Bioscience Discovery, 9(1): 135-140, Jan - 2018

Print & Online, Open Access, Research Journal Available on http://jbsd.in

ISSN: 2229-3469 (Print); ISSN: 2231-024X (Online)

Research Article

Ordination analysis for determining distributional patterns of diatom communities in different ecoregions of Indian subcontinent

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Article Info

Received: 19-09-2017,
Revised: 22-11-2017,
Accepted: 05-12-2017

Keywords:
Diatom, ecoregion, Himalaya, Principal Component Analysis, Vindhya

Abstract

River communities are structured by a combination of local (environmental filtering and biotic interactions) and regional factors (e.g., dispersal related processes). An ordination analysis (Principal Component Analysis) was performed on the diatom assemblages from two different highland ecoregions of the Indian subcontinent. Our results showed that the diatom communities were different in both the ecoregion structured mainly by differences in the environmental variables.

INTRODUCTION

Correspondence between the ecoregional classification and the biota should depend on the extent to which environmental variables differ between ecoregions, and on the extent of influence of ecoregional variables on biota. Ecoregions, a non-hierarchically based classification system, may poorly correspond to components of the biota that are strongly regulated by local factors. Algae, macroinvertebrate and fish assemblages respond to environmental changes at different temporal and spatial scales because of their differing life histories, physiologies and mobilities. Thus, changes in each assemblage may reflect environmental conditions of hierarchically organized stream habitats and associated human influences (e.g., microhabitat, channel unit, reach and catchment) (Frissel *et al.*, 1986). Comparison of ecoregional differences in periphyton, macroinvertebrates, and fish in 48 Oregon streams, revealed that the correspondence between ecoregions and the biota was clearest in fish and very subtle in periphyton (Whittier *et al.*, 1988). Macroinvertebrate taxa traits and taxa compositions exhibited much stronger relationships to local environmental conditions (at reach scale) than to catchment variables (Carter *et al.*, 1996, Richards *et al.*, 1996). Benthic diatoms in the Mid Atlantic Highlands streams may respond much more strongly to local conditions than to regional factors such as climate, geology, soil and vegetation (Pan *et al.*, 2000, Flower *et al.*, 2012; Gothe *et al.* 2013). In view of these observations a study was designed to elicit information on the correspondence of diatom communities in the Himalaya and Vindhya (is it a ecoregion) ecoregions.

STUDY AREA

The streams of two ecoregions the Himalaya and Central Highlands (Bundelkhand Plateau, Central India) were selected for the study. They differ in extent of mountain area, topography, elevation and climate by virtue of geographical location. The streams and rivers also vary due to higher current velocities in the Himalaya as compared to the Central Highlands. The former region possesses glaciers resulting in coldwaters compared to the warm waters of the latter.

In Central Highlands, the rivers Ken, Paisuni and Tons were selected for longitudinal and interbasin studies because distributional patterns varied significantly. In the Himalaya, only one springfed stream Nagni Gad was selected for longitudinal analysis, as the glacierfed Alaknanda has been examined in this respect. The other stream, Dharasu Gad and rivers Supin-Tons, Yamuna, Bhagirathi and Alaknanda selected in the Himalaya were in the western part of Garhwal region drained by the Yamuna and Bhagirathi river system in (Verma, 2009)

MATERIALS AND METHODS

Diatom samples were cleaned from organic substance in the laboratory using acid and peroxide treatment and slides mounted in Naphrax. Two slides of each sample were prepared. A total of 250-500 valves per sample were identified from standard literature (Krammer and Lange-Bertalot, 1986-1991; Lange-Bertalot, 2001; Krammer, 2002; 2003; Werum and Lange-Bertalot, 2004; Metzeltin *et al.*, 2005).and counted using Olympus BX-40 microscope (oil immersion magnification 1500x).

Principal Component Analysis (PCA): Principal Component Analysis (PCA) is a linear, indirect ordination technique (CANOCO version 4.5; ter Braak 2002 [15]). It helps to compare more easily two data sets and reduces the dimensionality of the multivariate data. In our study it enabled graphical presentation of the relationships between the taxon (arrows) and stations (♦). This analysis was used to identify the characteristic taxa within and among the rivers of Central Highlands and the Himalaya.

RESULTS AND DISCUSSION

CH Eco-region: PCA axis 1 (horizontal) explained 41.4% variation in the taxon data. Axis 2 (vertical) and axis 3 accounted for a further 29.1% and 11% of the variation in the taxon data, respectively. The first four axes cumulatively explained 89.1% variability in the taxonomic group of diatoms (Table 1).

The taxon *C. excisa*, *S. ulna*, *A. lineare* cf. *crassa* and *N. cryptotenella* along the right upper axis were associated with P1, while *A. minutissima* var. *gracillima, N. rostellata*, *N. seminulum* and *A. petersenii* on the right lower axis with stations P2, P3 and T2. *A. minutissima* var. *minutissima*, *G. parvulum*, *N. viridula* and *C. diversa, M. granulata, C. turgidula* along the left upper axis were associated with stations K4 and T4. No taxa were characteristic at stations K1, K2, K3 and T4 (Fig. 3).

Himalayan Ecoregion: PCA axis 1 (horizontal) explained 23.1% of the variation in the taxon data. Axis 2 (vertical) accounted for a further 21.3% variability where as Axis 3 explained 16.7% of the variation in the taxon data and finally the first four axes cumulatively explained 74.3% variability in taxonomic group of diatom (Table 1).

Along the right upper axis, *A. subhudsonis*, *E. minutum* and *C. turgidula were* closely associated with Nagni at N4 where as *N. capitellata, P. lanceolata* var. *frequentissima, N. sinuta* var. *tabellaria, C. tropica, C. parva, N. fonticola, M. varians, C. excisa, N. frustulum* and *S. ulna* var. *aequalis* taxa were associated distantly. Along the right lower axis *N. palea*, *A. biasolettiana* var. *biasolettiana* were closely associated with the Yamuna while *A. biasolettiana*, *A. minutissima* var. *jackii, C. excisa* var. *angusta*, *S. pupula*, *N. linearis*, *A. minutissima* var. *minutissima*, *C. australica*, *P. lanceolata* var. *elliptica* and *N. exilis* taxa with river Alaknanda. On the left upper axis *N. antonii, N. capitellata*, *A. marginulata, N. amphibia, C. tumida*, *S. ulna, N. crytotenella* and *N. seminulum* were characteristic taxa of the Dharasu Gad and Nagni station 1. On the left lower axis of ordination diagram *A. minutissima*, *A. petersenii*, *S. ulna* var. *oxyrhynchus*, *A. helvetica*, and *N. vitabunda* were associated with Bhagirathi, Sankari, Nagni station 2 and Nagni 3 (Fig. 4).

DISCUSSION

There was greater taxonomic variability in the CH ecoregion where PCA axis 1 (horizontal) explained 41.4% compared with 23.1% in the Himalaya, total variability amounting to 89.1% in the former and 74.3% in the latter. In both regions the taxa were not only characteristic to stations within a river but also among rivers (**P2, P3, T2**: *A. minutissima* var. *gracillima*, *N. rostellata*, *N. seminulum* and *A. petersenii*; **K4, T4**: *A. minutissima* var. *minutissima*, *G. parvulum*, *N. viridula* and *C. diversa, A. granulata, C. turgidula*; **Bhagirathi, Supin, N2, N3**: *A. minutissima*, *A. petersenii*, *S. ulna* var. *oxyrhynchus*, *A. helvetica*, and *N. vitabunda*). Some taxa were characteristic to one station only (**P1**: *C. excisa*, *S. ulna*, *A. lineare* cf. *crassa*, *N. cryptotenella*; **N4**: A. *subhudsonis*, *E. minutum* and *C. turgidula*; Yamuna: *N. palea*, *A. biasolettiana* var. *biasolettiana*; **Alaknanda**: *C. excisa* var. *angusta*, *S. pupula*, *N. lineare*, *C. australica*. Some stations lacked characteristic taxa (K1, K2, K3 and T4).

Table 1. Variances in the taxonomic groups determined by the PCA in the different rivers of the CH and Himalaya ecoregion.

Axes	**1**	**2**	**3**	**4**	**Total variance**
Central Highlands ecoregion					
Eigen values	0.414	0.291	0.110	0.076	1.000
Cumulative percentage variance of species data	41.4	70.5	81.5	89.1	
Sum of all Eigen values					1.000
Himalaya ecoregion					
Eigen values	0.231	0.212	0.167	0.132	1.000
Cumulative percentage variance of species data	23.1	44.4	61.1	74.3	
Sum of all Eigen values					1.000

Figure 1. PCA biplot to identify the characteristic taxa at the each station of Vindhyan river: Ken, Paisuni and Tons.

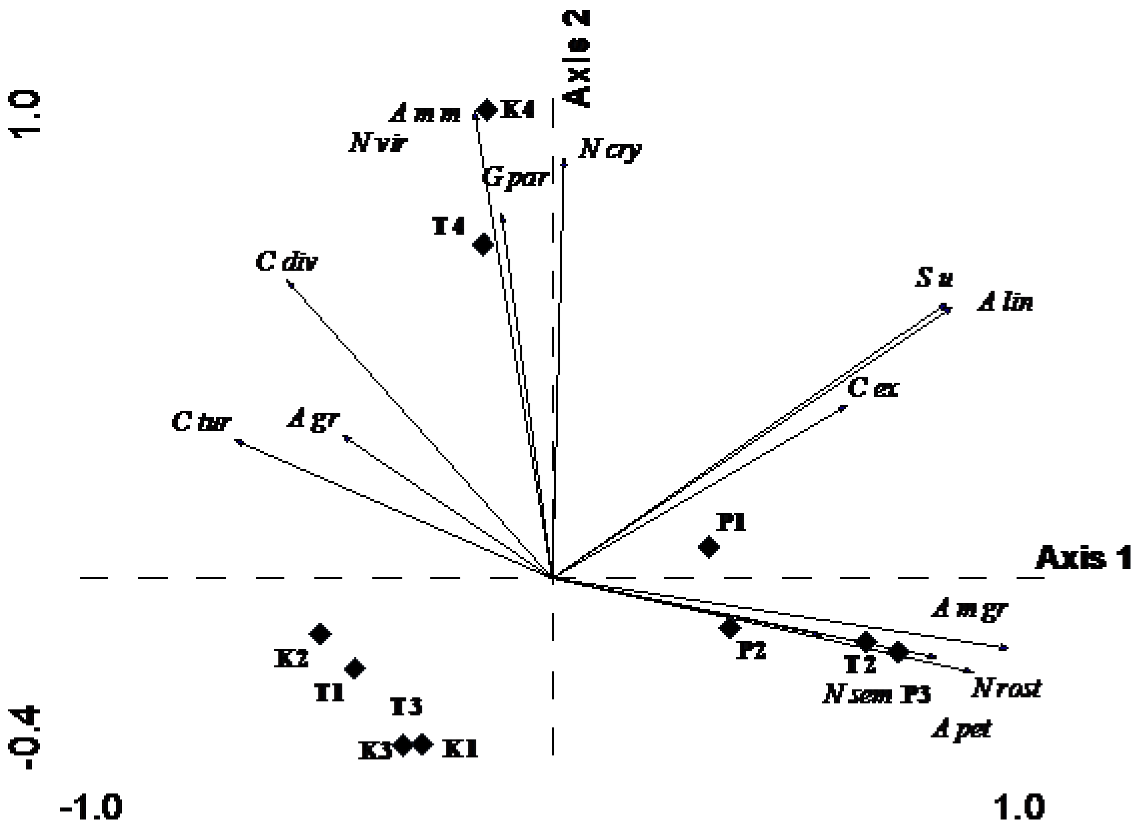
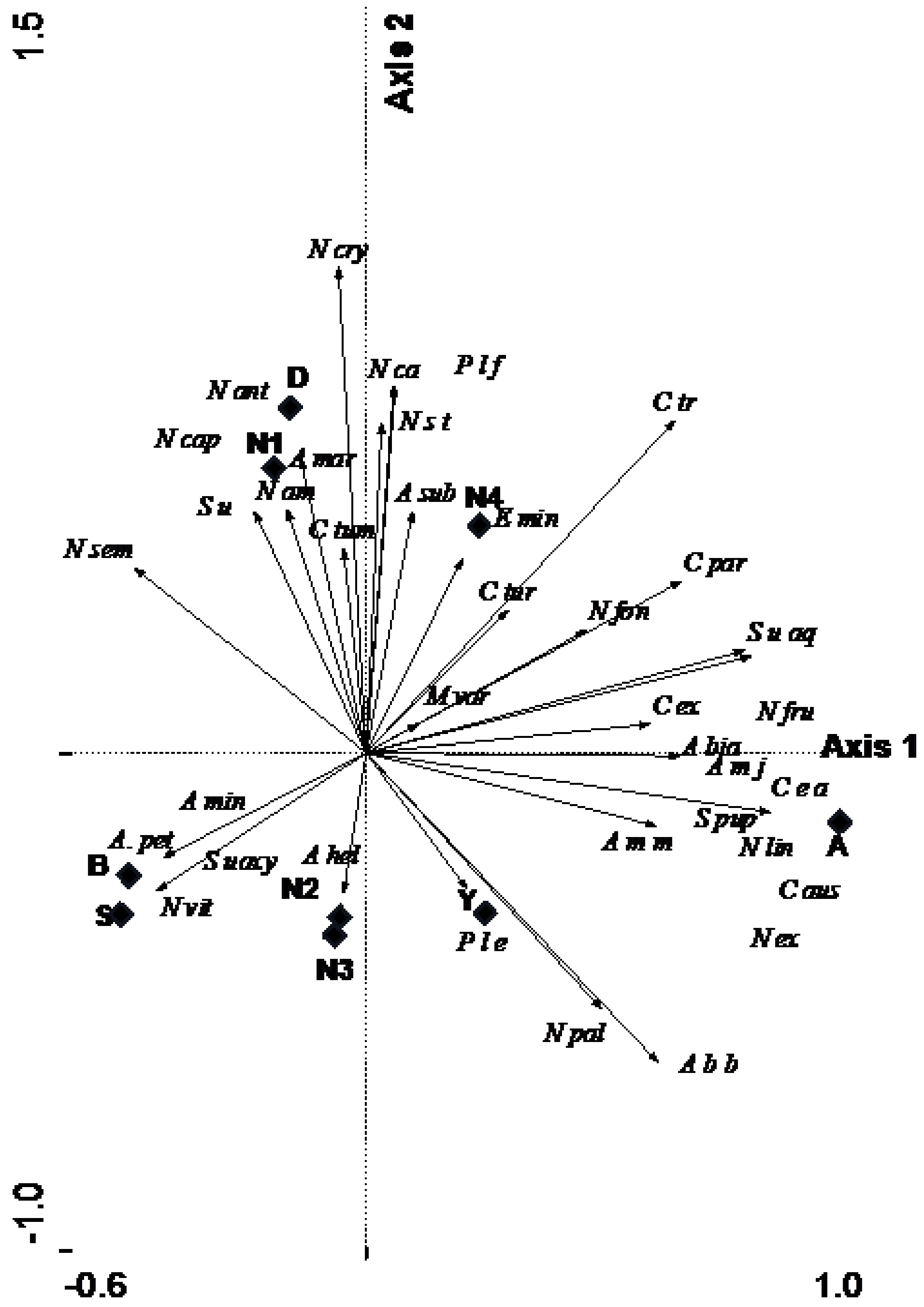


Figure 2. PCA biplot to identify the characteristic taxa at the each station/stream/river of the Garhwal region Himalaya: Supin, Yamuna, Bhagirathi, Dharasu, Nagni and Alaknanda.


1.5
Axis 2
N cry
N ca
P l f
N ant
D
N cap
N1
A mar
N s t
C tr
Su
N am
A sub
N4
E min
N sem
C hum
C par
C tur
N fon
Su aq
M var
C ex
N fru
A bia
Axis 1
A m j
C e a
A min
S pup
A m m
N lin
A
A. pet
Su acy
A hel
B
N2
Y
C aus
S
Nvit
P l e
N ex
N3
N pal
A b b
-1.0
-0.6
1.0

ABBREVIATIONS USED FOR PCA

A cr Achnanthes crenulata
A b b Achnanthidium biasolettiana var. biasolettiana
A bs A. biasolettiana
A hel A. helvetica
A lin A. linearis
A m j A. minutissima var. jackii
A m m A. minutissima var. minutissima
A m gr A. minutissima var. gracillima
A mar A. marginulata
A pet A. petersenii
A sub A. subhudsonis
C aus Cymbella australica
C div C. diversa
C e a C. excisa var. angusta
C ex C. excisa
C par C. parva
C tr C. tropica
C tum C. tumida
C tur C. turgidula
E min Encyonema minutum
A. min Adlafia miniscula
G par Gomphonema parvulum
A gr Aulacoseira granulata
M v Melosira varians
N ant Navicula antonii
N cap N. capitatoradiata
N cat N. caterva
N cry N. crytotenella
N rost N. rostellata
N sem N. seminulum
N vir N. viridula
N vit N. vitabunda
N am Nitzschia amphibia
N ca N. capitellata
N fon N. fonticola
N fru N. frustulum
N lin N linearis
N pal N. palea
N s t N. sinuata var. tabelaria
P l f Planothidium lanceolata var. frequentissima
P l e P. lanceolata var. elliptica
S pup Sellaphora pupula
S u Synedra ulna
S u aq S. ulna var. aequalis
S u oxy S. ulna var. oxyrhynchus

Jüttner *et al.,* (1996) found that the Kathmandu valley sites were characterised by the extremely pollution-tolerant *N. palea*, *N. atomus*, *N. cryptocephala*, *N. minima* and *G. parvulum*, the Likhu Khola valley by *A. biasolettiana* var. *subatomus*, *C. placentula* and *G. minutum*, while the semi-natural Arun valley with pollution sensitive taxa typical of hill-streams (*A. biasolettiana* var. *biasolettiana*, *A. b.* v. *subatomus*, *A. minutissima* var. *minutissima*, *F. arcus* and *C. minuta*). Ormerod *et al.,* (1994) observed the abundance of N. *heimansioides*, tolerant to agricultural enhancement, in the Likhu Khola and the Middle hills. Kawecka, (1980) found that the taxa typical for streams at higher altitudes in Alpine tundra and boulder fields *D. hyemalis*, *G. calcifugum*, *E. silesiacum*, *D. mesodon* and *H. arcus* var. *recta*. *D. hyemalis*, *D. mesodon* and *H. arcus* var. *recta* also occur in freshwaters of the alpine and montane zones in other geographic regions. Synder *et al.*, (2002) found that *N. amphibia*, *N. paleacea* and *C. placentula* which differ in tolerances to nutrient loading contributed conspicuously to site separation in the PCA analysis.

Present studies reveal that the diatom communities have weak resemblance with distantly situated rivers across the continents and this demonstrates that the diatom flora is more influenced by local scale factors compared to large-scale or geographical factors (Frissel *et al.*, 1986, Gothe *et al.*, 2013). The differences vis-à-vis lack of significant similarity among the diatom flora of the CH and Himalayan ecoregions can be explained on the basis of geographical factors. It is for this reason that certain taxa were characteristic to the stations on different rivers within the CH or Himalaya. There is a need for further study to know which factors influence the distribution patterns within and among the ecoregions, as it was not within the scope of present study. Our observation shows that assemblages of diatom in these ecoregional rivers are mainly the result of local control, supporting the hypothesis that the local ecological factors are consistently and strongly associated to the diatom community composition.

Acknowledgement

The authors acknowledge the academic support granted by Head, Department of Zoology, University of Allahabad, Allahabad. First author (JV) is very thankful to University Grant Commission, New Delhi, for providing research fellowship during D.Phil. degree course from the University of Allahabad, Allahabad, Uttar Pradesh.

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