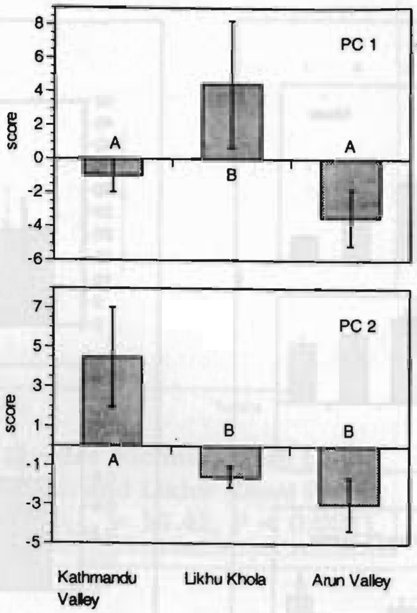

Figure 7: Mean Scores on Principal Components 1 and 2 from Diatom Communities in 15 Rivers in Three Groups of Nepalese Catchments; Significant Differences According to One-way ANOVAs and Tukey-Kramer Range Tests ($p < 0.05$) are indicated by A and B (PC 1: $F_{1,8} = 13.78$, $P < 0.001$: PC 2: $F_{1,8} = 27.36$, $P < 0.001$) (Species contributing to the PCs are shown in Table 2.)

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