University of Bielefeld

Faculty of Biology

Chair for Animal Ecology

Diatoms as Indicators of Environmental Change in Lakes and Ponds of the Lowlands, Middle Hills and High Himalaya of Nepal

Bishnu Simkhada

Thesis submitted to obtain the academic degree of

Doktor der Naturwissenschaften

Acknowledgements

I sincerely would like to thank the following people for their help and support throughout my thesis:

- My supervisor Dr. Ingrid Jüttner, Department of Biodiversity and Systematic Biology, National Museum of Wales, for providing me with the theme of the thesis, her help with planning and conducting the field work, introduction into laboratory methods, assistance during the analysis of the diatom samples, help with the statistical analysis of the data and advice on the written text. I highly appreciate the encouragement and support I received from her during the years of my study.
- Prof. Dr. Walter Traunspurger, Animal Ecology, Faculty of Biology, University of Bielefeld, for accepting me as his Ph.D. student.
- Dr. Graham Oliver, Head of Department of Biodiversity and Systematic Biology, National Museum Wales, for providing me with laboratory space and for support with equipment and consumables, and for his encouragement to complete my thesis.
- Dr. Frank Krell, Department of Entomology, Natural History Museum, London, for providing me an opportunity to work as a part-time Technical Research Assistant enabling me to support myself financially for almost four years.
- My sincere thanks go to all the members of staff of the National Museum Wales, who made me feel welcome and at home during my four and a half years in the Museum.

- For their generous help and moral support I would like to thank staff of the Department of Biodiversity and Systematic Biology especially Dr. Deborah Spillards, Dr. Mike Wilson, Mr Chris Meechan, Mr Piers Langhelt, Dr. John Deeming, Ms Kate Mortimer, Mr Ben Rowson, Ms Michelle Forty, Ms Sarah Lendrum, Ms Wendy Ladd, Ms Yvonne Boothright, and staff of the ICT unit especially Mr Chris Bowler, Ms Emma Ashley, Ms Sarah Hatton and Mr Prakash Dabasia, and Ms Becky Brumbill in Photography for their cooperation during my study period.
- Mr Som Gharti-Chhetri, Himalayan Nature, and all staff of the Koshi Tappu Camp, Nepal, for their assistance during the field work in Koshi Tappu and Gosainkunda.
- Mr P.D. James Chimonides, Department of Zoology, Natural History Museum, London, for support in mapping and the statistical analysis of some of the data.
- Mr Gary Jones, Department of Mineralogy, Natural History Museum, London, for the chemical analysis of the water samples.
- Dr. Eileen J. Cox, Department of Botany, and Dr. Alex Ball, Department of Mineralogy, Natural History Museum, London, for access to facilities at the Natural History Museum during the first year of my thesis.
- Prof. Dr. Steve Ormerod, Dr. Dave Pascoe, Dr. Rob Thomas, Dr. Carsten T. Müller and Dr. David Bowker, Cardiff University, for allowing me to attend their lectures and seminars.
- The science faculty Dean Prof. Dr. G. P. Ghimire and Assistant Dean Mr Ashok Koirala, Tribhuvan University, Nepal, the Campus Chief, the Head of

the Department of Chemistry of Tri-Chandra College, for giving me leave to pursue my Ph.D. studies.

- Many thanks to my English grand parents the late Mr Huge Thomas and Mrs Miriam V. Thomas, their family members, to Dr. Irina V. Perminova, Department of Chemistry, Lomonosov State University, Moscow, and Prof. Dr. Marjorie Collins, Wales for their generosity, love and care, and to my friends Heike and Peter Hirst, Cardiff, and Hem Sagar Baral, Kathmandu, for their moral support.
- Last but not least, I would like to thank my father Mr Sheshnath Simkhada, mother Mrs Dhana Kumari Simkhada, my brothers Uttam Simkhada and Prakash Simkhada, my brothers-in-law Suresh Raj Kalika, Bhuban Dhakal and Tara Lamsal, my sisters Radha Kalika, Tara Dhakal and Geeta Lamsal, my sisters-in-law Parbati Simkhada and Laxmi Simkhada, my nieces Shubheksha Kalika and Pratiksha Dhakal and my nephews Pratik Dhakal, Shubodh Kalika, Shital Simkhada, Upahar Simkhada for their love and unending moral support.

INDEX OF CONTENTS

1. INTRODUCTION ... 1

1.1 BIOLOGY OF DIATOMS ... 1

1.2 DIATOMS AS INDICATORS OF ENVIRONMENTAL CHANGE ... 2

1.3 STANDING WATERS IN NEPAL ... 5

1.4 MAIN OBJECTIVES ... 8

1.5 REFERENCES ... 9

2. DIATOMS IN PONDS AND SMALL LAKES OF THE KATHMANDU VALLEY, NEPAL – RELATIONSHIPS WITH CHEMICAL AND HABITAT CHARACTERISTICS ... 20

2.1 ABSTRACT ... 20

2.2 INTRODUCTION ... 21

2.3 MATERIALS AND METHODS ... 22

2.3.1 Study area ... 22

2.3.2 Field and laboratory procedures ... 24

2.3.3 Data analysis ... 25

2.4 RESULTS ... 28

2.4.1 Habitat character and water chemistry ... 28

2.4.2 Species richness, diversity and microhabitat distribution ... 33

2.4.3 Relationships with habitat character and water chemistry ... 36

2.5 DISCUSSION ... 40

2.5.1 Relationships with habitat character and water chemistry ... 40

2.5.2 Implications for biodiversity assessments and monitoring of pollution ... 44

2.6 REFERENCES ... 46

3. DIATOMS IN LOWLAND PONDS OF KOSHI TAPPU, EASTERN NEPAL – RELATIONSHIPS WITH CHEMICAL AND HABITAT CHARACTERISTICS ... 54

3.1 ABSTRACT ... 54

3.2 INTRODUCTION ... 54

3.3 MATERIALS AND METHODS ... 57

3.3.1 Study site ... 57

3.3.2 Field investigations and laboratory procedures ... 59

3.3.3 Data analysis ... 61

3.4 RESULTS ... 63

3.4.1 Epiphytic diatom assemblages in 64 ponds *63*
3.4.1.1 Habitat character and water chemistry 63
3.4.1.2 Diversity of epiphytic diatom assemblages 65
3.4.1.3 Relationships with habitat and chemistry characteristics 67
3.4.2 Epiphytic and epipelic diatom assemblages in 41 ponds *70*
3.4.2.1 Diversity of epiphytic and epipelic diatom assemblages 70
3.4.2.2 Relationships between epiphytic, epipelic diatom assemblages, surface water and interstitial water chemistry 72
3.5 DISCUSSION 76
3.6 REFERENCES 81
4. DIATOMS IN HIGH ALTITUDE LAKES OF GOSAINKUNDA, LANGTANG NATIONAL PARK, CENTRAL NEPAL – RELATIONSHIPS WITH CHEMICAL AND HABITAT CHARACTERISTICS 89
4.1 ABSTRACT 89
4.2 INTRODUCTION 90
4.3 MATERIALS AND METHODS 93
4.3.1 Study area *93*
4.3.2 Field investigations and laboratory procedures *95*
4.3.3 Data analysis *97*
4.4 RESULTS 98
4.4.1 Habitat character and water chemistry *98*
4.4.2 Diversity and assemblage composition *101*
4.4.3 Relationships with habitat character and water chemistry *110*
4.5 DISCUSSION 114
4.5.1 Acidification *114*
4.5.2 Biodiversity and relationships with environmental conditions *115*
4.6 REFERENCES 120
5. FINAL DISCUSSION 129
5.1 FRESHWATER ECOSYSTEMS IN NEPAL 129
5.2 DIATOM SPECIES RICHNESS AND DIVERSITY 131
5.3 RELATIONSHIPS BETWEEN DIATOMS AND ENVIRONMENTAL CHARACTER 135
5.4 IMPLICATIONS FOR THE FUTURE 141
5.5 REFERENCES 142

6. SUMMARY **158**

7. APPENDIX **165**

Index of common or abundant species

Tables with raw data

INDEX OF FIGURES

CHAPTER 1

Fig. 1.1 Areas of investigation in Nepal 7

CHAPTER 2

Fig. 2.1 Locations of study sites in the Kathmandu Valley 23

Fig. 2.2 Principal component analysis of water chemistry of Kathmandu Valley ponds 32

Fig. 2.3 Relative abundances of common and / or abundant diatom species in sixteen ponds and small lakes in the Kathmandu Valley. 34

Fig. 2.4 Detrended correspondence analysis (DCA) ordinations 37

Fig. 2.5 CCA of diatoms assemblages from ponds and small lakes in the Kathmandu Valley 39

CHAPTER 3

Fig. 3.1 Location of the sixty four study sites in the Koshi Tappu area, lowland of eastern Nepal. 58

Fig. 3.2 Detrended correspondence analysis (DCA) of diatom assemblages from different epiphytic microhabitats 68

Fig. 3.3 Canonical correspondence analysis (CCA) of epiphytic diatom assemblages 69

Fig. 3.4 DCA of epiphytic and epipelic diatoms from 41 ponds in the Koshi Tappu area 72

Fig. 3.5 Canonical correspondence analysis (CCA) of epiphytic diatom assemblages from 41 ponds in the Koshi Tappu area 75

CHAPTER 4

Fig. 4.1 Location of Gosainkund lakes, Langtang National Park, Nepal 94
Fig. 4.2 Relative abundances of common diatom species in Gosainkund lakes, November 2000. 104
Fig. 4.3 Relative abundances of common diatom species in Gosainkund lakes, May 2003. 104
Fig. 4.4 Differences in relative abundances of common and abundant diatom species of Gosainkund lakes in 2000 and 2003 105
Fig. 4.5 DCA ordinations of diatom assemblages of Gosainkund lakes in 2000 and 2003. 106
Fig. 4.6 DCA ordinations of microhabitat diatom assemblages of Gosainkund lakes, May 2003 107
Fig. 4.7 Relative abundances of common diatom species in different microhabitats of Gosainkund lakes, May 2003 108
Fig. 4.8 CCA ordinations of diatom assemblages of Gosainkund lakes, November 2000 111
Fig. 4.9 CCA ordinations of diatom assemblages of Gosainkund lakes May 2003 113

N.B.: Figures in the subject content are referred only with figure number without including chapter number, for example:Fig. 3.2 is referred in the text of chapter 3 as Fig. 2 and Fig. 4.1 as Fig. 1 in the text of chapter 4 and so on.

INDEX OF TABLES:

CHAPTER 2:

Table 1. Ponds surveyed for diatoms, water chemistry and habitat character in the Kathmandu Valley. 27

Table 2. Water chemistry principal components and habitat principal components reflecting major environmental gradients in ponds and small lakes of the Kathmandu Valley. 29

Table 3. Water chemistry of ponds and small lakes of the Kathmandu Valley. 31

Table 4. Common diatom species in 16 ponds and small lakes of the Kathmandu Valley. 35

Table 5. Species richness, diversity and evenness of diatoms on different substrates in ponds and small lakes of the Kathmandu Valley. 35

CHAPTER 3:

Table 1. Pond water chemistry and habitat principal components reflecting major environmental gradients in 64 ponds of Koshi Tappu. 64

Table 2. Surface and interstitial water chemistry and habitat character of 64 ponds of Koshi Tappu. 66

Table 3. Summary of canonical correspondence analysis (CCA) of epiphytic diatoms from 64 ponds in Koshi Tappu. 70

Table 4. Species richness, diversity and evenness of epiphytic and epipelic diatom assemblages from ponds in Koshi Tappu. 71

Table 5. Summary of canonical community ordination of epiphytic and epipelic diatoms from ponds in Koshi Tappu. 74

CHAPTER 4

Table 1. GIS position of the assessed Gosainkund lakes, November 2000. 95

Table 2. GIS position of the assessed Gosainkund lakes, May 2003. 95

Table 3. Habitat character of Gosainkund lake sites in 2000 and 2003. 99

Table 4. Temperature and water chemistry of Gosainkund lakes in 2000. 100

Table 5. Temperature and water chemistry of Gosainkund lakes in 2003. 100

Table 6. Species richness, diversity and evenness of diatom assemblages of Gosainkund lakes in 2000 and 2003. 101
Table 7. Mean species richness, diversity and evenness of diatoms in Gosainkund Lakes in 2000 and 2003. 101
Table 8. Substrates collected in Gosainkund lakes in 2003. 102
Table 9. Habitat preferences of diatoms in Gosainkund lakes 2003. 109

1. Introduction

1.1 Biology of diatoms

Diatoms (Bacillariophyta) are a species rich group of unicellular, eukaryotic micro-organisms, which are characterised by siliceous (SiO_2 x nH_2O) cell walls (Round *et al*. 1990, Cox 1996). Their ecological diversity is reflected by their occurrence in almost all aquatic habitats, where they play an important role as primary producers and in geochemical cycling of various naturally occurring elements in particular C and Si (Round *et al.* 1990). The importance of diatoms as major autotrophs which form a substantial fraction of the organic biofilm and represent a readily available food source to primary consumers has been widely recognised (Anderson *et al.* 1999, Bergey 1995, Bott & Borchardt 1999, Dillon & Davis 1991, Peterson & Boulton 1999). Diatoms grow on different aquatic substrates such as silt or mud (epipelic assemblages), on sand (epipsammic assemblages) and on stones or other hard surfaces (epilithic assemblages). They also live on other plants (epiphytic assemblages) and on animals (epizoic assemblages, Round *et al.* 1990). They interact to varying degrees with the substrates and assemblage composition on different substrates can differ significantly (Burkholder 1996). Because of short life cycle, species richness as well as species specific response to environmental factors such as nutrient concentrations (Borchardt 1996), acid-base status (Smol *et al*. 1986), salinity (Snoeijs 1999), dystrophy (Fallu & Pienitz 1999), light (Hill 1996), temperature (DeNicola 1996), hydrological conditions (Fritz *et al*. 1999, Biggs & Hickey 1994), substrate character (Burkholder 1996) and grazing (Steinman 1996) diatoms are sensitive indicators of abiotic and biotic environmental conditions (Stevenson *et al*. 1996, Stoermer & Smol 1999).

1.2 Diatoms as indicators of environmental change

Environmental change due to anthropogenic impacts has affected many freshwater ecosystems (Steinberg & Wright 1994, Smol 2002, Welch & Jacoby 2004). Monitoring aquatic health using suitable indicator organisms has become increasingly important to document changes, identify causes of impairment and help better management and implementation of policies to prevent further deterioration. Due to their abundance, species richness, wide geographical distribution, ease of collection and preservation, relatively well known taxonomy and their central role in aquatic ecosystems, diatoms have been frequently used as bioindicators for a large range of applications in the environmental and earth sciences (Stoermer & Smol 1999). They have been used most often to assess environmental change and monitor water quality of streams and deeper lakes while their use in shallow lakes and ponds has been less extensive. Many studies on lakes and ponds have applied paleolimnological techniques while studies on recent periphytic assemblages were less frequent. Previous investigations have often addressed the two most common environmental problems affecting aquatic ecosystems, eutrophication referring to the enrichment by inorganic nutrients such as phosphorus and nitrogen (Mason 1991), and acidification resulting from the deposition of acidifying pollutants such as oxides of sulphur and nitrogen (Steinberg & Wright 1994). Both can cause considerable change in biochemical cycles and biological assemblages including changes of the food web structure, decrease in diversity or the disappearance of entire organism groups (Tilman *et al*. 1986, Schindler 1994). Many diatom species have specific optima and tolerance ranges for nutrients as well as pH and have therefore been used successfully to quantify responses to changes in nutrient concentrations or acid-base status (Fritz *et al*. 1993, Dixit *et al*. 1993). A major focus has been on the development of methods for paleolimnological reconstructions to demonstrate long-term anthropogenic impacts since the beginning of human settlements and accompanying changes in land use (Birks *et al*. 1995), or to study more recent changes in water quality since the onset of industrialisation (Hall & Smol 1992, Anderson 1995). Some studies have included large-scale monitoring projects for regional assessments of water quality to identify problem areas where lakes have been most severely affected (Dixit & Smol 1994). Most investigations in standing waters have used diatom assemblages from sediment cores, while there are fewer investigations on periphytic diatoms from the littoral. However, diatoms are important constituents of the periphytic algal assemblages in the littoral zone of lakes and ponds and their use as indicators might be advantageous particularly for smaller water bodies, where frequent disturbances can prevent the accumulation of uninterrupted sediment records, or in remote regions due to logistical constraints the collection of sediment cores can be difficult. The response of littoral diatom assemblages to changes in water quality such as increased nutrient loading can be rapid (Hawes & Smith 1992), and this can be beneficial to detect localised or short to medium term changes for example acid episodes after snow melt or pollution resulting from the release of sewage. A number of studies have shown that diatoms from littoral areas can indicate major environmental gradients. They reflected changes in pH, salinity as well as concentrations of nutrients, calcium and silica in ponds of the Arctic (Lim *et al*. 2001, Douglas & Smol 1993, 1995). In Germany diatoms from stones and macrophytic plants in the littoral were investigated in oligo-, meso- and eutrophic lakes to derive trophic preferences of species and to develop a trophic diatom index (Hofmann 1994). Round (1957) has used littoral sediment diatoms to determine trophic preferences in base-poor lakes of the English Lake District, and in Spanish shallow lakes they were used to assess trophic and saprobic conditions (Blanco *et al.* 2004). Effects of nutrient enrichment and the importance of inorganic carbon for assemblage composition of epilithic diatoms in an oligotrophic, softwater mountain lake were discussed by Niederhauser and Schanz (1993). Littoral diatoms have also been successfully applied to monitor acidification in alpine lakes (Tolotti 2001 a,b) and in moorland pools in the Netherlands and Belgium (Denys & van Straaten 1992, van Dam & Buskens 1993).

Several studies have evaluated the use of different substrates to monitor water quality. Although stones are the most commonly used substrates for monitoring in running waters (Kelly *et al*. 1998), importance of other substrates and their use for monitoring lakes and ponds has been advocated (Lim *et al*. 2001, Poulíčková *et al*. 2004). Kitner & Poulíčková (2003) found assemblages from different substrates such as stones, macrophytes and sediments equally suitable to indicate trophic status of fish ponds, howerver, Poulíčková *et al*. (2004) observed assemblages from different substrates indicating different trophic status for the investigated sites where only epiphytic diatoms from young macrophytes were significantly correlated with phosphorus concentrations. These results suggest that the most suitable substrate might vary depending on local conditions and has to be specifically selected for each application.

So far most studies using diatoms as indicators have been conducted on lakes, while much fewer studies have involved in smaller standing water bodies. However, ponds and small lakes can be species rich and their diverse habitats can play a key role in safeguarding aquatic biodiversity (Williams *et al*. 2004). Though values of small lakes and ponds for a range of organism groups in particular amphibians, macroinvertebrates and macrophytes are well known (Brodman *et al*. 2003, Nicolet *et al*. 2004), the potential of diatoms as indicators of ecological conditions affecting biodiversity in these ecosystems has not been sufficiently exploited. This is unfortunate since small lakes and ponds are threatened by numerous anthropogenic impacts such as eutrophication, acidification and pollution from a range of industrial sources (Pechar 2000, Ruan & Gilkes 2000, Graney & Eriksen 2004, Razo *et al.* 2004, van Dam & Busken 1993) and are often degraded or lost due to poor management and inappropriate protection. The role of ponds for diversity, biogeography and conservation of diatoms has also rarely been addressed (Jones 1996, Flower 2005).

1.3 Standing waters in Nepal

Nepal is rich in freshwater resources with an estimated 6000 rivers, 660 lakes and ponds with more than 1 ha in surface area and numerous smaller water bodies (CBS 1995, Shrestha 1995). There are varieties of natural lake types such as glacial and tectonic lakes in the mountains or oxbow lakes in the lowlands, artificial ponds many at prayer sites and fish ponds. Direct human influence is mostly absent in remote aquatic systems of the high Himalaya (Lami & Giussani 1998), but can be intensive and lead to eutrophication, pollution and degradation at intermediate altitudes and in the lowlands particularly in urban and agricultural areas (Pandit 1999, Rai 2000, Thapa & Weber 1995). Both lakes and ponds are important ecosystems playing a vital role as habitat for flora and fauna and serving as water resources for domestic uses such as farming and house hold purposes. In spite of their diverse significance there are only a relatively limited number of studies on lakes and ponds in Nepal investigating various aspects of their limnology (Ferro 1978, Okino & Satoh 1986, Aizaki *et al.* 1987, Nakanishi *et al.* 1988, Jones *et al.* 1989, McEachern 1994, Rai 1998, Tartari *et al.* 1998, Rai 2000, Lacoul & Freedman 2005), plankton, macrophytes, macroinvertebrates (Löffler 1969, Manca *et al.* 1998, Bhatt *et al.* 1999, Lacoul & Freedman 2006) and environmental change (Lami *et al.* 1998). There are very few data on diatoms in standing waters of

Nepal. Apart from Hickel (1973a, b) and Lohman *et al.* (1988), who investigated diatoms in the phytoplankton of lakes and ponds from the Kathmandu and Pokhara Valleys, other investigators in Nepal studied diatoms in other freshwater ecosystems such as streams and springs (Jüttner *et al.* 1996, Rothfritz *et al.* 1997, Cantonati *et al.* 2001, Jüttner *et al.* 2003, 2004, Dahal & Jüttner 2004). Benthic diatoms in the littoral of small lakes and ponds, and their potential use as bioindicators for environmental change has so far not been investigated. Their inclusion in biological monitoring would however be beneficial since there are multiple threats to freshwater ecosystems in Nepal. These include phenomena which occur naturally due to highly dynamic processes linked to geographical character such as geomorphology and climatic conditions, in particular erosion, transportation, sedimentation and other hydrological changes. In addition, human practises such as land use change, for example deforestation, urbanisation, intensification of agriculture, industrialisation, increase polluting emissions and direct inputs of sewage, pesticides and other pollutants into freshwaters (Ives & Messerli 1989, Thapa & Weber 1995) are intensifying these threats. At the same time, rising water demands for a fast growing population adds to the complex problems of conservation and sustainable use of these resources. The overwhelming importance of Himalayan waters for wildlife and the livelihood of millions of people in Nepal and northern India as well as their great cultural significance demands a greater effort to gain basic knowledge about these ecosystems and develop strategies and methods to monitor environmental change and protect them in the future (Subba 2001). This study is a contribution to achieve these aims through the investigation of diatom assemblages in relation to environmental conditions in different types of standing water bodies in the Nepalese lowlands (Koshi Tappu), in the Middle Hills (Kathmandu Valley) and in the high Himalaya (Gosainkund) (Fig. 1). It investigated physical and chemical conditions as well as littoral diatom assemblages in lakes and ponds in three geographical areas of Nepal, where standing waters are subject to a range of anthropogenic impacts, which have potential negative effects on aquatic biodiversity. Here, I address particular issues such as chemical and habitat change in densely populated and intensively used agricultural areas of the Middle Hills and the lowlands, and acidification through long distance transport of air born pollutants in a remote mountain area and whether diatoms can be used as bioindicators to assess and monitor such impacts in these freshwater ecosystems. In addition, it also investigated whether assemblages on specific substrates are particularly suitable to indicate environmental change.

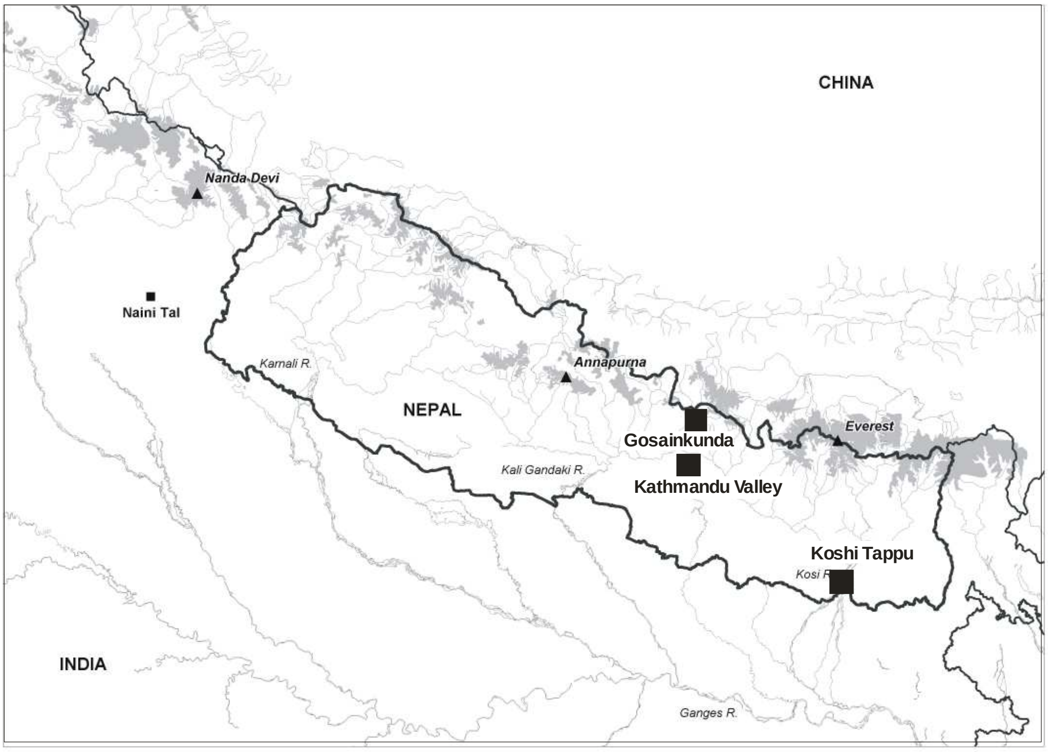


Fig. 1.1 Areas of investigation in Nepal
(Koshi Tappu in the lowlands, Kathmandu Valley in the Middle Hills and Gosainkund area in the high Himalaya).

1.4 Main objectives

The main objectives of this study were to investigate diatom diversity and assemblage composition from a range of microhabitats in the littoral of lakes and ponds in three geographical areas of Nepal and their relationships to the gradients of chemical and habitat characters of the lakes and ponds and immediate surroundings.

In the Middle Hills, diatoms were studied from ponds and small lakes in densely populated urban and agricultural areas of the Kathmandu Valley to assess whether they can be used as indicators of pollution, and whether diatoms from different microhabitats would respond in similar ways to major gradients in chemical and habitat character. Difference in assemblage composition on stones, walls, macrophytes and sediments and their potential for substrate preferences were also investigated.

In the lowlands diatoms were investigated from ponds of the Koshi Tappu Wildlife Reserve and adjacent agricultural areas to evaluate whether they can indicate chemical and habitat change resulting from intensive agriculture in their catchments. The response of epiphytic and epipelic diatoms to chemical gradients in the surface and interstitial water was investigated to assess whether epiphytic and epipelic assemblages indicated the same gradients in the surface water and whether epipelic assemblages responded equally to gradients in the surface and in the interstitial water. Differences in assemblage composition and diversity of epiphytic and epipelic diatoms including their substrate specificity as well as differences in assemblage composition in epiphytic microhabitats on aquatic macrophytes were investigated.

In high altitude diatoms from the Gosainkunda lakes were investigated to assess whether diatoms and water chemistry indicate differences in acid-base status between autumn and spring after the snow melt. Epilithic diatom assemblages in both seasons were studied to assess their response to gradients in chemical and habitat character and whether they responded to the same gradients in autumn and spring. In spring diatoms were also studied from stones, sand, sediments and macrophytes to assess assemblage composition and diversity in the respective substrates.

1.5 References

Aizaki M., Terashima A., Nakahara H., Nishio T. & Ishida Y. 1987. Trophic status of Tilitso, a high altitude Himalayan lake. *Hydrobiologia* **153**, 217–224.

Anderson N.J. 1995. Using the past to predict the future: Lake sediments and the modelling of limnological disturbance. *Ecological Modelling* **78**, 149–172.

Anderson E.L., Welch E.B., Jacoby J.M., Schimek G.M. & Horner R.R. 1999. Periphyton removal related to phosphorus and grazer biomass level. *Freshwater Biology* **41**, 633–651.

Bergey E.A. 1995. Local effects of a sedentary grazer on stream algae. *Freshwater Biology* **33**, 401–409.

Bhatt L.R., Lacoul H.D., Lekhak H.D. & Jha P.K. 1999. Physico-chemical characteristics and phytoplanktons of Taudaha Lake, Kathmandu. *Pollution Research* **18**, 353–358.

Biggs B.J.F. & Hickey C.W. 1994. Periphyton responses to a hydraulic gradient in a regulated river in New Zealand. *Freshwater Biology* **32**, 49–59.

Birks H.J.B., Anderson N.J. & Fritz S.C. 1995. Post-glacial changes in total phosphorus at Diss Mere, Norfolk, inferred from fossil diatom assemblages. In: *Ecology and*

Paleoecology of Lake Eutrophication. Patrick S.T. & Anderson N.J. (eds), pp.48–49. Geological Survey of Denmark DGU Service Report No.7, Copenhagen.

Blanco S., Ector L. & Bécares E. 2004. Epiphytic diatoms as water quality indicators in Spanish shallow lakes. *Vie Milieu* **54**, 71–79.

Borchardt M.A. 1996. Nutrients. In: *Algal Ecology. Freshwater Benthic Ecosystems*. Stevenson R.J., Bothwell M.L. & Lowe R.L. (eds), pp. 184–228. Academic Press, San Diego.

Bott T.L. & Borchardt M.A. 1999. Grazing of protozoa, bacteria, and diatoms by meiofauna in lotic epibenthic communities. *Journal of the North American Benthological Society* **18**, 499–513.

Brodman R., Ogger J., Bogard T., Long A.J., Pulver R.A., Mancuso K. & Falk D. 2003. Multivariate analyses of the influences of water chemistry and habitat parameters on the abundances of pond-breeding amphibians. *Journal of Freshwater Ecology* **18**, 425–436.

Burkholder J.M. 1996. Interactions of benthic algae with their substrata. In: *Algal Ecology. Freshwater Benthic Ecosystems*. Stevenson R.J., Bothwell M.L. & Lowe R.L. (eds), pp. 253–297. Academic Press, San Diego.

Cantonati M., Corradini G., Jüttner I. & Cox E.J. 2001. Diatom assemblages in high mountain streams of the Alps and the Himalaya. *Nova Hedwigia Beiheft* **123**, 37–61.

CBS 1995. Statistical Year Book of Nepal. CBS, Kathmandu.

Cox E.J. 1996. *Identification of Freshwater Diatoms from Live Material*. 158 pp. Chapman & Hall, London.

Dahal B.M. & Jüttner I. 2004. Monitoring water quality in springs of the Nepalese Middle Hills using diatoms. Report to the British Ecological Society SEPG No. 2235–2003.

DeNicola D.M. 1996. Periphyton responses to temperature at different ecological levels. In: *Algal Ecology. Freshwater Benthic Ecosystems*. Stevenson R.J., Bothwell M.L. & Lowe R.L. (eds), pp. 150–183. Academic Press, San Diego.

Denys L. & van Straaten D. 1992. A survey of the acid water diatom assemblages of two heathland relics in the Belgian Northern Campine (Groot & Klein Schietveld, Brasschaat) with an assessment of their conservation value. *Diatom Research* **7**, 1–13.

Dillon R.T.J. & Davis K.B. 1991. The diatom ingested by freshwater snails: temporal, spatial, and interspecific variation. *Hydrobiologia* **210**, 233–242.

Dixit S.S. & Smol J.P. 1994. Diatoms as indicators in the Environmental Monitoring and Assessment Program-Surface Waters (EMAP-SW). *Environmental Monitoring and Assessment* **31**, 275–306.

Dixit S.S., Cumming B.F., Birks H.J.B., Smol J.P., Kingston J.C., Uutala A.J., Charles D.F. & Camburn K.E. 1993. Diatom assemblages from Adirondack lakes (New York, USA) and the development of inference models for retrospective environmental assessment. *Journal of Paleolimnology* **8**, 27–47.

Douglas M.S.V. & Smol J.P 1993. Freshwater diatoms from high arctic ponds (Cape Herschel, Ellesmere Island, N.W.T.). *Nova Hedwigia, Beiheft* **57**, 511–552.

Douglas M.S.V. & Smol J.P 1995. Periphytic diatom assemblages from high Arctic ponds. *Journal of Phycology* **31**, 60–69.

Fallu M.-A. & Pienitz R. 1999. Diatomées lacustres de Jamésie-Hudsonie (Québec) et modèle de reconstitution des concentrations de carbone organique dissous. *Ecoscience* **6**, 603–620.

Ferro W. 1978. Limnology of the Pokhara Valley Lakes (Himalayan region, Nepal) and its Implication for Fishery and Fish Culture. Report Integrated Fishery and Fish Culture Development Project, FAO, Rome.

Flower R. 2005. A taxonomic and ecological study of diatoms from freshwater habitats in the Falkland Islands, South Atlantic. *Diatom Research* **20,** 23–96.

Fritz S.C., Kingston J.C. & Engstrom D.R. 1993. Quantitative trophic reconstructions from sedimentary diatom assemblages. A cautionary tale. *Freshwater Biology* **30**, 1–23.

Fritz S.C., Cumming B.F., Gasse F. & Laird K.R. 1999. Diatoms as indicators of hydrologic and climatic change in saline lakes. In: *The Diatoms. Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J.P. (eds), pp. 41–72. Cambridge University Press, Cambridge.

Graney J.R. & Eriksen T.M. 2004. Metals in pond sediments as archives of anthropogenic activities: a study in response to health concerns. *Applied Geochemistry* **19**, 1177–1188.

Hall R.I. & Smol J.P. 1992. A weighted-averaging regression and calibration model for inferring total phosphorus concentration from diatoms in British Columbia (Canada) lakes. *Freshwater Biology* **27**, 417-434.

Hawes I.H. & Smith R. 1992. Effect of localised nutrient enrichment on the shallow epilithic periphyton of oligotrophic Lake Taupo. *New Zealand Journal of Marine and Freshwater Research* **27**, 365–372.

Hickel B. 1973a. Phytoplankton in two ponds in Kathmandu Valley, Nepal. *International Revue of Hydrobiology* **58**, 835–842.

Hickel B. 1973b. Limnological Investigations in Lakes of the Pokhara Valley, Nepal. *International Revue of Hydrobiology* **58**, 659–672.

Hill W.R. 1996. Effects of Light. In: *Algal Ecology. Freshwater Benthic Ecosystems*. Stevenson R.J., Bothwell M.L. & Lowe R.L. (eds), pp. 121–149. Academic Press, San Diego.

Hofmann G. 1994. Aufwuchs-Diatomeen in Seen und ihre Eignung als Indikatoren der Trophie. *Bibliotheca Diatomologica* **30**, 241 pp., J. Cramer, Berlin.

Ives J.D. & Messerli B. 1989. The Himalayan Dilemma. Reconciling development and conservation. Routledge, London.

Jones J.R., Knowlton M.F. & Swar D.B. 1989. Limnological reconnaissance of waterbodies in central and southern Nepal. *Hydrobiologia* **184**, 171–189.

Jones V.J. 1996. The diversity, distribution and ecology of diatoms from Antarctic inland waters. *Biodiversity and Conservation* **5**, 1433–1449.

Jüttner I., Rothfritz H. & Ormerod S.J. 1996. Diatoms as indicators of river quality in the Nepalese Middle Hills with consideration of the effects of habitat-specific sampling. *Freshwater Biology* **36**, 475–486.

Jüttner I., Sharma S., Dahal B.M., Ormerod S.J. & Cox E.J. 2003. Diatoms as indicators of stream quality in the Kathmandu Valley and Middle Hills of Nepal and India. *Freshwater Biology* **48**, 2065–2084.

Jüttner I., Reichardt E. & Cox E.J. 2004. Taxonomy and ecology of some new *Gomphonema* species common in Himalayan streams. *Diatom Research* **19**, 235–264.

Kelly M.G., Cazaubon A., Coring E., Dell'Uomo A., Ector L., Goldsmith B., Guasch H., Hürlimann J., Jarlman A., Kawecka B., Kwandrans J., Laugaste R., Lindstrom E.-A., Leitao M., Marvan P., Padisak J., Pipp E., Prygiel J., Rott E., Sabater S., Van Dam H. & Vizinet J. 1998. Recommendations for the routine sampling of diatoms for water quality assessments in Europe. *Journal of Applied Phycology* **10**, 215–224.

Kitner M. & Poulíčková A. 2003. Littoral diatoms as indicators for the eutrophication of shallow lakes. *Hydrobiologia* **506–509**, 519–524.

Lacoul P. & Freedman B. 2005. Physical and chemical limnology of 34 lentic waterbodies along a tropical-to-alpine altitudinal gradient in Nepal. *International Review of Hydrobiology* **90**, 254–276.

Lacoul P. & Freedman B. 2006. Relationships between aquatic plants and environmental factors along a steep Himalayan altitudinal gradient. *Aquatic Botany* **84**, 3–16.

Lami A. & Giussani G. (eds) 1998. Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal). *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 235 pp. Istituto Italiano di Idrobiologia, Pallanza.

Lami A., Guilizzoni P., Marchetto A., Bettinetti R. & Smith D.J. 1998. Paleolimnological evidence of environmental changes in some high altitude Himalayan lakes (Nepal). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 107–130.

Lim D.S.S., Kwan C. & Douglas M.S.V. 2001. Periphytic diatom assemblages from Bathurst Island, Nunavut, Canadian High Arctic: an examination of community relationships and habitat preferences. *Journal of Phycology* **37,** 379–392.

Löffler H. 1969. High altitude lakes in Mt Everest region. *Verhandlungen Internationale Vereinigung Limnologie* **17**, 373–385.

Lohman K., Jones J.R., Knowlton M.F., Swar D.B., Pamperl M.A. & Brazos B.J. 1988. III. Lakes. 3. Asia: Pre– and postmonsoon limnological characteristics of lakes in the Pokhara and Kathmandu Valleys, Nepal. *Verhandlungen Internationale Vereinigung Limnologie* **23**, 558–565.

Manca M., Ruggiu D., Panzani P., Asioli A., Mura G. & Nocentini A.M. 1998. Report on a collection of aquatic organisms from high mountain lakes in the Khumbu Valley (Nepalese Himalayas). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 77–98.

Mason C.F. 1991. *Biology of Freshwater Pollution*. Longman Group UK, Essex.

McEachern P. 1994. Limnology and the national wetlands survey. In: Safe Guarding Wetlands in Nepal. Proceedings of the National Workshop on Wetlands Management in Nepal, Bhandari B., Shrestha T.B. & McEachern J. (eds), pp. 88–103, 3–5 March 1993, Kathmandu, IUCN, Nepal.

Nakanishi M., Watanabe M.M., Terashima A., Sako Y., Kondo T., Shrestha K., Bhandary H. & Ishida Y. 1988. Studies on some limnological variables of subtropical lakes of the Pokhara valley, Nepal. *Japanese Journal of Limnology* **19**, 71–86.

Nicolet P., Biggs J., Fox G., Hodson M.J., Reynolds C., Whitfield M. & Williams P. 2004. The wetland plant and macroinvertebrate assemblages of temporary ponds in England and Wales. *Biological Conservation* **120**, 261–278.

Niederhauser P. & Schanz F. 1993. Effects of nutrient (N, P, C) enrichment upon the littoral diatom community of an oligotrophic high-mountain lake. *Hydrobiologia* **269/270**, 453–462.

Okino T. & Satoh Y. 1986. Morphology, physics, chemistry and biology of Lake Rara in West Nepal. *Hydrobiologia* **140**, 125–133.

Pandit A.K. 1999. *Freshwater ecosystems of the Himalaya*. Panthenon Publishing, New York.

Pechar L. 2000. Impacts of long-term changes in fishery management on the trophic level water quality in Czech fish ponds. *Fisheries Management and Ecology* **7**, 23–31.

Peterson C.G. & Boulton A.J. 1999. Stream permanence influences microalgal food availability to grazing tadpoles in arid-zone springs. *Oecologia* **118**, 340–352.

Poulíčková A., Duchoslav M. & Dokulil M. 2004. Littoral diatom assemblages as bioindicators of lake trophic status: A case study from perialpine lakes in Austria. *European Journal of Phycology* **39**, 143–152.

Rai A.K. 1998. Trophic status of Phewa, Begnas and Rupa lakes in Pokhara valley, Nepal: Past, present and future. *Journal of Lake Science* **10**, 179–200.

Rai A.K. 2000. Limnological characteristics of subtropical Lakes Phewa, Begna, and Rupa in Pokhara Valley, Nepal. *Limnology* **1**, 33–46.

Razo I., Carrizales L., Castro J., Diaz-Barriga F. & Monroy M. 2004. Arsenic and heavymetal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. *Water Air Soil Pollution* **152**, 129–152.

Rothfritz H., Jüttner I., Suren A.M. & Ormerod S.J. 1997. Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity and water quality. *Archiv für Hydrobiologie* **138**, 465-482.

Round F.E. 1957. The distribution of Bacillariophyceae on some littoral sediments of the English Lake District. *Oikos* **8**, 16–37.

Round F.E., Crawford R.M. & Mann D.G. 1990. *The Diatoms: Biology & Morphology of the Genera.* 747 pp. Cambridge University Press, Cambridge.

Ruan H.D. & Gilkes R.J. 2000. Phosphorus accumulation in farm ponds and dams in southwestern Australia. *Journal of Environmental Quality* **29**, 1875–1881.

Schindler D.W. 1994. Changes caused by acidification to the biodiversity: Productivity and biogeochemical cycles of lakes. In: *Acidification of Freshwater Ecosystems. Implications for the Future*. Steinberg C.E.W. & Wright R.F. (eds), pp. 153–164. Wiley, Chichester.

Shresta R.R. 1995. Limnological investigation of Gosainkund lake and impact of Janaipurnima festival. Environment and Public Health Organization (ENPHO), Nepal.

Smol J.P. 2002. *Pollution of Lakes and Rivers. A Paleolimnological Perspective*. Key Issues in Environmental Change. Matthews J.A., Bradley R.S., Roberts N. & Williams M.A.J. (eds), 280 pp. Arnold, London.

Smol J.P., Battarbee R.W., Davies R.B. & Meriläinen J. 1986. Diatoms and Lake Acidity. Reconstructing pH from siliceous algal remains in lake sediments. *Developments in Hydrobiology* **29**, Dumont H.J. (ed.), Dr W. Junk Publishers, Dordrecht.

Snoeijs P. 1999. Diatoms and environmental change in brackish waters. In: *The Diatoms. Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J.P. (eds), pp. 298–333. Cambridge University Press, Cambridge.

Steinberg C.E.W. & Wright R.F. 1994. Acidification of Freshwater Ecosystems. Implications for the Future. 404 pp. Wiley, Chichester.

Steinman A.D. 1996. Effects of grazers on freshwater benthic algae. In: *Algal Ecology. Freshwater Benthic Ecosystems*. Stevenson R.J., Bothwell M.L. & Lowe R.L. (eds), pp. 341–374. Academic Press, San Diego.

Stevenson R.J., Bothwell M.L. & Lowe R.L. 1996. *Algal Ecology. Freshwater Benthic Ecosystems*. 753 pp. Academic Press, San Diego.

Stoermer E.F. & Smol J.P. 1999. *The Diatoms: Applications for the Environmental and Earth Sciences*. 469 pp. Cambridge University Press, Cambridge.

Subba B. 2001. *Himalayan Waters*. 307 pp. Jagadamba Press, Lalitpur.

Tartari G.A., Tartari G. & Mosello R. 1998. Water chemistry of high altitude lakes in the Khumbu and Imja Kola valleys (Nepalese Himalayas). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 51–76.

Tilman D., Kiesling R., Sterner R., Kilham S.S. & Johnson F.A. 1986. Green, bluegreen and diatom algae: Taxonomic differences in competitive ability for phosphorus, silicon and nitrogen. *Archiv für Hydrobiologie Beiheft* **106**, 473–485.

Thapa G.B. & Weber K.E. 1995. Status and management of watersheds in the upper Pokhara Valley, Nepal. *Environmental Management* **19**, 497–513.

Tolotti M. 2001a. Littoral diatom communities in high mountain lakes of the Adamello-Brenta Regional Park (Trentino, Italy) and their relation to acidification. In: *Lange-Bertalot-Festschrift*. Jahn R., Kocioloek J.P., Witkowski A. & Compère P. (eds), pp. 327–352. Gantner, Ruggell.

Tolotti M. 2001b. Phytoplankton and littoral epilithic diatoms in high mountain lakes of the Adamello-Brenta Regional Park (Trentino, Italy) and their relation to trophic status and acidification risk. *Journal of Limnology* **60**, 171–188.

Van Dam H. & Buskens R.F.M. 1993. Ecology and management of moorland pools: balancing acidification and eutrophication. *Hydrobiologia* **265**, 225–263.

Welch E.B. & Jacobi J.M. 2004. *Pollutant Effects in Freshwater*. 504 pp. Spon Press, London.

Williams P., Whitfield M., Biggs J., Bray S., Fox G., Nicolet P. & Sear D. 2004. Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. *Biological Conservation* **115**, 329–341.

2. Diatoms in ponds and small lakes of the Kathmandu Valley, Nepal – relationships with chemical and habitat characteristics

2.1 Abstract

Diatoms were examined in twelve ponds and four small lakes of the Kathmandu Valley, Nepal, to assess their biodiversity, response to environmental conditions and potential use as bioindicators for water quality. They were investigated from different substrates and relationships with water chemistry and habitat character were assessed. In total 213 diatom species were found with 98 taxa at relative abundances > 1 %. The most species-rich genera were *Navicula* (42), *Gomphonema* (39), *Achnanthes* sensu lato (27), *Nitzschia* (27) and *Fragilaria* sensu lato (20). Species diversity was low (mean 0.95 ± 0.17 sd) and most assemblages were dominated by 1-3 taxa. Thirty percent of the taxa found could not be identified using relevant literature. Species richness, diversity and evenness were not related to water chemistry or habitat character, but varied significantly on different substrate types and were higher in the sediment compared to stones and macrophytes. At five of seven sites, where several substrates were collected, the most abundant species occurred on all substrates. Canonical correspondence analysis (CCA) revealed that changes in species composition were most strongly correlated with gradients in water chemistry. *Achnanthidium minutissimum* was characteristic at sites with higher Ca concentrations, while *Eolimna minima*, *Nitzschia palea*, *Nitzschia palea* cf. var. *debilis* and *Gomphonema parvulum* indicated higher concentrations of K, Cl, Na, As, Ni, Fe and Al. *E. minima* and *N. palea* were also typical at sites with higher concentration of SO_4, Sr and Al. Assemblage composition was also significantly correlated with habitat character such as aquatic vegetation, substrate composition, bank character and land use.

2.2 Introduction

Ponds and small lakes are important habitats for aquatic biota. There is an increasing number of studies investigating their diatom diversity in relation to major environmental factors (Douglas & Smol 1993, Gaiser *et al*. 1998, LIM *et al*. 2001a), to reconstruct environmental change (Bennion 1994, Denys 2003) or to predict their value for biodiversity (Bellemakers & van Dam 1992, van Dam & Buskens 1993). However, only a few studies exist that use diatoms to monitor pollution in ponds despite impacts from agriculture and industrial emissions such as eutrophication resulting from agricultural runoff and fish farming, metal contamination from mining activities, and atmospheric deposition of emissions from metal industries and power plants (Pechar 2000, Ruan & Gilkes 2000, Graney & Eriksen 2004, Razo *et al*. 2004).

During the last decades many standing waters in the Kathmandu Valley, Nepal, have been degraded or have disappeared due to the expansion of settlements, heavy abstraction of groundwater for consumption and the intensification of agriculture (Jha 1992). Many of the remaining ponds are artificial, often situated at prayer and recreational sites or were formerly used as fish ponds. Most of the former fish ponds will either dry out or become overgrown by plants within a short period of time due to the lack of management and will therefore lose their potential as refuge for aquatic life in this area. Most of the artificial ponds are polluted due to urban runoff and sewage inputs from various sources, and some have experienced fish kills (Baral pers. comm.). Information about the biota is patchy and restricted to a few sites such as the small, ancient Lake Taudaha, where a restoration project was implemented by a local conservation organisation (Bird Conservation Nepal 1997, Baral pers. comm.). Since these ecosystems are the last remaining refuges in the Kathmandu Valley for lake or pond biota, an inventory of their biodiversity as well as appropriate management guidelines for conservation are timely. It is particularly useful to include diatoms in such investigations, since they have been used successfully in other studies in Nepal to assess the influence of environmental factors on biodiversity (Ormerod *et al.* 1994, Rothfritz *et al.* 1997) and to monitor pollution (Jüttner *et al.* 1996, Jüttner *et al.* 2003). There are few published studies about lakes and ponds in Nepal, particularly in the Middle Hills. These include investigations on the phytoplankton of ponds in the Pokhara and Kathmandu Valleys (Hickel 1973, Lohman *et al.* 1988) and on the water chemistry of lakes and ponds in the Nepalese Middle Hills and lowlands (Jones *et al.* 1989). This is the first study on benthic diatoms in standing waters of the Middle Hills. Our aim was to investigate diatom diversity and assemblage composition in ponds of the Kathmandu Valley with respect to (i) their distribution on different substrates in the ponds such as macrophytes, stones, walls and sediment, and (ii) their relationship with water chemistry and habitat character of the ponds, their bank and the catchment.

2.3 Materials and Methods

2.3.1 Study area

The study area in the Kathmandu Valley (85°12’ - 85°30’ E, 27°35’ - 27°47’ N) extended from the settlements of Thankot in the west, Bhaktapur in the east, Sundarijal in the north, and Godawari in the south and included the cities of Kathmandu and Patan (Fig. 1, Table 1). We investigated sites in densely populated urban areas and villages (8, of which 6 were at prayer sites), in agricultural areas (5)

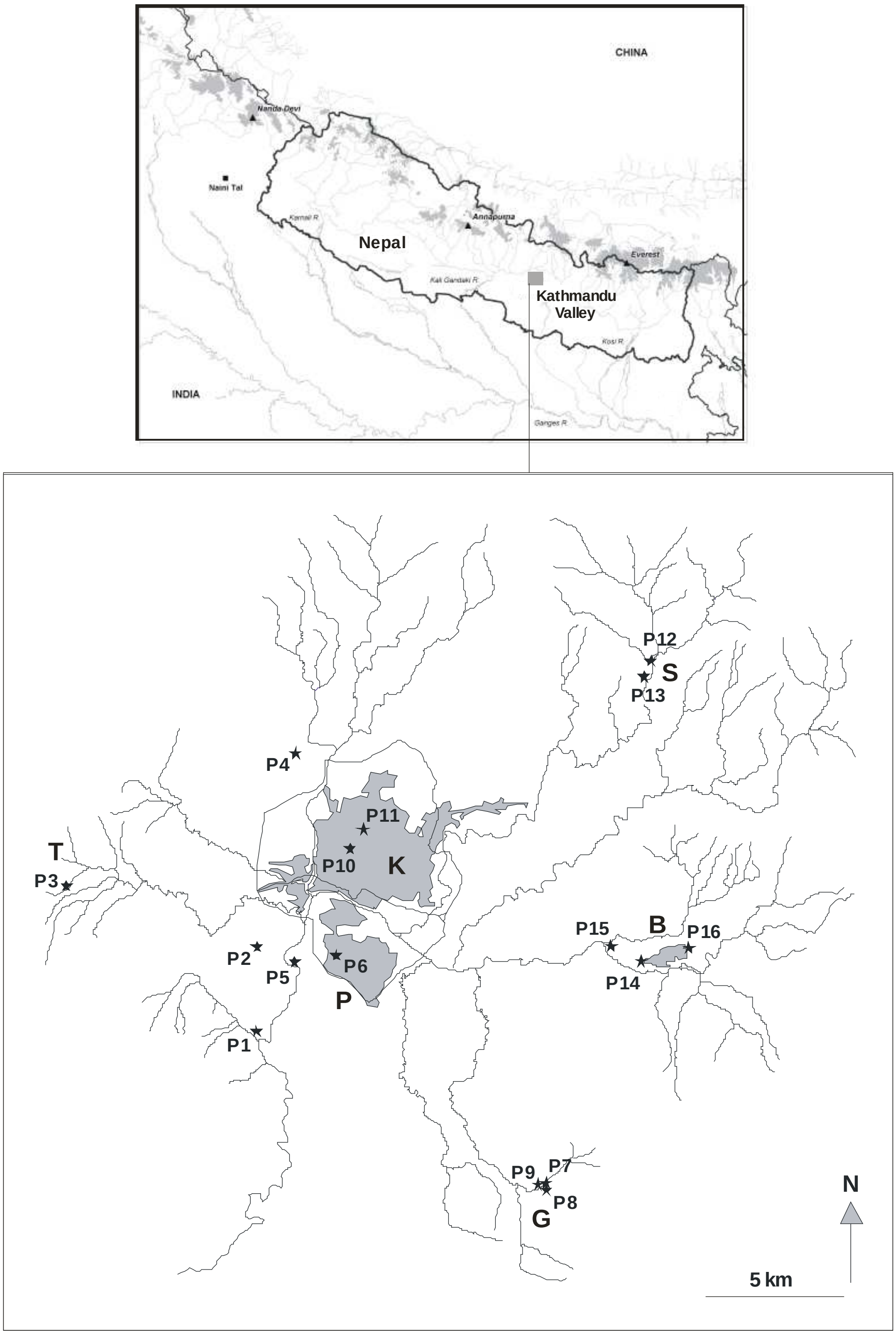


Fig. 2.1 Locations of study sites in the Kathmandu Valley
(P1 – P16 indicates the assessed sites, codes for cities and villages: K = Kathmandu, P = Patan, B = Bhaktapur, T = Thankot, S = Sundarijal, G = Godawari).

and in public parks (3). The ponds (≤ 2 ha) and small lakes were located between 1290 – 1600 m altitude a.s.l.. The ancient Lake Taudaha (P1) was the only remaining natural lake in the Kathmandu Valley, the other fifteen sites were artificial, some of which date back several hundred years and have great cultural importance. All but two sites were located in areas underlain by base cation rich Plio- Pleistocene fluvial sediments, lacustrine clay deposits or calcareous rocks. Two ponds were situated on the northern slope of the Kathmandu Valley consisting of less-buffered Precambrian metamorphic rocks comprising gneisses, quartzites and marbles.

2.3.2 Field and laboratory procedures

In March 2002, 16 sites were surveyed. Conductivity and pH were measured on site using portable meters (pH 340A, LF 197, WTW Weilheim, Germany). Water chemistry samples were filtered (0.45 μm, 2 x 30 ml) and one sample for cation analysis acidified on site with 1 ml nitric acid. Some elements were analysed by inductively-coupled plasma optical emission spectrometry (ICP-OES for Al, Fe, Mn) and inductively-coupled plasma mass spectrometry (ICP-MS for Ni, Zn, As, Pb, Department of Mineralogy, Natural History Museum, London). Anions (Cl, NO_3, PO_4, SO_4) and other cations (Na, K, Mg, Ca, NH_4) were analysed by ion chromatography (Department of Mineralogy, Natural History Museum, London). Total inorganic nitrogen was estimated as the summed concentrations of NO_3 and NH_4.

Habitat character was assessed recording 67 variables which described substrate composition of the littoral (lowest water level - 2 m beyond), the riparian zone (lowest - highest water level) and the bank, aquatic vegetation, bank profile and vegetation, trees within 50 m of the sampling site and surrounding land use within 100 m.

Diatoms were collected from available substrates such as macrophytes (mac), fine sediments (sed), stones or bricks (sto), and concrete walls (wal, Table 1), and preserved with formalin (c. 4% final concentration). Samples from at least ten stones or bricks in several locations of each pond were taken using a toothbrush, and from concrete walls by scraping the wall also at several locations with a knife blade. For epiphytic diatoms leaves and stems from different species of macrophytes in several areas of the pond were collected and digested whole. At ponds where fine sediment was present and within reach the upper centimetre of the sediment was collected at a number of locations within the pond using a polyethylene tube, 3.5 cm in diameter and mounted to a wooden stick, by sliding it across the sediment surface. The sediment sample was digested whole. Samples were processed using standard methods (H_2O_2 for oxidation, Naphrax as mountant). A minimum of 500 valves were counted and identified at 1000 x magnification (Zeiss Axioplan, DIC) and relative abundances were calculated. Identifications were based on Krammer & Lange-Bertalot (1986-1991), Lange-Bertalot & Krammer (1989), Krammer (1997), Reichardt (1999), and for some nomenclatural revisions we followed Williams & Round (1987), Round & Bukhtiyarova (1996) and the diatom software Omnidia (Version 3, Lecointe *et al*. 1999).

2.3.3 Data analysis

To reduce the dimensionality of the original data matrix of water chemistry and habitat character and derive major chemical and habitat gradients, environmental parameters were reduced by principal component analyses based on correlation matrices (PCA, MINITAB 14). To derive two separate sets of habitat principal components representing different aspects of the pond and its surroundings, habitat variables were divided into two groups to describe bank / catchment character and pond character. Dimensions (e.g. bank height) were log-transformed and arcsine transformation was used for proportions (e.g. percentage substrate type). Presence / absence categories (0, 1, 2 [> 30%], e.g. for aquatic vegetation) were not transformed.

To derive principal components reflecting gradients in water chemistry I performed two PCAs. PCA1 used chemical data from all 16 ponds and identified 4 ponds which differed substantially in their chemical character from the other ponds. In a second PCA only chemical data from twelve ponds were used after the four chemically different ponds (P11, P12, P13, P15) were removed from the analysis. Two of those (P12, P13) were located on base-poor bedrock, and one (P15) was almost completely covered by water hyacinth. Chemical data except pH were log-transformed prior to ordination.

Diatom diversity H' (Shannon diversity index) and evenness were calculated. Species richness was calculated using Rarefaction on PRIMER 6. Differences in species richness, diversity and evenness between different substrates were investigated using one-way analysis of variance (ANOVA on MINITAB 14) following procedures recommended by Fry (1994). Relationships between species richness, diversity H', evenness, habitat principal components and chemistry principal components (PCA2) were explored by regression (MINITAB 14).

To investigate relationships between variations in assemblage composition and environmental gradients with respect to habitat and chemical character in twelve ponds a canonical correspondence analysis (CCA, CANOCO 4.5) was performed. Four ponds which were chemically very different were excluded from the analysis. For environmental variables in the CCA we used PCA axes 1-3 scores describing habitat character of the ponds and the banks / catchments, respectively, and water chemistry in twelve ponds (chemistry PCA2).

Table 1. Ponds surveyed for diatoms, water chemistry and habitat character in the Kathmandu Valley, Nepal, March 2002.

Site code	Name of pond	Location	Position (north, east)	Length/width (m) approx.	Substrate	Main land use within 100 m	Collected substrates				Observed/known use
							mac	sed	sto	wal	
P1	Taudaha Lake	Taudaha, south of Chobhar	27° 38.88’ 85° 17.05’	400/300	Natural	Agriculture	x	x	x		Water fowl
P2	Dhungapokhari	Kirtipur	27° 40.50’ 85° 17.05’	30/20	Artificial	Settlement, sealed surface				x	Water fowl, washing
P3		Thankot	27° 41.65’ 85° 12.91’	25/15	Artificial	Settlement, forest, sealed surface				x	Prayer area, washing
P4		Balaju Water Garden, Kathmandu	27° 44.24’ 85° 17.85’	35/10	Artificial	Managed park				x	Public park
P5	Malpokhari	North of Chobar, near Bagdol	27° 40.21’ 85° 17.87’	30/5	Natural	Pasture, rough grassland	x	x			Remaining area of former fish pond
P6	Zoo pond	Jawalakhel Zoo, Patan	27° 40.35’ 85° 18.77’	200/150	Natural	Animal shelters, trees			x		Public park, boating
P7		Godawari, below fish farm	27° 36.00’ 85° 23.35’	150/30	Natural	Agriculture, trees	x	x			Picnic area
P8		Godawari	27° 35.86’ 85° 23.36’	20/10	Artificial	Settlement, forest, sealed surface				x	Prayer area
P9		Botanical Garden, Godawari	27° 35.97’ 85° 23.18’	25/15	Artificial	Managed park/forest	x	x			Public park
P10	Ranipokhari	Near Ratna Park, Kathmandu	27° 42.41’ 85° 19.06’	250/250	Artificial	Settlement, road			x		Prayer area
P11	Naranpokhari	Near south gate Royal Palace, Kathmandu	27° 42.78’ 85° 19.35’	15/15	Artificial	Settlement, road, sealed surface	x			x	Prayer area
P12		North of Sundarijal	27° 46.08’ 85° 25.55’	400/20	Natural	Agriculture, forest		x	x		Reservoir
P13		Sundarijal	27° 45.77’ 85° 25.41’	30/10	Artificial	Settlement				x	Sedimentation tank for drinking water supply
P14	Siddhapokhari	Bhaktapur	27° 40.29’ 85° 25.39’	200/100	Artificial	Settlement, sealed surface				x	Prayer area
P15		West of Bhaktapur, north of Sallaghari	27° 40.58’ 85° 24.73’	100/100	Natural	Settlement, pasture	x	x			Overgrown, former fish pond
P16	Kamalpokhari	Kamalbinayak, Bhaktapur	27° 40.56’ 85° 26.42’	200/150	Artificial	Settlement, sealed surface				x	Prayer area

2.4 Results

2.4.1 Habitat character and water chemistry

Habitat character varied particularly between ponds with artificial concrete basins and those with other substrates. At ten ponds, most of them at prayer sites, the dominating substrate was concrete. Cobble sized substrata (64 – 256 mm) and smaller substrata such as pebble, gravel, sand and silt were most common at the other six sites, which included former fish ponds, the zoo pond and the natural Lake Taudaha. Macrophytes were present in seven ponds, filamentous green algae were abundant at two sites (P1, P5) and green algae blooms occurred at three sites (P4, P14, P16). At eight ponds the banks were ≥ 90% bare, while grass and herbs were most common at the remaining sites. On the banks, scrub and trees were present at five sites, and trees were common within 50 m of the sampling site at eight ponds. Shading of less than 30% of the littoral was recorded at six ponds.

Ordination of bank and catchment variables resulted in three principal components explaining a total of 67.7 % of the variance (Table 2). PC1 (34.5 %) reflected differences between natural banks with sand or pebble substrata and vegetation, mainly located in agricultural catchments, and bare artificial banks mainly found in settlements. Bank / catchment PC2 (17.2 %) reflected differences in substrate size from silt to pebble / sand of natural banks and a difference in land use from pasture to trees, while PC3 (16.0 %) reflected differences in substrate size from silt to cobbles and land use from pasture to agriculture. The first three principal components describing pond character explained 76.0 % of the variance and reflected differences in ponds with respect to substrate types and vegetation. Pond PC1 (38.7 %) represented a change from

Table 2. Water chemistry principal components (water chemistry PCA 2 for 12 ponds) and habitat principal components reflecting major environmental gradients in ponds and small lakes of the Kathmandu Valley, Nepal, March 2002, and most important variables.

	Chemistry			Pond habitat			Bank and catchment character		
Principal components	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3
% Variance	33.1	22.4	13.6	38.7	22.2	15.1	34.5	17.2	16.0
Eigenvalue	6.6	4.5	2.7	7.3	4.2	2.9	12.4	6.2	5.8
Positive correlation and loadings	Ca (0.289)	Mg (0.417) Conductivity (0.400) N_{tot} (0.364) Sr (0.288) Ca (0.280)	SO_4 (0.518) Sr (0.262) Al (0.221)	Concrete littoral (0.296) Concrete rip. zone (0.294)	Concrete littoral (0.233) Concrete rip. zone (0.233)	Submerged plants (0.451) Emergent herbs (0.333) Sand littoral (0.311) Filamentous algae (0.259)	Steep bank (0.230) Scrub (0.228) Sand bank (0.217) Herbs (0.213) Pebbles bank (0.210)	Pasture (0.315) Silt bank (0.313) Gentle bank (0.233)	Underwater roots (0.297) Pasture (0.227) Silt bank (0.213) Resectioned bank (0.193) Fallen trees (0.183) Overhanging boughs (0.183)
Negative correlation and loadings	K (-0.368) Cl (-0.361) Na (-0.350) As (-0.335) Ni (-0.311) Fe (-0.273) Al (-0.335)	Al (-0.269) F (-0.273) pH (-0.175) Pb (-0.171)	Mn (-0.348) Fe (-0.345) Pb (-0.341)	Gravel littoral (-0.340) Gravel rip. zone (-0.339) Cobble littoral (-0.315) Sand rip. zone (-0.311) Pebble littoral (-0.279)	Silt rip. zone (-0.479) Silt littoral (-0.465) Rooted floating leaves (-0.330) Width rip. zone (-0.313)	Cobbles rip. zone (-0.365) Boulders littoral (-0.340) Pebbles rip. zone (-0.239)	Vertical bank (-0.267) Concrete bank (-0.261) Embanked (-0.261) Weir, dam (-0.237) Bare bank (-0.232)	Pebble bank (-0.236) Partly reinforced bank (-0.225) Fallen trees (-0.225) Overhanging boughs (-0.225) Woody debris (-0.216) Sand bank (-0.211)	Scrub (-0.306) Cobble bank (-0.266) Agriculture (-0.263) Reinforced bank (-0.231) Vertical + toe bank (-0.231) Trees (-0.197) Herbs (-0.176) Riparian roots (-0.171)

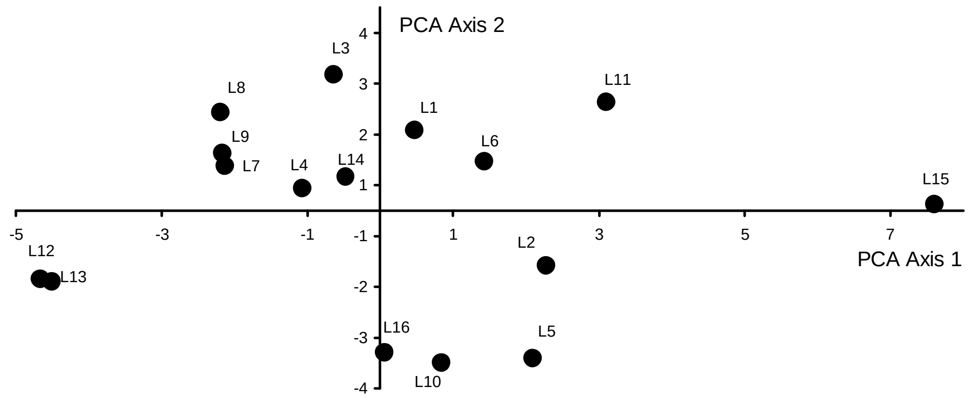
concrete to a natural substrata with gravels, cobbles, sand or pebbles. Pond PC2 (22.2 %) reflected a substrate change from concrete to silt,while PC3 (13.6 %) represented a change from a sandy littoral with plants to a littoral with boulders and cobbles / pebbles in the riparian zone.

Variation was identified for most measured water chemistry variables at ponds in central and southern areas of the Kathmandu Valley with base-rich geology. Here conductivity ranged between 134 – 360 μS/cm (402 and 679 μS/cm in two ponds P11 and P15), and Ca ranged between 15.5 – 52.4 mg/L (68.6 mg/L in P11). Values were much lower with 22 / 23 μS/cm and 2.4 / 2.7 mg/L Ca at the two sites (P12, P13) on the base-poor northern slope of the valley (Table 3). Total nitrogen concentrations varied between 0.0 – 1.5 mg/L for most ponds, but reached higher values of 2.2 and 12.6 mg/L at pond P11 and P15, respectively. These two ponds in the central part of the Kathmandu Valley differed in chemical character from other ponds and had much higher conductivities and very high Ca concentrations in P11. While P11 did not differ in habitat character from many other ponds, P15 was almost entirely covered by water hyacinth and had much higher concentrations of most measured anions and cations. The different chemical character of these two ponds in the base-rich central part of the valley as well as two ponds (P12, P13) in the base-poor northern part of the valley was also captured by ordination (water chemistry PCA1, Fig. 2a). For the other base-rich ponds P1-10, 14, 16, ordination (water chemistry PCA2) revealed three major trends in chemical character explaining a total of 69.1 % of the variance in the chemical data (Fig. 2b). The first principal component (33.1 %) reflected increased concentrations of Ca and a decrease in concentrations of K, Cl, Na, As, Ni, Fe and Al. The second principal component (22.4 %) reflected higher conductivity and increased

Table 3. Water chemistry of ponds and small lakes of the Kathmandu Valley, March 2002.

Site code	**pH**	**Conductivity**	**Na**	**K**	**Mg**	**Ca**	**Cl**	**N_{tot}**	**PO_4**	**SO_4**	**Al**	**Mn**	**Fe**	**Ni**	**Zn**	**As**	**Pb**
		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L
P1	7.8	241	6.1	4.2	7.9	41.2	5.9	0.4	0.000	5.0	0.010	0.025	0.079	1.08	3.75	0.71	0.05
P2	8.8	333	24.5	27.7	6.2	38.0	21.4	1.5	0.591	2.7	0.015	0.295	0.567	1.34	4.01	0.81	0.20
P3	8.0	228	2.1	0.8	5.1	50.1	0.4	0.3	0.000	2.5	0.013	0.006	0.014	0.67	14.68	0.24	0.08
P4	8.5	191	10.3	1.1	3.2	32.9	2.2	0.0	0.000	3.8	0.015	0.009	0.060	0.55	3.93	0.94	0.06
P5	7.3	269	18.2	34.9	5.5	16.8	37.0	0.2	0.000	0.1	0.054	0.225	1.890	2.02	5.58	1.80	0.79
P6	8.8	360	25.3	13.5	10.1	45.0	24.4	0.9	0.000	12.2	0.012	0.006	0.027	0.75	4.38	0.48	0.09
P7	8.0	222	1.5	0.7	3.2	52.4	0.3	0.0	0.000	0.9	0.011	0.023	0.032	0.67	4.24	0.28	1.72
P8	7.8	221	1.3	0.7	3.0	51.2	0.2	0.2	0.079	0.9	0.009	0.002	0.005	0.69	3.38	0.20	0.07
P9	8.4	195	2.1	1.0	3.1	47.5	0.3	0.1	0.000	0.9	0.013	0.011	0.020	0.72	2.73	0.27	0.04
P10	9.7	200	22.6	11.3	2.5	17.5	24.4	0.1	0.000	4.4	0.171	0.007	0.024	2.61	5.25	1.68	0.23
P11	6.8	402	16.8	8.2	8.1	68.6	11.5	2.2	1.601	11.3	0.009	0.031	0.030	2.41	7.46	1.15	0.11
P12	7.8	23	4.4	0.7	0.5	2.7	0.3	0.1	0.000	0.4	0.034	0.002	0.014	0.23	1.28	0.42	0.05
P13	7.5	22	4.3	0.6	0.5	2.4	0.2	0.1	0.000	0.2	0.031	0.004	0.022	0.19	1.32	0.37	0.05
P14	8.1	152	6.4	6.1	3.6	25.6	5.4	0.0	0.000	1.0	0.056	0.004	0.039	0.78	5.29	0.29	0.18
P15	7.0	679	56.9	59.1	17.6	50.4	94.8	12.6	16.156	37.7	0.016	0.252	0.188	2.71	12.06	2.26	0.14
P16	9.9	134	10.2	8.7	2.2	15.5	5.2	0.3	0.000	3.2	0.076	0.013	0.583	0.86	4.18	1.11	0.68

a)



b)

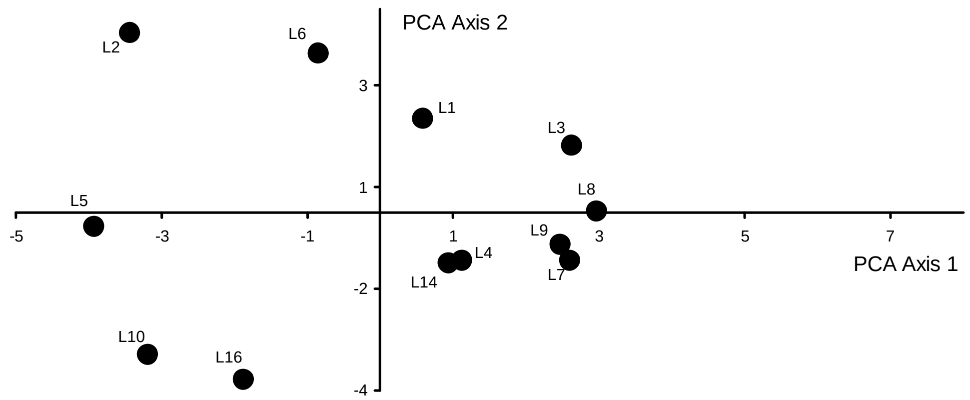


Fig. 2.2 Principal component analysis of water chemistry of Kathmandu Valley ponds - (a)sixteen sites and (b) twelve twelve sites.

concentrations of Mg, total N, Sr and Ca but lower concentrations in Al, F and Pb, as well as lower pH (range 7.3-9.9, Table 2, 3). The third principal component (13.6 %) represented higher concentrations in SO_4, Sr and Al, and lower concentrations inMn, Fe and Pb. There were no correlations between principal components describing changes in chemical character and those describing changes in habitat character. Trends in water chemistry were also not related to land use.

2.4.2 Species richness, diversity and microhabitat distribution

In total 213 diatom species were found with 98 species present at relative abundances > 1 %. Of these 29 (30 %) could not be identified after rigorous searching of relevant literature, although most of the unidentified taxa were not abundant. Twenty two *Gomphonema* species (8 > 1 %) could not be identified, followed by *Navicula* (11, 5 > 1 %) and *Fragilaria* sensu lato (8, 2 > 1 %). The most species-rich genera were *Navicula* (42), *Gomphonema* (39), *Achnanthes* sensu lato (27) including taxa formerly in *Achnanthes*, which have been transferred to other genera such as *Achnanthidium*, *Planothidium* and *Psammothidium*, *Nitzschia* (27) and *Fragilaria* (20). Other genera were represented only by five or less species. Most ponds were dominated by one to three species (relative abundances > 20 %) and one or two species with relative abundances > 10 % (Fig. 3). The most common and abundant species was *Achnanthidium minutissimum* (Kützing) Czarnecki. Other common taxa included *Nitzschia palea* cf. var. *debilis* (Kützing) Grunow, *Eolimna minima* (Grunow) Lange-Bertalot and *Nitzschia palea* (Kützing) W. Smith (Fig. 3, Table 4). There were marked differences in assemblage composition. Twelve ponds contained taxa at > 5 % relative abundance, which were rare or absent at other sites. These taxa included *Fragilaria nanana* Lange-Bertalot (P1 stones 71 %, sediment 37 %, macrophyte 12 %), *Epithemia sorex* Kützing (P4 wall, 63 %) and several unidentified taxa belonging to the genera *Gomphonema* (3), *Navicula* (2), *Achnanthidium* (1), *Aulacoseira* (1), *Diploneis* (1) and *Fragilaria* (1).,

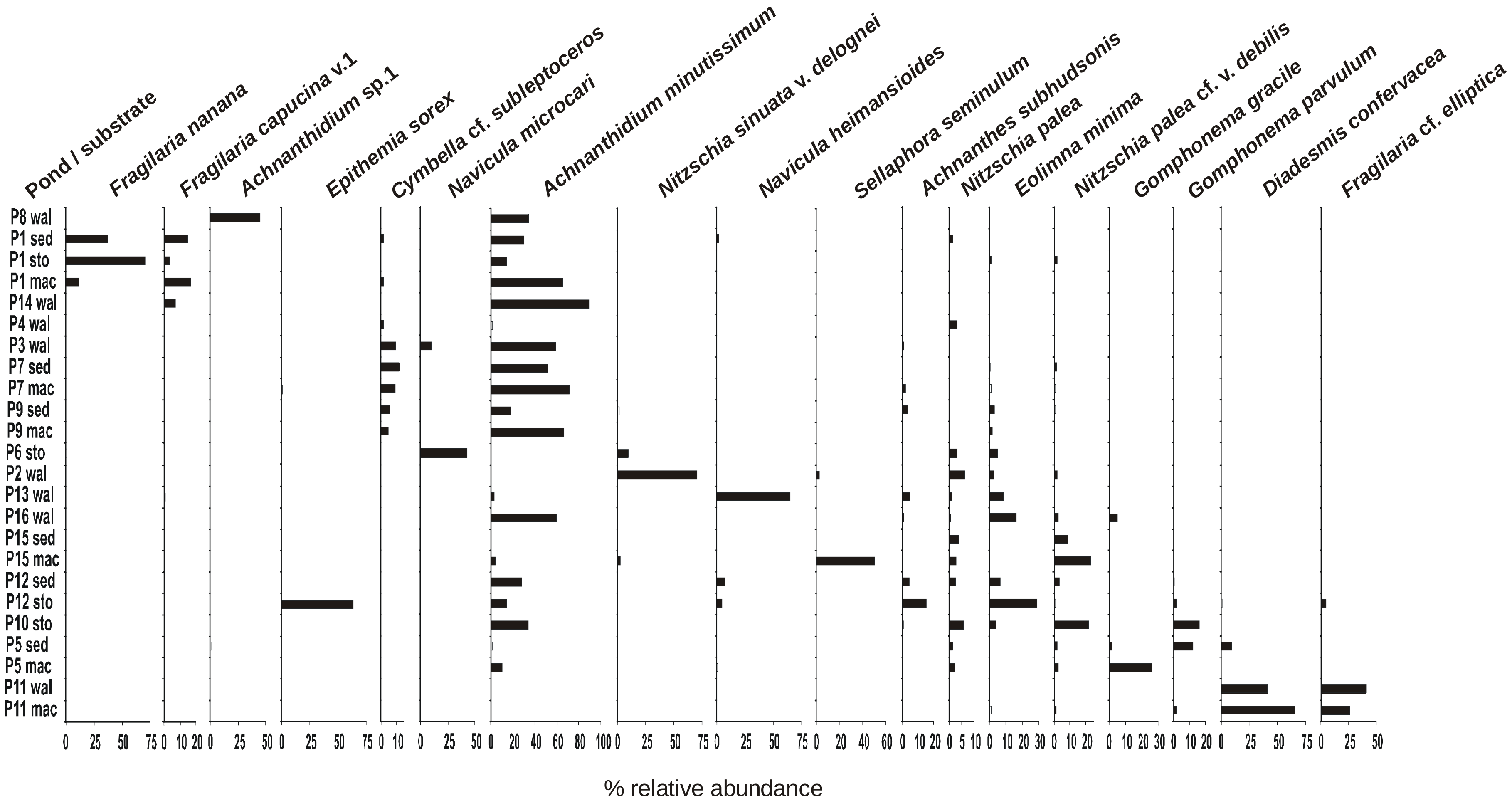


Fig. 2.3 Relative abundances of common and / or abundant diatom species in sixteen ponds and small lakes in the Kathmandu Valley.

Table 4. Common (occurrence at six or more sites with a minimum of 1.5 %) and / or abundant (≥ 10%) diatom species in 16 ponds and small lakes of the Kathmandu Valley, Nepal.

Taxon	Authority	No. of ponds present	Max. rel. abundance (%)
Achnanthidium sp.1		2	44.6
Achnanthes inflata	(Kützing) Grunow	1	12.7
Achnanthes minutissima	(Kützing) Czarnecki	15	88.9
Achnanthes subhudsonis	Hustedt	3	15.3
Aulacoseira cf. *crassipunctata*	Krammer	1	10.0
Cocconeis placentula var. *euglypta*	Ehrenberg	10	16.1
Cyclotella cf. *bodanica* var. *lemanica*	(O. Müller ex Schröter) Bachmann	1	32.3
Cyclotella ocellata	Pantocsek	1	14.4
Cyclostephanos cf. *invisitatus*	(Hohn & Hellerman) Theriot, Stoermer & Håkansson	3	13.2
Cymbella cf. *subleptoceros*	Krammer	9	11.9
Diploneis cf. *boldtiana*	Cleve	1	25.9
Epithemia sorex	Kützing	2	63.5
Pseudostaurosira brevistriata	(Grunow in Van Heurck) Williams & Round	2	18.9
Fragilaria capucina var.1		8	16.8
Staurosira construens var. *venter*	(Ehrenberg) Hustedt	2	12.7
Staurosira cf. *elliptica*	(Schuhmann) Williams & Round	2	41.0
Fragilaria nanana	Lange-Bertalot	3	70.7
Staurosirella pinnata	(Ehrenberg) Williams & Round	10	13.7
Gomphonema cf. *pseudoaugur*	Lange-Bertalot	1	24.0
Gomphonema cf. *angustatum*	(Kützing) Rabenhorst	3	26.2
Gomphonema cf. *angustatum* var.1		1	11.4
Gomphonema cf. *angustatum* var.2		1	13.6
Gomphonema cf. *minutum*	Agardh (Agardh)	1	11.9
Gomphonema parvulum	Kützing	8	16.6
Diadesmis cf. *confervacea*	Kützing	4	65.5
Navicula cryptocephala	Kützing	9	6.2
Navicula heimansioides	Lange-Bertalot	4	65.0
Navicula microcari	Lange-Bertalot	2	42.8
Eolimna minima	(Grunow) Lange-Bertalot	11	29.0
Sellaphora seminulum	(Grunow) D.G. Mann	6	50.8
Nitzschia gracilis	Hantzsch	1	12.3
Nitzschia palea cf. var. *debilis*	(Kützing) Grunow	10	23.2
Nitzschia palea	(Kützing) W. Smith	13	6.1
Nitzschia sinuata var. *delognei*	(Grunow) Lange-Bertalot	10	70.7
Surirella cf. *roba*	Leclercq	3	11.1

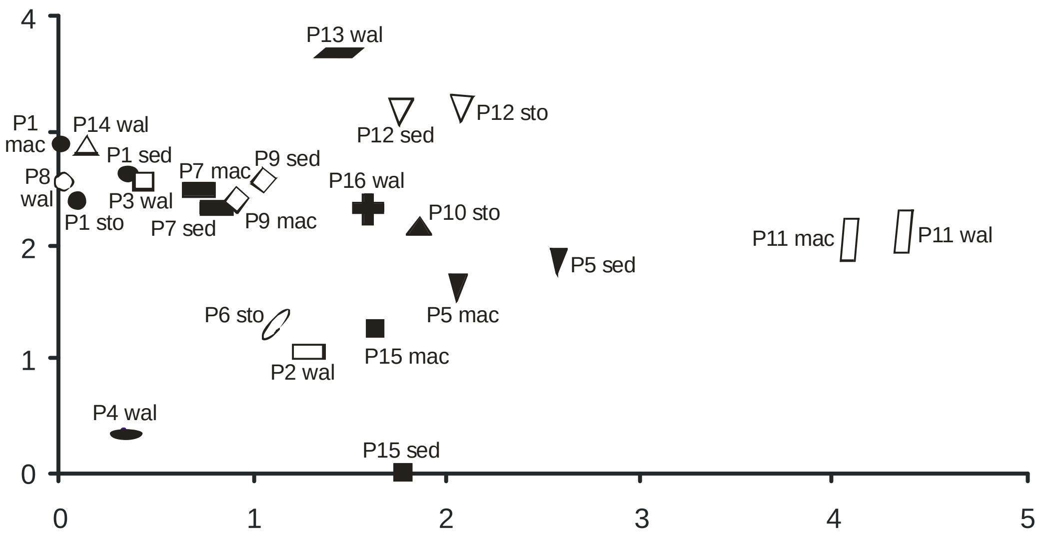
Table 5. Diatom species richness, diversity H' and evenness on different substrates in 16 ponds and small lakes of the Kathmandu Valley, Nepal.

	Species richness	Diversity H'	Evenness
Sediment	27.0 ± 7.0	0.95 ± 0.17	0.69 ± 0.11
Stones or walls	14.3 ± 4.9	0.60 ± 0.20	0.53 ± 0.12
Macrophytes	16.8 ± 6.3	0.60 ± 0.22	0.51 ± 0.13
ANOVA	$F_{(2,23)}$ 9.6 $p < 0.01$	$F_{(2,23)}$ 6.9 $p < 0.01$	$F_{(2,23)}$ 4.6 $p < 0.05$

Species richness, diversity H' and evenness were not related to gradients in water chemistry and did not reflect differences in habitat character such as pond size vegetation, substrate, bank character or surrounding land use. However, they varied significantly on different substrate types and were higher in the sediment compared to stones and walls or macrophytes (Table 5). With respect to the most abundant species, assemblages on different substrates within the same pond were similar at five of seven sites, where several substrates were collected (Fig. 4). At two very shallow ponds, assemblages on macrophytes and sediments were more different. At P15, which was entirely covered by water hyacinth, assemblages on macrophytes and in the sediment differed markedly, with two *Staurosira* species, and one species each belonging to *Staurosirella*, *Pseudostaurosira* and *Aulacoseira* occurring at 8 – 19 % relative abundance only in the sediment, while *Sellaphora seminulum* (Grunow) D.G. Mann and *Nitzschia palea* cf. var. *debilis* dominated the epiphyton. At P5 one *Cyclotella* species, *Diadesmis* cf. *confervacea* Kützing and *Navicula cryptocephala* Kützing were much more abundant on the sediment, while three *Gomphonema* species dominated on the macrophytes. At the six ponds, where sediment samples were collected, between 28 – 73 % of the species found occurred exclusively in the sediment. They belonged to the genera *Cyclotella*, *Diploneis*, *Navicula*, *Pinnularia* and *Surirella*. The most species-rich site was P9, the pond of the Royal Botanical Garden, where 73 % of all species found in the sediment occurred in the sediment only, including an unidentified *Diploneis* species at 26 % relative abundance. There were no common species, which were restricted either to macrophytes or stones / walls.

2.4.3 Relationships with habitat character and water chemistry

Canonical correspondence analysis (CCA) revealed significant relationships between assemblage composition and environmental gradients of water chemistry and habitat a)



b)

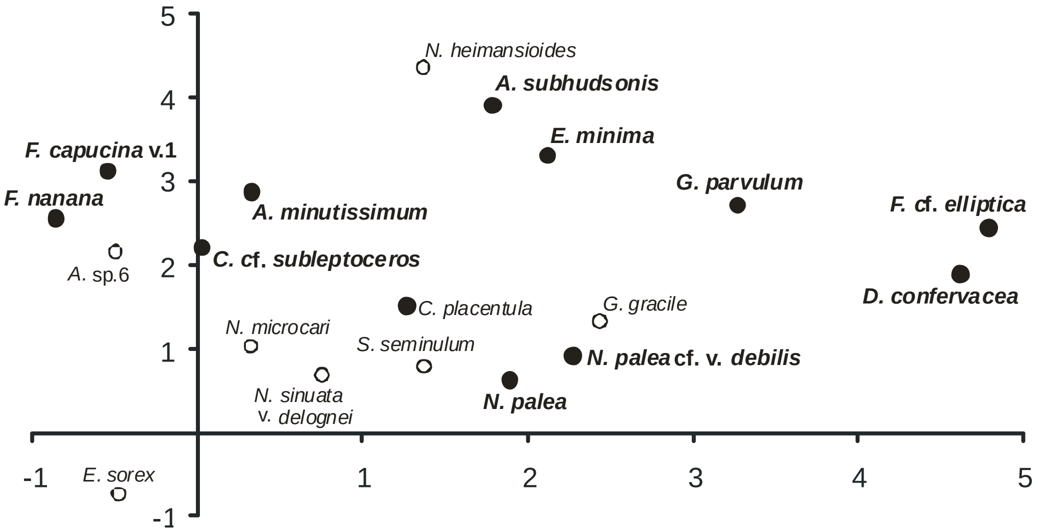


Fig. 2.4 Detrended correspondence analysis (DCA) ordinations

(a) Assemblages ordination, identical symbols indicate assemblages from different substrates of the same site (sto = stone or walls, sed = sediment, and mac = macrophytes), (b) Species ordination, large font = common and abundant species, small font = abundant species with restricted distribution character. CCA axis 1 (18.1 % variance) was significantly correlated with chemistry PC1, pond and bank / catchment PC3. At sites with higher Ca concentrations and lower concentrations of K, Cl, Na, As, Ni, Fe and Al *A. minutissimum* was the most common and abundant species, and *F. nanana*, *F. capucina* var.1 and *Cymbella* cf. *subleptoceros* Krammer were typical at some of the sites. These ponds had also submerged and emergent aquatic plants, filamentous algae and sand substrate in the littoral. At sites with higher concentrations of K, Cl, Na, As, Ni, Fe and Al *Eolimna minima*, *Nitzschia palea*, *Nitzschia palea* cf. var. *debilis* and *Gomphonema parvulum* Kützing were most common or abundant. Bank / catchment PC3 and PC2, representing gradients from banks with silt and pasture land use to banks with coarser substrata, were significantly correlated with CCA axis 1 and 2, respectively. *G. parvulum* and *N. palea* cf. var. *debilis* were most characteristic at sites with gentle banks, silt and pasture. Chemistry PC3 and pond PC2 were significantly correlated with CCA axis 2. *E. minima* and *N. palea* were more typical at sites with higher concentrations of SO_4, Sr and Al and in artificial ponds with concrete substrate. There were no relationships between CCA axes and chemistry PC2, including changes in conductivity and total nitrogen. Assemblages from different substrates within the same pond were located close to each other in the ordination, reflecting a similar response to environmental gradients

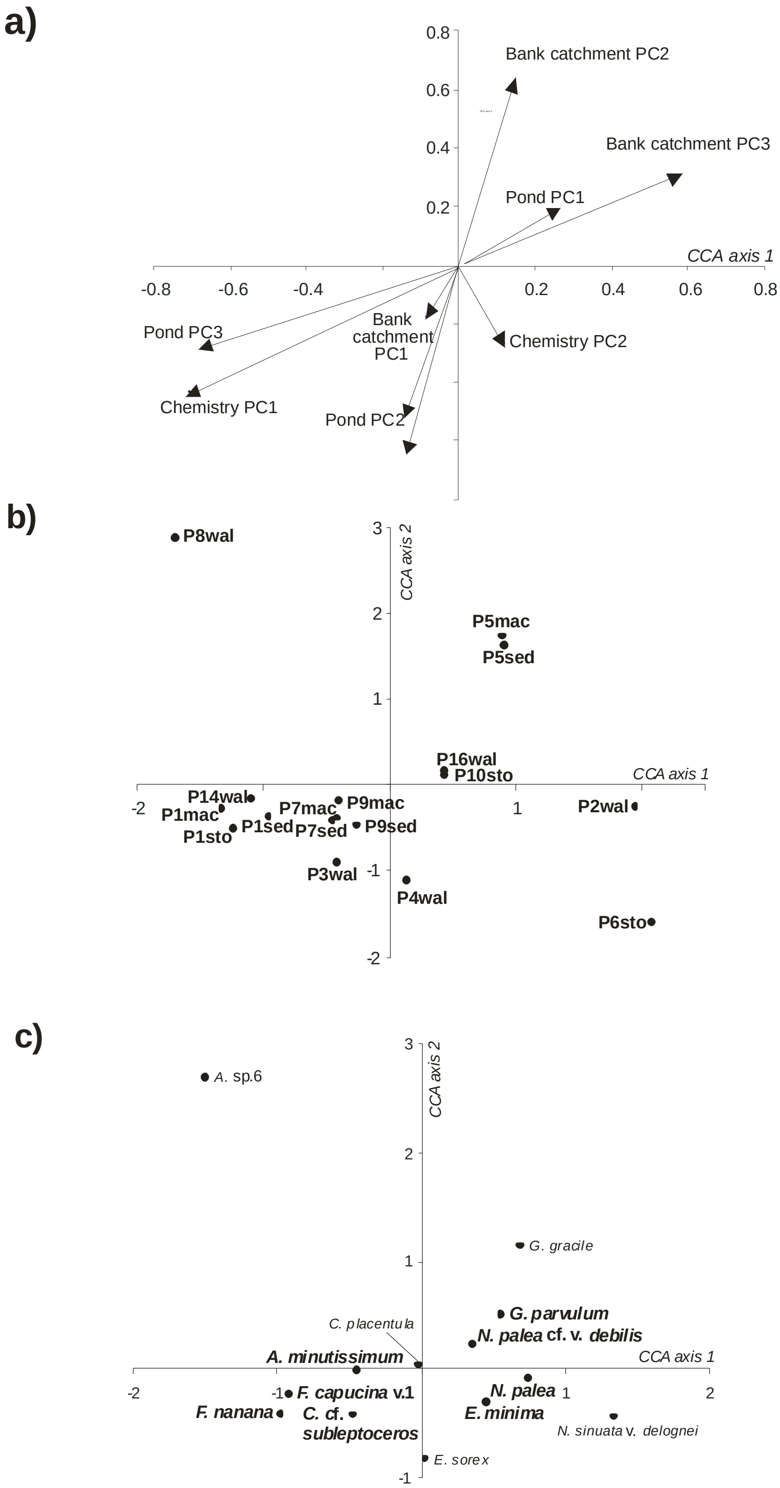


Fig. 2.5 CCA of diatoms assemblages from ponds and small lakes in the Kathmandu Valley (a) environmental gradients correlated with assemblage change along CCA axes 1 and 2, (b) assemblages ordination, (c) species ordination, large font = common and abundant species, small font = abundant species with restricted distribution.

2.5 Discussion

Despite their great historical and cultural significance, potential economic value and importance for conserving aquatic biodiversity, ponds, lakes and other freshwater ecosystems in the Kathmandu Valley are subjected to pollution and habitat degradation (Sharma & Moog 1996, Ha & Pokhrel 2001, Jüttner *et al.* 2003). Many of the investigated ponds and lakes were used inappropriately such as washing, dumping of litter and received pollutants from drainage pipes, surface runoff and air pollution. Some will be lost soon due to the cessation of former use such as fish farming. Although the most common diatom taxa found are widespread in all types of freshwaters, many of the taxa present in these ponds were not found during previous extensive surveys of streams and rivers in this area and might be restricted to standing waters. Many could not be identified suggesting that they have a restricted geographical distribution and might be endangered if these ponds continue to deteriorate. These findings coupled with high species turnover between ponds emphasise the important contribution of pond ecosystems to aquatic biodiversity (Douglas & Smol 1993). Preventing further degradation of the few remaining ponds and small lakes, and restoring or recreating new ponds would be particularly important in a biologically impoverished area such as the densely populated Kathmandu Valley.

2.5.1 Relationships with habitat character and water chemistry

In contrast to a study on streams in the Kathmandu Valley and the Middle Hills there were no significant relationships between diatom diversity and habitat character such as land use, shading, bank character or substrate composition. However, the presence of different microhabitats was important and contributed significantly to biodiversity. Like in other studies abundant taxa often occurred on all collected substrates in most ponds

(Gaiser & Johansen 2000), but some species were apparently restricted to a particular microhabitat (Cox 1984, 1988a, Douglas & Smol 1995, Soininen & Eloranta 2004). Similar to findings in other studies (Czarnecki 1979, Lim *et al*. 2001b, Michelutti *et al*. 2003) species restricted or more abundant in a particular habitat found in the sediment. In this study this included a number of *Navicula* species, and unidentified species belonging to the genera *Diploneis*, *Cyclotella*, *Surirella*, *Pinnularia* and *Nitzschia*. The unidentified taxa occurred only in one or two ponds. None of the common or abundant taxa were restricted to macrophytes, stones or walls. The latter substrates also had fewer species and since no live material was examined it is likely that some of the species found in the sediments were transported there, but had actually lived in other habitats (Cox 1988b). However, some taxa found such as *Cyclotella* cf. *bodanica* var. *lemanica* (O. Müller ex Schröter) Bachmann, *Diploneis* cf. *boldtiana* Cleve, *Pseudostaurosira brevistriata* (Grunow in Van Heurck) Williams & Round and *Surirella* cf. *roba* Leclercq occurred exclusively in the sediments, including in two very shallow ponds (P5, P15). Providing a specific microhabitat for some species coupled with the highest species richness and probability of accumulation of diatoms from different substrates emphasises the particular importance of sediments in diatom diversity.

Similarly to a stream survey in this area (Jüttner *et al*. 2003) there were relationships between diatom assemblage composition, water chemistry and habitat character such as land use, bank character and substrate composition. In another pond study in the Nepalese lowlands, which included 64 ponds, there were also significant relationships between water chemistry, habitat character with respect to littoral vegetation, land use and assemblage composition (Simkhada & Jüttner in press).

Other studies dealing with the relationships between pond diatom assemblages and chemical character revealed significant correlation of diatom distribution to gradients in nutrient concentrations or salinity. In a study of shallow, artificial ponds in southeast England Bennion (1994) found that total phosphorus explained most of the variance in the diatom species data, but water depth, soluble reactive phosphorus, pH and nitrate nitrogen were also important. A study of saline and freshwater lakes and ponds from the Windmill Islands, East Antarctica, found that salinity and phosphate gradients significantly influenced diatom composition and distribution (Roberts *et al*. 2001), while total nitrogen best explained species distribution in ponds on Bathurst Island in the Canadian high arctic lakes and ponds (Lim *et al*. 2001a). Other factors such as Na, total phosphorus, pH, Fe and temperature were also important, but their contribution varied depending on the type of microhabitat (Lim *et al.* 2001b). In contrast diatom assemblage composition in this study was unrelated to the second chemical gradient, which was related to concentrations of total nitrogen. This might be explained by the relatively small range in nitrogen concentrations found in twelve Kathmandu Valley ponds. Phosphate concentrations were below the detection limit of 50 µg/L at all but two of the twelve sites, hence it was unlikely that a relationship with diatoms could have been detected. Green algal blooms in some of the ponds and rapid uptake of available nutrients might explain the relatively low nutrient concentrations in these ponds despite their location in urban and agricultural areas with potentially high nutrient inputs from surrounding areas. There was, however, a significant relationship between diatom assemblage composition and other chemical gradients, which most likely reflected increased pollution probably from several sources including agriculture, surface runoff, dust and air pollution from industrial sources and traffic (Carrico *et al.* 2003, Jüttner *et al*. 2003, Shrestha 2003). At sites with higher concentrations of Na, Cl, K, Al, Ni and As taxa which are well known as pollution indicators such as *E. minima*, *N. palea* and *G. parvulum* were common, while species such as *A. minutissimum* were most abundant at cleaner sites (Kelly & Whitton 1995, Jüttner *et al*. 2003). As for streams in the Kathmandu Valley and the Nepalese Middle Hills, Na was strongly correlated with the major gradient in water chemistry and reflects impacts from agriculture in the catchments (Jenkins *et al*. 1995). Also strongly correlated with the same water chemistry gradient were metals and arsenic. The latter is a major problem for groundwater contamination in parts of South Asia including Nepal, where areas in the lowlands are particularly affected (Shrestha *et al*. 2003). However, only a few wells in the Kathmandu Valley exceeded the World Health Organisation drinking water guideline value of 10 µg/L (Khatiwada *et al*. 2002), and in this study arsenic concentrations were below this limit ranging from 0.2 – 2.6 µg/L (median 0.6). Some studies suggested positive correlations between the relative abundance of certain diatom taxa including *Nitzschia palea* to As and other metals (Rushforth *et al*. 1981). Other studies showed effects of As on species composition and abundances (Riedel *et al*. 2003, Howard *et al*. 1995). Whether diatoms respond to arsenic pollution in Nepalese freshwater ecosystem independent of other factors and could therefore be used for monitoring in this area would require further studies involving a larger number of ponds or lakes including highly contaminated ones. Investigations of metal contamination in streams and effects on periphytic communities showed marked changes in species composition (Hill *et al*. 2000, Gold *et al*. 2002). Some studies suggested that *A. minutissimum* was particularly tolerant to higher metal concentrations (Medley & Clements 1998, Nakanishi *et al*. 2004), which cannot be confirmed by our study where relative abundances of *A. minutissimum* were not related to metal concentrations.

2.5.2 Implications for biodiversity assessments and monitoring of pollution

For a comprehensive assessment of diatom diversity, assemblages from all available substrates must be investigated to include species restricted to a particular habitat type such as many motile taxa, which occur in sediments only. Samples from hard substrates such as stones and walls as well as sediment samples should be taken from different areas of the pond to maximize the investigated area and allow for a possible patchy distribution within the pond. For epiphytic assemblages, samples from all macrophytic plant species should be collected to account for possible species or host morphology-type specific diatom distribution. The significant number of unidentified taxa in this study demands further taxonomic investigations to provide a comprehensive species inventory and meaningful assessment of the significance of these ecosystems for the conservation of diatom biodiversity in this area. Although most common and abundant species belonged to *Achnanthes* sensu lato, *Fragilaria* sensu lato, *Gomphonema*, *Navicula* and *Nitzschia*, which are also the most species rich genera in Nepalese streams (Jüttner *et al.* 2003, Jüttner *et al.* unpublished data), a considerable number of unidentified and possibly unknown taxa belonged to 11 genera / groups. These included *Achnanthes* sensu lato, Thalassiosiraceae, *Diploneis*, *Eunotia*, *Fragilaria* sensu lato, *Gomphonema*, *Navicula*, *Nitzschia*, *Pinnularia*, *Surirella* and a genus, which has not been described yet. Many of the unidentified taxa have so far not been found in streams and springs of this area. Most of the common and abundant species such as *Achnanthidium minutissimum*, *Eolimna minima* and *Nitzschia palea* are also common and abundant species in Nepalese streams. However, the overall species composition in the ponds and the presence of many taxa, which were apparently specific to standing waters, clearly distinguished the ponds from stream and spring assemblages in the Nepalese Middle Hills (Jüttner *et al.* 1996, 2003, Dahal & Jüttner 2004).

Assemblages from different substrates such as stones / walls, macrophytes and sediments responded similarly to environmental conditions. This suggests that the use of different substrates is possible for monitoring purposes in cases where the more favourable approach of restricting sampling to one particular substrate cannot be followed due to the absence of that substrate at some sites. Although epilithic diatom samples are most commonly used for monitoring streams, the use of macrophytes as an alternative substrate has been suggested (O'Connell *et al*. 1997, Kelly *et al*. 1998, Passy *et al*. 1999) and was found most appropriate to indicate trophic status at some lakes (Poulíčková *et al*. 2004). Other pond surveys have revealed that many ponds do not have a consistent set of microhabitats (Jüttner unpubl. data) and using a combination of several substrates would allow the inclusion of different pond types for water quality monitoring.

To develop diatoms as indicators for monitoring of standing waters in this area of Nepal a much larger survey of ponds and lakes in the Middle Hills would be required. This could include ponds and lakes in neighbouring valleys to the Kathmandu Valley and in the Pokhara Valley of western Nepal, which has a much larger number of standing waters (Rai 2000). Here water quality has decreased substantially due to pollution from settlements and land use change in the catchments (Thapa & Weber 1995). Regular biological monitoring of these ecosystems would help to compile data describing the current situation and aid environmental management including the development and implementation of monitoring tools and an action plan to prevent further deterioration.

2.6 References

Bellemakers M.J.S. & Van Dam H. 1992. Improvement of breeding success of the moor frog (Rana arvalis) by liming of acid moorland pools and the consequences of liming for water chemistry and diatoms. *Environmental Pollution* **78**, 165–171.

Bennion H. 1994. A diatom–phosphorus transfer function for shallow, eutrophic ponds in southeast England. *Hydrobiologia* **275/276**, 391–410.

Bird Conservation Nepal 1997. Lake Taudaha Restoration Project. Report to the King Mahendra Netherland's Trust for Nature Conservation.

Carrico C.M., Bergin M.H., Shrestha A.B., Dibb J.E., Gomes L., Harris J.M. 2003. The importance of carbon and mineral dust to seasonal aerosol properties in the Nepal Himalaya. *Atmospheric Environment* **37**, 2811–2824.

Cox E.J. 1984. Observations on some benthic diatoms from North German lakes: The effect of substratum and light regime. *Verhandlungen Internationale Vereinigung Limnologie* **22**, 924–928.

Cox E.J. 1988a. Has the role of the substratum been underestimated for algal distribution patterns in freshwater ecosystems? *Biofouling* **1**, 49–63.

Cox E.J. 1988b. Microdistributional patterns of freshwater diatoms in relation to their use as bioindicators. In: Proceedings of the 10th International Diatom Symposium, Joensuu, Finnland. Simola H. (ed.), pp. 521–528. Koeltz, Koenigstein.

Czarnecki D.B. 1979. Epipelic and epilithic diatom assemblages in Montezuma Well National Momunment, Arizona. *Journal of Phycology* **15**, 346–352.

Dahal B.M. & Jüttner I. 2004. Monitoring water quality in springs of the Nepalese Middle Hills using diatoms. Report to the British Ecological Society SEPG No. 2235–2003.

Denys L. 2003. Environmental changes in man-made coastal dune pools since 1850 as indicated by sedimentary and epiphytic diatom assemblages (Belgium). *Aquatic Conservation* **13**, 191–211.

Douglas M.S.V. & Smol J.P. 1993. Freshwater diatoms from high arctic ponds (Cape Herschel, Ellesmere Island, N.W.T.). *Nova Hedwigia* **57**, 511–552.

Douglas M.S.V. & Smol J.P. 1995. Freshwater diatoms from high arctic ponds. *Journal of Phycology* **31**, 60–69.

Fry J.C. 1994. *Biological Data Analysis. A Practical Approach*. Oxford University Press, Oxford.

Gaiser E.E. & Johansen J. 2000. Freshwater diatoms from Carolina Bays and other isolated wetlands on the Atlantic coastal plain of south Carolina, U.S.A., with descriptions of seven taxa new to science. *Diatom Research* **15,** 75–130.

Gaiser E.E., Philippi T.E. & Taylor B.E. 1998. Distribution of diatoms among intermittent ponds on the Atlantic Coastal Plain: development of a model to predict drought periodicity from surface-sediment assemblages. *Journal of Paleolimnology* **20**, 71–90.

Gold C., Feurtet-Mazel A., Coste M., Boudou A. 2002. Field transfer of periphytic diatom communities to assess short-term structural effects of metals (Cd, Zn) in rivers. *Water Research* **36**, 3654–3664.

Graney J.R. & Eriksen T.M. 2004. Metals in pond sediments as archives of anthropogenic activities: a study in response to health concerns. *Applied Geochemistry* **19**, 1177–1188.

Ha S.R. & Pokhrel D. 2001. Water quality management planning zone development by introducing a GIS tool in Kathmandu Valley, Nepal. *Water Science and Technology* **44**, 209–221.

Hickel B. 1973. Phytoplankton in two ponds in Kathmandu Valley, Nepal. *International Revue of Hydrobiology* **58**, 835–842.

Hill B.H., Willingham W.T., Parrish L.P. & McFarland B.H. 2000. Periphyton community responses to elevated metal concentrations in a Rocky Mountain stream. *Hydrobiologia* **428**, 161–169.

Howard A. G., Comber S. D. W., Kifle D., Antai E.E. & Purdie D. A. 1995. Arsenic speciation and seasonal changes in nutrient availability and micro–plankton abundance in Southampton water, U.K. *Estuarine Coastal and Shelf Science* **40**, 435–450.

Jenkins A., Sloan W.T. & Cosby B.J. 1995. Stream chemistry in the Middle Hills and high mountains of the Himalayas, Nepal. *Journal of Hydrology* **166**, 61-79.

Jha P.K. 1992. *Environment and Man in Nepal*. Know Nepal Series No 5. Craftsman Press, Bangkok.

Jones J.R., Knowlton M.F. & Swar D.B. 1989. Limnological reconnaissance of waterbodies in central and southern Nepal. *Hydrobiologia* **184**, 171–189.

Jüttner I., Rothfritz H. & Ormerod S.J. 1996. Diatoms as indicators of river quality in the Nepalese middle hills with consideration of the effects of habitat-specific sampling. *Freshwater Biology* **36**, 101–112.

Jüttner I., Sharma S., Dahal B.M., Ormerod S.J. & Cox E.J. 2003. Diatoms as indicators of stream quality in the Kathmandu Valley and Middle Hills of Nepal and India. *Freshwater Biology* **48**, 2065–2084.

Kelly M.G. & Whitton B.A. 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers. *Journal of Applied Phycology* **7**, 433–444.

Kelly M.G., Cazaubon A., Coring E., Dell'Uomo A., Ector L., Goldsmith B., Guasch H., Hürlimann J., Jarlman A., Kawecka B., Kwandrans J., Laugaste R., Lindstrom E.-A., Leitao M., Marvan P., Padisak J., Pipp E., Prygiel J., Rott E., Sabater S., Van Dam H. & Vizinet J. 1998. Recommendations for the routine sampling of diatoms for water quality assessments in Europe. *Journal of Applied Phycology* **10**, 215–224.

Khatiwada N.R., Takizawa S., Tran T.V.N. & Inoue M. 2002. Groundwater contamination assessment for sustainable water supply in Kathmandu Valley, Nepal. *Water Science and Technology* **46**, 147–154.

Krammer K. 1997. Die cymbelloiden Diatomeen. Eine Monographie der weltweit bekannten Arten. Vol. **1,2**. J. Cramer, Berlin.

Krammer K. & Lange-Bertalot H. 1986–1991. *Bacillariophyceae, Süßwasserflora von Mitteleuropa*, Vol. **2**, Parts 1–4, Ettl H., Gerloff J., Heynig H. & Mollenhauer D. (eds), Gustav Fischer Verlag, Stuttgart.

Lange-Bertalot H. & Krammer K. 1989. Achnanthes. Monographie der Gattung. *Bibliotheca Diatomologica* **18**, J. Cramer, Berlin.

Lecointe C., Coste M. & Prygiel J. 1999. OMNIDA version 3: notice d'utilisation. CLC1 Monbazillac.

Lim D.S.S., Douglas M.S.V. & Smol J.P. 2001a. Diatoms and their relationship to environmental variables from lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. *Hydrobiologia* **450**, 215–230.

Lim D.S.S., Kwan C. & Douglas M.S.V. 2001b. Periphytic diatom assemblages from Bathurst Island, Nunavut, Canadian High Arctic: an examination of community relationships and habitat preferences. *Journal of Phycology* **37**, 379–392.

Lohman K., Jones J.R., Knowlton M.F., Swar D.B., Pamperl M.A. & Brazos B.J. 1988. III. Lakes. 3. Asia: Pre– and postmonsoon limnological characteristics of lakes in the Pokhara and Kathmandu Valleys, Nepal. *Verhandlungen Internationale Vereinigung Limnologie* **23**, 558–565.

Medley C.N. & Clements W.H. 1998. Responses of diatom communities to heavy metals in streams: the influence of longitudinal variation. *Ecological Applications* **8**, 631–644.

Michelutti N., Holtham A.J., Douglas M.S.V. & Smol J.P. 2003. Periphytic diatom assemblages from ultra-oligotrophic and UV transparent lakes and ponds on Victoria Island and comparisons with other diatom surveys in the Canadian Arctic. *Journal of Phycology* **39,** 465–480.

Nakanishi Y., Sumita M., Yumita K., Yamada T. & Honjo T. 2004. Heavy-metal pollution and its state in algae in Kakehashi River and Godani River at the foot of Ogoya Mine, Ishikawa Prefecture. *Analytical Sciences* **20**, 73–78.

O'Connell J.M., Reavie E.D. & Smol J.P. 1997. Assessment of water quality using epiphytic diatom assemblages on Cladophora from the St. Lawrence River (Canada). *Diatom Research* **12**, 55–70.

Ormerod S.J., Rundle S.D., Wilkinson S.M., Daly G.P., Dale K.M. & Jüttner I. 1994. Altitudinal trends in the diatoms, bryophytes, macroinvertebrates and fish of a Nepalese river system. *Freshwater Biology* **32**, 309–322.

Passy S.I., PanY. & Lowe R.L. 1999. Ecology of the major periphytic diatom communities from the Mesta River, Bulgaria. *International Revue of Hydrobiology* **84**, 129–174.

Pechar L. 2000. Impacts of long-term changes in fishery management on the trophic level water quality in Czech fish ponds. *Fisheries Management and Ecology* **7**, 23–31.

Poulíčková A., Duchoslav M. & Dokulil M. 2004. Littoral diatom assemblages as bioindicators of lake trophic status: A case study from perialpine lakes in Austria. *European Journal of Phycology* **39**, 143–152.

Rai A.K. 2000. Limnological characteristics of subtropical Lakes Phewa, Begna, and Rupa in Pokhara Valley, Nepal. *Limnology* **1**, 33–46.

Razo I., Carrizales L., Castro J., Diaz-Barriga F. & Monroy M. 2004. Arsenic and heavymetal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. *Water Air Soil Pollution* **152**, 129–152.

Reichardt E. 1999. Zur Revision der Gattung *Gomphonema*. Die Arten um *G.affine*/*insigne*, G. *angustum*/*micropus*, G. *accuminatum* sowie gomphonemoide Diatomeen aus dem Oberoligozän in Böhmen. In: *Iconographia Diatomologica* **8**, Lange-Bertalot H. (ed.), A.R.G. Gantner, Rugell.

Riedel G.F., Sanders J.G. & Breitburg D.L. 2003. Seasonal variability in response of estuarine phytoplankton communities to stress: linkages between toxic trace elements and nutrient enrichment. *Estuaries* **26**, 323–338.

Roberts D., McMinn A., Johnston N., Gore D.B., Melles M. & Cremer H. 2001. An analysis of the limnology and sedimentary diatom flora of fourteen lakes and ponds from the Windmill Islands, East Antarctica. *Antarctartic Science* **13**, 410–419.

Rothfritz H., Jüttner I., Suren A.M. & Ormerod S.J. 1997. Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity and water quality. *Archive for Hydrobiology* **138**, 465–482

Round F.E. & Bukhtiyarova L. 1996. Four new genera based on *Achnanthes* (*Achnanthidium*) together with a re-definition of *Achnanthidium*. *Diatom Research* **11**, 345–361.

Ruan H.D. & Gilkes R.J. 2000. Phosphorus accumulation in farm ponds and dams in southwestern Australia. *Journal of Environmental Quality* **29**, 1875–1881.

Rushforth S.R., Brotherson J.D., Fungladda N. & Evenson W.E. 1981. The effects of dissolved heavy metals on attached diatoms in the Uintah Basin of Utah, U.S.A.. *Hydrobiologia* **83**, 313–323.

Sharma S. & Moog O. 1996. The applicability of biotic indices and scores in water quality assessment of Nepalese rivers. In: *Ecohydrology of High Mountain Areas*. Proceedings of the International Conference on Ecohydrology of High Mountain Areas. Chalise S.R. *et al*. (eds.), pp. 641–657. ICIMOD, UNESCO, Kathmandu, Nepal,

Shrestha H.D. 2003. Heavy metals pollution in the environment of Kathmandu. *Journal de Physique IV* **107**, 1239–1246.

Shrestha R.R., Shrestha M.P., Upadhyay N.P., Pradhan R., Khadka R., Maskey A., Maharjan M., Tuladhar S., Dahal B.M. & Shrestha K. 2003. Ground water arsenic contamination, its health impact and mitigation program in Nepal. *Journal of Environmental Science and Health Part A* **A38**, 185–200.

Simkhada B., Jüttner I. & Chimonides P.J. Diatoms in lowland ponds of Koshi Tappu, Eastern Nepal – relationships with chemical and habitat characteristics. *International Revue of Hydrobiology*, in press.

Soininen J. & Eloranta P. 2004. Seasonal persistence and stability of diatom communities in rivers: are there habitat specific differences? *European Journal of Phycology* **39,** 1–8.

Thapa G.B. & Weber K.E. 1995. Status and management of watersheds in the upper Pokhara Valley, Nepal. *Environmental Management* **19**, 497–513.

Van Dam H. & Buskens R.F.M. 1993. Ecology and management of moorland pools – balancing acidification and eutrophication. *Hydrobiologia* **265**, 225–263.

Williams D.M. & Round F.E. 1987. Revision of the genus *Fragilaria*. *Diatom Research* **2**, 267–288.

3. Diatoms in lowland ponds of Koshi Tappu, Eastern Nepal – relationships with chemical and habitat characteristics

3.1 Abstract

Epiphytic and epipelic diatom assemblages were studied in relation to water chemistry and habitat character in lowland ponds of Koshi Tappu, Nepal. Epiphytic assemblages from different microhabitats, such as morphologically different plants, roots, stems, filamentous algae and decomposing leaves within the same ponds were similar. Assemblage composition of epiphytic diatoms reflected gradients in water chemistry and habitat character of the pond with respect to pond vegetation and substratum type, bank profile and land use in the catchment. Epiphytic and epipelic assemblages responded to chemical gradients in the surface water particularly concentrations of Ca, Mg and Na, but epipelic diatoms also indicated differences in SO_4 concentration. Epipelic diatoms were also sensitive to interstitial water chemistry variations in PO_4, Si, Ca and Mg. There were no relationships between species richness, diversity or evenness and gradients in water chemistry and habitat character.

3.2 Introduction

Epiphytic and epipelic diatoms are important and diverse components of aquatic biodiversity in shallow freshwater ecosystems such as ponds and small lakes (Douglas & Smol 1993, Jones 1996, Gaiser & Johansen 2000, Flower 2005). They are good indicators of chemical and physical conditions and respond to a variety of factors such as nutrient enrichment (Kawecka *et al*. 1998, Lim *et al*. 2001a, b), salinity (Roberts *et al*. 2001), acid-base status and alkalinity (Haworth & Atkinson 1988, Douglas & Smol 1993, Douglas & Smol 1995), hydrological conditions such as water level fluctuations, hydroperiod and drought (Gaiser *et al*. 1998) and habitat character (Douglas & Smol 1993, Michelutti *et al*. 2003). Although diatoms have been widely used to monitor water quality in running water and lakes (Stevenson & Pan 1999, Hall & Smol 1999), fewer studies have investigated their application to indicate environmental change in small water bodies such as ponds. In Europe pond diatoms were used to assess recent changes in environmental conditions. In coastal dune pools in Belgium, eutrophication led to changes in assemblages consisting of species tolerant of high nutrient concentrations, and acidification of isolated moorland pools in Belgium and The Netherlands resulted in very low biological diversity and the dominance of one acid-tolerant diatom species (Denys & van Straaten 1992, van Dam & Buskens 1993, Denys 2003). For English lowland ponds a transfer function was established to infer past changes in phosphorus concentrations from sediment records and the problems which arise from using diatoms from shallow water bodies to develop diatom-nutrient training sets (Bennion 1994, 1995) are discussed. In Asia there have been studies of the diatom flora in ponds from Japan (Kobayasi & Ando 1975, 1977), India (Ghandi 1960, 1962, Rao 1977), Malaysia (Douglas *et al*. 1998), Indonesia and the Philippines (Hustedt 1937-39, 1942).

In Nepal diatoms have been used in streams to study relationships between environmental conditions and biodiversity (Ormerod *et al.* 1994, Rothfritz *et al*. 1997) and to monitor pollution (Jüttner *et al.* 1996, 2003). However, there have been few investigations of lakes and ponds in this region. These latter include studies of water chemistry in the Middle Hills and lowlands (Jones *et al*. 1989; Sah 1997), phytoplankton of ponds in the Pokhara and Kathmandu Valleys (Hickel 1973, Lohman *et al.* 1988), the limnology of high altitude lakes in the Himalaya (Aizaki *et al*. 1987, Lami & Giussani 1998) and one study on periphytic diatoms in ponds of the Kathmandu Valley (Simkhada & Jüttner 2006). Other studies on the Indian subcontinent have often focused on economically important algae groups such as cyanobacteria from rice fields (Anand & Hopper 1987, Sahu *et al*. 1992). Developing biological indicators to monitor environmental change in standing waters of Nepal would be timely, since these ecosystems are threatened by pollution and many have been degraded as a result of expanding settlements and intensification of agriculture (Jha 1992, Thapa & Weber 1995).

The Koshi Tappu Wildlife Reserve is one of five protected areas in the lowlands of Nepal and has a range of freshwater ecosystems including the main Kosi river with numerous side channels, streams, ditches, oxbow lakes, marshes and ponds. While natural ponds are mainly located within the reserve, there are many artificial ponds in adjacent agricultural areas. Some of the latter have economic value for local people and are used as fish ponds, while others are unused and provide valuable habitat for aquatic flora and fauna. Unauthorised practice of expansion of agricultural land to grow crops and extension of cattle grazing into the reserve area has increasing impact on wildlife and its habitats. Therefore effective measures are needed to manage land use more effectively and prevent further deterioration. Diatoms have been used successfully to monitor impacts from agriculture, including changes in chemistry and habitat character (Leland 1995, Carpenter & Waite 2000), and might also provide powerful indicators to investigate environmental changes affecting freshwater ecosystems in this area.

To evaluate whether diatom-based methods could be useful for pond monitoring to assess anthropogenic impacts, diatoms were studied from 64 ponds inside the Koshi Tappu Wildlife Reserve and in adjacent agricultural areas covering a wide range of environmental conditions. This is the first study on diatoms in the Nepalese lowlands. The main aims of the study were to investigate (i) diatom diversity of epiphytic and epipelic diatoms, (ii) the relationships between epiphytic diatoms to water chemistry and habitat character of the ponds, bank type and land use, (iii) relationships between epiphytic and epipelic diatoms, and chemical gradients in surface and interstitial water and (iv) diatom assemblage composition in different epiphytic microhabitats.

3.3 Materials and methods

3.3.1 Study site

Koshi Tappu is located in the Saptari and Sunsari districts of eastern Nepal extending northwards from the Indian/Nepalese border between 26º38.882 - 26º39.742 N and 87º03.203 - 87º03.983 E and lies at an elevation of 70 – 120 m a.s.l. (Fig 1). The climate is subtropical with the highest temperatures occurring during the dry season between March and May. The monsoon starts in late May to early June and the highest rainfall normally occurs during July. The natural vegetation consists mainly of riverine deciduous forests with *Acacia catechu* Wight & Arn, *Dalbergia sissoo* Roxb., *Bombax ceiba* L., and *Trewia nudiflora* L., and of grassland with *Saccharum spontaneum* L., *S. arundinaceum* Retz., *Phragmites karka* (Retz.) Trin. ex Steud., *Typha elephantine* Thwaites and *Imperata cylindrica* P. Beauv.

The Koshi Tappu Wildlife Reserve was established as a protected area in 1976 and declared a Ramsar site in 1987 to conserve habitat for a number of endangered species including the water buffalo (*Bubalus arnee*), the Gharial (*Gavialis gangeticus* Gmelin) and the Gangetic dolphin (*Platanista gangetica* Roxburgh, Sah 1997). Koshi Tappu is also designated as an Important Bird Area with 486 out of 862 bird species of Nepal recorded in the area (Baral pers. communication). The reserve extends over 175 km^2 in the flood plain of the Sapta Kosi River, one of the main tributaries of the Ganges, including a 24 km long section of the river. The study area included parts of the reserve and adjacent agricultural areas on the eastern side of the Kosi River.

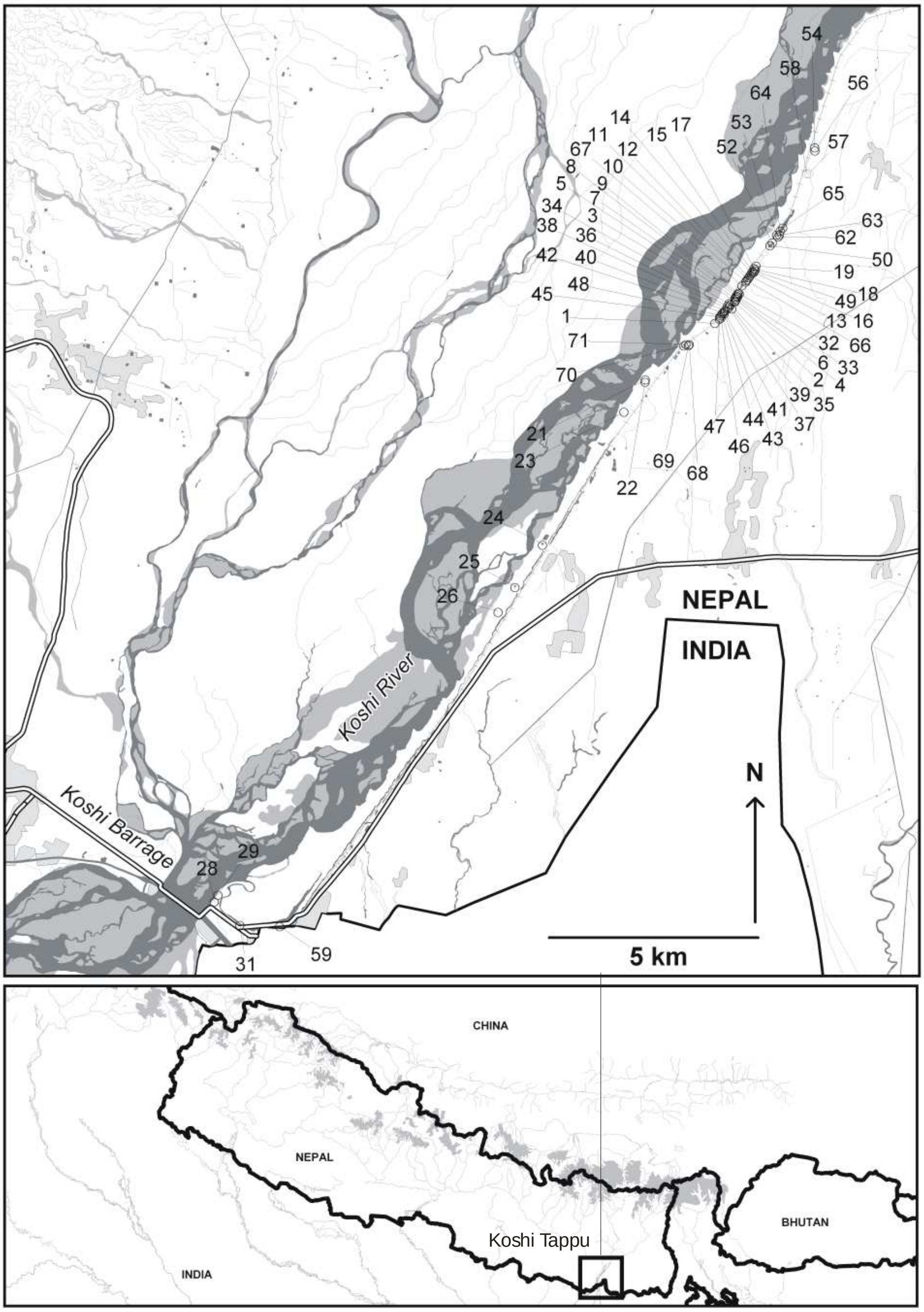


Fig. 3.1 Location of the sixty four study sites in the Koshi Tappu area, lowland of eastern Nepal.

3.3.2 Field investigations and laboratory procedures

During the dry postmonsoon season of November 2002, sixty four ponds of the Koshi Tappu area were surveyed to investigate epiphytic and epipelic diatom assemblages, habitat character and water chemistry.

Precipitation during the postmonsoon season is < 50mm/month (Donner 1994) and water levels are low. Longitude, latitude and altitude were measured using a GPS meter (Garmin GPS 12 XL). A habitat survey recording 46 variables was conducted to describe pond character, the bank and surrounding land use. Measured variables included pond size, width of the riparian zone (highest to the lowest water level based on the presence/absence of certain types of vegetation), bank height, substrate composition of the pond littoral (1-5 m from the lowest water level towards the centre of the pond), riparian zone and bank, pond vegetation types (emergent herbs, reeds, sedges, rooted floating leaves, free floating plants, submerged plants, filamentous algae), bank vegetation (grass, herbs, scrub, trees), tree cover of the banks and shade, tree associated features (overhanging boughs, woody debris), shade, bank character including natural (vertical, steep, composite, gentle) and artificial (embanked) profile, artificial features on the bank (path, weir, dam), land use within 100 m of the sampling site and land use in the wider catchment. Substrate composition and bank vegetation were recorded as percentage cover. Pond vegetation types, tree-associated features, shade, bank profile, artificial features on the bank and land use were recorded in three categories 0 = absent, 1 = < 30% present, 2 > 30% present. The presence of trees was recorded on a scale from 0 - 0 with six categories (none [0], isolated/scattered [1,2], regularly spaced/single [3,4], occasional clumps [5,6], semi-continuous [7,8], continuous [9,10]) with each category either present (< 30% along the bank) or extensive (> 30% along the bank).

Temperature, conductivity and pH were measured on site using a portable meter (WTW pH/ Cond 340i, Weilheim, Germany). Surface water samples (2 x 30 ml) were filtered on site (0.45 µm, cellulose-nitrate filters, Millipore, Watford, England). Interstitial water (2 x 30 ml) was extracted from wet sediment. The sediment was placed in a Buchner funnel containing a filter (Whatman filters No. 1, Maidstone, England), positioned on a conical flask which was connected to a hand pump. Water was extracted from the sediment by operating the hand pump to generate low pressure in the flask. Water samples were stored at c. 20 ˚C and samples for cation analysis were acidified with 1 ml nitric acid on site. Fe, Mn, Al were analysed by inductively-coupled plasma optical emission spectrometry (ICP-OES), and Sr, Ba, Ni, Cu, Zn, Si, Pb, and As were analysed by inductively-coupled plasma mass spectrometry (ICP-MS), while Na, K, Mg, Ca, F, Cl, NO_3, PO_4, and SO_4 were analysed by ion chromatography (Department of Mineralogy, Natural History Museum, London).

Epiphytic diatoms were collected from macrophytes in 64 ponds. Leaves, stems and roots of free floating plants were taken from a variety of different species along the pond margins (c. 0.5 - 1.5 m from the water line) using a plant cutter and combined in one sample per pond. In eight ponds, separate samples from different microhabitats and morphologically different plant species were collected. They included *Elodea* sp. and other plants with a similar growth form, broad leaved submerged plants, fine leaved submerged plants, *Lemna*, roots of free-floating plants, stems, filamentous algae and decomposing floating leaves. In 41 of the 64 ponds sediment was accessible from the pond margin and epipelic diatoms were also collected. Sediment was obtained by sliding a cylindrical polyethylene tube across the surface to remove the top centimetre. Part of the sediment sample was used to extract live diatoms using lens tissue by exposing the sample to indirect sunlight for four hours (Eaton & Moss 1966). However, lens tissue samples contained very few diatoms and were therefore not analysed further. Collected diatom samples were preserved in c. 4 % formalin.

Diatom samples were processed following standard procedures (hot H_2O_2 oxidation, Naphrax as mountant). Macrophyte and sediment samples were digested whole. A minimum of 500 diatom valves per sample were counted (1000x, DIC, Nikon E600). Where possible, taxa were identified to species or subspecies level using Krammer & Lange-Bertalot (1986 - 1991), Lange-Bertalot & Krammer (1989), Krammer (1997) and Reichardt (1999). For some nomenclature revisions we followed Williams & Round (1987) and Round & Bukhtiyarova (1996). Slides have been deposited at the National Museum Wales, Cardiff.

3.3.3 Data analysis

Diatom diversity H' (Shannon diversity index) and evenness E were calculated (Shannon and Weaver 1949). Species richness S was calculated based on the lowest number of valves counted in any one sample using rarefaction (PRIMER 6). Relationships between S, H', E, water chemistry and habitat character were investigated by regression analysis. To investigate variations in assemblage composition between different microhabitats within the same pond, a detrended correspondence analysis (DCA, CANOCO 4.5) and a cluster analysis (group mean agglomerative method, Bray-Curtis similarity coefficient) were performed. Species data were square-root transformed prior to ordination and classification.

To relate diatom assemblage composition to environmental gradients of chemical and habitat character in 64 ponds a canonical correspondence analysis with forward selection of environmental variables (CCA, CANOCO 4.5) was performed. Prior to CCA the dimensionality of the original data matrix of water chemistry and habitat character variables were reduced by principal component analysis (PCA, CANOCO 4.5) to derive major chemical and habitat gradients. Chemical variables apart from pH were log transformed prior to PCA ordination. For habitat variables, dimensions (e.g. bank height) were log transformed, proportions (e.g. % substrate type) were arcsine transformed and categorical values were not transformed prior to ordination. For habitat character, three different PCAs were performed to describe habitat change in the pond (Pond PCA), of the banks (Bank PCA) and of the surrounding land use (Land use PCA). For the Pond PCA, variables used included width of the riparian zone, substratum composition of the pond littoral and riparian zone, and pond vegetation. For the Bank PCA, bank height, substratum composition of the bank, bank profile, bank vegetation, trees and associated features along the bank were used. Variables for the Land use PCA included land use within 100 m of the pond, in the wider catchment and artificial features on the bank. Water chemistry and habitat principal component axis 1 and 2 scores were subsequently used as environmental variables in the CCA.

To relate changes in assemblage composition to chemical gradients in the surface and interstitial water of 41 ponds, three CCAs with forward selection of environmental variables were performed which were CCA between (i) between epiphytic diatoms and surface water chemistry, (ii) epipelic diatoms and surface water chemistry, and (iii) epipelic diatoms and interstitial water chemistry. Concentrations of cations and anions were used as environmental variables. Conductivity and pH were not included in the CCA, because they were only measured in the surface water.

3.4 Results

3.4.1 Epiphytic diatom assemblages in 64 ponds

3.4.1.1 Habitat character and water chemistry

Habitat character between ponds varied. Ponds within the reserve had extensive growth of emergent herbs with tall grass, scrub or broad leaved mixed forest on the banks and in the catchments. Former fish ponds in the vicinity of the agricultural areas often had managed banks with cleared tall grass and shrubs, but had abundant aquatic macrophytes. In contrast, currently used fish ponds were managed by the removal of vegetation from the banks and the pond. Leaves and other plant remains were the dominant substrates in reserve and former fish ponds while silt was most common in fish ponds. The most abundant pond vegetation were emergent herbs, but reeds, rooted and free floating leaves, and submerged plants were also abundant and filamentous algae were present in most ponds. Bank vegetation was dominated by grass. Though shrubs and trees were regularly present they often covered less than 30% of the bank. Rough grassland, scrub and forest was the most common in the catchments of reserve ponds, whereas agricultural fields and pasture were widespread surrounding the former and currently used fish ponds.

Ordination of variables describing pond habitat character (Pond PCA) explained 51.3 % of the total variance along axis 1 and 2 (Table 1). Axis 1 represented a change in substrate composition with a decrease of silt in the littoral and riparian zone, and an increase in leaves and plant remains as well as submerged plants in the littoral, while axis 2 represented a gradient of decreasing sand in the littoral and riparian zone. Bank PCA axes 1 and 2 represented 38.0 % of the variance and gradients from embankments to gentle banks (axis 1), and shaded banks with trees to unshaded banks (axis 2). Land use PCA

Table 1. Pond water chemistry and habitat principal components reflecting major environmental gradients in 64 ponds of Koshi Tappu.

	Chemistry PCA		Pond PCA		Bank PCA		Land use PCA	
Principal components	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
% Variance	40.3	9.9	34.8	16.5	20.8	17.2	28.2	20.3
Significant positive correlation	Conductivity (0.356) Ca (0.343) Sr (0.330) Mg (0.313)	PO_4 (0.558) Mn (0.535)	Substrate littoral and riparian zone: leaves, plant remains (0.419, 0.401) Littoral submerged plants (0.385)		Gentle bank (0.364)		Agriculture (0.413) Weir, dam (0.397) Village (0.380)	Agriculture (0.352)
Significant negative correlation		pH (-0.432)	Substrate littoral and riparian zone: silt (-0.411, -0.400)	Substrate littoral and riparian zone: sand (-0.615, -0.601)	Embankment (-0.346)	Trees (-0.420) Shade (-0.390)	Rough grassland (-0.338)	Broad leaved forest (-0.470) Scrub (-0.448) Pasture (-0.333)

axis 1 and 2 explained 48.5% of the variance and represented gradients from rough grassland to agricultural fields and villages (axis 1), and from broad leaved forest, scrub and pasture to agriculture (axis 2).

Daytime water temperatures in November ranged from 20.6 - 27.7 °C (median 24.9). Water chemistry differed substantially between the ponds (Table 2). Ordination revealed major trends in chemical character with axis 1 and 2 explaining 50.2% of the total variance. Axis 1 represented an increase in conductivity and concentrations of Ca, Sr and Mg, while axis 2 reflected an increase in PO_4 and Mn, and a decrease in pH (Table 1). There were significant relationships between Chemistry PC1 and Pond PC1 ($F_{(1,63)}$ 15.2, $p < 0.001$, r^2 0.20), with higher conductivity, Ca, Sr and Mg in ponds aligning with a high percentage of silt in the riparian zone and the littoral. Chemistry PC1 was also significantly related to Bank PC1 ($F_{(1,63)}$ 24.1, $p < 0.001$, r^2 0.28) and Land use PC1 ($F_{(1,63)}$ 77.3, $p < 0.001$, r^2 0.55). Conductivity, Ca, Sr and Mg were higher in embanked ponds close to agricultural fields and villages. There were no relationships between Chemistry PC2 and any gradients in habitat character.

3.4.1.2 Diversity of epiphytic diatom assemblages

Twenty-two diatom genera comprising 87 species were found in 64 epiphytic assemblages, with 72 species occurring at ≥ 1 % relative abundances in at least one sample. Species richness varied between 3 and 27 (median 15). Diversity H’ and evenness were low and varied between 0.17 – 1.27 (median 0.94) and 0.17 – 0.91 (median 0.68). The most species-rich genera were *Gomphonema* (15), *Navicula* (15) and *Nitzschia* (14). Fewer species belonged to the achnanthoid diatoms (7), *Eunotia* (6), C*raticula* (4), *Epithemia* (3) and *Pinnularia* (3). The most common and abundant species (often > 20%) included

Table 2. Surface and interstitial water chemistry and habitat character of ponds of the Koshi Tappu area, Eastern Nepal, November, 2002.

	Surface water			Interstitial water				Habitat character		
	Median	Mean	Range	Median	Mean	Range		Median	Mean	Range
Temperature	24.7	24.8	20.6-27.7				Altitude (m a.s.l.)	90	88	73-102
pH	7.9	8.1	7.0-10.1				Pond area (m^3)	1500	6537	136-200000
Conductivity	259	249	74-382				Bank height (m)	1	1.5	0.5-7
Na	3.6	3.5	1.5-6.1	5.1	5.2	3.2-7.6	Width riparian zone (m)	1.5	1.9	0.5-5
K	5.9	6.0	0.8-12.7	7.7	7.9	1.4-12.7	Substrate composition %			
Mg	7.1	7.6	2.5-17.1	7.9	8.6	3.8-15.2	Littoral			
Ca	35.8	34.6	8.6-57.1	43.9	43.7	17.3-70.3	Sand	0	7	0-80
Sr	0.07	0.07	0.02-0.15	0.08	0.08	0.05-0.17	Silt	50	51	0-100
Ba	0.03	0.03	0.00-0.05	0.13	0.15	0.03-0.81	Leaves, plant remains	40	42	0-100
Si	2.0	2.3	0.1-6.5	4.9	5.2	2.0-11.0	Riparian zone			
F	0.11	0.11	0.05-0.22	0.11	0.11	0.05-0.21	Sand	0	5	0-60
Cl	0.5	0.6	0.0-1.9	1.3	1.4	0.4-3.1	Silt	30	39	0-98
NO_3	0.12	0.29	<0.01-0.85	0.03	0.23	<0.05-3.00	Leaves, plant remains	60	56	0-100
PO_4	0.01	0.02	<0.01-0.10	0.22	0.30	0.04-0.85	Bank			
SO_4	10.2	12.9	1.7-40.0	7.2	8.5	2.6-23.4	Silt	20	20	0-50
Al	0.02	0.02	<0.01-0.05	0.18	0.27	0.03-1.43	Leaves, plants	80	77	10-100
Mn	0.03	0.07	<0.01-0.54	1.67	2.11	0.04-7.93	Bank vegetation %			
Fe	0.05	0.06	<0.01-0.14	1.51	1.55	0.09-5.52	Bare	0	8	0-70
Zn	0.01	0.01	<0.01-0.01	0.02	0.04	<0.01-0.43	Short grass	20	28	0-80
							Tall grass, herbs	30	36	0-100
Concentrations in mg l^{-1}							Scrub	10	12	0-90
							Trees	10	15	0-45

Achnanthidium minutissimum (Kützing) Czarnecki, *Gomphonema* cf. *affine* Kützing, *Gomphonema parvulum* Kützing, *Navicula* cf. *minima* Grunow, *Nitzschia amphibia* Grunow, *Nitzschia* cf. *incognita* Krasske and *Synedra ulna* var. *acus* Ehrenberg.

Assemblages from epiphytic microhabitats such as morphologically different macrophyte, particular vegetative parts of the submerged or freefloating plants or from other microhabitats such as filamentous algae or decomposing leaves within the same ponds were similar. DCA ordination and cluster analysis grouped assemblages from the same ponds but not from the same microhabitat (Fig. 2). Species richness S, diversity H' and evenness E varied from 19 – 25, 0.53 - 1.02 and 0.41 – 0.75, respectively, with lowest values for assemblages on filamentous algae, but differences were not significant.

3.4.1.3 Relationships with habitat and chemistry characteristics

There were no relationships between species richness S, diversity H', evenness E and environmental gradients. However, canonical correspondence analysis revealed significant relationships between diatom assemblage composition and changes in water chemistry and habitat character (Table 3, Fig. 3) with the first two axes explaining 37.0 % and 19.0 % of the variance. Significant environmental gradients included water chemistry PC 1 and PC 2, Land use PC1, pond size, Pond PC1 and Land use PC2 (Fig. 3a). The most abundant diatom species at sites with high conductivity, Ca, Sr and Mg, and in ponds surrounded by agricultural land and close to villages included *Nitzschia amphibia*, *S. ulna* v. *acus*. *G*. cf. *affine* and *Navicula* cf. *minima* (Fig. 3b). Species, which were common but less abundant to these sites included *Gomphonema angustatum* (Kützing) Rabenhorst, *Achnanthes hungarica* (Grunow) Grunow and Gomphonema augur Ehrenberg. At the opposite end of these gradients *A. minutissimum* was the most abundant species and *Navicula*

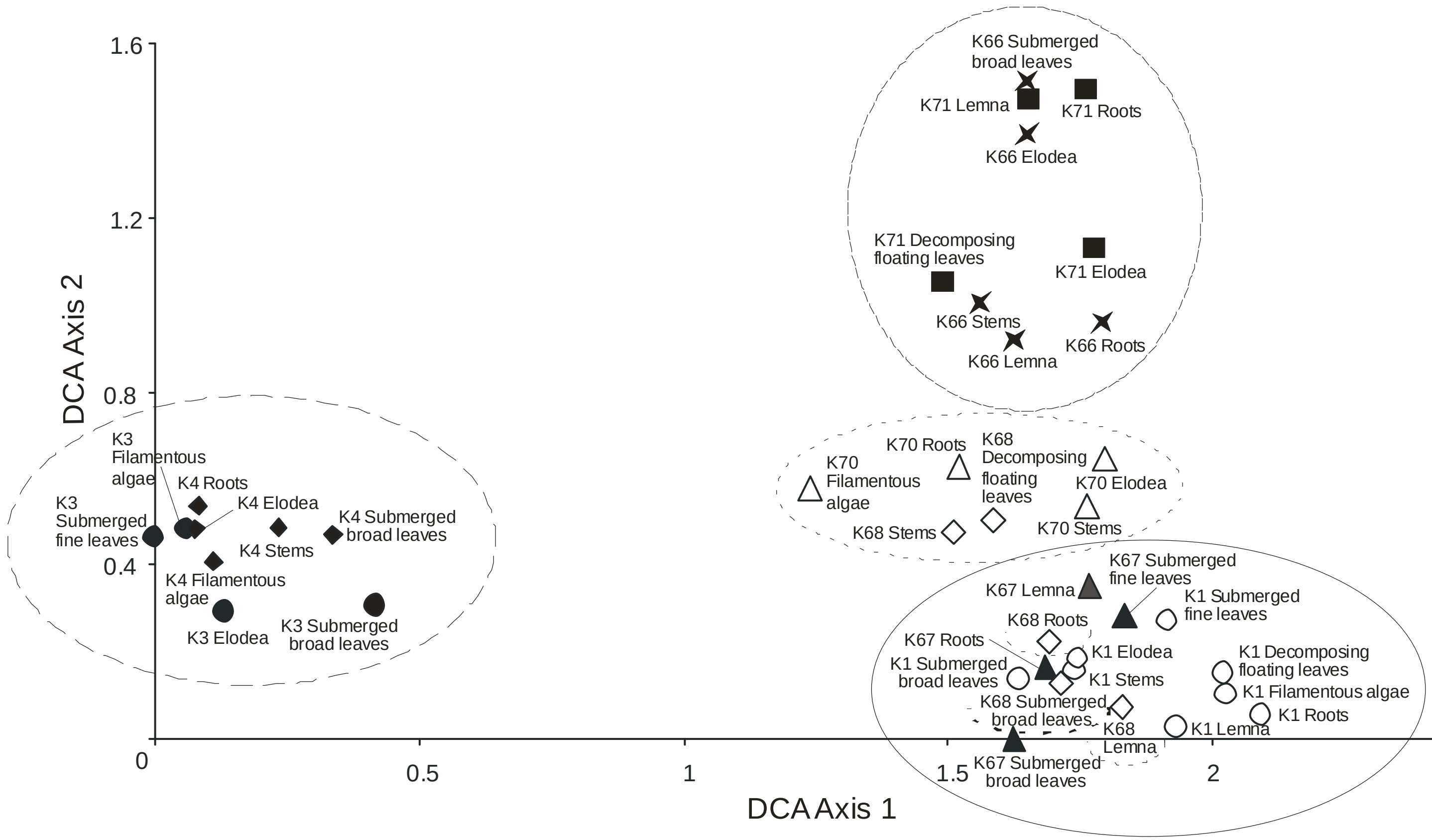


Fig. 3.2 Detrended correspondence analysis (DCA) of diatom assemblages from different epiphytic microhabitats

- in 8 ponds in the Koshi Tappu area, identical symbols indicate assemblages from different epiphytic microhabitats in the same pond.

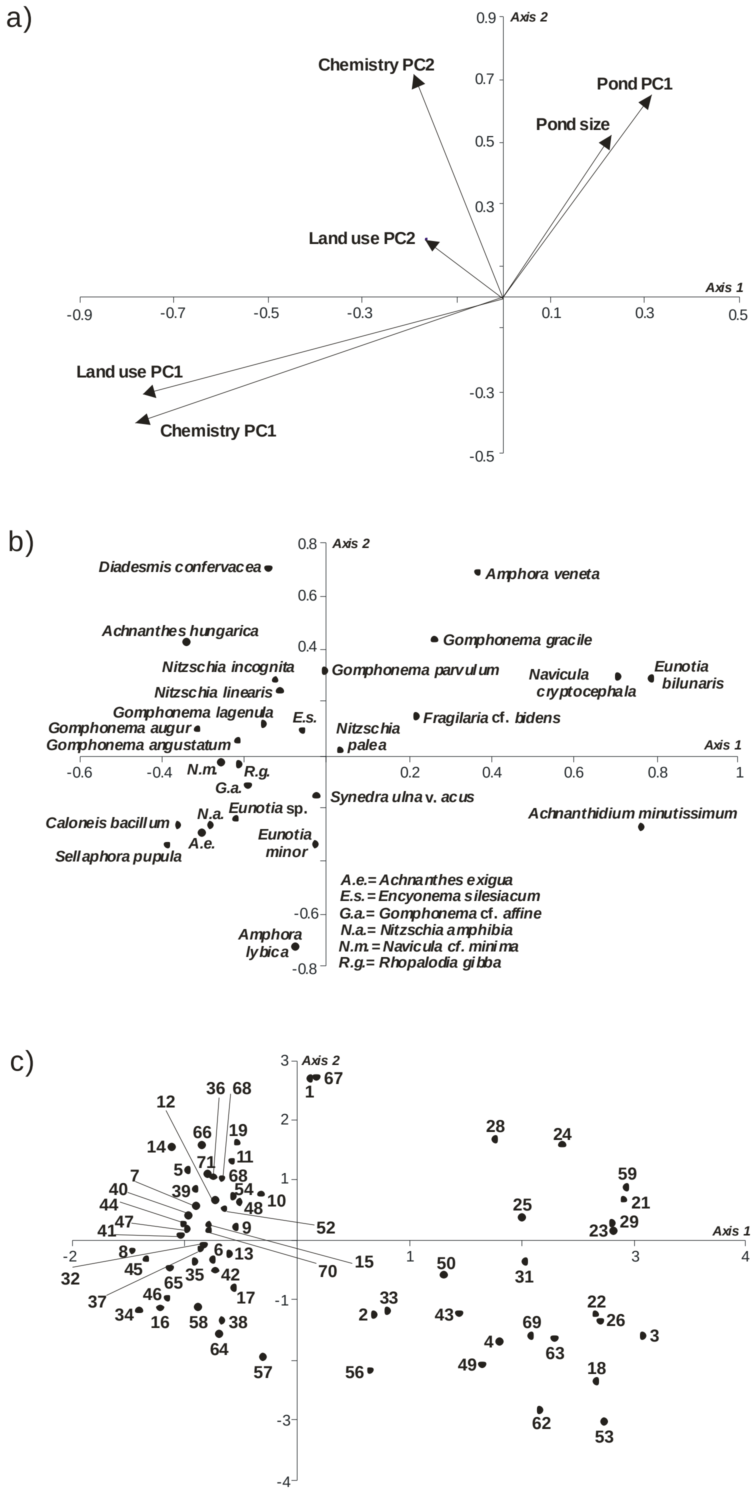


Fig. 3.3 Canonical correspondence analysis (CCA) of epiphytic diatom assemblages from 64 ponds in the Koshi Tappu area, eastern Nepal: (a) environmental gradients significantly correlated with assemblage change, (b) species ordination, (c) assemblages ordination.

cryptocephala Kützing was also common. Characteristic species in larger ponds with abundant submerged macrophytes and substrate consisting of leaves and plant remains were *Gomphonema parvulum*, *Nitzschia*. cf. *incognita* and *Encyonema silesiacum* (Bleisch in Rabenhorst) D.G. Mann. Similarly, *Diadesmis confervacea* Kützing, *Achnanthes*. *hungarica*, *Nitzschia* cf. *incognita* and *Gomphonema parvulum* were characteristic in ponds with higher PO4 and Mn concentrations.

Table 3. Summary of canonical correspondence analysis (CCA) of epiphytic diatom assemblages from 64 ponds in the Koshi Tappu area.

Axes	1	2	3	4	
Eigenvalues	0.143	0.073	0.051	0.032	
Species-environment correlations	0.748	0.828	0.794	0.761	
Cumulative percentage variance					
Of species data	8.9	13.4	16.5	18.5	
Of species-environment relation	37.0	56.0	69.2	77.5	
Sum of all eigenvalues					1.616
Sum of all canonical eigenvalues					0.386
Forward selection of environmental variables	Lambda A	p	F		
Significant variables					
Water chemistry PC1	0.10	0.002	4.21		
Water chemistry PC2	0.07	0.002	2.65		
Land use PC1	0.04	0.010	1.86		
Pond size	0.04	0.004	1.91		
Pond PC1	0.04	0.018	1.58		
Land use PC2	0.03	0.048	1.47		

3.4.2 Epiphytic and epipelic diatom assemblages in 41 ponds

3.4.2.1 Diversity of epiphytic and epipelic diatom assemblages

Species richness S and diversity H' were significantly higher in epipelic than in epiphytic diatom assemblages, but there was no significant difference between evenness E (Table 4).

In the epipelic assemblages 29 genera and 94 species observed, with species richness varying between 7 - 32 (median = 19), and diversity and evenness 0.34 – 1.25, and 0.30 – 0.91 respectively. In epiphytic assemblages, 22 genera and 75 species were observed. Species richness varied between 3 - 27 (median = 16), diversity and evenness between 0.17 – 1.25 and 0.17 – 0.91 respectively. The most speciesrich genera were *Navicula*, *Gomphonema* and *Nitzschia*. More *Navicula* species were epipelic (20) than epiphytic (12), while fewer *Gomphonema* (10, 13) and *Nitzschia* (9, 11) species occurred in the sediment than on macrophytes. Fewer epipelic and epiphytic species belonged to the achnanthoid diatoms (6, 7), *Eunotia* (6, 5), *Pinnularia* (5, 3), *Craticula* (4, 4) and *Sellaphora* (4, 2).

Table 4. Species richness (S), diversity (H'), and evenness (E) of epiphytic and epipelic diatom assemblages in 41 ponds of the Koshi Tappu area, Eastern Nepal, November 2002.

	Epiphytic diatoms (mean ± SD)	Epipelic diatoms (mean ± SD)	ANOVA
Species richness S	15.4 ± 5.4	19.5 ± 4.8	$F_{(1,80)}$ 13.3 $p < 0.001$
Diversity H'	0.87 ± 0.30	0.99 ± 0.18	$F_{(1,80)}$ 4.6 $p < 0.05$
Evenness E	0.65 ± 0.20	0.71 ± 0.11	n.s.

Though many species occurred frequently in both substrates, DCA ordination revealed that assemblages on macrophytes and on the sediment were often distinct (Fig. 4a). Species which were equally common and occurred at similar relative abundances in both habitats included *Nitzschia amphibia*, *Nitzschia palea* (Kützing) W. Smith, *Encyonema silesiacum* and *Caloneis bacillum* (Grunow) Cleve (Fig. 4b). However, a number of other species including *Achnanthidium minutissimum*, *Gomphonema* cf. *affine*, *Nitzschia* cf. *incognita*, *Synedra ulna* var. *acus*, *Gomphonema augur*, *Gomphonema lagenula, Gomphonema parvulum* and *Gomphonema angustatum* were abundant in epiphytic assemblages and species *Sellaphora pupula*, *Achnanthes exigua* and *Diadesmis confervacea* were common and more abundant in epipelic assemblages.

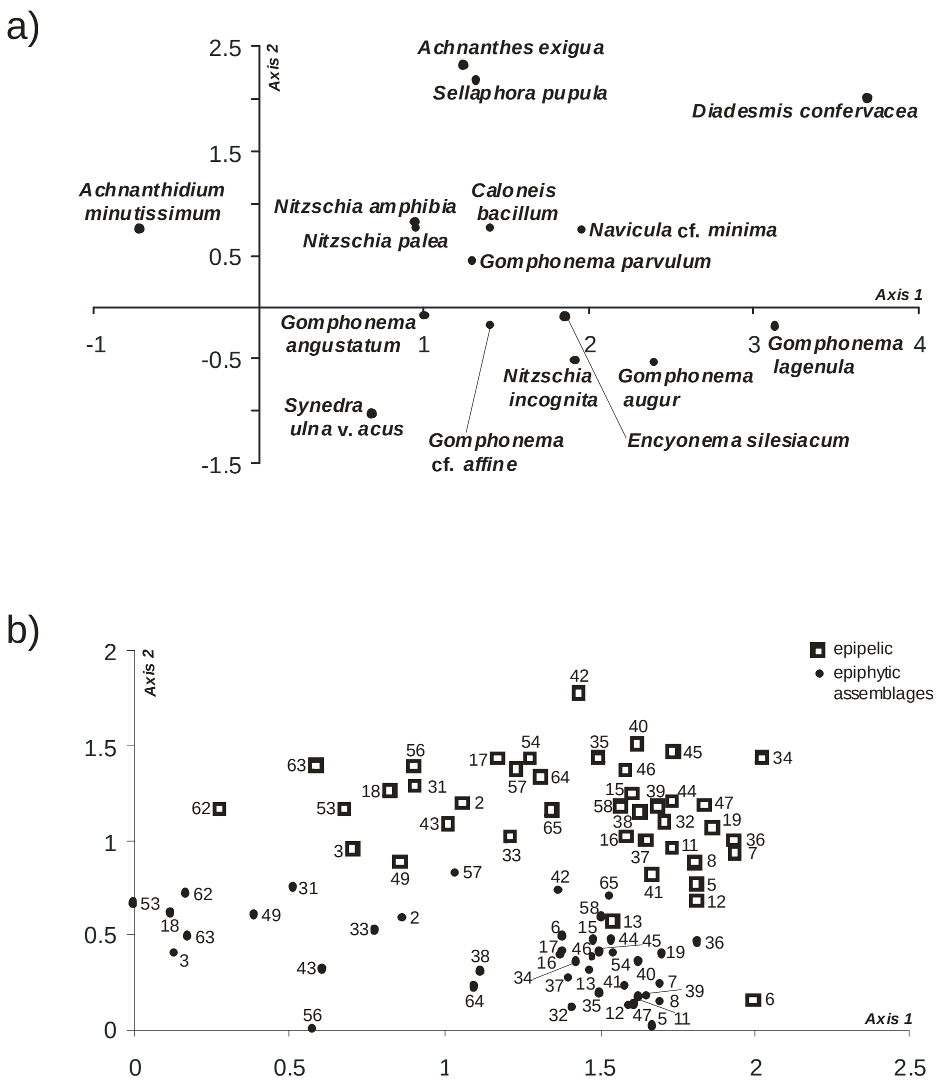


Fig. 3.4 DCA of epiphytic and epipelic diatoms from 41 ponds in the Koshi Tappu area - (a) species ordination, (b) assemblages ordination.

3.4.2.2 Relationships between epiphytic, epipelic diatom assemblages, surface water and interstitial water chemistry

Chemistry differed between the surface and the interstitial water. In most of the ponds concentrations of Na, K, Ca, Ba, Si, Cl, PO_4, Al, Mn, Fe and Zn were higher in the interstitial water than in the surface water, while SO_4 was higher in the surface water (Table 2). Concentrations of Na, K, Ca, Mg, Sr and F in both water samples were correlated, while concentrations of PO_4, NO_3, SO_4, Si, Ba, Al, Mn, Fe and Zn were unrelated. CCA ordination revealed that chemical gradients in the surface and interstitial water were significantly correlated with distribution of epiphytic and epipelic diatoms. However, some factors influencing both assemblages differed between the surface and the interstitial water (Table 5, Fig. 5). For epiphytic diatoms the first two axes explained 33.5% and 12.1% of the variance and significant variables were concentrations of Ca, Mg, Na and Sr. At higher concentrations of Na *Gomphonema lagenula*, *Nitzschia* cf. *incognita*, *Gomphonema augur* and *Navicula* cf. *minima* were the most abundant species, while *Achnanthidium minutissimum* was the most abundant at lower concentrations (Fig. 5a). At higher concentrations of Ca, Mg and Sr, *G. angustatum*, *G.* cf. *affine*, *N. amphibia* and *S. ulna* v. *acus* were most typical. Epipelic diatom distribution was explained by gradients in both interstitial and surface water chemistry. The variance explained by the CCA axes for the surface and interstitial water were similar with the first axes explaining 22.5% and 23.3%, and the second axes 13.8% and 13.1%, respectively. As with epiphytic assemblages, significant variables for surface water chemistry explaining epipelic diatom distribution were Ca, Mg, Na, and Sr (Fig. 5b). In addition, SO_4 was positively correlated with diatom distribution along axis 2. Of the epipelic diatoms, *D. confervacea* and *S. pupula* seemed to be good indicators of high and *A. minutissimum* of low Na concentrations in the surface water. *A. exigua* was most abundant and *N.* cf. *minima*, *C. bacillum* and *G.* cf. *affine* were common at higher Ca, Mg and Sr concentrations, while *N. palea* and *N. amphibia* indicated higher SO_4 concentrations in the surface water. For interstitial water in addition to Mg, Ca and Sr; concentration of PO_4 and Si were alos significantly correlated with diatom distribution however, in contrast to surface water,

Table 5. Summary of canonical correspondence analysis (CCA) of epiphytic and epipelic diatom assemblages from 41 ponds in the Koshi Tappu area, Eastern Nepal.

CCA epiphytic diatoms / surface water					
Axes	1	2	3	4	
Eigenvalues	0.204	0.074	0.060	0.053	
Species-environment correlations	0.860	0.913	0.905	0.827	
Cumulative percentage variance					
Of species data	13.9	18.9	22.9	26.5	
Of species- environment relation	33.5	45.6	55.3	64.0	
Sum of all eigenvalues					1.476
Sum of all canonical eigenvalues					0.611
Forward selection of environmental variables	Lambda A	p	F		
Significant variables					
Ca	0.07	0.012	2.08		
Mg	0.09	0.002	2.49		
Na	0.07	0.006	2.13		
Sr	0.07	0.004	1.96		
CCA epipelic diatoms / surface water					
Axes	1	2	3	4	
Eigenvalues	0.148	0.091	0.078	0.055	
Species-environment correlations	0.880	0.893	0.862	0.904	
Cumulative percentage variance					
Of species data	9.5	15.3	20.3	23.9	
Of species- environment relation	22.5	36.3	48.2	56.7	
Sum of all eigenvalues					1.558
Sum of all canonical eigenvalues					0.658
Forward selection of environmental variables	Lambda A	p	F		
Significant variables					
Ca	0.07	0.010	1.84		
Mg	0.07	0.004	1.94		
Na	0.07	0.012	1.79		
Sr	0.07	0.006	1.92		
SO_4	0.05	0.024	1.48		
CCA epipelic diatoms / interstitial water					
Axes	1	2	3	4	
Eigenvalues	0.169	0.095	0.074	0.064	
Species-environment correlations	0.908	0.889	0.862	0.836	
Cumulative percentage variance					
Of species data	10.9	17.0	21.7	25.8	
Of species- environment relation	23.3	36.4	46.6	55.5	
Sum of all eigenvalues					1.558
Sum of all canonical eigenvalues					0.726
Forward selection of environmental variables	Lambda A	p	F		
Significant variables					
PO_4	0.08	0.002	2.25		
Mg	0.09	0.002	2.20		
Si	0.06	0.008	1.66		
Ca	0.06	0.010	1.73		
Sr	0.06	0.010	1.72		

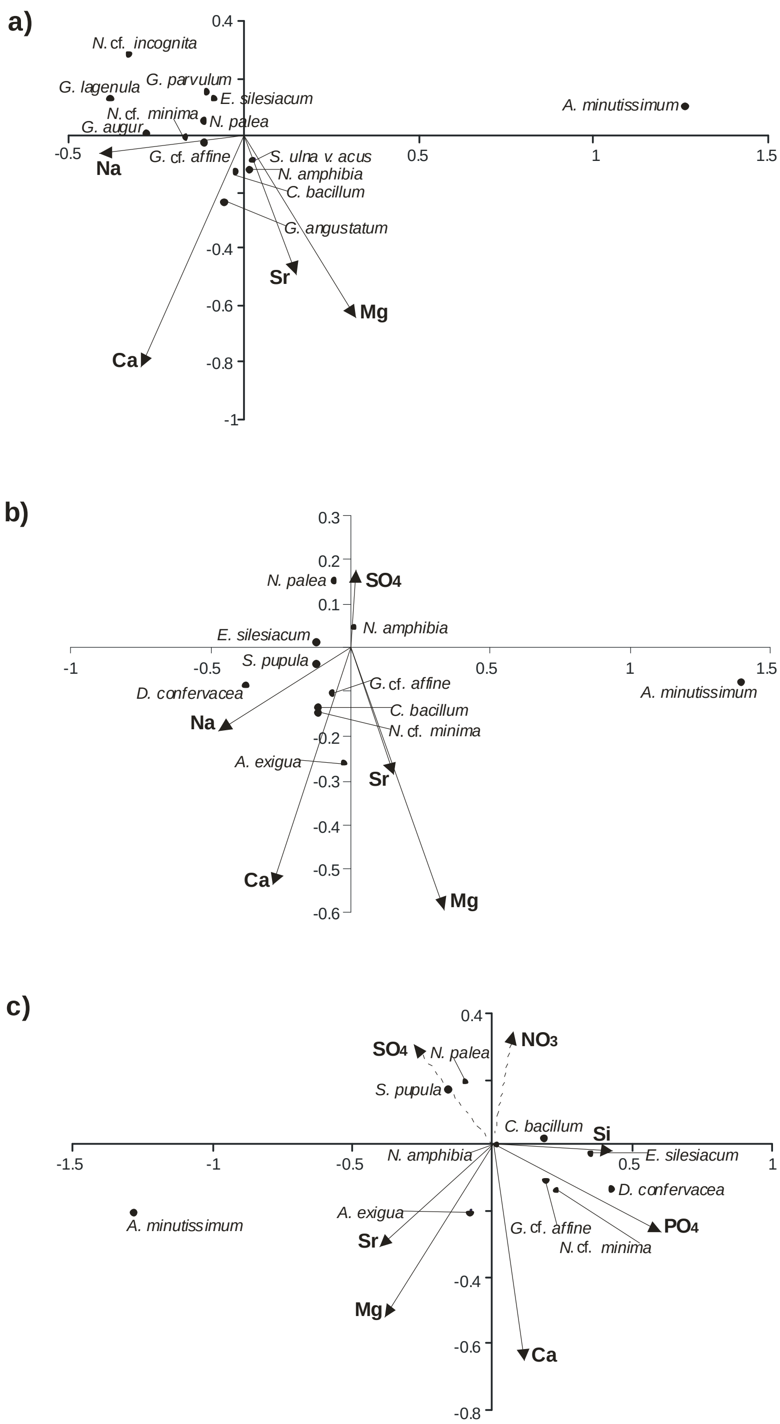


Fig. 3.5 Canonical correspondence analysis (CCA) of epiphytic diatom assemblages from 41 ponds in the Koshi Tappu area
_ (a) epiphytic diatoms and surface water, (b) epipelic diatoms and surface water, (c) epipelic diatoms and interstitial water.

Na had no influence (Fig. 5c). *Diadesmis confervacea*, *Encyonema ssilesiacum*, *Navicula* cf. *minima* and *Gomphonema*. cf. *affine* were most abundant at higher PO_4 and Si concentrations and *A. minutissimum* at lower concentrations. *Achnanthes exigua* was most abundant at higher ca and Mg concentrations, while *Nitzschia palea* and *Sellaphora pupula* were abundant towards sites with lower Ca and Mg but higher NO_3 and SO_4 concentrations; however, the latter were not significantly related to overall diatom distribution.

3.5 Discussion

Ponds in the Koshi Tappu Wildlife Reserve and adjacent agricultural areas are increasingly threatened by pollution from agriculture and habitat degradation due to the intensification of crop growing, fish farming and expansion of grazing into the reserve. There is a need to develop biological monitoring tools using organisms sensitive to the prevailing environmental problems of freshwater ecosystems in this area, in particular change of chemical character and habitat loss. This would aid efficient environmental management through the assessment of ecological status and target conservation actions through the identification of remaining seminatural habitats. This study investigated the response of diatoms to water chemistry and habitat character, both altered through agricultural practises, and their potential application for monitoring environmental change in pond ecosystems in the lowlands of Nepal.

Environmental conditions varied widely with respect to surface water and interstitial water chemistry as well as pond substrate and vegetation, bank character and surrounding land use. This reflected the large range of pond types investigated from natural ponds in the reserve, where human impacts were small, to artificial ponds in the agricultural areas subjected to management of varying degree. Major trends in water chemistry, in particular conductivity, Na, Ca, Ba, Sr, SO_4, Cl, F and Si, probably reflected agriculture and management of fish ponds. High Ca concentration should be from the lime used for treatment of fishponds, but high concentration of Na, Ba, Sr, SO_4, Cl, F and Si might indicate impacts from agriculture in the catchments. In a study on streams in the Nepalese Middle Hills and the Kathmandu Valley, conductivity and concentrations of Na, Si and Cl were higher in areas of intensive agriculture (Jüttner *et al.* 2003). Jenkins *et al.* (1995) concluded that agriculture contributed significantly to differences in chemistry between headwater streams of the Middle Hills and the Himalaya, where higher Si, Ba, Sr and F concentrations were due to increased weathering and high concentrations of acid anions (Cl, SO_4) resulting from mineral fertiliser inputs. However, further studies are needed to investigate how agriculture influences chemistry of aquatic ecosystems in areas with different geological and climatic conditions such as the lowlands of Nepal. Despite their location close to agricultural fields, concentrations of nutrients (NO_3 and PO_4) were often low or not detected in the surface water of the Koshi Tappu ponds; this might be due to rapid uptake by terrestrial and aquatic plants. Similar results were found in other studies (Jenkins *et al.* 1995, Jüttner *et al.* 2003, Simkhada & Jüttner 2006), but in contrast with results of Jones *et al.* (1989). In our study nutrient concentrations were higher in the interstitial water and contributed significantly to the main gradients in water chemistry. Major gradients in habitat character reflected habitat change as a result of pond management in agricultural areas. Ponds presently used for fish farming were highly managed with cleared of pond and bank vegetation while former fish ponds and reserve ponds had abundant aquatic vegetation and provided a variety of aquatic habitats.

Despite a wide range of chemical conditions and diversity of habitats, the overall number of diatom species, with 87 and 94 in the epiphytic and epipelic assemblages, respectively, was low. Epiphytic assemblages had fewer species than epipelic assemblages. However, since no live material from the sediment was examined to differentiate between live and dead valves, it is possible that some of the species collected in the sediment were deposited there, but had lived in other habitats (Cox 1988). The ponds also had very low diversity H’ and evenness E, and most assemblages were dominated by one or two species which were present at > 10 % relative abundance. In contrast, 213 species were found in ponds of the Kathmandu Valley (Simkhada & Jüttner 2006). A much larger number of 182- 249 taxa was also reported from artificial ponds in two areas of Japan (Kobayasi & Ando 1975, 1977). A possible reason for the low species richness in the Koshi Tappu area might be frequent disturbances, particularly of the artificial ponds, through fishing and clearance of aquatic vegetation (Gharti-Chhetri pers. communication). Environmental heterogeneity might also differ between these sets of ponds. Habitat differences between the ponds in the Kathmandu Valley were much greater than between the Koshi Tappu ponds (Simkhada & Jüttner 2006), while there is no information available about habitat diversity of the Japanese ponds.

Diatom assemblages from different epiphytic microhabitats were similar to each other and no species was characteristic for a particular microhabitat type. Similar observations were made for epiphytic algae assemblages on submerged parts of different macrophyte species in a lake in Argentina (Tesolín & Tell 1996). Others have found species characteristic for particular habitats in chemically similar lakes and ponds (Michelutti *et al*. 2003), suggesting that habitat preferences might only become apparent in the absence of strong chemical gradients or at very low nutrient concentrations.

As in other studies, several species were equally abundant on macrophytes and sediments (Gaiser & Johansen 2000). However, overall species composition differed between epiphytic and epipelic assemblages with several species significantly more abundant in either of the two habitats. Taxa more abundant in the epiphyton included non-motile attached species of the genus *Gomphonema*, while the motile *Sellaphora pupula* and

Diadesmis confervacea were the most characteristic species in the epipelon; observations similar to those reported by other investigators (Cox 1988, Douglas & Smol 1995).

Previous studies showed that diatom assemblage composition in ponds reflects chemical conditions, in particular gradients in nutrients concentrations, pH and salinity (Bennion 1994, Roberts *et al.* 2001, Lim *et al*. 2001 a,b). In arctic ponds of Canada, aquatic vegetation and substrate character were significant factors in addition to water chemistry (Douglas & Smol 1995). In ponds of the Koshi Tappu area epiphytic diatoms also reflected changes in chemical and habitat character. *Nitzschia amphibia*, *Synedra ulna* var. *acus*, *Gomphonema* cf. *affine* and *Navicula* cf. *minima* were the most common species at sites close to villages and agriculture. These ponds were probably affected by the application of $CaCO_3$ and the use of fertilisers on surrounding agricultural land. These species were also associated with silt in the riparian zone and littoral. In contrast, *Gomphonema parvulum*, *Nitzschia* cf. *incognita* and *Encyonema silesiacum* were characteristic in ponds with abundant submerged macrophytes and plant remains as substrate. As in ponds in the Kathmandu Valley (Simkhada & Jüttner 2006), *A. minutissimum* was characteristic of sites least impacted by agriculture. Correlations between assemblage change, chemical and habitat gradients were equally important. However, in many cases chemistry and habitat gradients were inter-correlated, in particular conductivity and Ca concentrations with substrate character, bank profile and land use. While epiphytic assemblage composition was correlated with the abundance of submerged aquatic plants, they did not indicate different types of aquatic vegetation reflecting the absence of specific assemblages in any particular microhabitat such as filamentous algae, free floating plants, submerged and emergent plants.

Comparing the response of epiphytic and epipelic assemblages to surface water chemistry revealed that both assemblages reflected similar chemical gradients in the surface water. The most abundant species at sites with higher Na concentrations differed between the epiphytic and epipelic assemblages, but *Achnanthidium minutissimum* was the most abundant species in both assemblages at sites with low Na concentrations. The most characteristic species at higher concentrations of Ca, Mg and Sr also differed between the two assemblages. In addition, epipelic species reflected gradients in SO_4 concentrations in surface water. Similarly, Douglas & Smol (1995) found that a gradient in alkalinity in arctic ponds reflected by epilithic, epiphytic and epipelic assemblages. In the study of Lim *et al*. (2001b) epiphytic, epilithic and epipelic diatoms reflected gradients with respect to total N and P, pH, Fe and temperature. In our study epipelic diatoms reflected not only gradients in the surface water but also in the interstitial water. In contrast to the surface water, epipelic diatoms reflected gradients in PO_4 and Si in the interstitial water but not in Na, suggesting their possible use as indicators of nutrient enrichment. Since epipelic diatoms indicated changes in interstitial water chemistry and the same chemical gradients in the surface water as epiphytic diatoms, epipelic diatoms might be good indicators of overall changes in chemical conditions (Lim *et al*. 2001b). Though in rivers most investigators use epilithic samples to monitor water quality (Kelly & Whitton 1995, Lobo *et al*. 1995, Jüttner *et al*. 2003), this study and other investigations have shown that both epiphytic and epipelic diatoms can be used successfully to assess water quality in lakes (Blanco *et al*. 2004, Poulíčková *et al*. 2004).

The abatement of pollution and habitat degradation of freshwater ecosystems in the Koshi Tappu area would benefit from regular biological monitoring to assess impacts of environmental change on pond ecosystems. Both chemical and physical habitat assessment provided valuable information that correlated with the state of the biota, demonstrating that the development of diatom-based monitoring tools would allow a comprehensive assessment of environmental quality of pond ecosystems in this region and contribute to environmental management to protect aquatic biodiversity.

3.6 References

Aizaki M., Terashima A., Nakahara H., Nishio T. & Ishida Y. 1987. Trophic status of Tilitso, a high altitude Himalayan lake. *Hydrobiologia* **153**, 217–224.

Anand N. & Hopper R.S.S.K. 1987. Blue-green-algae from rice fields in Kerala State, India. *Hydrobiologia* **144**, 223–232.

Bennion H. 1994. A diatom-phosphorus transfer function for shallow, eutrophic ponds in southeast England. *Hydrobiologia* **275/276**, 391–410.

Bennion H. 1995. Surface-sediment diatom assemblages in shallow, artificial, enriched ponds, and implications for reconstructing trophic status. *Diatom Research* **10,** 1–19.

Blanco S., Ector L. & Bécares E. 2004. Epiphytic diatoms as water quality indicators in Spanish shallow lakes. *Vie Milieu* **54**, 71–79.

Carpenter K.D. & Waite I.R. 2000. Relations of habitat-specific algal assemblages to land use and water chemistry in the Willamette Basin, Oregon. *Environmental Monitoring and Assessment* **64,** 247–257.

Cox E.J. 1988. Microdistributional patterns of freshwater diatoms in relation to their use as bioindicators. In: Proceedings of the 10th International Diatom Symposium, Joensuu, Finnland. Simola H. (ed.), pp. 521–528. Koeltz, Koenigstein.

Denys L. 2003. Environmental changes in man-made coastal dune pools since 1850 as indicated by sedimentary and epiphytic diatom assemblages (Belgium). *Aquatic Conservation: Marine and Freshwater Ecosystems* **13**, 191–211.

Denys L. & van Straaten D. 1992. A survey of the acid water diatom assemblages of two heathland relics in the Belgian Northern Campine (Groot & Klein Schietveld, Brasschaat) with an assessment of their conservation value. *Diatom Research* **7**, 1–13.

Donner W. 1994. *Lebenraum Nepal. Eine Entwicklungsgeographie*. Mitteilungen des Instituts für Asienkunde **226**, Hamburg.

Douglas G.E., John D.M., Williamson D.B. & REID G. 1998. The aquatic algae associated with mining areas in Peninsula Malaysia and Sarawak: their composition, diversity and distribution. *Nova Hedwigia* **67**, 189–211.

Douglas M.S.V. & Smol J.P 1993. Freshwater diatoms from high arctic ponds (Cape Herschel, Ellesmere Island, N.W.T.). *Nova Hedwigia*, *Beiheft* **57**, 511–552.

Douglas M.S.V. & Smol J.P 1995. Periphytic diatom assemblages from high Arctic ponds. *Journal of Phycology* **31**, 60–69.

Eaton J.W. & Moss B. 1966. The estimation of numbers and pigment content in epipelic algal populations. *Limnology & Oceanography* **11**, 584–595.

Flower R. 2005. A taxonomic and ecological study of diatoms from freshwater habitats in the Falkland Islands, South Atlantic. *Diatom Research* **20**, 23–96.

Gaiser E.E. & Johansen J. 2000. Freshwater diatoms from Carolina Bays and other isolated wetlands on the Atlantic coastal plain of South Carolina, U.S.A., with descriptions of seven taxa new to science. *Diatom Research* **15**, 75–130.

Gaiser E.E., Philippi T.E. & Taylor B.E. 1998. Distribution of diatoms among intermittent ponds on the Atlantic Coastal Plain: development of a model to predict drought periodicity from surface-sediment assemblages. *Journal of Paleolimnology* **20**, 71–90.

Ghandi H.P. 1960. On the diatom flora of some ponds around Vasna village near Ahmedabad. *Journal of the Indian Botanical Society* **39**, 558–567.

Ghandi H.P. 1962. Notes on the diatomaceae from Ahmedabad and its environs –IV. The diatom communities of some freshwater pools and ditches along Sarkhej road. *Phykos* **1**, 115–127.

Hall R.I. & Smol J.P. 1999. Diatoms as indicators of lake eutrophication. In: *The Diatoms: Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J. P. (eds), pp. 128–168. Cambridge University Press, Cambridge.

Haworth E.Y. & Atkinson K.M. 1988. The preliminary assessment of diatom distribution in the waterbodies of Cumbria, north-west England. In: Proceedings of the 10th International Diatom Symposium, 1988, Joensuu, Finnland. Simola, H. (ed.), pp. 459–470. Koeltz, Koenigstein.

Hickel B. 1973. Phytoplankton in two ponds in Kathmandu Valley, Nepal. *International Revue of Hydrobiology* **58**, 835–842.

Hustedt F. 1937-39. Systematische und ökologische Untersuchungen über die Diatomeen-Flora von Java, Bali und Sumatra nach dem Material der Deutschen Limnologischen Sunda-Expedition. *Archive for Hydrobiology Supplement* 15, 16.

Hustedt F. 1942. Süßwasser-Diatomeen des indomalayischen Archipels und der Hawaii-Inseln. Mitteilung XXXII der Wallacea-Expedition. *International Revue of Hydrobiology* **42**, 1–252.

Jenkins A., Sloan W.T. & Cosby B.J. 1995. Stream chemistry in the middle hills and high mountains of the Himalayas, Nepal. *Journal of Hydrology* **166**, 61–79.

Jha P.K. 1992. *Environment and Man in Nepal*. Know Nepal Series No.5, Craftman Press, Bangkok.

Jones V.J. 1996. The diversity, distribution and ecology of diatoms from Antarctic inland waters. *Biodiversity and Conservation* **5**, 1433–1449.

Jones J.R., Knowlton M.F. & Swar D.B. 1989. Limnological reconnaissance of waterbodies in central and southern Nepal. *Hydrobiologia* **184**, 171–189.

Jüttner I., Rothfritz H. & Ormerod S.J. 1996. Diatoms as indicators of river quality in the Nepalese middle hills with consideration of the effects of habitat-specific sampling. *Freshwater Biology* **36**, 101–112.

Jüttner I., Sharma S., Dahal B.M., Ormerod S.J. & Cox E.J. 2003. Diatoms as indicators of stream quality in the Kathmandu Valley and Middle Hills of Nepal and India. *Freshwater Biology* **48**, 2065–2084.

Kawecka B., Olech M., Nowogrodzka-Zagórska M. & Wojtuń B. 1998. Diatom communities in small water bodies at H. Arctowski Polish Antarctic Station (King George Island, South Shetland Islands, Antarctica). *Polar Biology* **19,** 183–192.

Kelly M.G. & Whitton B.A. 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers. *Journal of Applied Phycology* **7**, 433–444.

Kobayasi H. & Ando K. 1975. Diatoms from Hozoji-numa, Jizoin-numa and Nakashinden-numa Ponds in Hanyu City, Saitama Prefecture. *Bulletin of Tokyo Gakugei University Ser. IV.* **27**, 178–204.

Kobayasi H. & Ando K. 1977. Diatoms from irrigation ponds in Musashikyuryo – shinrin Park, Saitama Prefecture. *Bulletin of Tokyo Gakugei University Ser. IV*. **29**, 231–263.

Krammer K. 1997 Die cymbelloiden Diatomeen. Eine Monographie der weltweit bekannten Arten. Vol. **1,2**. J. Cramer, Berlin.

Krammer K. & Lange-Bertalot H. 1986–1991. *Bacillariophyceae, Süßwasserflora von Mitteleuropa*, Vol. **2**, Parts 1–4, Ettl H., Gerloff J., Heynig H. & Mollenhauer D. (eds), Gustav Fischer Verlag, Stuttgart.

Lami A. & Giussani G. (eds) 1998. Limnology of high altitude lakes in the Mt Everest Region (Himalayas, Nepal). *Memorie dell'Istituto Italiano di Idrobiologia* **57**. Istituto Italiano di Idrobiologia, Pallanza.

Lange-Bertalot H. & Krammer K. 1989. *Achnanthes.* Monographie der Gattung. *Bibliotheca Diatomologica* **18**, J. Cramer, Berlin.

Leland H.V. 1995. Distribution of phytobenthos in the Yakima River basin, Washington, in relation to geology, land use, and other environmental factors. *Canadian Journal of Fisheries and Aquatic Sciences* **52**, 1108–1129.

Lim D.S.S., Douglas M.S.V. & Smol J.P. 2001a. Diatoms and their relationship to environmental variables from lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. *Hydrobiologia* **450**, 215–230.

Lim D.S.S., Kwan C. & Douglas M.S.V. 2001b. Periphytic diatom assemblages from Bathurst Island, Nunavut, Canadian High Arctic: an examination of community relationships and habitat preferences. *Journal of Phycology* **37**, 379–392.

Lobo E.A., Katoh K. & Aruga Y. 1995. Response of epiplithic diatom assemblages to water pollution in rivers in the Tokyo Metropolitan area, Japan. *Freshwater Biology* **34**, 191–204.

Lohman K., Jones J.R., Knowlton M.F., Swar D.B., Pamperl M.A. & Brazos B.J. 1988. Pre- and postmonsoon limnological characteristics of lakes in the Pokhara and Kathmandu Valleys, Nepal. *Verhandlungen Internationale Vereinigung Limnologie* **23**, 558–565.

Michelutti N., Holtham A.J., Douglas M.S.V. & Smol J.P. 2003. Periphytic diatom assemblages from ultra-oligotrophic and UV transparent lakes and ponds on Victoria Island and comparisons with other diatom surveys in the Canadian Arctic. *Journal of Phycology* **39**, 465–480.

Ormerod S.J., Rundle S.D., Wilkinson S.M., Daly G.P., Dale K.M. & I. Jüttner 1994. Altitudinal trends in the diatoms, bryophytes, macroinvertebrates and fish of a Nepalese river system. *Freshwater Biology* **32**, 309–322.

Poulíčková A., Duchoslav M. & Dokulil M. 2004. Littoral diatom assemblages as bioindicators of lake trophic status: A case study from perialpine lakes in Austria. *European Journal of Phycology* **39,** 143–152.

Rao V.S. 1977. Ecological study of 3 freshwater ponds of Hyderabad – India. 5. Phytoplankton (Diatoms, Euglenineae and Myxophyceae). *Hydrobiologia* **53**, 13–32.

Reichardt E. 1999. Zur Revision der Gattung *Gomphonema*. Die Arten um *G.affine*/*insigne*, G. *angustum*/*micropus*, G. *accuminatum* sowie gomphonemoide Diatomeen aus dem Oberoligozän in Böhmen. *Iconographia Diatomologica* **8**, Lange-Bertalot H. (ed.), A.R.G. Gantner, Rugell.

Roberts D., McMinn A., Johnston N., Gore D.B., Melles M. & Cremer H. 2001. An analysis of the limnology and sedimentary diatom flora of fourteen lakes and ponds from the Windmill Islands, East Antarctica. *Antarctic Science* **13**, 410–419.

Rothfritz H., Jüttner I., Suren A.M. & Ormerod S.J. 1997. Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity and water quality. *Archive for Hydrobiology* **138**, 465–482.

Round F.E. & Bukhtiyarova L. 1996. Four new genera based on *Achnanthes* (*Achnanthidium*) together with a re-definition of *Achnanthidium*. *Diatom Research* **11**, 345–361.

Sah J.P. 1997. Koshi Tappu wetlands: Nepal's Ramsar site. IUCN, Bangkok.

Sahu J., Das M.K. & Adhikary S.P. 1992. Reaction of blue-green-algae of rice-field soils to pesticide application. *Tropical Agriculture* **69**, 362–364.

Shannon C. & Weaver W. 1949. *The mathematical theory of communication*. University Illinois Press, Urbana.

Simkhada B. & Jüttner I. Diatoms in ponds of the Kathmandu Valley, Nepal – relationships with chemical and habitat characteristics. *Archive for Hydrobiology*, in press.

Stevenson R.J. & Pan Y. 1999. Assessing environmental conditions in rivers and streams with diatoms. In: *The Diatoms: Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J. P. (eds), pp. 11–40. Cambridge University Press, Cambridge.

Tesolín G. & Tell G. 1996. The epiphytic algae on floating macrophytes of a Paraná river floodplain lake. *Hydrobiologia* **333**, 111–120.

Thapa G.B. & Weber K.E. 1995. Status and management of watersheds in the upper Pokhara Valley, Nepal. *Environmental Management* **19**, 497–513.

van Dam H. & Buskens R.F.M. 1993. Ecology and management of moorland pools: balancing acidification and eutrophication. *Hydrobiologia* **265**, 225–263.

Williams D.M. & Round F.E. 1987. Revision of the genus *Fragilaria*. *Diatom Research* **2**, 267–288.

4. Diatoms in high altitude lakes of Gosainkunda, Langtang National Park, Central Nepal – relationships with chemical and habitat characteristics

4.1 Abstract

Epilithic diatom assemblages in autumn 2000 in seven lakes, and epilithic, epipsammic, epipelic and epiphytic diatom assemblages in spring 2003 in ten lakes were studied in relation to water chemistry and habitat character of the Gosainkund area, Langtang National Park, Nepal. In May 2003 the mean pH of 6.5 was significantly lower than the mean pH of 7.4 in November 2000. Concentrations of K, Cl and N_{tot} were significantly higher in 2003 compare to 2000. Epilithic assemblages composition differed between the seasons. In spring species indicating higher acidity were more abundant than in autumn, and percentage composition of acid sensitive species had declined. In both seasons there were no significant correlations between species richness S, diversity H', evenness E and water chemistry or littoral substrate composition, except significantly lower evenness at sites with higher percentage of sand. However, canonical correspondence analysis (CCA) with forward selection of environmental variables revealed significant relationships between variation in assemblage composition and land use in autumn (2000) and between assemblage composition, land use and water chemistry in spring (2003). Ordination revealed a distinct variation in assemblage composition between different microhabitats in 2003 and S, H' and E were significantly higher ($p<0.05$) in the epilithic assemblages than in the epipelic assemblages.

4.2 Introduction

Mountain lakes are important aquatic ecosystems at high altitudes and provide habitats for diverse diatom assemblages, which often include only recently described taxa (Kwandrans 1994, Reichardt 1988, Tolotti 2001). Despite their remote locations many of them are affected by anthropogenic impacts such as the deposition of atmospheric pollutants in particular nitrogen and sulphur oxides (Psenner *et al*. 2000), toxic metal and organic compounds (Köck *et al.* 1995, Jüttner *et al.* 1997, Grimalt *et al*. 2001) or climatic change such as increase in temperature (Sommaruga-Wögrath *et al.* 1997) and higher UV radiation (Vinebrooke & Leavitt 2005). High mountain freshwater ecosystems are increasingly important to assess the impact of such environmental stressors (Sommaruga & Psenner 2001). They have been used to study hydrological changes and chemical conditions including changes in flux rates of chemical compounds (Leydecker *et al*. 2001), erosion (Noda *et al.* 2001), the influence of catchment vegetation (Kamenik *et al*. 2001) and altered light conditions linked to changes in radiation and concentrations of dissolved organic matter (Reche *et al*. 2001). Several studies have successfully used diatoms in mountain lakes to monitor environmental change. Diatoms in sediment cores of 209 high altitude lakes from eleven European countries revealed significant changes over the last 150 years. Climate change affecting ice-cover and mixing regimes as well as increased nutrient loads were discussed as the main responsible factors (Clarke *et al*. 2005). Studies on other continents came to similar conclusions. In the Colorado Mountains of North America changes of diatom assemblage composition since 1900 and particularly since the 1950s were attributed to enhanced atmospheric deposition of nitrogen from anthropogenic sources (Wolfe *et al*. 2001). Sediment diatom records from alpine lakes in the Canadian Cordillera were linked to altered limnological conditions as a result of climate change during the Holocene (Karst-Riddoch *et al*. 2005a) and recent climate change in the 20th

century (Karst-Riddoch *et al*. 2005b). Training sets and transfer functions were developed for mountain lakes in several regions to reconstruct environmental conditions. In Europe surface-sediment and epilithic diatoms have been used to construct a pH calibration set for remote mountain lakes to assess acidification (Cameron *et al*. 1999). In Tasmania diatoms and water chemistry from 76 mountain lakes were used to derive the TASDIAT training set for the reconstruction of chemical conditions (Vyverman *et al*. 1995), and diatom-based transfer functions for paleolimnological reconstructions of conductivity and alkalinity were developed for mountain lakes in central Mexico (Davies *et al*. 2002).

In the Himalaya, mountain lakes at medium altitudes are vulnerable due to rising pressures on water resources as a result of population growth, agricultural intensification and land use change, urban and industrial development and at higher altitudes due to increased mountain tourism (Schreier 2005). Remote high altitude lakes without land use change and pollution inputs from their catchments are threatened by airborne pollution originating from long-distance atmospheric transport and global climate change (Battarbee 2005). Studies of air pollution in Asia have shown the formation the so-called "Asian Brown Haze", a vast blanket of pollution stretching over South Asia. It consists of ash, aerosols and acids resulting from forest fires, increased emission from households and the burning of fossil fuels by vehicles, industry and power stations. The brown haze influences climate and local weather pattern and is thought to be the reason for increased flooding in high rainfall areas of Nepal. The acid compounds can lead to damage of sensitive ecosystems when they fall as acid rain (UNEP 2002). Higher nitrogen loads can cause eutrophication and acidification in oligotrophic mountain lakes reflected by higher productivity and changes of biological assemblages (Baron *et al*. 2005). As in Europe where high mountain lakes are severely impacted by atmospheric pollutants (Battarbee 2002, Battarbee *et al*. 2005), lakes in the Himalaya are probably also affected due to rise in pollutant emissions on the Indian subcontinent (Ramanathan *et al*. 2002). Many mountain lakes in the Nepalese Himalaya are located in remote areas of National Parks including Lake Tilitso in the Annapurna area and the lakes in the Everest National Park in eastern Nepal. The trophic status of Lake Tilitso has been studied and estimated to be ultraoligotrophic (Aizaki *et al*. 1987) and several other studies investigated morphometry, water chemistry and some biological aspects such as phytoplankton, zooplankton and macrozoobenthos of lakes in the Everest area (Löffler 1969, Tartari *et al*. 1997, 1998, Manca *et al*. 1998). A paleolimnological study involving four lakes in the Everest National Park was also carried out and provided a historical record of considerable environmental change as reflected by changes in primary production, algal assemblages and concentrations of trace elements (Lami *et al*. 1998).

High altitude lakes closest to the densely populated urban centres are located in the Gosainkund area of the Langtang National Park, Central Nepal, c. 32 km north of the densely populated Kathmandu Valley, the capital city of Nepal. There are 30 lakes in the Gosainkund area and ten of which were selected for this study. These lakes could be affected by atmospheric pollution particularly from the Kathmandu Valley, and also from the lowlands of Nepal and northern India. Compared with other high mountain lakes in Nepal, the lakes in the Gosainkund area can be accessed relatively quickly and hence provide an opportunity for regular monitoring of chemical and biological change through direct measurements. Previous studies in streams, ponds and springs of Nepal have shown that diatoms are good indicators of chemical conditions (Dahal & Jüttner 2004, Jüttner *et al*. 1996, Jüttner *et al.* 2003, Rothfritz *et al*. 1997, Simkhada & Jüttner 2006, Simkhada *et al*. in press) and are likely to be equally suitable indicators of chemical change in these high altitude lakes. This study investigated environmental conditions including water chemistry and habitat character as well as diatom assemblages in two different seasons namely during the autumn in 2000 and during spring, shortly after the main snow melt, in 2003 to examine whether (i) chemical conditions in the lakes differed between the two seasons, (ii) diatom assemblages reflected differences in environmental conditions between lakes and between seasons and (iii) diatom diversity differed between microhabitats within the same lake.

4.3 Materials and methods

4.3.1 Study area

The lakes are located in the Gosainkund area of the Langtang National Park, Rasuwa district, central Nepal, between 28˚04.365' - 28˚05.027' N and 85˚24.322' - 85˚25.716' E, and at altitudes between 4329 – 4654 m a.s.l. (Fig. 1). The Langtang National Park is the park close to the densely populated Kathmandu Valley and extends from 32 km north of Kathmandu to the Nepal – China (Tibet) border. The lakes lie just beyond of the first major mountain range north of the Kathmandu Valley with the highest elevations between 4517 and 5359 m. The geology consists of base-poor metamorphic rocks comprising gneisses, quartzites and marbles. The climate is alpine with mean winter temperatures of -5 ˚C and summer temperatures between 10 and 15 ˚C (Donner 1994). The wet monsoon season lasts from June until the end of September, and the dry season from October to May. The lakes are situated above the tree line (4200m) and the main land use is rough grassland, alpine scrub and boulder fields. Some of the lakes are connected with each other through seepage or small streams. There is a small settlement and prayer sites on the northern shore of the largest lake (Lake 3, Gosainkund Lake). The lakes are important pilgrimage sites and visited by many Hindu pilgrims during the Janai Purnima festival in August. A popular trekking route from the Helambu area in the south to the Langtang Valley in the north also passes the lakes.

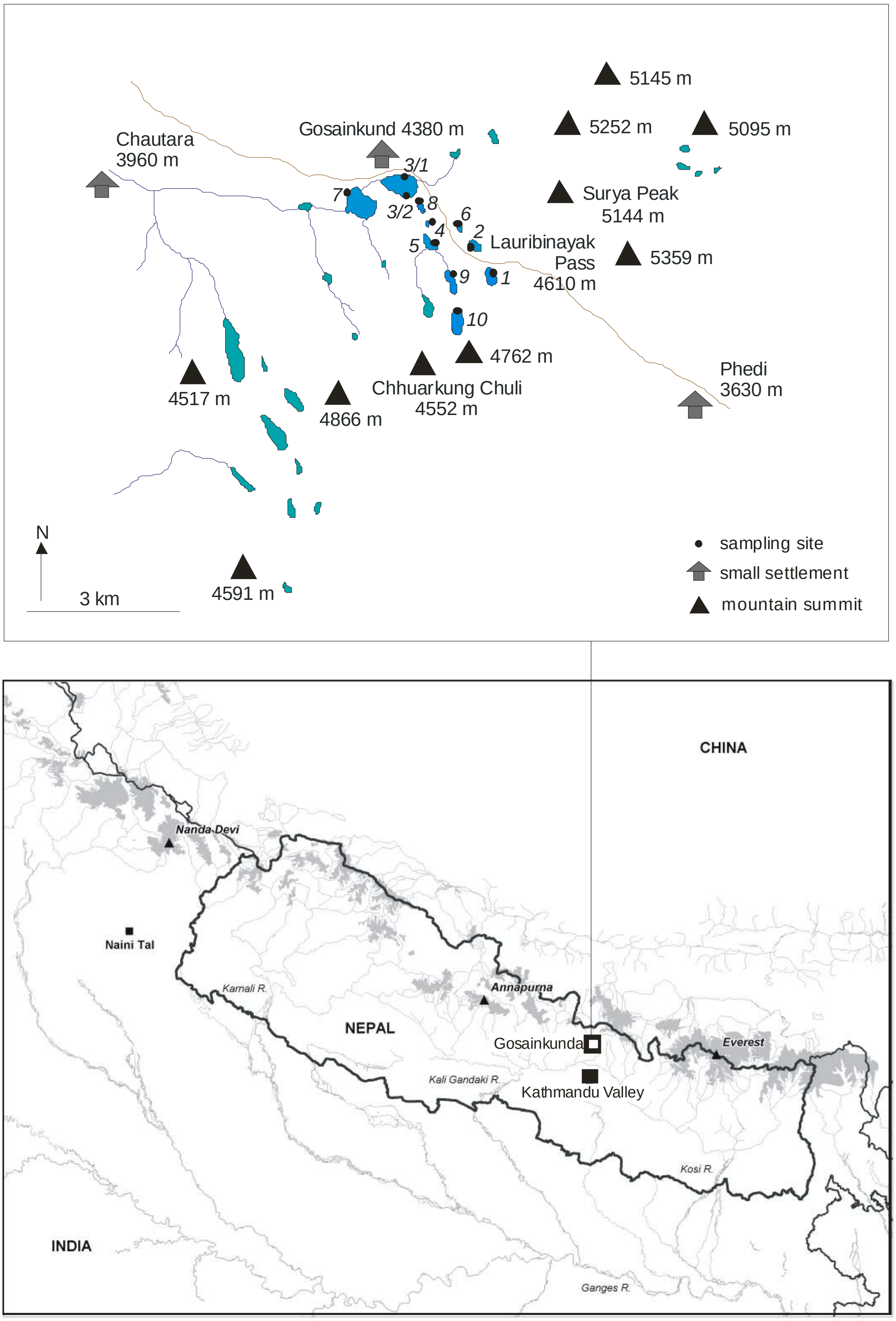


Fig. 4.1 Location of Gosainkund lakes, Langtang National Park, Nepal (The numbers 1 – 10 in the inset showing sampling sites).

4.3.2 Field investigations and laboratory procedures

The lakes were surveyed on two occasions. The first survey was conducted assessing seven lakes during the dry postmonsoon season of November 2000 (Table 1).

Table 1. GIS position of the assessed Gosainkund lakes, November 2000.

Local name	*Site label*	*GIS position* North	*GIS position* East	*Altitude* (m)	*Collection date*
Suryakund	**Lake 1**	28°04.365'	85°25.716'	4651	17.11.00
Ganeshkund	**Lake 2**	28°04.509'	85°25.549'	4621	17.11.00
Gosainkund	**Lake 3/2**	28°04.881'	85°24.934'	4407	18.11.00
	Lake 4	28°04.755'	85°25.057'	4411	18.11.00
Dudhkund	**Lake 5**	28°04.644'	85°25.083'	4419	18.11.00
Bardakund	**Lake 6**	28°04.730'	85°25.307'	4611	18.11.00
Bhairavkund	**Lake 7**	28°04.945'	85°24.408'	4336	19.11.00

The second survey was conducted assessing ten lakes during the dry pre-monsoon season of May 2003, shortly after the main snow melt (Table 2).

Table 2. GIS position of the assessed Gosainkund lakes, May 2003.

Local name	*Site label*	*GIS position* North	*GIS position* East	*Altitude* (m)	*Collection date*
Suryakund	**Lake 1**	28°04.386'	85°25.655'	4654	25.5.03
Ganeshkund	**Lake 2**	28°04.568'	85°25.481'	4627	25.5.03
Gosainkund	**Lake 3/1**	28°05.042'	85°24.878'	4409	27.5.03
Gosainkund	**Lake 3/2**	28°04.857'	85°24.921'	4413	24.5.03
	Lake 4	28°04.760'	85°25.053'	4412	24.5.03
Dudhkund	**Lake 5**	28°04.642'	85°25.081'	4417	24.5.03
Bardakund	**Lake 6**	28°04.728'	85°25.315'	4613	25.5.03
Bhairavkund	**Lake 7**	28°04.874'	85°24.322'	4329	27.5.03
	Lake 8	28°04.870'	85°24.963'	4412	24.5.03
Chandrakund	**Lake 9**	28°04.292'	85°25.305'	4513	26.5.03
Amakund	**Lake 10**	28°04.053'	85°25.388'	4545	26.5.03

The locations of the sampling sites on the lakes’ shores were similar in both years except for Lake 2, where a different location was used during the 2003 survey due to snow cover and access problems. Longitude, latitude and altitude were measured using a GPS meter (Garmin GPS 12 XL).

Habitat surveys recording twelve variables were conducted to describe substrate composition in the lake littoral, bank profile and land use within 100 m of the sampling sites. Substrate composition was recorded as percentage cover. Bank profile and land use were recorded in three categories 0 = absent, 1 = < 30% present, 2 > 30% present. Temperature, conductivity and pH were measured on site using a portable meter (WTW pH/ Cond 340i, Weilheim, Germany). Water samples (2 x 30 ml) were filtered (0.45 μm cellulose-nitrate filters, Millipore, Watford, England) and the samples for cation analysis were acidified with 1 ml nitric acid on site. Cations and anions were analysed by standard method namely inductively-coupled plasma optical emission spectrometry (ICP-OES) and ion chromatography respectively (Department of Mineralogy, Natural History Museum, London). Total inorganic nitrogen was estimated as the summed concentrations of NO_3 and NH_4. Rain water and snow close to the lakes were also collected, analysed for ion concentrations and pH was measured on the site.

In 2000, only epilithic diatoms were collected from stone surfaces using toothbrushes. In 2003, diatoms were collected from different microhabitats such as stone surfaces, sand, fine sediments and submerged macrophytes, depending on the availability of these substrates in the lake littoral. To collect epiphytic diatoms leaves and stems were taken from plants along the lake margin. Where sand or sediment was accessible from the lake shore epipsammic and epipelic diatoms were collected by sliding a cylindrical polyethylene tube across the surface to remove the top centimetre. Diatom samples were preserved in c. 4 % formalin.

Samples were processed following standard procedures (hot H_2O_2 oxidation, Naphrax as mountant). A minimum of 500 diatom valves per sample were counted (1000x, DIC, Zeiss Axioplan and Nikon E600) except for samples with very few diatoms. Where possible taxa were identified to species or subspecies level using Krammer & Lange-Bertalot (1986 - 1991), Lange-Bertalot & Krammer (1989), Krammer (1997) and Reichardt (1999). For some nomenclatural revisions followed Williams & Round (1987), and Round & Bukhtiyarova (1996). Slides have been deposited at the National Museum Wales, Cardiff.

4.3.3 Data analysis

Diatom diversity H' (Shannon diversity index) and evenness (E) were calculated (Shannon & Weaver 1949). Species richness S was calculated based on the lowest number of valves counted in any one sample using rarefaction on PRIMER 6. Relationships between S, H', E, water chemistry and littoral substrate composition were investigated by regression analysis (MINIAB 14). Differences in S, H' and E between different substrates and differences in water chemistry between 2000 and 2003 were investigated using one-way analysis of variance (ANOVA on MINITAB 14).

To investigate variations in assemblage composition between epilithic diatoms collected during different seasons in 2000 and 2003, and between different microhabitats within the same lakes collected in 2003 two detrended correspondence analyses (DCA, CANOCO 4.5) were performed.

To relate diatom assemblage composition to environmental gradients of chemical and habitat character in 2000 and 2003 two canonical correspondence analyses with forward selection of environmental variables (CCA, CANOCO 4.5) were performed. Prior to ordination chemical variables apart from pH were log transformed. For habitat variables proportions (e.g. % substrate type) were arcsine transformed and categorical values (e.g.

presence absence data) were not transformed. Species data were square-root transformed prior to ordination.

4.4 Results

4.4.1 Habitat character and water chemistry

Mostly habitat character between the lakes differed with respect to substrate composition in the littoral (Table 3). Boulders were common at five sites in 2000 and 2003, but almost absent at two sites in 2000 and six sites in 2003. Coarser substrate types such as cobbles and gravel varied between 20 – 45% and 10 – 35 % in 2000, and between 5 – 50 % and 10 - 30 % in 2003. Smaller substrate types such as gravel and sand varied between 0 – 30 % and 0 – 25 % in 2000, and between 5 – 40 % and 0 – 40 % in 2003. Silt was only present ≤ 5 % at four sites in 2003. Bank profiles varied less and most lakes had gentle and composite banks with some steep sections present at some of the lakes. Tundra with alpine scrub and boulder fields were the most abundant land use types at most lakes, while the cover of rough grassland within 100 m of the sampling site varied to a greater extend. Water temperature was lower in November 2000 (mean 4.8, range 3.4 – 6.8) than in May 2003 (mean 9.1, range 1.0 – 15.1, Tables 4, 5). Water chemistry varied for some chemical parameters between the two years. In May 2003 pH was significantly lower (mean 6.5, median 6.5, range 6.1 – 7.1 for seven lakes investigated in both years) than in November 2000 (mean 7.4, median 7.4, range 7.2 – 7.6, ANOVA $p < 0.001$, $F_{(1,13)}$ 30.3).

Table 3. Habitat character of Gosainkund lakes in 2000 and 2003.

	Substrate littoral						***Bank profile***			***Land use***		
	Boulder	***Cobble***	***Pebble***	***Gravel***	***Sand***	***Silt***	***Steep***	***Composite***	***Gentle***	***Rough grass***	***Tundra***	***Boulders***
2000	*%*	*%*	*%*	*%*	*%*	*%*						
Lake 1	20	40	30	10	0	0	1	1	2	1	2	2
Lake 2	45	45	10	0	0	0	0	1	2	1	1	2
Lake 3/2	5	25	20	30	20	0	1	1	1	2	1	1
Lake 4	40	40	15	5	0	0	0	1	2	1	1	2
Lake 5	5	20	25	25	25	0	0	1	2	2	2	2
Lake 6	20	35	35	10	0	0	1	1	1	1	2	2
Lake 7	20	40	20	20	0	0	1	1	0	1	1	2
2003												
Lake 1	25	30	25	15	5	0	0	1	2	1	2	2
Lake 2	0	5	20	40	35	0	1	1	2	1	2	2
Lake 3/1	5	20	10	20	40	5	2	1	0	2	1	1
Lake 3/2	5	20	20	25	25	5	0	2	1	2	2	1
Lake 4	25	40	30	2.5	0	2.5	0	1	2	2	2	2
Lake 5	5	25	30	20	20	0	1	1	1	2	2	2
Lake 6	25	25	20	10	20	0	1	1	1	1	2	2
Lake 7	20	30	20	10	20	0	1	1	0	2	1	1
Lake 8	5	20	15	20	35	5	0	2	1	2	2	1
Lake 9	5	50	30	5	10	0	1	1	1	1	2	2
Lake 10	30	40	20	10	0	0	1	1	1	1	2	2

Table 4. Temperature and water chemistry of Gosainkund lakes, November 2000.

Site label	*Temperature*	*pH*	*Conductivity*	*Na*	*K*	*Mg*	*Ca*	*Cl*	*N_{tot}*	*SO_4*
	(°C)		(µS/cm)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Lake 1	3.6	7.2	3	0.02	0.28	0.06	0.27	0.04	0.06	0.24
Lake 2	3.4	7.2	7	0.25	0.05	0.12	0.63	0.03	0.04	0.81
Lake 3/2	6.8	7.6	9	0.29	0.25	0.16	0.90	0.03	0.05	1.42
Lake 4	5.5	7.2	12	0.40	0.21	0.19	1.10	0.06	0.10	1.81
Lake 5	4.9	7.4	12	0.40	0.35	0.20	1.06	0.03	0.09	1.88
Lake 6	4.0	7.4	7	0.19	0.18	0.11	0.61	0.03	0.06	0.65
Lake 7	5.7	7.6	9	0.28	0.13	0.16	0.91	0.05	0.07	1.20

Table 5. Temperature and water chemistry of Gosainkund lakes, May 2003.

Site label	*Temperature*	*pH*	*Conductivity*	*Na*	*K*	*Mg*	*Ca*	*Cl*	*N_{tot}*	*SO_4*
	(°C)		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Lake 1	5.9	6.9	5	0.18	0.72	0.08	0.53	0.06	0.10	0.35
Lake 2	1.0	6.1	5	0.36	0.79	0.15	0.92	0.05	0.08	0.89
Lake 3/1	10.1	7.3	10	0.39	0.83	0.18	1.07	0.07	0.13	1.16
Lake 3/2	14.4	7.1	9	0.40	0.80	0.18	1.00	0.05	0.09	1.21
Lake 4	15.1	6.2	11	0.35	0.79	0.17	1.05	0.07	0.10	1.18
Lake 5	11.3	6.2	7	0.25	0.76	0.14	0.78	0.06	0.14	0.72
Lake 6	5.9	6.5	7	0.25	0.77	0.12	0.76	0.06	0.12	0.68
Lake 7	9.3	6.5	10	0.39	0.80	0.19	1.11	0.06	0.09	1.21
Lake 8	12.5	7.4	9	0.30	0.77	0.16	0.95	0.07	0.14	0.87
Lake 9	9.7	6.9	6	0.22	0.76	0.10	0.64	0.08	0.12	0.38
Lake 10	5.1	6.4	5	0.15	0.75	0.08	0.48	0.04	0.10	0.29

Concentrations of K, Cl and N_{tot} were significantly higher in May 2003 (K mean 0.78, median 0.79, range 0.72 – 0.80 mg/L; Cl mean 0.06, median 0.06, range 0.05 – 0.07 mg/L; N_{tot} mean 0.10, median 0.10, range 0.08 – 0.14 mg/L for seven lakes investigated in both years) than in 2000 (K mean 0.21, median 0.21, range 0.05 – 0.35 mg/L, ANOVA $p < 0.001$, $F_{(1,13)}$ 212.4; Cl mean 0.04, median 0.03, range 0.03 – 0.06 mg/L, ANOVA $p < 0.01$, $F_{(1,13)}$ 14.3; N_{tot} mean 0.07, median 0.06, range 0.04 – 0.10 mg/L, ANOVA $p < 0.01$,

$F_{(1,13)}$ 10.1). Conductivity, Na, Mg, Ca and SO_4 varied little between 2000 and 2003. Phosphate was below the detection limit (< 0.01 mg/L in 2000 and < 0.05 mg/L in 2003).

Rain water collected in May 2003 at Tharepati, 3600 m, c. 12 km south of the lakes had a pH of 6.6 and snow collected at the Laurebina Pass (4670 m) in close proximity to the lakes had a pH of 6.5. Total nitrogen concentrations were 1.11 mg/L in rain and 0.32 mg/L in snow.

4.4.2 Diversity and assemblage composition

Species richness S, diversity H' and evenness E of diatom assemblages in the Gosainkund lakes were low in both years and in all microhabitats in 2003 (Table 6).

Table 6. Species richness S, diversity H' and evenness E of diatom assemblage in Gosainkund lakes in the years 2000 and 2003.

	2000			2003											
	Stones			*Stones*			*Sand*			*Sediment*			*Macrophytes*		
	S	H'	E	S	H'	E	S	H'	E	S	H'	E	S	H'	E
Lake 1	28	1.27	0.83	21	1.10	0.84	11	0.75	0.64						
Lake 2	27	1.11	0.70	17	0.87	0.63	11	0.61	0.53						
Lake 3/1				15	0.67	0.5008	20	1.01	0.719						
Lake 3/2	25	1.11	0.75	19	0.93	0.68				6	0.43	0.43	11	0.50	0.43
Lake 4	22	1.11	0.75	22	0.94	0.68				12	0.86	0.79			
Lake 5	18	1.16	0.79	21	1.23	0.84	16	1.02	0.78	17	0.84	0.66			
Lake 6	16	0.61	0.45	12	0.78	0.72									
Lake 7	21	0.97	0.71	25	1.20	0.84				12	0.77	0.63			
Lake 8				20	1.01	0.7296				18	0.91	0.6969			
Lake 9				24	1.13	0.7803				8	0.47	0.4933	13	0.92	0.7473
Lake 10				17	0.99	0.8031									

In 2003 there were no significant differences between S, H and E of epilithic and epipsammic assemblages. However, S, H' and E were significantly higher in epilithic assemblages than in epipelic assemblages.

There were no significant differences between S, H' and E of epilithic assemblages in 2000 and 2003 (Table 7).

Table 7. Mean (± sd) of species richness, diversity and evenness of diatoms in Gosainkund lakes in 2000 and 2003.

	S	H'	E
Epilithon			
2000	22.4 ± 4.5	1.05 ± 0.21	0.71 ± 0.12
2003	19.6 ± 4.2	1.01 ± 0.17	0.75 ± 0.09
ANOVA	ns	ns	ns
2003 Comparison of different substrates			
Stones	18.5 ± 3.0	0.97 ± 0.25	0.70 ± 0.17
Sand	14.5 ± 4.4	0.85 ± 0.20	0.67 ± 0.11
ANOVA	ns	ns	ns
Stones	21.8 ± 2.3	1.07 ± 0.13	0.76 ± 0.07
Sediment	12.2 ± 4.7	0.71 ± 0.21	0.62 ± 0.13
ANOVA	$p = 0.001$ $F_{(1,11)}$ 20.1	$p = 0.005$ $F_{(1,11)}$ 12.7	$p = 0.047$ $F_{(1,11)}$ 5.1

In 2000, 67 benthic species (41 ≥ 1 % relative abundance) were found on stones in seven lakes, while in 2003, 77 benthic species (59 ≥ 1 %) were found on stones in 10 lakes. The most species rich genera or groups in 2000 and 2003 were *Achnanthes* sensu lato with 13 species including several species formerly in *Achnanthes* but now transferred to other genera in particular *Psammothidium*, *Eunotia* (10, 13), *Navicula* sensu lato (12, 7), *Fragilaria* sensu lato (6, 7), *Gomphonema* (5, 5) and *Aulacoseira* (3, 4). Assemblages of both years possessed many taxa with unclear species level identity (2000: 39 %, 2003: 51 %) and some of these taxa without precise taxonomic indentification were frequent and abundant in the lakes. Comparisons between species numbers found in different microhabitats can only be made with reservation because stones were collected in ten lakes, sediments in six lakes, sand in four lakes and macrophytes only in two lakes (Table 8). However, it seems that species belonging to *Achnanthes* sensu lato occurred equally on stones (10), sediments (11), sand (10) and macrophytes (6). Similar number of species belonging to *Navicula* sensu lato (6, 4, 4) and *Fragilaria* sensu lato (5, 5, 3,) occurred on stones, sediments and sand respectively. Four *Gomphonema* species were found on stones, three on sand, two on macrophytes but only one on the sediments. There were also more *Eunotia* species on stones (13) than on sediments (3) and sand (5), but five species occurred on macrophytes in only two lakes. Species richness was higher on stones (63, 47 ≥ 1 %) than on sediments (40, 18 ≥ 1 %), sand (40, 16 ≥ 1 %) and macrophytes (22, 13 ≥ 1 %).

Table 8. Substrates collected from different lakes of Gosainkund area in 2003

	Stones	***Sediments***	***Sand***	***Macrophytes***
Lake 1	X		X	
Lake 2	X		X	
Lake 3/1	X		X	
Lake 3/2	X	X		X
Lake 4	X	X		
Lake 5	X	X	X	
Lake 6	X			
Lake 7	X	X		
Lake 8	X	X		
Lake 9	X	X		X
Lake 10	X			

In 2000, the most common and abundant species in epiplithic assemblages were *Achnanthidium minutissimum* (Kützing) Czarnecki, *Achnanthes* cf. *linearis* (W. Smith) Grunow and *Aulacoseira* sp.1. (Fig. 2) and in 2003 they were *A. minutissimum*, *Psammothidium* cf. *marginulatum* (Grunow) Bukhtiyarova & Round and *A.* cf. *linearis* (Fig. 3). Assemblage composition differed substantially between different lakes in both years. *Eunotia muscicola* v. *tridentula* (Nörpel & Lange-Bertalot), *Eunotia* sp.1, *Anomoeoneis brachysira* (Brébisson) Grunow were typical at Lakes 1, 2 and 4 in 2000 and were absent or occurred only at very low abundances at the other lakes. In 2003 the same *Eunotia* species were typical at Lake 1, 9 and 10 and *A. brachysira* was typical in Lake 1, 7 and 9. Characteristic species in Lakes 3/2, 4 and 5 in 2000 included *Psammothidium* *subatomoides* (Hustedt) Bukhtiyarova & Round and *Staurosira* cf. *construens* Ehrenberg v. *venter* (Ehrenberg) Hustedt. The former two species and *Navicula* cf. *digitulus* Hustedt

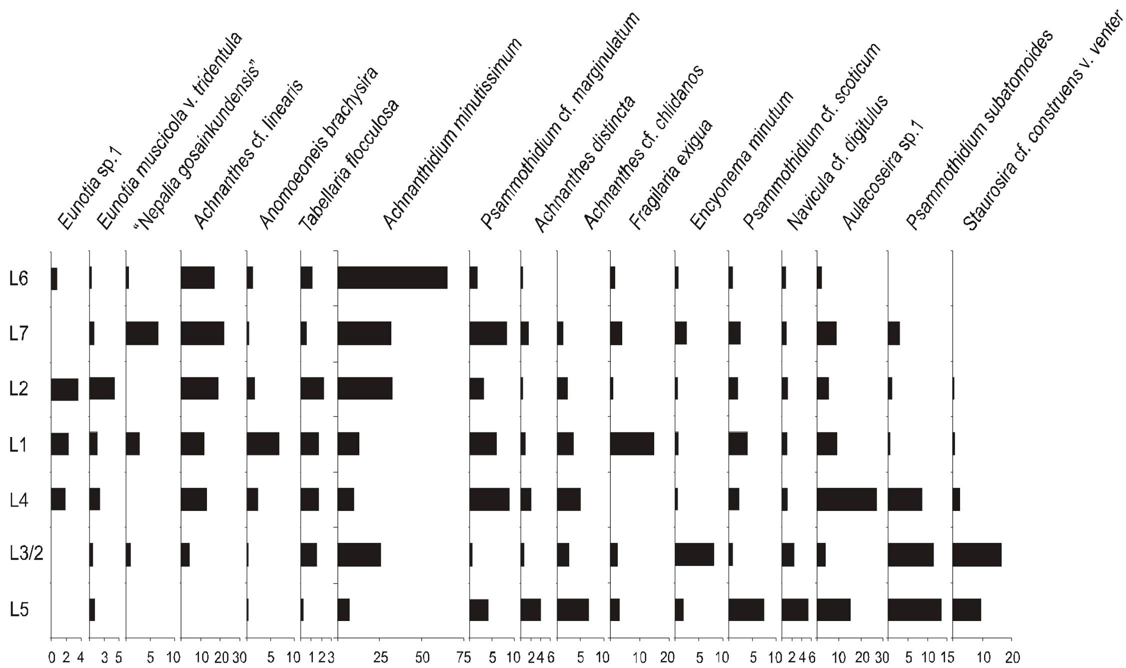


Fig. 4.2 Relative abundances of common diatom species in Gosainkund lakes, November 2000.

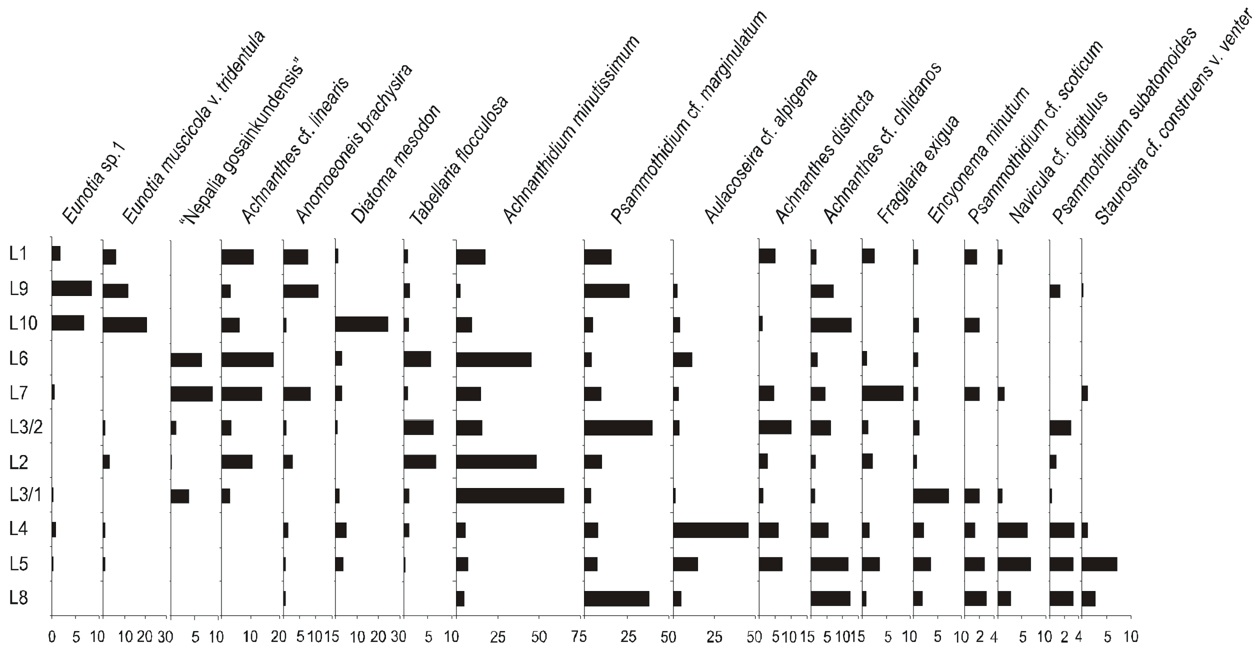


Fig. 4.3 Relative abundances of common diatom species in Gosainkund lakes, May 2003.

were typical at Lakes 4, 5 and 8 in 2003. *Encyonema minutum* (Hilse in Rabenhorst) D.G. Mann was most abundant at Lake 3/1 in 2003 and at Lake 3/2 in 2000.There was a considerable change in assemblage composition in all lakes between 2000 and 2003 (Figs 4, 5 a, b). The most common species *A. minutissimum* was more abundant in 2003 at Lakes 1 and 2, but less abundant at Lakes 3/2, 4, 6 and 7. At Lakes 1 and 2 species such as *Fragilaria exigua* Grunow (at Lake 1), *Aulacoseira* sp. 1, *Psammothidium* cf. *scoticum* (Flower & Jones) Bukhtiyarova & Round, *Achnanthes* cf. *chlidanos* Hohn & Hellermann and *Eunotia* sp.1 declined. Species which were more abundant in 2003 at many lakes included *Aulacoseira* cf. *alpigena* (Grunow) Krammer, *P.* cf. *marginulatum*, *Achnanthes distincta* Messikommer, *Tabellaria flocculosa* (Roth) Kützing, *A. brachysira* and "*Nepalia gosainkundensis*" manuscript name. Species which declined in many lakes included *Aulacoseira* sp.1, *P. subatomoides*, *S.* cf. *construens* v. *venter* and *P.* cf. *scoticum*.

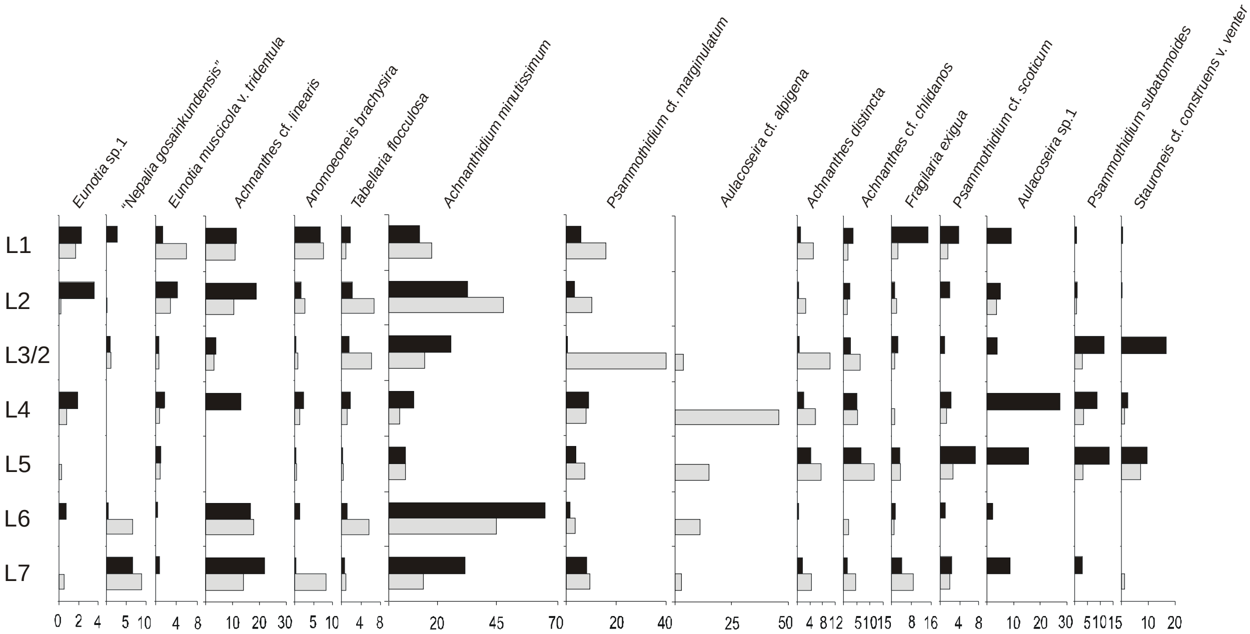
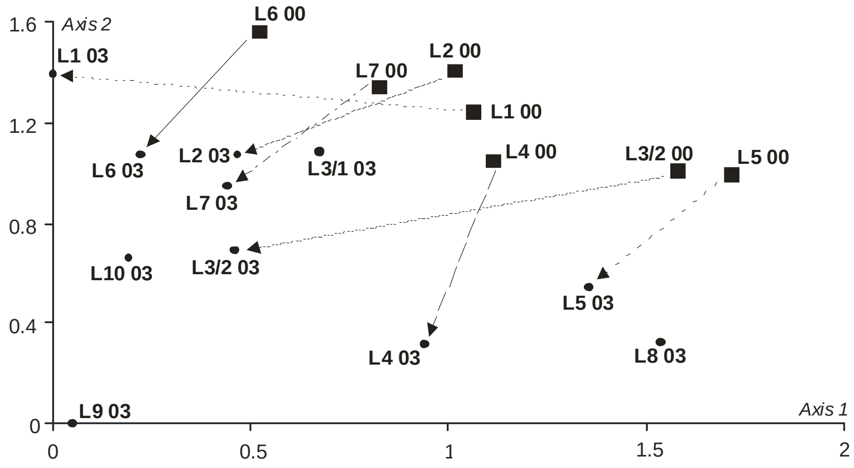
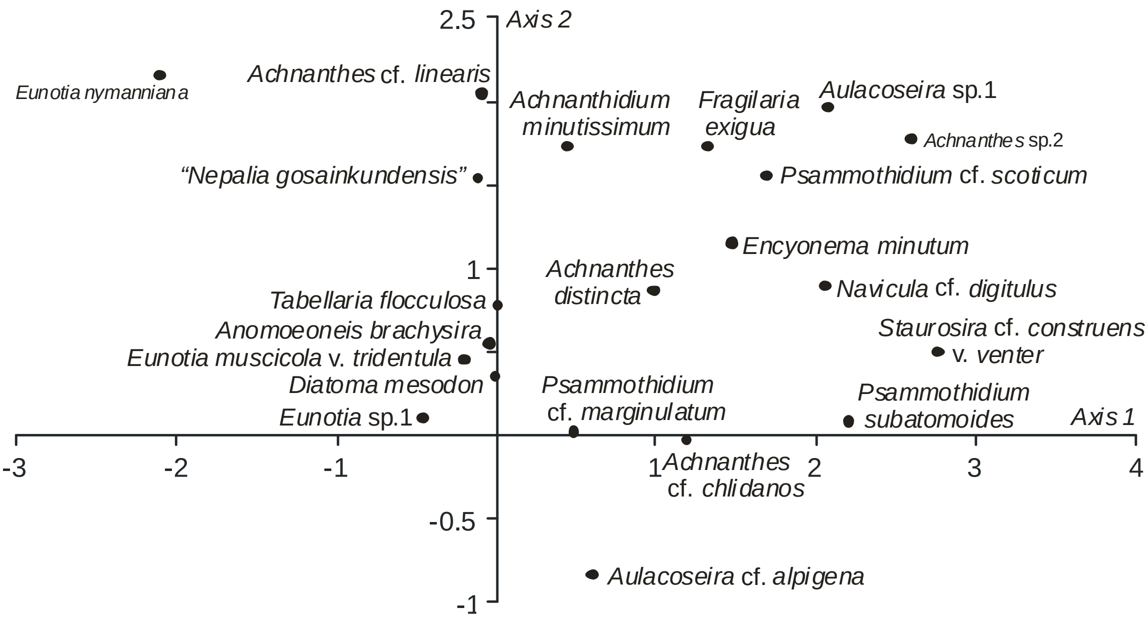


Fig. 4.4 Differences in relative abundances of common and abundant diatom species of Gosainkund lakes in 2000 and 2003
[November 2000 (black bars) and May 2003 (grey bars)].

There were substantial differences between assemblages in different microhabitats within the same lake for most lakes where several substrates were collected (Figs 6 a, b, 7, Table 9).

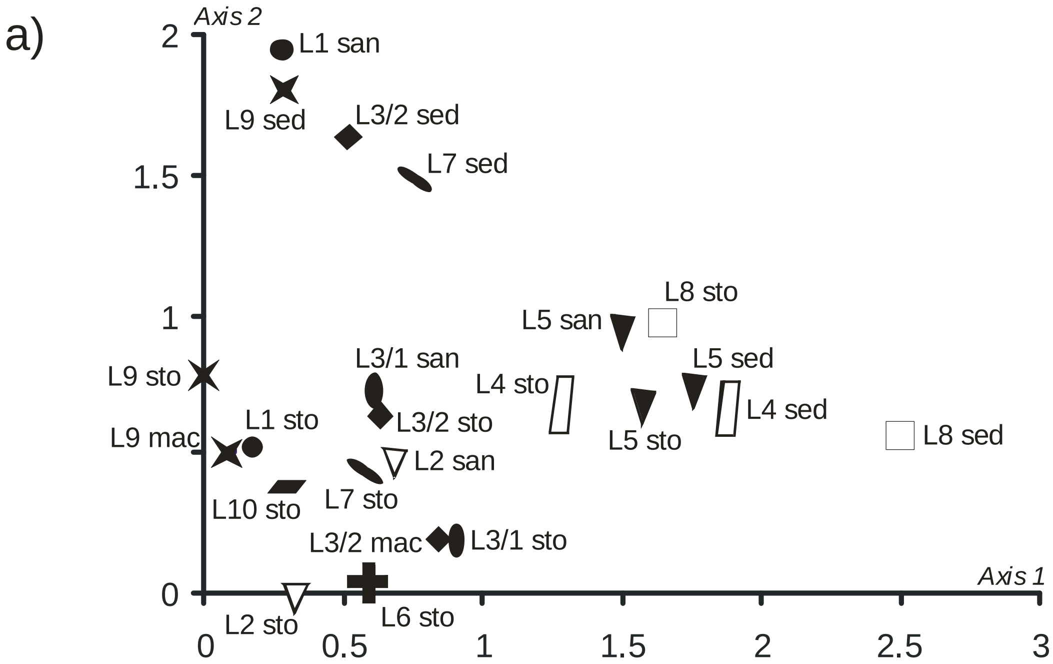


5. (a). DCA ordination of diatom assemblages in Gosainkund lakes in 2000 (-00)and 2003 (03), arrows indicate differences in ordination scores of assemblages from the same lakes.



5. (b). DCA species ordination of Gosainkund lakes in November 2000 and May 2003, small font = species with low frequency.

Fig. 4.5 DCA ordinations of diatom assemblages of Gosainkund lakes in 2000 and 2003.



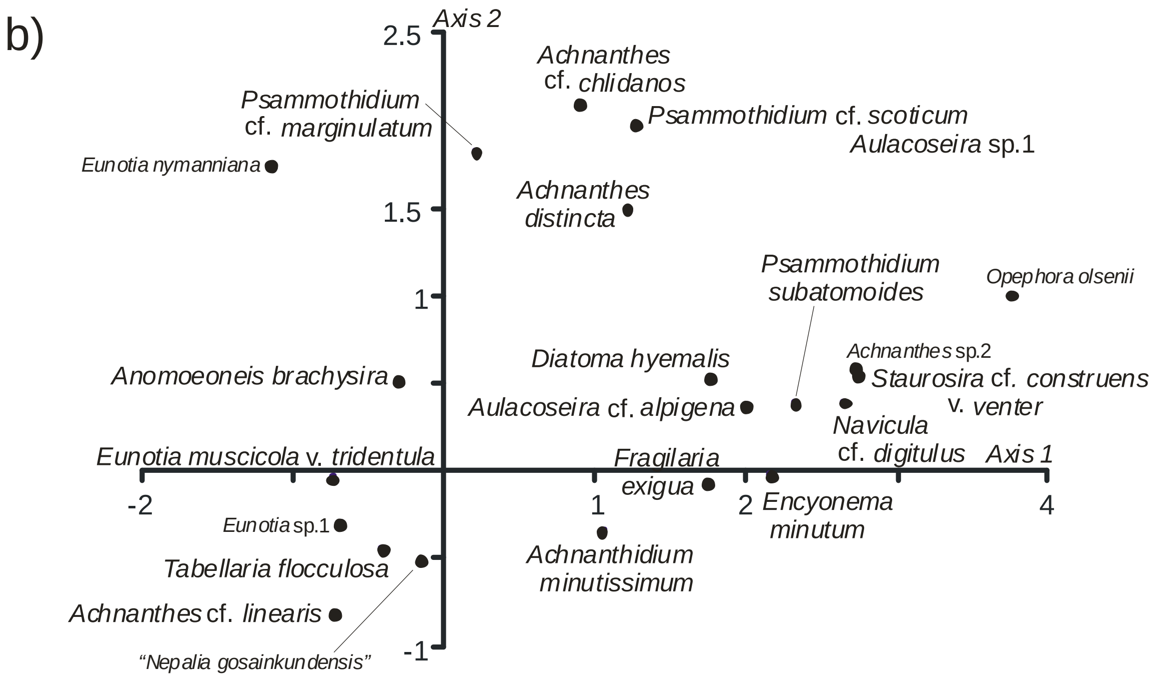


Fig. 4.6 DCA ordinations of microhabitat diatom assemblages of Gosainkund lakes, May 2003
a) ordination of assemblages, identical symbols indicate different substrates from the same lake, b) species ordination, small font size = species with low frequency.

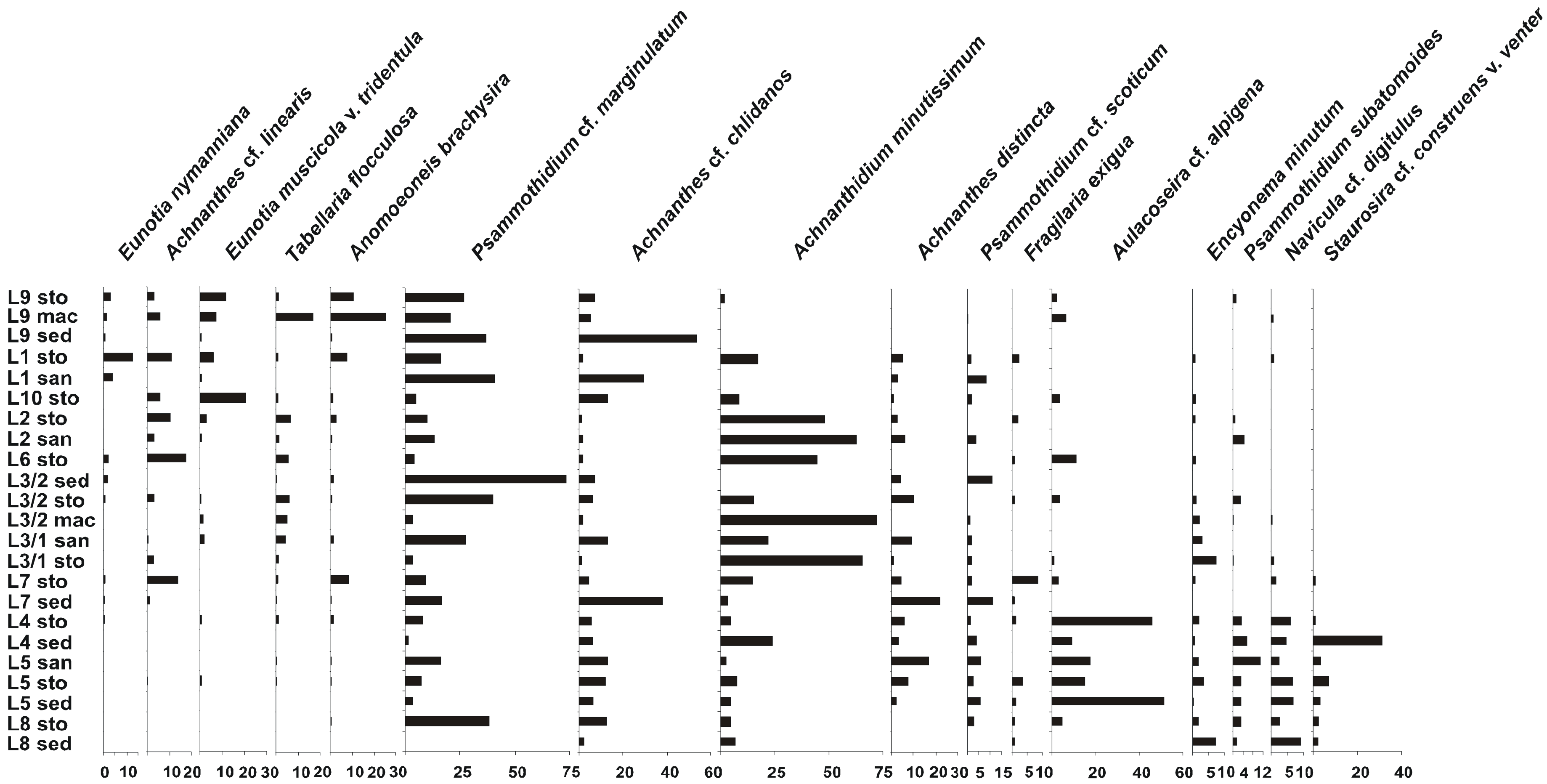


Fig. 4.7 Relative abundances of common diatom species in different microhabitats of Gosainkund lakes, May 2003

Table 9. Habitat preferences (relative abundances) of diatom species in Gosainkund lakes in 2003.

	Achnanthidium minutissimum		***Achnanthes* cf. *linearis***		***Encyonema minutum***		***Psammothidium* cf. *marginulatum***		***Achnanthes* cf. *chlidanos***		***Achnanthes distincta***		***Psammothidium* cf. *scoticum***		***Psammothidium subatomoides***	
	Stones	**Sand**	**Stones**	**Sand**	**Stones**	**Sand**	**Stones**	**Sand**	**Stones**	**Sand**	**Stones**	**Sand**	**Stones**	**Sand**	**Stones**	**Sand**
Lake 1	17.6	0.3	10.9	0.0	0.8	0.0	16.0	40.6	1.7	29.5	5.0	2.8	1.7	8.2	0.0	0.0
Lake 2	47.9	62.7	10.5	3.2	0.7	0.0	10.1	13.3	1.3	1.8	2.6	6.2	0.0	3.8	0.9	4.4
Lake 3/1	65.3	22.1	2.8	0.6	7.3	2.9	3.4	27.3	1.1	12.9	1.1	8.8	2.0	2.1	0.3	0.0
Lake 5	7.1	2.6	0.3	0.0	3.5	1.7	7.4	16.0	11.5	13.1	7.4	16.9	2.7	5.8	3.2	10.8

	Achnanthes* cf. *linearis		***Tabellaria flocculosa***		***Anomoeoneis brachysira***		***Psammothidium* cf. *scoticum***	
	Stones	**Sedim.**	**Stones**	**Sedim.**	**Stones**	**Sedim.**	**Stones**	**Sedim.**
Lake 3/2	3.2	0.0	6.1	0.3	0.9	1.5	0.0	10.8
Lake 4	0.0	0.0	1.1	0.0	1.4	0.0	1.4	4.1
Lake 5	0.3	0.0	0.3	0.0	0.6	0.0	2.7	5.6
Lake 7	13.9	1.2	0.8	0.3	8.3	0.6	1.9	11.0
Lake 8	0.0	0.0	0.0	0.0	0.6	0.3	2.9	0.0
Lake 9	3.2	0.0	1.1	0.0	10.7	0.9	0.0	0.0

Assemblage composition in different microhabitats was similar in Lake 5 and differed most in Lakes 1, 3/2, 7, 8 and 9 for some of the microhabitats. Several species showed clear habitat preferences. For example *P.* cf. *marginulatum, A.* cf. *chlidanos*, *A. distincta*, and *P. subatomoides* were abundant on sand than on stones, and *P.* cf. *scoticum* was abundant in sediments than on stones in four out of five lakes where it occurred. *A*. cf. *linearis* and *E. minutum* were more abundant on stones than on sand. *T. flocculosa* and . *A. brachysira* were common on stones than on sediment. Other common or abundant species (Fig. 7) showed no preference for any particular microhabitat.

4.4.3 Relationships with habitat character and water chemistry

In both years, there were no significant correlations between species richness S, diversity H', evenness E and water chemistry or littoral substrate composition, except significantly lower evenness at sites with higher percentage of sand ($F_{(1,10)}$ 5.3, $p < 0.001$) in 2003. There was also a trend that diversity was lower at these sites, but this was not significant. Sites with higher percentage of gravel also tended to have lower evenness.

Canonical correspondence analysis (CCA) with forward selection of environmental variables revealed significant relationships between changes in species composition and land use in 2000 and between species composition, land use and water chemistry in 2003. In 2000, CCA axis 1 explained 29.2 % and axis 2 explained 23.0 % of the variance. Forward selection of environmental variables revealed that only land use "rough grassland" contributed significantly to the model and was most strongly correlated with axis 1, while bank profile "gentle banks" was almost significant and most strongly correlated with axis 2 (Fig. 8 a). However, several other variables, reflecting gradients in littoral substrate composition, land use and water chemistry, also seemed to be correlated with diatom assemblage change represented by axis 1 but did not significantly contribute

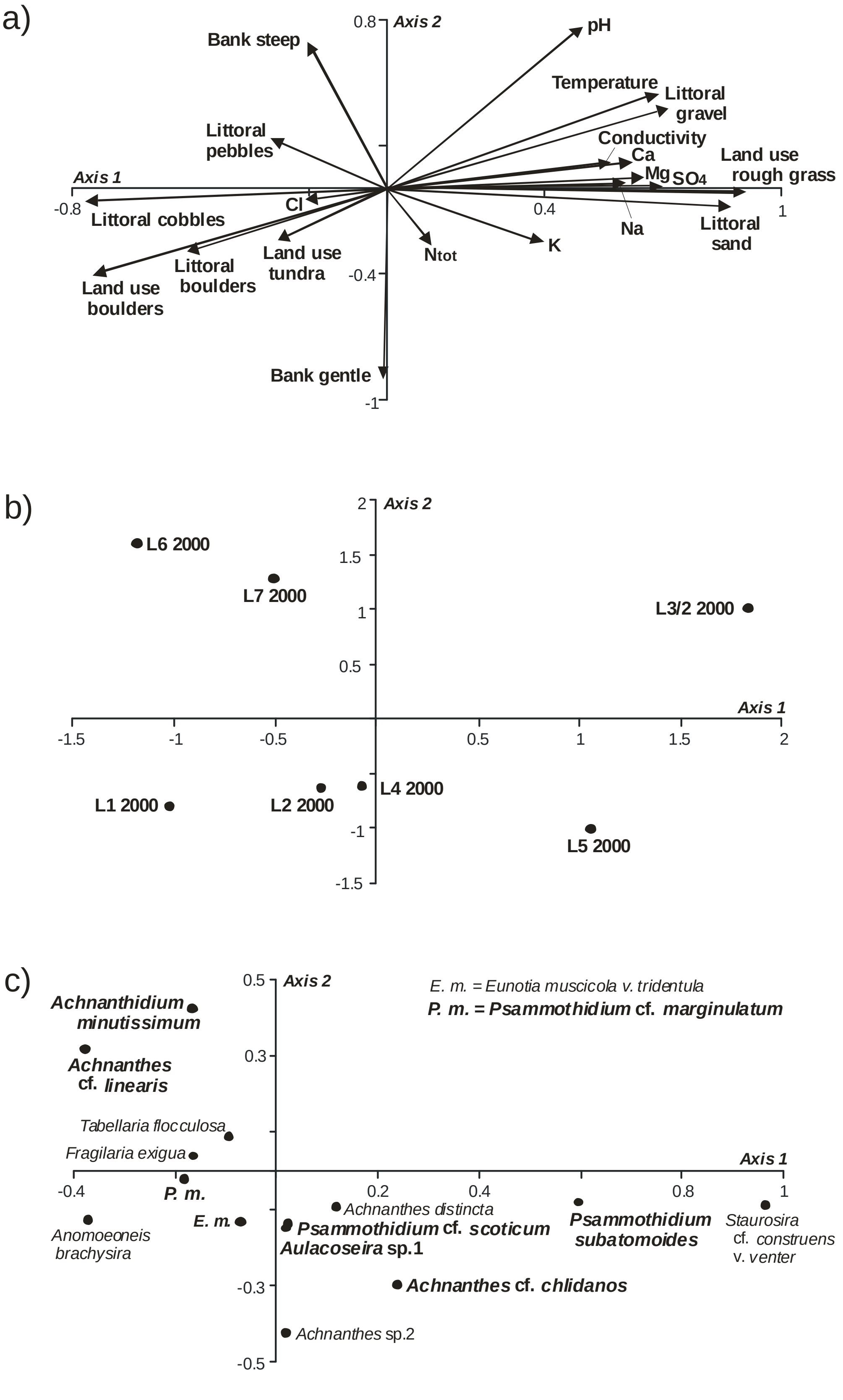


Fig. 4.8 CCA ordinations of diatom assemblages of Gosainkund lakes, November 2000

a) ordination of environmental variables, b) assemblages ordination, c) species ordination, small font = species with low frequency.

to the model. Species most abundant at lakes with higher percentage of rough grassland in the catchment, smaller substrate sizes (sand, gravel) in the lake littoral and higher concentrations of Na, Ca, Mg and SO_4 were *S.* cf. *construens* v. *venter*, *P. subatomoides*, *A.* cf. *chlidanos*, *A. distincta*, *P.* cf. *scoticum*, *Aulacoseira* sp.1 and *Achnanthes* sp. 2 (Figs 8 b, c). In lakes with boulder fields as main land use and coarser substrate types (cobbles, boulders) in the littoral *A. brachysira*, *A.* cf. *linearis*, *P.* cf. *marginulatum*, *A. minutissimum*, *F. exigua*, *T. flocculosa* and *E. muscicola* v. *tridentula* were typical. *A. minutissimum* and *A.* cf. *linearis* also seemed more characteristic in lakes with steeper banks, while *P.* cf. *scoticum*, *Aulacoseira* sp.1, *A.* cf. *chlidanos* and *P. subatomoides* were the most abundant species in lakes with predominantly gentle banks.

In 2003, CCA axis 1 explained 23.3 % of the variance and axis 2 explained 18.0 % of the variance. Forward selection of environmental variables revealed that land use “rough grassland” and Na concentrations contributed significantly to the model, but total nitrogen, Cl, conductivity, temperature, littoral substrate composition and bank profile also seemed to be correlated with changes in assemblage composition represented by axis 1 and 2 (Fig. 9a). While *A.* cf. *alpigena* and *P.* cf. *marginulatum* were the most abundant species at lakes with more rough grass as catchment land use, higher total nitrogen, conductivity, littoral silt and composite banks, *A. minutissimum* and *A.* cf. *linearis* were the most abundant species at the opposite end of this gradient and as in 2000 associated with coarser substrate types in the littoral, steeper banks and boulder fields as predominant land use. In 2003 *A. minutissimum* and *A.* cf. *linearis* also indicated higher Na concentrations (Figs 9b, c).

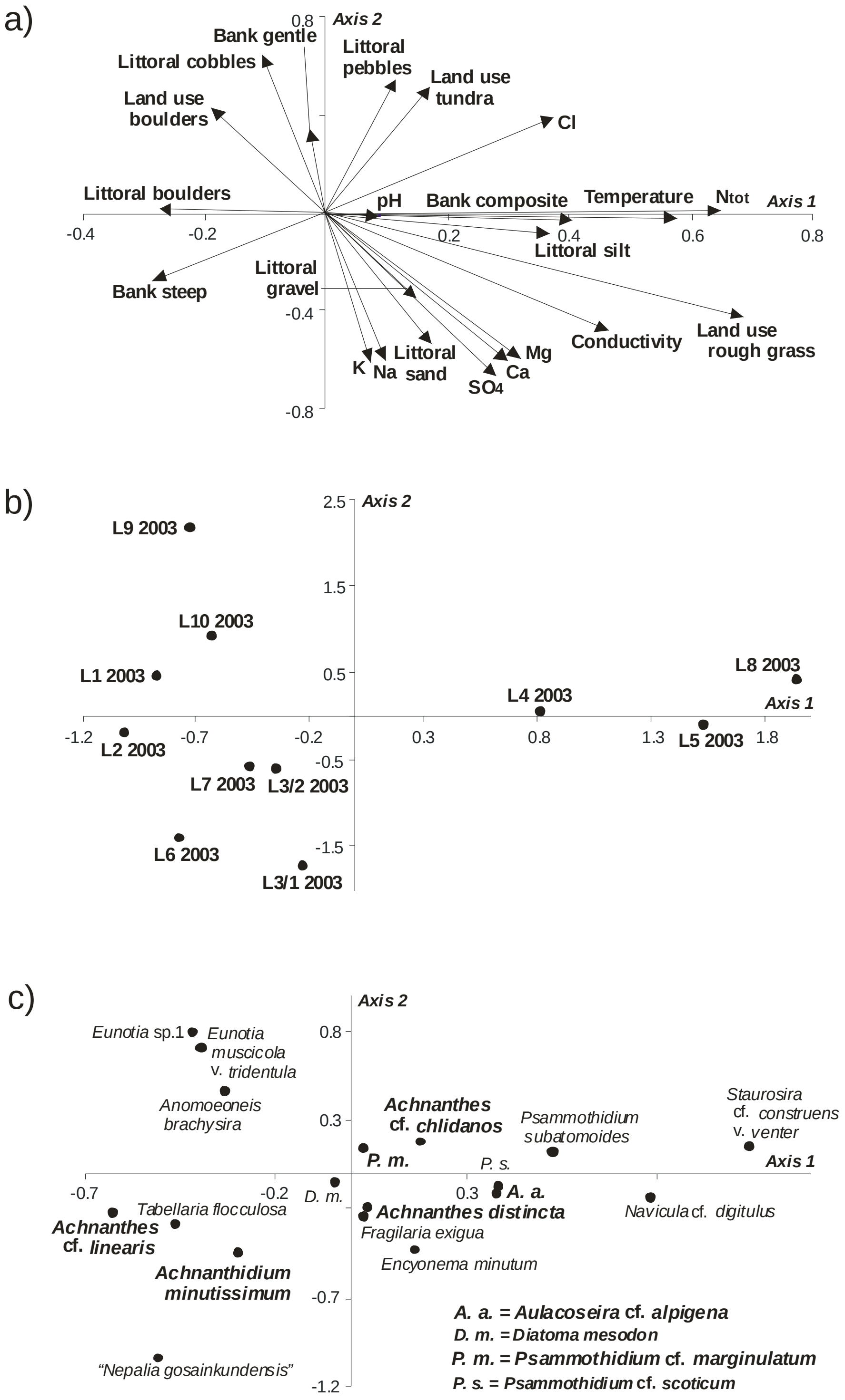


Fig. 4.9 CCA ordinations of diatom assemblages of Gosainkund lakes May 2003
a) ordination of environmental parameters, b) assemblages ordination, c) species ordination, small font = species with low frequency.

4.5 Discussion

4.5.1 Acidification

Lakes in the Gosainkund area of high altitude regions of central Nepal are at risk of environmental degradation such as acidification, eutrophication and climate related change due to their geology composed of base-poor bedrock, their location in close proximity to a major regional urban centre and impacts of rising atmospheric pollution over the Indian subcontinent. The present study indicates differences in chemical conditions between the autumn and spring after the main snow melt, which was also reflected by changes in diatom assemblages. The findings stress the need for further investigations to assess consequences of long distance transport of atmospheric pollutants and other anthropogenic impacts for these sensitive ecosystems.

The ionic content and conductivity of water in the Gosainkund lakes was low, probably reflecting bedrock mineralogy, which has great influence on water chemistry in mountain lakes (Kamenik *et al*. 2001). In Gosainkund area water chemistry varied very little between lakes in contrast to eastern Himalayan lakes of the Everest National Park with similar geological background (Tartari *et al*. 1998). The main cause of a much greater variability in water chemistry of the former lakes was due to the presence of glaciers in some of the watersheds, while glaciers were absent in the catchments of the investigated lakes at Gosainkund. There were significant variations in water chemistry between seasons with pH significantly lower and K, Cl and total nitrogen significantly higher during May 2003. Most of the snow in the lakes' catchments had melted and it is possible that acids stored in the snow cover had been released and were responsible for higher acidity during spring. Acid episodes with high concentration of NO_3 also occurred during snow melt in other alpine ecosystems and had toxic effects on biota (Lepori *et al*. 2003, Lepori & Ormerod

2005). Sulfate concentration was low in the Gosainkund lakes during spring, suggesting possibly NO_3 is the main factor responsible for lowering water pH. This would be similar to the situation in Europe, where SO_4 has decreased and NO_3 increased over the last decades (Psenner & Catalan 1994). In May 2003 rain water collected c. 12 km south of the Gosainkund lakes and snow collected at the Laurebina Pass (4670 m) close to the lakes had pH values of 6.6 and 6.5 similar to a mean pH of 6.5 found for the lakes. However, total nitrogen concentrations in rain (1.11 mg/L) and in snow (0.32 mg/L) were considerably higher than in the lakes (mean 0.10 mg/L). Low pH values were also measured in December 2003 in 30 springs in the Nepalese Middle Hills close to the Kathmandu Valley (mean pH 5.7, median 5.8, Dahal & Jüttner 2004) and in May 2003 in springs of the Helambu area north of the Kathmandu Valley and south of Gosainkunda (pH 4.9 and 5.9, Jüttner unpubl. data). These findings suggest that acid depositions are the most likely source of pollution at present affecting high altitude lakes in the Gosainkund area during spring. Other aquatic ecosystems closer to the highly polluted area of the Kathmandu Valley such as springs might be already more severely affected.

4.5.2 Biodiversity and relationships with environmental conditions

Species richness, diversity and evenness were low in all lakes. However, assemblage with high number of taxa whose species level identification is not clear consulting the published floras suggest that further taxonomic investigations might reveal the importance of these lakes as habitats for a specific high altitude diatom flora. In contrast to other studies in standing waters of Nepal, where epipelic assemblages were significantly more species rich and diverse (Simkhada & Jüttner 2006, Simkhada *et al*. in press) in the Gosainkund lakes species richness, diversity and evenness were significantly higher in epilithic assemblages. Similarly, in the Gosainkund area assemblages show microhabiat selectivity. Several species showed clear habitat preferences with some being more abundant on stones and others more abundant on sand or sediments. Habitat preferences of certain diatom species were also found in ultra-oligotrophic ponds and in the Canadian arctic lakes where water chemistry conditions were similar across sites as in this study (Michelutti *et al*. 2003). However, assemblages also differed between microhabitats such as sediments and aquatic macrophytes in ponds of the Nepalese lowlands despite the presence of strong chemical gradients suggesting specific habitat properties rather than chemical conditions are important factors in determining habitat preferences of certain species.

Many of the common and most abundant diatom taxa were similar to species characteristic for mountain lakes in Europe and belong to the genera *Achnanthes* sensu lato, *Eunotia* and *Aulacoseira*. The total number of taxa found in the Gosainkund lakes ranged between 22 - 38 in 2000 and 9 – 30 in 2003 and was lower on average than in 17 lakes in the Italian Alps (25 – 122) which are also situated on crystalline rocks (Tolotti 2001). In the Italian lakes *Achnanthes marginulata* Grunow (transferred to *Psammothidium marginulatum*) and a related but yet unidentified species were the most frequent taxa. In May 2003 when the Gosainkund lakes were more acidic a species similar to *P. marginulatum* occurred abundantly and further taxonomic studies on specimen from both regions would be interesting to establish their true identity. In contrast to the lakes in the Italian Alps species which are typical in strongly acidified waters such as *Eunotia exigua* (Brébisson) Rabenhorst or *Eunotia subarcuatoides* Alles, Nörpel-Schempp & Lange-Bertalot Cleve (Tolotti 2001, Lewis *et al*. in press), were not present in the Gosainkund lakes. However, another species *T. flocculosa* (Jüttner *et al.* 1997, Jüttner unpubl. data) characteristic for moderate acidification occurred in the Gosainkund lakes and was more abundant in spring 2003 than in autumn 2000.

Despite the absence of strong environmental gradients, in 2000 there were clear variations in species composition between lakes. In 2003 differences in temperature and pH were more pronounced and so were changes in assemblage composition as reflected by DCA axis 1 and 2. DCA ordination also revealed that diatom assemblages differed between autumn 2000 and spring 2003. Although there were differences in the direction of change with respect to relative abundances of several species and some species increased in some lakes but decreased in others, overall change between 2000 and 2003 as indicated by DCA axis 1 and 2 scores were the same for all lakes. Several species were less abundant in 2003 including two unidentified species of the genera *Aulacoseira* and *Eunotia*. Similar to changes in low alkalinity mountain lakes in Scotland (Jones *et al*. 1993, Battarbee 2005) *P.* cf. *scoticum* (transferred from *Achnanthes scotica* Flower) had decreased and *P.* cf. *marginulatum* had increased in spring 2003 with the latter indicating increased acidity. As in the Scottish lakes *A. minutissimum* had also decreased in the majority of the Gosainkund lakes except in Lake 1 and 2 where it was more abundant in spring 2003. At Lochnagar in Scotland *Aulacoseira distans* v. *nivalis* (Smith) Haworth had increased from the 1960s while at the Gosainkund lakes *A.* cf. *alpigena* was absent in autumn 2000 but appeared in five of the seven lakes in May 2003, and might be an indicator of changes in environmental conditions between both years. *P. subatomoides* had declined significantly in three lakes in spring 2003 while *A.* cf. *chlidanos* had increased in several lakes. The former species occurred at higher pH in 17 high latitude lakes of the Italian Alps and the latter species occurred at lower pH and alkalinity (Tolotti 2001). Although most of the changes in assemblages composition indicated that higher acidity during spring was likely to be the main cause, other differences in environmental conditions between the two surveys such as higher temperature in spring or differences between lakes such as substratum composition in the littoral or catchment land use cannot be ruled out as important factors. Despite the observation of few significant relationships between diatoms and environmental variables, CCA ordinations showed these factors were responsible for assemblages change. However, the very small number of lakes might have hampered the analysis and results should therefore be interpreted with caution and regarded as preliminary unless a larger number of lakes in the region have been investigated. In both years water chemistry in particular conductivity and concentrations of Ca, Mg, SO_4, K and Na, land use and substrate composition in the littoral seemed to be associated with assemblage change similar to findings in lowland ponds of Nepal (Simkhada *et al*. in press). Though a more pronounced gradient in pH was observed in May 2003, the pH differences between lakes were unrelated to assemblage changes represented by CCA axis 1 and 2, and in some cases assemblages from lakes with similar pH were not grouped together by DCA ordination supporting the hypothesis that other factors might have also affected for change in diatom assemblages composition.

Climate related changes such as altered levels of UV radiation and temperatures can have significant effects on sensitive ecosystems including pH shifts, particularly in lakes with low levels of UV- screening and dissolved organic carbon such as lakes at high altitudes or latitudes (Koinig *et al*. 1998, Vincent & Pienitz 1996), and these should be considered as potentially important stressors in Himalayan lakes. In addition, increased nutrient concentrations due to long distant atmospheric transport and direct release of untreated sewage from local settlements are the potential threats to the health of these ecosystem. In the Gosainkund area during Janai Purnima festival in August brings a large number of pilgrims to the lakes and a study during this time of the year could investigate potential effects on nutrient concentrations and biological assemblages. Epipsammic diatoms which have proved as sensible indicators of short-term nutrient enrichment in an oligotrophic lake in Germany (Raeder & Busse 2001) are also common at the Gosainkund lakes, and could be used to monitor such changes at Gosainkund. Littoral diatoms from stones, mud and reeds were used in a study on Austrian lakes and showed that epiphytic assemblages were most suited to indicate lake trophic status (Poulíčková *et al*. 2004). The choice of the most suitable substrate might vary with the location and environmental conditions of the lakes and should therefore be carefully considered. Further surveys can identify particular indicator species and compile autecological information to establish pH and nutrient optima (Potapova & Charles 2003). These data could then be applied in paleolimnological reconstructions of recent environmental change using sediment cores (Bennion *et al*. 2004). A wider survey to relate environmental conditions and diatom assemblage distribution in Himalayan high altitude lakes, could also characterise reference assemblages before more pronounced environmental changes have occurred and against which future changes can be judged (Simpson *et al*. 2005). A large scale survey in Nepal could involve more lakes in the area of Gosainkund as well as a large number of lakes further east in the Everest National Park. These lakes are located above the tree line (4200m) and in areas of similar geological background, but represent a wide range of ecological conditions due to variations in land use and the presence and absence of glaciers. The proposed study could assess their current ecological status and provide important information for monitoring environmental change and for the future protection of these ecosystems.

In addition to further ecological studies there is an urgent need for more taxonomic work. This study highlighted that the absence of taxonomic literature prevented the identification of many species, without which comparisons with respect to ecological preferences of species in other parts of the world and their use as indicator organisms remains unclear. Previous studies in Nepal have shown that new diatom species occur more often in the eastern parts of the Himalayas (Jüttner *et al*. 2004) and some seem to be characteristic of particular environmental conditions (Jüttner *et al.* 2000). One species in the Gosainkund lakes has been identified as a member of a new genus (Jüttner *et al.* in prep.) and further taxonomic studies on the diatom flora of these lakes will follow with particular emphasise on taxa of uncertain taxonomic status and comparisons with other high altitude lake floras.

4.6 References

Aizaki M., Terashima A., Nakahara H., Nishio T. & Ishida Y. 1987. Trophic status of Tilitso, a high altitude Himalayan lake. *Hydrobiologia* **153**, 217–224.

Baron J.S., Nydick K.R., Rueth H.M., Lafrancois B.M. & Wolfe A.P. 2005. High elevation ecosystem responses to atmospheric deposition of nitrogen in the Colorado Rocky Mountains, USA. In: Global Change and Mountain Regions. Huber U.M., Bugmann H.K.M. & Reasoner M.A. (eds), pp. 429–436, *Advances in Global Change Research* 23, Springer, Dordrecht.

Battarbee R.W (ed.) 2002. MOLAR: Mountain lake research. *Journal of Paleolimnology* **28**, 1–179.

Battarbee R.W 2005. Mountain lakes, pristine or polluted? Limnetica 24, 1–8.

Battarbee R.W., Patrick S., Kernan M., Psenner R., Thies H., Grimalt J., Rosseland B.O., Wathne B., Catalan J., Mosello R., Lami A., Livingstone D., Stuchlik E., Straskrabova V. & Raddum G. 2005. High mountain lakes and atmospherically transported pollutants. In: Global Change and Mountain Regions. Huber U.M., Bugmann H.K.M. & Reasoner M.A. (eds), pp. 113–121, *Advances in Global Change Research* 23, Springer, Dordrecht.

Bennion H., Fluin J. & Simpson G.L. 2004. Assessing eutrophication and reference conditions for Scottish freshwater lochs using subfossil diatoms. *Journal of Applied Ecology* **41**, 124–138.

Cameron N.G., Birks H.J.B., Jones V.J., Berge F., Catalan J., Flower R.J., Garcia J., Kaweka B., Koinig K.A., Marchetto A., Sanchez-Castillo P., Schmidt R., Šisko M., Soloveiva N., Stefkova E. & Toro Valasquez M. 1999. Surface-sediment and epilithic diatom calibration sets for remote European mountain lakes (AL:PE Project) and their comparison with the Surface Waters Acidification Programme (SWAP) calibration set. *Journal of Paleolimnology* **22**, 291–317.

Clarke G., Kernan M., Marchetto A., Sorvari S. & Catalan J. 2005. Using diatoms to assess geographical patterns of change in high-altitude European lakes from pre-industrial times to the present day. *Aquatic Sciences* **67**, 224–236.

Dahal B.M. & Jüttner I. 2004. Monitoring water quality in springs of the Nepalese Middle Hills using diatoms. Report to the British Ecological Society SEPG No. 2235–2003.

Davies S.J., Metcalfe S.E., Caballero M.E. & Juggins S. 2002. Developing diatom-based transfer functions for Central Mexican lakes. *Hydrobiologia* **467**, 199–213.

Donner W. 1994. *Lebensraum Nepal. Eine Entwicklungsgeographie*. Mitteilungen des Instituts für Asienkunde 226. Hamburg.

Grimalt J.O., Fernandez P., Berdie L., Vilanova R.M., Catalan J., Psenner R., Hofer R., Rosseland B.-O., Lien L., Massabuau J.C. & Battarbee R.W. 2001. Selective trapping of organochlorine compounds in mountain lakes of temperate areas. *Environmental Science & Technology* **35**, 2690–2697.

Jones V.J., Flower R.J., Appleby P.G., Natkanski J., Richardson N., Rippey B., Stevenson A.C. & Battarbee R.W. 1993. Paleolimnological evidence for the acidification and atmospheric contamination of lochs in the Cairngorm and Lochnagar areas of Scotland. *Journal of Ecology* **81**, 3–24.

Jüttner I., Rothfritz H. & Ormerod S.J. 1996. Diatoms as indicators of river quality in the Nepalese Middle Hills with consideration of the effects of habitat-specific sampling. *Freshwater Biology* **36**, 101–112.

Jüttner I., Lintelmann J., Michalke B., Winkler R., Steinberg C.E.W. & Kettrup A. 1997. The acidification of the Herrenwieser See, Black Forest, Germany, before and during industrialisation. *Water Research* **31**, 1194–1206.

Jüttner I., Cox E.J. & Ormerod S.J. 2000. New and poorly known diatoms from Himalayan streams. *Diatom Research* **15**, 237–262.

Jüttner I., Sharma S., Dahal B.M., Ormerod S.J. & Cox E.J. 2003. Diatoms as indicators of stream quality in the Kathmandu Valley and Middle Hills of Nepal and India. *Freshwater Biology* **48**, 2065–2084.

Jüttner I., Reichardt E. & Cox E.J. 2004. Taxonomy and ecology of some new *Gomphonema* species common in Himalayan streams. *Diatom Research* **19**, 235–264.

Kamenik C., Schmidt R., Kum G. & Psenner R. 2001. The influence of catchment characteristics on the water chemistry of mountain lakes. *Arctic, Antarctic, and Alpine Research* **33**, 404–409.

Karst-Riddoch T.L., Pisaric M.F.J., Youngblut D.K. & Smol J.P. 2005a. Postglacial record of diatom assemblage changes related to climate in an alpine lake in the northern

Rocky Mountains, Canada. *Canadian Journal of Botany – Revue Canadienne de Botanique* **83**, 968–982.

Karst-Riddoch T.L., Pisaric M.F.J. & Smol J.P. 2005b. Diatom responses to 20th century climate-related environmental changes in high-elevation mountain lakes of the northern Canadian Cordillera. *Journal of Paleolimnology* **33**, 265–282.

Köck G., Hofer R. & Wögrath S. 1995. Accumulation of trace metals (Cd, Pb, Cu, Zn) in Arctic char (*Salvelinus alpinus*) from oligotrophic alpine lakes: relation to alkalinity. *Canadian Journal of Fisheries and Aquatic Sciences* **52**, 2367–2376.

Koinig K.A., Schmidt R., Sommaruga-Wögrath S., Tessadri R. & Psenner R. 1998. Climate change as the primary cause for pH shifts in a high alpine lake. *Water, Air, and Soil Pollution* **104**, 167–180.

Krammer K., 1997. Die cymbelloiden Diatomeen. Eine Monographie der weltweit bekannten Arten. Vol. **1,2**. J. Cramer, Berlin.

Krammer K. & H. Lange-Bertalot, 1986–1991. *Bacillariophyceae, Süßwasserflora von Mitteleuropa*, Vol. **2**, Parts 1–4, Ettl H., Gerloff J., Heynig H. & Mollenhauer D. (eds), Gustav Fischer Verlag, Stuttgart.

Kwandrans J. 1994. Benthic diatom communities in two acidic mountain lakes (Sudeten Mts, Poland). In: Proceedings of the Thirteenth International Diatom Symposium. Marino D. & Montresor M. (eds), pp. 281–293. Biopress, Bristol.

Lami A., Guilizzoni P., Marchetto A., Bettinetti R. & Smith D.J. 1998. Paleolimnological evidence of environmental changes in some high altitude Himalayan lakes (Nepal). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 107–130.

Lange-Bertalot H. & Krammer K. 1989. Achnanthes. Monographie der Gattung. *Bibliotheca Diatomologica* **18**, J. Cramer, Berlin.

Lepori F. & Ormerod S.J. 2005. Effects of spring acid episodes on macroinvertebrates revealed by population data and in situ toxicity tests. *Freshwater Biology* **50,** 1568–1577.

Lepori F., Barbieri A. & Ormerod S.J. 2003. Causes of episodic acidification in alpine streams. *Freshwater Biology* **48**, 175–189.

Lewis B., Jüttner I., Reynolds B. & Ormerod S.J. Comparative assessment of stream acidity using diatoms and macroinvertebrates: implications for river management and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, in press.

Leydecker A., Sickman J.O. & Melack J.M. 2001. Spatial scaling of hydrological and biogeochemical aspects of high-altitude catchments in the Sierra Nevada, California, U.S.A. *Arctic, Antarctic, and Alpine Research* **33**, 391–396.

Löffler H. 1969. High altitude lakes in Mt Everest region. *Verhandlungen Internationale Vereinigung Limnologie* **17**, 373–385.

Manca M., Ruggiu D., Panzani P., Asioli A., Mura G. & Nocentini A.M. 1998. Report on a collection of aquatic organisms from high mountain lakes in the Khumbu Valley (Nepalese Himalayas). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 77–98.

Michelutti N., Holtham A.J., Douglas M.S.V. & Smol J.P. 2003. Periphytic diatom assemblages from ultra-ologotrophic and UV transparent lakes and ponds on Victoria Island and comparisons with other diatom surveys in the Canadian Arctic. *Journal of Phycology* **39**, 465–480.

Noda T., Onodera S., Hirose T. & Naruoka T. 2001. Sediment yield variation in small catchments with different bedrock in a humid temperate region. *Arctic, Antarctic, and Alpine Research* **33**, 435–439.

Potapova M. & Charles D.F. 2003. Distribution of benthic diatoms in U.S. rivers in relation to conductivity and ionic composition. *Freshwater Biology* **48**, 1311–1328.

Poulíčková A., Duchoslav M. & Dokulil M. 2004. Littoral diatom assemblages as bioindicators of lake trophic status: a case study from perialpine lakes in Austria. *European Journal of Phycology* **39**, 143–152.

Psenner R. & Catalan J. 1994. Chemical composition of lakes in crystalline basins: a combination of atmospheric deposition, geologic background, biological activity and human action. In: *Limnology Now: A Paradigm of Planetary Problems*. Margalef R. (ed.), pp. 255-314. Elsevier Science, Amsterdam.

Psenner R., Mosello R., Boggero A., Marchetto A., Wathne B. & Lien L. 2000. Mountain lake research (MOLAR): atmospheric deposition and lake water chemistry. *Verhandlungen Internationale Vereinigung Limnologie* **27**, 1008–1012.

Raeder U. & Busse L.B. 2001. Composition and development of epipsammic diatoms in an oligotrophic lake (Lake Lustsee, Germany) under natural conditions and under artificial phosphate supply using enclosure experiments. In: *Lange-Bertalot-Festschrift*. Jahn R., Kocioloek J.P., Witkowski A. & Compère P. (eds), pp. 384–400. Gantner, Ruggell.

Ramanathan V., Crutzen P.J., Mitra A.P. & Sikka D. 2002. The Indian Ocean experiment and the Asian brown cloud. *Current Science* **83**, 947 – 955.

Reche I., Pulido-Villena E., Conde-Porcuna J. M. & Carrillo P. 2001. Photoreactivity of dissolved organic matter from high-mountain lakes of Sierra Nevada, Spain. *Arctic, Antarctic, and Alpine Research* **33**, 426–434.

Reichardt E. 1988. Neue Diatomeen aus Bayerischen und Nordtiroler Alpenseen. *Diatom Reseach* **3**, 237–244.

Reichardt E. 1999. Zur Revision der Gattung *Gomphonema*. Die Arten um *G.affine*/*insigne*, G. *angustum*/*micropus*, G. *accuminatum* sowie gomphonemoide Diatomeen aus dem Oberoligozän in Böhmen. *In*: Lange-Bertalot, H. (ed.), *Iconographia Diatomologica* **8**, A.R.G. Gantner, Rugell.

Rothfritz H., Jüttner I., Suren A.M. & Ormerod S.J. 1997. Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity and water quality. *Archive for Hydrobiology* **138**, 465–482.

Round F.E. & L. Bukhtiyarova 1996. Four new genera based on *Achnanthes* (*Achnanthidium*) together with a re-definition of *Achnanthidium*. *Diatom Research* **11**, 345–361.

Schreier H. 2005. Challenges in Mountain Watershed Management. In: Global Change and Mountain Regions. Huber U.M., Bugmann H.K.M. & Reasoner M.A. (eds), pp. 615–625, *Advances in Global Change Research* **23**, Springer, Dordrecht.

Shannon C. & W. Weaver 1949. *The mathematical theory of communication*. University Illinois Press, Urbana.

Simkhada B. & Jüttner I (2006). Diatoms in ponds of the Kathmandu Valley, Nepal – relationships with chemical and habitat characteristics. *Archive for Hydrobiology*, **166** (1), 41–65.

Simkhada B., Jüttner I. & Chimonides P.J. Diatoms in lowland ponds of Koshi Tappu, Eastern Nepal – relationships with chemical and habitat characteristics. *International Revue of Hydrobiology*, in press.

Simpson G. L., Shilland E. M., Winterbottom J. M. & Keay J. 2005. Defining reference conditions for acidified waters using a modern analogue approach. *Environmental Pollution* **137**, 119–133.

Sommaruga R. & Psenner R. 2001. High-mountain lakes and streams: indicators of a changing world. *Arctic, Antarctic, and Alpine Research* **33**, 383–384.

Sommaruga-Wögrath S., Koinig K.A., Schmidt R., Sommaruga R., Tessadri R. & Psenner R. 1997. Temperature effects on the acidity of remote alpine lakes. *Nature* **387**, 64–67.

Tartari G., Tartari G.A., Valsecchi S. & Camusso M. 1997. Cadastre and hydrochemistry of high altitude lakes in the Mount Everest region. *Verhandlungen Internationale Vereinigung Limnologie* **26**, 397–402.

Tartari G.A., Tartari G. & Mosello R. 1998. Water chemistry of high altitude lakes in the Khumbu and Imja Kola valleys (Nepalese Himalayas). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 51–76.

Tolotti M. 2001. Littoral diatom communities in high mountain lakes of the Adamello-Brenta Regional Park (Trentino, Italy) and their relation to acidification. In: *Lange-*

Bertalot-Festschrift. Jahn R., Kocioloek J.P., Witkowski A. & Compère P. (eds), pp. 327–352. Gantner, Ruggell.

UNEP 2002. The Asian brown cloud: climate and other environmental impacts. UNEP, Nairobi. – Executive Summary. *Environmental Science and Pollution Research* **9**, 289–295.

Vincent W.F. & Pienitz R. 1996. Sensitivity of high-latitude freshwater ecosystems to global change: temperature and solar ultraviolet radiation. *Geoscience Canada* **23**, 231–236.

Vinebrooke R.D. & Leavitt P.R. 2005. Mountain lakes as indicators of the cumulative impacts of ultraviolet radiation and other environmental stressors. In: Global Change and Mountain Regions. Huber U.M., Bugmann H.K.M. & Reasoner M.A. (eds), pp. 437 – 447. Springer, Dordrecht.

Vyverman W., Vyverman R., Hodgson D. & Tyler P. 1995. Diatoms from Tasmanian mountain lakes: a reference data-set (TASDIAT) for environmental reconstruction and a systematic and autecological study. *Bibliotheca Diatomologica* **33**, Cramer, Berlin.

Williams D.M. and F.E. Round 1987. Revision of the genus *Fragilaria*. *Diatom Research* **2**, 267–288.

Wolfe A.P., Baron J.S. & Cornett R.J. 2001. Anthropogenic nitrogen deposition induces rapid ecological changes in alpine lakes of the Colorado Front Range (USA). *Journal of Paleolimnology* **25**, 1–7.

5. Final discussion

5.1 Freshwater ecosystems in Nepal

Nepal possesses a diversity of standing freshwater systems with great ecological, cultural and economic value. They include high altitude lakes such as the large and remote Lake Rara and Lake Phoksumdo in Mugu and Dolpa districts of mid-western Nepal respectively and Lake Tilitso in the Manang district of western Nepal as well as many smaller high altitude lakes such as those in the Gosainkund area of central Nepal and in the Everest region of Solukhumbu district of eastern Nepal. Some of these lakes were studied previously to investigate geology, hydrology, morphometry, water chemistry, trophic status, plankton, macrozoobenthos and paleolimnological records (Okino & Satoh 1986, Aizaki *et al.* 1987, Bortolami 1998, Bertoni *et al*. 1998, Tartari *et al*. 1998, Tartari *et al*. 1998, Manca *et al*. 1998, Lami *et al*. 1998). However, no attempt had been made to study high altitude lakes in relative proximity to a major population centre and its potential impacts due to polluting emissions. Data from the high altitude lakes at Gosainkunda collected for this study provide the first evidence of such impacts and the vulnerability of these ecosystems to acidification in the future. While acidification of soils and surface water, particularly a decrease of soil base saturation and stream water acid neutralising capacity, was predicted as a result of increased acid depositions and fertiliser use in the Nepalese Middle Hills (Renshaw *et al*. 1997), acidification of mountain lakes in base-poor geological regions of the high Himalaya would be most likely a result of increasing atmospheric pollution and long-distance transport of acidifying substances (Shrestha & Malla 1996, Shrestha *et al*. 2000, Hindman & Upadhyay 2002, Carrico *et al*. 2003, Kondo *et al*. 2005). Future long-term studies and the investigation of sediment records could reveal to what extend these ecosystems have been or will be affected by acid depositions.

In the Middle Hills there are a large number of lakes in the Pokhara Valley of western Nepal, while in the Kathmandu Valley there are fewer standing waters including some ancient ponds of great historical and cultural significance. In contrast to the Pokhara Valley, where deterioration of watersheds due to poor land management and environmental degradation of the lakes has been documented and led to the development of conservation plans (Rana 1990, Thapa & Weber 1995, IUCN 1995, Bista 2002, Shrestha 2004), the standing waters of the Kathmandu Valley have received much less attention. Studies in the Kathmandu Valley focused on the ancient Lake Taudaha, where a restoration project was implemented by a local conservation organisation (Bird Conservation Nepal 1997, Baral pers. comm.), and on investigations of phytoplankton and benthic fauna in some ponds (Hickel 1973a, Yadav *et al*. 1983, Lohman *et al*. 1988). The paucity of data is unfortunate because many aquatic ecosystems in the Kathmandu Valley might soon or have already disappeared due to the absence of adequate management, or they are polluted (Jüttner *et al*. 2003, Sharma *et al*. 2005). There are now very few remaining ponds, which can provide habitat for aquatic biota. The study of the benthic diatom assemblages in these ponds provided evidence that these ecosystems supported a diverse flora with many species restricted to very few locations. This might also be true for other aquatic biota and demands further investigations as well as better protection to preserve these habitats.

In the lowlands of Nepal there are several lakes of high significance for nature conservation such as the recently declared Ramsar wetlands Beeshazar in the Royal Chitwan National Park, the Ghodaghodi Lake area in the Kailali district and the Jagadishpur Reservoir in the Kapilvastu district of western Nepal. The significance of these ecosystems for some wildlife particularly vertebrates is well known (Baral 1992, Majupuria & Kumar 1998, 1999), but there is very limited information about their limnological character (McEachern 1993). Another internationally important wetland area declared as the first Ramsar site of Nepal in 1987, is the Koshi Tappu Wildlife Reserve situated on the flood-plain of the Sapta-Kosi River in the lowlands of eastern Nepal. It is famous for its bird fauna as well as for providing habitat to the last surviving population of the wild buffalo. Diverse aquatic ecosystems such as rivers, streams, ditches, oxbow lakes, ponds and marshland provide valuable habitat for a diverse aquatic flora and fauna (Sah 1997). However, substantial areas of adjacent wetlands have been lost to agriculture, and increasing pressure on the reserve itself for firewood, fodder, livestock and thatch collection as well as hunting and fishing threatens aquatic and terrestrial ecosystems (Baral pers. communication). Although some agricultural practises such as aqua culture and fishing have maintained or created additional wetlands in particular ponds, intensive use by livestock and crop farming in the immediate vicinities might have substantially altered the habitat and chemical conditions of these ecosystems. There are yet no methods available to monitor such changes in Koshi Tappu, but the present investigation of epiphytic and epipelic diatoms has shown that they can be used successfully as indicators of water chemistry changes linked to agriculture in the catchment and of habitat character. The current data and further investigations could lead to the development of methods for regular monitoring of environmental change in ponds of the Nepalese lowlands to assists better environmental management of these ecosystems.

5.2 Diatom species richness and diversity

Diatom diversity and assemblage composition differed significantly between the ponds in the lowlands and in the Middle Hills of Nepal and between the ponds and the lakes in the high Himalaya reflecting contrasting environmental conditions between these ecosystems such as temperature, water chemistry and habitat character. Changing physical and chemical conditions were also found in 34 lentic waterbodies along an altitudinal gradient in Nepal with ion concentrations and trophic status increasing with decreasing altitude (Lacoul & Freedman 2005). Similarly recent study of macrophytic plants showed an approximately linear decline in species richness and diversity with increasing altitude (Lacoul & Freedman 2006), while species richness of diatoms was highest in the ponds at intermediate altitudes in the Kathmandu Valley. Although only 16 ponds were surveyed in the Kathmandu Valley 213 species were found, many more than in the lowland ponds with 119 species (64 ponds) or 77 species in ten high altitude lakes. However, the numbers of genera found in the different areas were similar with 27 in the Kathmandu Valley ponds, 29 in the Koshi Tappu ponds, and 23 in the Gosainkund lakes. The most species rich genera dominating the assemblages in the different areas varied. In the Gosainkund lakes they were *Achnanthes* sensu lato including several species formerly in *Achnanthes* but now transferred to other genera, followed by *Eunotia* and *Navicula* sensu lato. These included several taxa found in other high altitude lakes or unidentified taxa similar to well known taxa from mountain lakes such as *Psammothidium* (transferred from *Achnanthes*) cf. *marginulatum* (Grunow) Bukhtiyarova & Round and *Psammothidium subatomoides* (Hustedt) Bukhtiyarova & Round (Tolotti 2001). Many of the species observed could not be identified, with 9 of 15 in *Achnanthes* sensu lato and 7 of 18 *Eunotia* species. In the Middle Hills and low land the number of unidentified species in species rich genera differed and included *Navicula* with 13 of 42 unidentified, and *Gomphonema* with 20 of 37 unidentified taxa in the middle Hills, while in the Koshi Tappu ponds *Gomphonema* with 7 of 15 unidentified, *Navicula* with 5 of 27 unidentified, and *Nitzschia* with 4 of 15 unidentified taxa. In total a much higher percentage of taxa could not be identified in the high altitude lakes (2000: 39 %, 2003: 51 %) compared to the middle Hills (30% %) and in lowland ponds (29 %). Although cosmopolitan taxa were generally common, a significant proportion of the diatom flora was represented by taxa which probably have a restricted distribution. Similar findings were reported from other previously poorly investigated areas such as the inland waters of the Falkland Islands, where approximately one third of the taxa had regionally restricted distributions (Flower 2005), and the Andes in South America, where a large number of new taxa was found (Rumrich *et al*. 2000).

The role of substrata for benthic algae has long been recognised (Burkholder 1996) particularly with respect to chemical interactions (Burkholder & Wetzel 1990), but effects of microtopography and substratum stability have also been investigated (Whitton 1975, Cattaneo & Kalff 1978, Burkholder & Wetzel 1989). Although there is conflicting evidence and many algae are habitat generalists some species seem to have more specific habitat preferences and contribute to significant differences in assemblage composition on different substrates (Reavie & Smol 1997, Soininen & Eloranta 2004). In the Koshi Tappu ponds and in the Gosainkund lakes assemblages also differed significantly between different microhabitats. As in other studies the abundant species in epipelic assemblages were motile diatoms of genera such as *Sellaphora*, *Navicula* and *Diadesmis* (Cox 1988, Douglas & Smol 1995, Soininen 2004), while taxa more abundant in the epiphyton included non-motile attached species such as members of the genus *Gomphonema*. Species with clear habitat preferences also occurred in the lakes. Most of them were characteristic on sand and included well known epipsammic species or similar taxa living attached to sand grains such as *P.* cf. *marginulatum*, *P. subatomoides* and *Psammothidium* cf. *scoticum* (Flower & Jones) Bukhtiyarova & Round (Bukhtiyarova & Round 1996), while some taxa were more characteristic on stones. In contrast, most assemblages found in different microhabitats of the Kathmandu Valley ponds were similar except in two ponds where the assemblages on macrophytes and sediments differed markedly. Strong habitat affinities of some taxa were also found by other investigators. In high arctic ponds moss and sediment assemblages were more distinguishable than assemblages on rocks and most species with habitat preferences occurred on the sediment, while fewer were specific to mosses and only one to rocks (Lim *et al*. 2001a). Douglas & Smol (1995) and Michelutti *et al*. (2003) also found the highest numbers of habitat specific taxa on sediments and fewer on mosses and stones. The latter is in contrast to findings from the Koshi Tappu ponds, where fewer species were more abundant in sediments than in the epiphyton, but similar to findings in the Kathmandu Valley ponds, where many more species were confined to the sediment than to other substrates. Cox (1988) also found characteristic assemblages in different habitats and suggested that the habitat affinities of species from the genera *Eunotia* and *Pinnularia* on mosses reflected particular microhabitat conditions with respect to lower pH. Differences between assemblages on sediments and other substrate types could reflect a range of distinct chemical conditions such as higher ion and nutrient concentrations as found in the interstitial water of ponds in Koshi Tappu. Specific assemblages on sand in the Gosainkund lakes are more likely to reflect differences in microhabitat topography (Round & Bukhtiyarova 1996). However, assemblages from morphologically different macrophyte species in the Koshi Tappu ponds were very similar to each other and indicated no influence of microhabitat topography on assemblage composition. Michelutti *et al*. (2003) found higher diversity in assemblages on sediments than in other habitats, however, Cox (1988) stressed that epipelic assemblages can present an integrated sample from all habitats including species which did not live on the sediment, but accumulated there and were never found when live material was examined. In the Koshi Tappu and Kathmandu Valley ponds species richness and diversity were also higher in the epipelic assemblages, but in the Gosainkund lakes species richness, diversity and evenness were significantly higher in the epilithon than in the epipelon. These differences might have been due to the intensity of grazing with possibly lower numbers of grazers in the high altitude lakes than in the ponds, and the lack of removal of species susceptible to grazing (Medlin 1980, Peterson *et al*. 1998). Czarnecki (1979) reported that during biweekly collections over one year epipelic assemblages had higher diversity most of the time, but diversity fluctuated more in the epilithon and was sometimes higher than in the epipelon. The present study and previous investigations have shown that pattern of diversity and species richness as well as habitat specificity can vary considerably between locations. The nature of the microhabitat and chemical conditions are probably the most important factors (Burkholder 1996), but further studies under a range of conditions are needed to clarify the role of these factors for assemblages in different microhabitats.

5.3 Relationships between diatoms and environmental character

While relatively few studies have investigated the importance of habitat character for diatom distribution (Rothfritz *et al*. 1997, Jüttner *et al*. 2003, Lewis *et al*. in press) many investigations have shown that chemical gradients are major determinants in diatom distribution in freshwaters including lakes and ponds (Potapova & Charles 2003, Clarke *et al*. 2005). Acidification, eutrophication and pollution for example with heavy metals had considerable impact on diatom assemblages in many lakes (Dixit *et al*. 1991, Battarbee *et al*. 1999, Hall & Smol 1999). Lake acidification and its negative impact on economic value has been recognised in many parts of Europe and North America since the late 1960s and early 1970s, where major decline in fish populations observed (Jensen & Snekvik 1972, Beamish & Harvey 1972). It has since led to a large number of studies and the development of training sets and transfer functions to reconstruct pH and related hydrochemical variables (Charles & Whitehead 1986, Battarbee & Renberg 1990, Birks *et al*. 1990, Battarbee 2002). Acid rain has also emerged as a major environmental problem in Asia particularly in China and Japan, where acidifying emissions have risen dramatically and lead to extremely low rain water pH, but effects on ecosystems are still poorly understood (Streets *et al*. 2001, Han *et al*. 2006, Larsen *et al*. 2006). Studies in India revealed that rain water in some parts of India was extremely acidic and the problems of further increasing emissions for north-eastern areas with low buffer capacity were highlighted (Aggarwal *et al*. 2001, Granat *et al.* 2001). A large part of the eastern Himalaya in Nepal also consists of base-poor bedrock (Johnson *et al*. 1998). The ionic content and conductivity of water in the Gosainkund lakes was low, probably reflecting bedrock mineralogy with low buffer capacity and high sensitivity to acid depositions. An ice-core study from Mount Everest showed a dramatic increase in NH_4 since the 1950s. High positive correlations with SO_4 and NO_3 suggested that a portion of the NH_4 concentration was probably related to enhanced atmospheric acidification (Kang *et al*. 2002). Chemical properties such as pH and nitrogen concentrations of rain water and snow collected near the Gosainkund lakes suggest that they might be affected by atmospherically transported pollutants possibly originating in the densely populated area of the Kathmandu Valley, which lies only c. 32 km to the south, or additionally also by pollutants transported north from the Indian subcontinent. Several studies have shown that air pollution in the Kathmandu Valley was higher during the winter with a gradual built-up of pollutants during the winter season in mountain areas and maximum levels during the pre-monsoon and early-monsoon seasons (Shrestha *et al*. 2000, Carrico *et al.* 2003, Kondo *et al.* 2005). This might explain higher acidity in the Gosainkund lakes in May compared to the post-monsoon season in November. Changes in diatom assemblage composition with decrease in acid sensitive species such as *Achnanthidium minutissimum* (Kützing) Czarnecki, *P.* cf. *scoticum* and *P. subatomoides* and increase in acid tolerant species such as *P.* cf. *marginulatum, Achnanthes* cf. *chlidanos* Hohn & Hellermann and *Tabellaria flocculosa* (Roth) Kützing also suggested that acidity had increased during the spring. Most of the abundant species in spring assemblages were similar to the assemblages of lakes in the

Alps and Scotland (Jones *et al*. 1993, Tolotti 2001, Battarbee 2005) indicating higher acidity. However, uncertainty about the true taxonomic status of several species common in Gosainkund lakes and the lack of knowledge about their autecology hampers the interpretation of the observed changes in these lakes. More taxonomic investigations and a larger survey including Himalayan lakes over a wider range of acid-base status would provide much needed information to monitor environmental changes related to acid deposition in this region.

Eutrophication has been another major environmental problem affecting a large number of aquatic ecosystems (Stevenson & Pan 1999, Hall & Smol 1999). Although eutrophication can occur as a result of natural processes, in most cases it is due to anthropogenic inputs of nutrients from domestic sewage, industrial effluents, agricultural runoffs and soil erosion which result widespread negative impacts in freshwater ecosystem (Harper 1992). Further threats to freshwater ecosystems stem from a range of other pollutants from point sources such as municipal and industrial wastewaters or from diffuse sources such as urban and agricultural runoff, mine effluents and atmospheric deposition. They include organic sewage, metals, pesticides or other toxic chemicals, and oil (Welch & Jacoby 2004). Responsible management using appropriate methodologies is of paramount importance to reduce pollution and to allow the preservation of ecosystem health to ensure the provision of adequate resources for humans and wildlife (Smol 2002). However, with a rising human population and technological growth the pollution of many freshwaters has increased and the access to unpolluted water is increasingly difficult, particularly in densely populated areas such as South Asia (Das 2005). This problem is exacerbated by a still relatively low numbers of experts in this region, poor dissemination of knowledge and few effective partnerships between stakeholders (Dudgeon 2003). Recently, diatoms have been central to the development of tools to monitor eutrophication in lakes and rivers including paleolimnological methods to reconstruct past changes or the development of indices using recent assemblages (Kelly & Whitton 1995, Bennion *et al.* 1996). In Nepal the pollution of freshwaters is relatively well documented and methods have been developed to monitor water quality of rivers using biological indicators (e.g. Moog & Sharma 1996, Sharma & Moog 1996, Sharma 1996, Jüttner *et al*. 2003, Sharma *et al*. 2005). Many of these studies have focused on rivers and streams, although some have investigated the lakes in the Pokhara Valley of western Nepal and lakes in the Everest National Park of eastern Nepal (Hickel 1973b, Ferro 1978, Lami & Giussani 1998).

Although water quality in remote mountain lakes should be largely unaffected through direct inputs of pollutants, some such as the lakes in the Gosainkund area could be periodically affected. These lakes are important pilgrimage sites and are visited by a large number of people during the Janai Purnima festival in August. This might lead to pollution through the release of nutrients and sewage into the lake (ENPHO 1995) and further studies during this time of the year would be needed to assess potential effects on aquatic biota.

In contrast to lakes there are fewer studies on ponds despite their importance as habitat for aquatic biota (Biggs *et al*. 2004, Williams *et al*. 2004) and threats to their ecological quality (Pechar 2000, Ruan & Gilkes 2000, Graney & Eriksen 2004, Razo *et al.* 2004). As with lakes negative impacts of acidification and eutrophication have been demonstrated (Denys & van Straaten 1992, van Dam & Busken 1993, Bennion 1995), but the use of diatoms for monitoring of pond quality is still insufficiently explored (Bennion 1994, Denys 2003). Previous studies on pond diatoms showed that nutrient concentrations, pH and salinity were the most important factors (Bennion 1994, Roberts *et al*. 2001, Lim *et al*.

2001 a,b), but aquatic vegetation and substrate character also played a role in some Arctic ponds (Douglas & Smol 1995).

In Nepal ponds in Koshi Tappu and in the Kathmandu Valley are likely to be affected by agriculture in their catchments, and in the Kathmandu Valley also by urban pollution and industrial emissions. In addition, habitat degradation either due to intensive use or inappropriate management might further impair the ecological quality of these ecosystems. Despite their location close to farmland and in densely populated areas nutrient concentrations in the Kathmandu Valley ponds were not high or below the detection limit (<0.05mg/L) and were unrelated to changes in diatom assemblage composition. This might be due to rapid uptake of nutrients by terrestrial or aquatic plants such as algae blooms, which occurred in some of the ponds, resulting in low levels of available nutrients in the water. However, diatoms were related to other chemical gradients such as concentrations in Na, Cl, K, Al, Ni and As suggesting the influence of agriculture, surface run-off, dust and air-pollution from industry and traffic (Carrico *et al*. 2003, Jüttner *et al.* 2003, Shrestha 2003). Pollution indicator species such as *Eolimna (Navicula) minima* (Grunow) Lange-Bertalot, *Nitzschia palea* (Kützing) W. Smith and *Gomphonema parvulum* Kützing were characteristic at impacted sites. Diatom assemblages also indicated differences in habitat character with respect to the presence of aquatic macrophytes, substrate character in the pond and on the banks as well as the land use. Similarly, in the Koshi Tappu ponds diatoms responded to changes in water chemistry which were most likely the result of agricultural land use in the catchments and habitat characteristics such as land use, substrate type and the presence of aquatic macrophytes. Water chemistry differed between the surface and the interstitial water in the Koshi Tappu ponds with higher concentrations of most ions in the latter. Concentrations of Ca, Na, Mg and Sr were strongly related to variation in epiphytic and epipelic diatom assemblage, but SO_4, Si and PO_4 were also significant to cause variation in epipelic assemblages. Higher concentration of SO_4 in the surface water were indicated by *Nitzschia palea* (Kützing) W. Smith and *Nitzschia amphibia* Grunow, and higher concentrations of Si and PO_4 in the interstitial water by *Diadesmis confervacea* Kützing, *Encyonema silesiacum* (Bleisch in Rabenhorst) D.G. Mann, *N.* cf. *minima* Grunow and *Gomphonema* cf. *affine* Kützing. The most characteristic species indicating differences in chemical conditions differed between the epiphytic and epipelic assemblages. For example in the epiphyton *Gomphonema angustatum* (Kützing) Rabenhorst, *G.* cf. *affine*, *N. amphibia* and *Synedra ulna* v. *acus* Ehrenberg were typical of high concentrations of Ca, Mg and Sr in the surface water, while *Achnanthes exigua* Grunow was typical to the sites with higher Ca and Mg concentrations in the interstitial water.

In Koshi Tappu and in the Kathmandu Valley assemblages from different substrates reflected the same gradients in environmental conditions. Douglas & Smol (1995) reported that epilithic, epiphytic and epipelic assemblages equally reflected a gradient in alkalinity and Lim *et al*. (2001a) found that assemblages from these microhabitats reflected gradients in total N, P, pH, Fe and temperature. Although the use of epilithic assemblages is recommended for monitoring rivers (Kelly *et al*. 1998) others have shown that different substrates might be preferable in monitoring standing waters (Blanco *et al*. 2004, Poulíčková *et al*. 2004). Despite the preferential use of one particular habitat for monitoring purpose, ponds often lack of a consistent set of particular substrates for sampling. This study showed that providing the assemblages from different substrates respond in similar ways to environmental conditions the simultaneous use of different substrates is possible and allows the inclusion of a larger number of pond types.

5.4 Implications for the future

Recent environmental change in Nepal such as air pollution, agricultural intensification, urbanisation, industrialisation, habitat degradation (Thapa & Weber 1995, Karn & Harada 2001, Shrestha 2003, Gautam *et al*. 2004, Merz *et al*. 2004) and widespread damage to ecosystems (Chaudhary 1998) demands a rapid increase of fundamental knowledge in biodiversity. Efforts should focus particularly on organism groups such as diatoms, which have proven to be sensitive indicators of environmental change in aquatic ecosystems that also affect a wide range of other biota (Stoermer & Smol 1999). The present study is the first systematic investigation of diatoms in standing waters of Nepal. Observation of a sizable proportion of the flora with taxonomic uncertainity emphasises the need of further taxonomic work to allow a comprehensive assessment of diatom biodiversity in lakes and ponds of this region. Other diatom studies in Nepalese streams have found a number of new species particularly in central and eastern parts of the country with base-poor geology (Jüttner *et al.* 2004). Some of these species occupied very specific habitats and might be particularly useful to monitor environmental change (Jüttner *et al*. 2000). Many species in the investigated lakes and ponds responded to changes in environmental conditions, but their true taxonomic identity remained often unclear. Therefore comparative taxonomic studies including species of uncertain taxonomic status from other geographical areas could clarify their taxonomy as well as establish ecological preferences and thus aid the use of these species as bioindicators.

Using benthic diatoms from a range of microhabitats in ponds and lakes in three eco-regions of Nepal has suggested that they are sensitive indicators of environmental change resulting from the intensification of agriculture, growing industrialisation and urbanisation. This includes changes in chemical conditions and habitat character of the aquatic environment and the immediate surroundings. These changes are likely to accelerate with increasing pressure on water resources particularly in densely populated areas such as the Middle Hills, the lowlands and in urban areas. Demands are rising to meet water supply for consumption, irrigation and industries (Yogacharya 1996, Bhusal 1999). At the same time uncontrolled release of waste, increased use of agro-chemicals, land use change, lack of management and watershed degradation leads to the deterioration or disappearance of natural and artificial aquatic ecosystems (Devkota & Neupane 1994, Palikhe 1999, Pradhan 2000). Major urban rivers and the large lakes in the Pokhara Valley are polluted (ENPHO 1996, 1998), while information on other standing water bodies is patchy. The development of methods using biological indicators to monitor ecological quality in standing waters of Nepal would be urgently needed to assess their current status and monitor future change. Further large scale diatom surveys in the high altitude, middle hills and low land areas of Nepal including a larger number of lakes and ponds of these areas, covering a wider geography are required to establish a diatom database with precise taxonomic identification and auto-ecological information. These data could then be used to develop monitoring methods such as indices or predictive tools to assess present ecological status and deviation from reference conditions. This would be a valuable contribution to better environmental management and conservation of aquatic ecosystems in Nepal.

5.5 References

Aggarwal S.G., Chandrawabshi C.K., Patel R.M., Agarwal S., Kamavisdar A. & Mundhara G.L. 2001. Acidification of surface water in central India. *Water Air Soil Pollution* **130**, 855–862.

Aizaki M., Terashima A., Nakahara H., Nishio T. & Ishida Y. 1987. Trophic status of Tilitso, a high altitude Himalayan lake. *Hydrobiologia* **153**, 217–224.

Baral H.S. 1992. Ghodaghodi Lake System a National Treasure. Report Asian Wetland Bureau, Kuala Lumpur.

Battarbee R.W (ed.) 2002. MOLAR: Mountain lake research. *Journal of Paleolimnology* **28**, 1–179.

Battarbee R.W 2005. Mountain lakes, pristine or polluted? *Limnetica* **24**, 1–8.

Battarbee R.W. & Renberg I. 1990. The Surface Water Acidification Project (SWAP) paleolimnology programme. *Philosophical Transactions of the Royal Society, London* **B327**, 227–232.

Battarbee R.W., Charles D.F., Dixit S.S. & Renberg I. 1999. Diatoms as indicators of surface water acidity. In: *The Diatoms: Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J.P. (eds), pp. 85–127. Cambridge University Press, Cambridge.

Beamish J. & Harvey H.H. 1972. Acidification of La Cloche Mountain lakes, Ontario, and resulting fish mortalities. *Journal of the Fisheries Research Board of Canada* **29**, 1131–1143.

Bennion H. 1994. A diatom–phosphorus transfer function for shallow, eutrophic ponds in southeast England. *Hydrobiologia* **275/276**, 391–410.

Bennion H. 1995. Surface-sediment diatom assemblages in shallow, artificial, enriched ponds, and implications for reconstructing trophic status. *Diatom Research* **10**, 1–19.

Bennion H., Juggins S. & Anderson N.J. 1996. Predicting epilimnetic phosphorus concentrations using an improved diatom-based transfer function and its application to lake management. *Environmental Science & Technology* **30**, 2004–2007.

Bertoni R., Callieri C. & Contesini M. 1998. Organic carbon and microorganisms in two Nepalese lakes. In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 99–106.

Bhusal J.K. 1999. Renewable surface waters of Nepal – uses and constraints to 21st century. 3rd National Conference on Science and Technology, 8 – 11 March 1999, Kathmandu, Nepal.

Biggs J., Bilton D., Williams P., Nicolet P., Briggs L., Eeles B. & Whitfield M. 2004. Temporary ponds of eastern Poland: an initial assessment of their importance for nature conservation. *Archives des Sciences* **57**, 73–83.

Birks H.J.B., Line J.M., Juggins S., Stevenson A.C. & ter Braak C.J.F. 1990. Diatoms and pH reconstruction. *Philosophical Transactions of the Royal Society, London* **B327**, 263–278.

Bista J.D., Dhakal R.P. & Gurung T.B. 2002. Changing environmental status and its impact on flora and fauna of Pokhara valley, Nepal. Proceedings of International Seminar on Mountains, Kathmandu, March 6 – 8, pp. 447–456, Royal Nepal Academy of Science & Technology, Kathmandu.

Blanco S., Ector L. & Bécares E. 2004. Epiphytic diatoms as water quality indicators in Spanish shallow lakes. *Vie Milieu* **54**, 71–79.

Bortolami G. 1998. Geology of the Khumbu Region, Mt Everest, Nepal. In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 41–49.

Bukhtiyarova L. & Round F.E. 1996. Revision of the genus *Achnanthes* sensu lato. *Psammothidium*, a new genus based on *A. marginulatum*. *Diatom Research* **11**, 1–30.

Burkholder J.M. 1996. Interactions of benthic algae with their substrata. In: *Algal Ecology. Freshwater Benthic Ecosystems*. Stevenson R.J., Bothwell M.L. & Lowe R.L. (eds), pp. 253–297. Academic Press, San Diego.

Burkholder J.M. & Wetzel R.G. 1989. Epiphytic microalgae on a natural substratum in a phosphorus-limited hardwater lake: Seasonal dynamics of community structure, biomass and ATP content. *Archive for Hydrobiology Supplement* **83**, 1–56.

Burkholder J.M. & Wetzel R.G. 1990. Epiphytic alkaline phosphatase activity on natural and artificial plants in a P-limited lake: Re-evaluation of the role of macrophytes as a phosphorus source for epiphytes. *Limnology and Oceanography* **35**, 736–746.

Carrico C.M., Bergin M.H., Shrestha A.B., Dibb J.E., Gomes L. & Harris J.M. 2003. The importance of carbon and mineral dust to seasonal aerosol properties in the Nepal Himalaya. *Atmospheric Environment* **37**, 2811–2824.

Cattaneo A. & Kalff J. 1978. Seasonal changes in the epiphyte community of natural and artificial macrophytes in Lake Memphremagog (Qne. Vt.). *Hydrobiologia* **60**, 135–144.

Charles D.F. & Whitehead D.R. 1986. The PIRLA project: Paleoecological investigation of recent lake acidification. *Hydrobiologia* **143**, 13–20.

Chaudhary R.P. 1998. *Biodiversity in Nepal. Status and Conservation*. Know Nepal Series No. 17., Craftsman Press. Bangkok.

Clarke G., Kernan M., Marchetto A., Sorvari S. & Catalan J. 2005. Using diatoms to assess geographical patterns of change in high-altitude European lakes from pre-industrial times to the present day. *Aquatic Sciences* **67**, 224–236.

Cox E.J. 1988. Microdistributional patterns of freshwater diatoms in relation to their use as bioindicators. In: Proceedings of the 10th International Diatom Symposium, Finnland. Simola H. (ed.), pp. 521-528. Koeltz Scientific Books, Koenigstein.

Czarnecki D.B. 1979. Epipelic and epilithic diatom assemblages in Montezuma Well National Monument, Arizona. *Journal of Phycology* **15**, 346–352.

Das B.K. 2005. Environmental pollution impact on water and sediments of Kumaun lakes, Lesser Himalaya, India: a comparative study. *Environmental Geology* **49**, 230–239.

Denys L. 2003. Environmental changes in man-made coastal dune pools since 1850 as indicated by sedimentary and epiphytic diatom assemblages (Belgium). *Aquatic Conservation: Marine and Freshwater Ecosystems* **13**, 191–211.

Denys L. & van Straaten D. 1992. A survey of the acid water diatom assemblages of two heathland relics in the Belgian Northern Campine (Groot & Klein Schietveld, Brasschaat) with an assessment of their conservation value. *Diatom Research* **7,** 1–13.

Devkota S.R. & Neupane C.P. 1994. Industrial pollution inventory of the Kathmandu Valley and Nepal. Industrial Pollution Control Management Project. HMG, MOI, UNIDO, Kathmandu.

Dixit S.S., Dixit A.S. & Smol J.P. 1991. Multivariable environmental inferences based on diatom assemblages from Sudbury (Canada) lakes. *Freshwater Biology* **26**, 251–266.

Douglas M.S.V. & Smol J.P. 1995. Periphytic diatom assemblages from high Arctic ponds. *Journal of Phycology* **31,** 60–69.

Dudgeon D. 2003. The contribution of scientific information to the conservation and management of freshwater biodiversity in tropical Asia. *Hydrobiologia* **500**, 295–314.

ENPHO 1995. Limnological Investigation of Gosainkund Lake and impact of Janai Purnima Festival. ENPHO, Kathmandu.

ENPHO 1996. Trend of Degrading Water Quality of the Bagmati River (1988 – 1995). ENPHO, Kathmandu.

ENPHO 1998. A Report on Water Quality Assessment of Lake Begnas and Rupa. ENPHO, Kathmandu.

Ferro W. 1978. Limnology of the Pokhara Valley lakes (Himalayan region, Nepal) and its implication for fishery and fish culture. Report Integrated Fishery and Fish Culture Development Project, FAO, Rome.

Flower R. 2005. A taxonomic and ecological study of diatoms from freshwater habitats in the Falkland Islands, South Atlantic. *Diatom Research* **20**, 23–96.

Gautam P., Blaha U., Appel E. & Neupane G. 2004. Environmental magnetic approach towards the quantification of pollution in Kathmandu urban area, Nepal. *Physics and Chemistry of the Earth* **29**, 973–984.

Granat L., Das S.N., Tharkur R.S. & Rodhe H. 2001. Atmospheric deposition in a rural area in India – Net and potential acidity. *Water Air Soil Pollution* **130**, 469–474.

Graney J.R. & Eriksen T.M. 2004. Metals in pond sediments as archives of anthropogenic activities: a study in response to health concerns. *Applied Geochemistry* **19**, 1177–1188.

Hall R.I. & Smol J.P. 1999. Diatoms as indicators of lake eutrophication. In: *The Diatoms: Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J.P. (eds), pp. 128–168. Cambridge University Press, Cambridge.

Han Z.W., Ueda H. & Sakurai T. 2006. Model study on acidifying wet deposition in East Asia during wintertime. *Atmospheric Environment* **40**, 2360–2373.

Harper D. 1992. *Eutrophication of Freshwaters*. Chapman & Hall, London.

Hickel B. 1973a. Phytoplankton in two ponds in Kathmandu Valley, Nepal. *International Revue of Hydrobiology* **58**, 835–842.

Hickel B. 1973b. Limnological Investigations in Lakes of the Pokhara Valley, Nepal. *International Revue of Hydrobiology* **58**, 659–672.

Hindman E.E. & Udaphyay B.P. 2002. Air pollution transport in the Himalayas of Nepal and Tibet during the 1995-1996 dry season. *Atmospheric Environment* **36**, 727–739.

IUCN 1995. Phewa Lake conservation action plan. National Planning Commission in collaboration with IUCN – the World Conservation Union, Kathmandu.

Jensen K.W. & Snekvik E. 1972. Low pH level wipe out salmon and trout populations in southernmost Norway. *Ambio* **1**, 223–225.

Johnson R.C., Ormerod S.J., Jenkins A., Bharal H.S., Brewin P.A., Bronsdon R.K., Buckton S.T., Jüttner I., Rothfritz H., Suren A.M. & Wilkinson R.J. 1998. Aquatic Biodiversity in the Himalaya. Final Scientific Report to the Darwin Initiative.

Jones V.J., Flower R.J., Appleby P.G., Natkanski J., Richardson N., Rippey B., Stevenson A.C. & Battarbee R.W. 1993. Paleolimnological evidence for the acidification and atmospheric contamination of lochs in the Cairngorm and Lochnagar areas of Scotland. *Journal of Ecology* **81**, 3–24.

Jüttner I., Cox E.J. & Ormerod S.J. 2000. New and poorly known diatoms from Himalayan streams. *Diatom Research* **15**, 237–262.

Jüttner I., Sharma S., Dahal B.M., Ormerod S.J. & Cox E.J. 2003. Diatoms as indicators of stream quality in the Kathmandu Valley and Middle Hills of Nepal and India. *Freshwater Biology* **48**, 2065–2084.

Jüttner I., Reichardt E. & Cox E.J. 2004. Taxonomy and ecology of some new *Gomphonema* species common in Himalayan streams. *Diatom Research* **19**, 235–264.

Kang S.C., Mayewski P.A., Qin D.H., Yan Y.P. Zhang D.Q., Hou S.G. & Ren J.W. 2002. Twentieth century increase of atmospheric ammonia recorded in Mount Everest ice core. *Journal of Geophysical Research-Atmospheres* **107**, Art. No. 4595.

Karn S.K. & Harada H. 2001. Surface water pollution in three urban territories of Nepal, India and Bangladesh. *Environmental Management* **28**, 483–496.

Kelly M.G. & Whitton B.A. 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers. *Journal of Applied Ecology* **7**, 433 – 444.

Kelly M.G., Cazaubon A., Coring E., Dell'Uomo A., Ector L., Goldsmith B., Guasch H., Hürlimann J., Jarlman A., Kawecka B., Kwandrans J., Laugaste R., Lindstrom E.-A., Leitao M., Marvan P., Padisak J., Pipp E., Prygiel J., Rott E., Sabater S., van Dam H.

& Vizinet J. 1998. Recommendations for the routine sampling of diatoms for water quality assessments in Europe. *Journal of Applied Phycology* **10**, 215–224.

Kondo A., Kaga A., Imamura K., Inoue Y., Sugisawa M., Shrestha M.L. & Sapkota B. 2005. Investigation of air pollution concentration in Kathmandu valley during winter season. *Journal of Environmental Sciences-China* **17**, 1008–1013.

Lacoul P. & Freedman B. 2005. Physical and chemical limnology of 34 lentic waterbodies along a tropical-to-alpine altitudinal gradient in Nepal. *International Review of Hydrobiology* **90**, 254–276.

Lacoul P. & Freedman B. 2006. Relationships between aquatic plants and environmental factors along a steep Himalayan altitudinal gradient. *Aquatic Botany* **84**, 3–16.

Lami A. & Giussani G. (eds) 1998. Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal). *Memorie dell'Istituto Italiano di Idrobiologia* **57**, pp. 235, Istituto Italiano di Idrobiologia, Pallanza.

Lami A., Guilizzoni P., Marchetto A., Bettinetti R. & Smith D.J. 1998. Paleolimnological evidence of environmental changes in some high altitude Himalayan lakes (Nepal). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 107–130.

Larsen T., Lydersen E., Tang D.G., He Y., Gao J.X., Liu H.Y., Duan L., Seip H.M., Vogt R.D., Mulder J., Shao M., Wang Y.H., Shang H., Zhang X.S., Solberg S., Aas W., Okland T., Eilertsen O., Angell V., Liu Q.R., Zhao D.W., Xiang R.J., Xiao J.S. & Luo J.H. 2006. Acid rain in China. *Environmental Science & Technology* **40**, 418–425.

Lewis B.R., Jüttner I., Reynolds B. & Ormerod S.J. Comparative assessment of stream acidity using diatoms and macroinvertebrates: implications for river management and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*. In press.

Lim D.S.S., Kwan C. & Douglas M.S.V. 2001a. Periphytic diatom assemblages from Bathurst Island, Nunavut, Canadian High Arctic: an examination of community relationships and habitat preferences. *Journal of Phycology* **37**, 379–392.

Lim D.S.S., Douglas M.S.V. & Smol J.P. 2001b. Diatoms and their relationship to environmental variables from lakes and ponds on Bathurst Island, Nunavut, Canadian High Arctic. *Hydrobiologia* **450**, 215–230.

Lohman K., Jones J.R., Knowlton M.F., Swar D.B., Pamperl M.A. & Brazos B.J. 1988. III. Lakes. 3. Asia: Pre– and postmonsoon limnological characteristics of lakes in the Pokhara and Kathmandu Valleys, Nepal. *Verhandlungen Internationale Vereinigung Limnologie* **23**, 558–565.

Majupuria T.C. & Kumar R. 1998. *Wildlife, National Parks & Reserves of Nepal. Resources & Management*. Know Nepal Series No. 11., Craftsman Press, Bangkok.

Majupuria T.C. & Kumar R. 1999. Nepal – Nature's Paradise. Insight into Divers Facets of Topography, Flora & Ecology. Hillside Press, Kathmandu.

Manca M., Cammarano P. & Spagnuolo T. 1994. Notes on Cladocera and Copepoda from high-altitude lakes in the Mount Everest region (Nepal). *Hydrobiologia* **287**, 225–231.

Manca M., Ruggiu D., Panzani P., Asioli A., Mura G. & Nocentini A.M. 1998. Report on a collection of aquatic organisms from high mountain lakes in the Khumbu Valley (Nepalese Himalayas). In: Limnology of high altitude lakes in the Mt Everest region

(Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 77–98.

McEachern P. 1993. Limnological Survey of Devital Wetland Chitwan, Nepal. National Wetland Inventory, IUCN Nepal.

Medlin L.K. 1980. Effects of grazers on epiphytic diatom communities. In: Proceedings 6th Symposium on Recent and Fossil Diatoms. Ross (ed.), pp. 399–412. Koeltz, Koenigstein.

Merz J., Nakarmi G., Shrestha S., Dahal B.M., Dongol B.S., Schaffner M., Shakya S., Sharma S. & Weingartner R. 2004. Public water sources in rural watersheds of Nepal's Middle Mountains: Issues and constraints. *Environmental Management* **34**, 26–37.

Michelutti N., Holtham A.J., Douglas M.S.V. & Smol J.P. 2003. Periphytic diatom assemblages from ultra-oligotrophic and UV transparent lakes and ponds on Victoria Island and comparisons with other diatom surveys in the Canadian Arctic. *Journal of Phycology* **39,** 465–480.

Moog O. & Sharma S. 1996. Biological rapid field assessment of water quality in the Bagmati river and its tributaries of Kathmandu Valley, Nepal. In: *Ecohydrology of High Mountain Areas*. Chalise S.R. (ed.), Proceedings of the International Conference on Ecohydrology of High Mountain Areas, pp. 609–621, ICIMOD, UNESCO, Kathmandu, Nepal.

Okino T. & Satoh Y. 1986. Morphology, physics, chemistry and biology of lake Rara in west Nepal. *Hydrobiologia* **140**, 125–133.

Palikhe B.R. 1999. Pesticide management in Nepal: implementation issues and experiences. Workshop on Present Environmental Challenges and Management of Pesticides, Chemical Fertilisers and Solid Waste. 3 – 4 October, Kathmandu, Nepal.

Pechar L. 2000. Impacts of long-term changes in fishery management on the trophic level water quality in Czech fish ponds. *Fisheries Management and Ecology* **7**, 23–31.

Peterson C.G., Vormittag K.A. & Valett H.M. 1998. Ingestion and digestion of epilithic algae by larval insects in a heavily grazed montane stream. *Freshwater Biology* **40**, 607–623.

Potapova M. & Charles D.F. 2003. Distribution of benthic diatoms in U.S. rivers in relation to conductivity and ionic composition. *Freshwater Biology* **48**, 1311–1328.

Poulíčková A., Duchoslav M. & Dokulil M. 2004. Littoral diatom assemblages as bioindicators of lake trophic status: A case study from perialpine lakes in Austria. *European Journal of Phycology* **39**, 143–152.

Pradhan P.K. 2000. Urban growth pattern and food security in Kathmandu Valley. Workshop on Integrative Strategies for Food Improvements in the Kathmandu Valley. 30 April – 1 May, Kathmandu, Nepal.

Rana K. 1990. Water pollution assessment of Phewa Lake, Pokhara, Nepal. M.S. thesis. Asian Institute of Technology, Bangkok.

Razo I., Carrizales L., Castro J., Diaz-Barriga F. & Monroy M. 2004. Arsenic and heavy metal pollution of soil, water and sediments in a semi-arid climate mining area in Mexico. *Water Air Soil Pollution* **152**, 129–152.

Reavie E.D. & Smol J.P. 1997. Diatom-based model to infer past littoral habitat characteristics in the St. Lawrence River. *Journal of Great Lakes Research* **23**, 339–348.

Renshaw M., Collins R.P., Jenkins A., Arndt R. & Carmichael G. 1997. Predicting the effect of atmospheric pollution on soil and surface water acidification in the Middle Hills of Nepal. *Science of the Total Environment* **208**, 71–79.

Roberts D., McMinn A., Johnston N., Gore D.B., Melles M. & Cremer H. 2001: An analysis of the limnology and sedimentary diatom flora of fourteen lakes and ponds from the Windmill Islands, East Antarctica. *Antarctic Science* **13**, 410–419.

Rothfritz H., Jüttner I., Suren A.M. & Ormerod S.J. 1997. Epiphytic and epilithic diatom communities along environmental gradients in the Nepalese Himalaya: implications for the assessment of biodiversity and water quality. *Archive for Hydrobiology* **138**, 465–482.

Round F.E. & Bukhtiyarova L. 1996. Epipsammic diatoms – communities of British rivers. *Diatom Research* **11**, 363–372.

Ruan H.D. & Gilkes R.J. 2000. Phosphorus accumulation in farm ponds and dams in southwestern Australia. *Environmental Quality* **29**, 1875–1881.

Rumrich U., Lange-Bertalot H. & Rumrich M. 2000. *Diatomeen der Anden. Iconographia Diatomologica* **9**, A.R.G. Gantner, Ruggell.

Sah J.P. 1997. Koshi Tappu wetlands: Nepal's Ramsar site. IUCN, Bangkok.

Sharma S. 1996. Biological assessment of water quality in the rivers of Nepal. PhD thesis, University of Agricultural Sciences, Vienna.

Sharma S. & Moog O. 1996. The applicability of biotic indices and scores in water quality assessment of Nepalese rivers. In: *Ecohydrology of High Mountain Areas*. Chalise S.R. (ed.), Proceedings of the International Conference on Ecohydrology of High Mountain Areas, pp. 641–657, ICIMOD, UNESCO, Kathmandu, Nepal.

Sharma S., Bajracharya R.M., Sitaula B.K. & Merz J. 2005. Water quality in the Central Himalaya. *Current Science* **89**, 774–786.

Shrestha A.B., Wake C.P., Dibb J.E., Mayewski P.A., Whitlow S.I., Carmichael G.R. & Ferm M. 2000. Seasonal variations in aerosol concentrations and compositions in the Nepal Himalaya. *Atmospheric Environment* **34**, 3349–3363.

Shrestha H.D. 2003. Heavy metals pollution in the environment of Kathmandu. *Journal de Physique* IV **107**, 1239–1246.

Shrestha P. 2004. Conservation and management of Phewa Lake ecosystem, Nepal. Proceedings International Conference on the Great Himalayas: Climate, Health, Ecology, Management and Conservation. 12 – 14 January, Kathmandu.

Shrestha R.M. & Malla S. 1996. Air pollution from energy use in a developing country city: The case of Kathmandu Valley, Nepal. *Energy* **21**, 785–794.

Smol J.P. 2002. Pollution of Lakes and Rivers. A Paleolimnological Perspective. Arnold, London.

Soininen J. 2004. Benthic diatom community structure in boreal streams. Distribution patterns along environmental and spatial gradients. PhD thesis, University of Helsinki.

Soininen J. & Eloranta P. 2004. Seasonal persistence and stability of diatom communities in rivers: are there habitat specific differences? *European Journal of Phycology* **39**, 153–160.

Stevenson R.J. & Pan Y. 1999. Assessing environmental conditions in rivers and streams with diatoms. In: *The Diatoms: Applications for the Environmental and Earth Sciences*. Stoermer E.F. & Smol J.P. (eds), pp. 11–40. Cambridge University Press, Cambridge.

Stoermer E.F. & Smol J.P. 1999. *The Diatoms: Applications for the Environmental and Earth Sciences*. 469 pp. Cambridge University Press, Cambridge.

Streets D.G., Tsai N.Y., Akimoto H. & Oka K. 2001. Trends in emissions of acidifying species in Asia 1985 – 1997. *Water Air Soil Pollution* **130**, 187–192.

Tartari G.A., Tartari G. & Mosello R. 1998. Water chemistry of high altitude lakes in the Khumbu and Imja Kola valleys (Nepalese Himalayas). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 51-76.

Tartari G., Previtali L. & Tartari G.A. 1998. Genesis of the lake cadastre of Khumbu Himal region (Sagarmatha National Park, East Nepal). In: Limnology of high altitude lakes in the Mt Everest region (Himalayas, Nepal), Lami A. & Giussani G. (eds), *Memorie dell'Istituto Italiano di Idrobiologia* **57**, 139-149.

Thapa G.B. & Weber K.E. 1995. Status and management of watersheds in the upper Pokhara Valley, Nepal. *Environmental Management* **19**, 497–513.

Tolotti M. 2001. Littoral diatom communities in high mountain lakes of the Adamello-Brenta Regional Park (Trentino, Italy) and their relation to acidification. In: *Lange-*

Bertalot-Festschrift. Jahn R., Kocioloek J.P., Witkowski A. & Compère P. (eds), pp. 327–352. Gantner, Ruggell.

van Dam H. & Busken R.F.M. 1993. Ecology and management of moorland pools: balancing acidification and eutrophication. *Hydrobiologia* **265**, 225–263.

Welch E.B. & Jacoby J.M. 2004. *Pollutant Effects in Freshwater*. Spon Press, London.

Whitton B.A. 1975. Algae. In: *River Ecology*. Whitton B.A. (ed.), pp. 81–105. University of California Press, Berkeley.

Williams P., Whitfield M., Biggs J., Bray S., Fox G., Nicolet P. & Sear D. 2004. Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. *Biological Conservation* **115**, 329–341.

Yadav U.R., Basnet K. & Mehta J. 1983. Studies on the benthic fauna of four ponds of Godavari fish farm, Kathmandu Valley, Nepal. *Journal of the Natural History Museum* **7**, 1–7.

Yogacharya K.S. 1996. Assessment of water resources of Nepal and its economical [sic] values. WECS, Kathmandu.

6. Summary

Diatoms were collected from different microhabitats in high altitude lakes of Gosainkunda, Langtang National Park, in ponds and small lakes of the Kathmandu Valley in the Middle Hills, and in lowland ponds of Koshi Tappu, Nepal.

Temperature, conductivity and pH were measured at the same time and water samples taken for the analysis of major cations and anions. Water samples were taken from the surface water in Gosainkunda and the Kathmandu Valley sites, and from the surface and the interstitial water in Koshi Tappu. Habitat surveys were also conducted to assess the character of the lakes and ponds with respect to substrate types and aquatic vegetation, of the banks with respect to substrate types, bank profile and vegetation, and to assess land use in the immediate catchments.

Diatom diversity and assemblage composition differed significantly between the high altitude, the middle hills, and the lowland lakes and ponds reflecting contrasting environmental conditions. Species richness was highest in ponds and lakes of the Kathmandu Valley, where 213 species were found, in contrast to 119 species in the Koshi Tappu ponds and 77 species in the high altitude lakes. The numbers of genera found in the different areas were similar and varied between 23 and 29. However, the most species rich genera varied. In the Gosainkund lakes *Achnanthes* sensu lato, *Eunotia* and *Navicula* sensu lato were the most species rich genera, in the Kathmandu Valley they included *Navicula* and *Gomphonema*, and in Koshi Tappu *Gomphonema*, *Navicula* and *Nitzschia*. Although cosmopolitan taxa were common in all three areas, species whose taxonomic identity could not be ascertained consulting published floras varied from 29 % – 51 % showing the possibility of many species in these lakes and ponds to have regionally restricted distribution.

Species with preferences for a particular habitat were found in all areas. Assemblages differed significantly between microhabitats in Gosainkunda, where many species living on sand grains were typical in the epipsammon, and in Koshi Tappu and the Kathmandu Valley, where many motile species characterised the epipelon. However, differences in assemblage composition between microhabitats were smaller in the Kathmandu Valley. In Koshi Tappu and the Kathmandu Valley species richness and diversity were highest in the epipelon, but in Gosainkunda species richness, diversity and evenness were higher in the epilithon than in the epipelon.

Changes in diatom assemblage composition reflected gradients in chemical and habitat character. In the Gosainkund lakes assemblages differed between autumn 2000 and spring 2003. Acid-tolerant taxa such as *Psammothidium* cf. *marginulatum* (Grunow) Bukhtiyarova & Round and *Tabellaria flocculosa* (Roth) Kützing were abundant during spring and acid-sensitive taxa such as *Psammothidium subatomoides* (Hustedt) Bukhtiyarova & Round and *Psammothidium* cf. *scoticum* (Flower & Jones) Bukhtiyarova & Round were abundant during autumn. This reflected changes in acidity between the seasons, which might have resulted from atmospheric deposition.

In the Kathmandu Valley assemblages reflected gradients in water chemistry and habitat character with respect to aquatic vegetation, substrate composition, bank character and land use. *Achnanthidium minutissimum* (Kützing) Czarnecki was typical at sites with higher Ca concentrations. Pollution tolerant taxa such as *Eolimna (Navicula) minima* (Grunow) Lange-Bertalot, *Nitzschia palea* (Kützing) W. Smith and *Gomphonema parvulum* Kützing were abundant at sites with higher concentrations of K, Cl, Na, As, Ni, Fe and Al and probably indicated influences from agriculture, urban run-off and atmospheric deposition.

In Koshi Tappu assemblage composition of epiphytic diatoms reflected gradients in water chemistry and land use with respect to pond vegetation and substratum type, bank profile and land use, which indicated influence of agriculture in the catchments. Epiphytic and epipelic assemblages responded to chemical gradients in the surface water, particularly concentrations of Ca, Mg, Sr and Na but epipelic diatoms also indicated gradients in SO4. Epiphytic species typical at higher Na concentrations included *Gomphonema lagenula* Kützing, *Nitzschia* cf. *incognita* Krasske, *Gomphonema augur* Ehrenberg and *Navicula* cf. *minima* Grunow. *Gomphonema angustatum* (Kützing) Rabenhorst, *Gomphonema* cf. *affine* Kützing, *Nitzschia amphibia* Grunow and *Synedra ulna* v. *acus* Ehrenberg indicated higher concentrations of Ca, Mg and Sr. Epipelic diatoms were also sensitive to interstitial water chemistry variations. *Diadesmis confervacea* Kützing, *Encyonema silesiacum* (Bleisch in Rabenhorst) D.G. Mann, *N*. cf. *minima* and *G*. cf. *affine* were abundant towards sites with higher concentration of PO4 and Si and *Achnanthes exigua* Grunow was characteristic towards sites with high Ca and Mg concentrations.

Studies of benthic diatoms from a range of microhabitats in ponds and lakes in the three eco-regions of Nepal have revealed that diatoms are sensitive indicators of environmental change resulting from the intensification of agriculture, industrialisation and urbanisation. These changes are likely to accelerate with increasing pressure on water resources. Additional surveys of a larger number of lakes and ponds over a wider geographical area could lead to the establishment of a diatom database and the development of monitoring methods for the assessment of present ecological status, better environmental management and conservation of standing waters in Nepal.

Zusammenfassung

Kieselalgen wurden in verschiedenen Mikrohabitaten von Hochgebirgsseen in der Region von Gosainkunda, Langtang National Park, in Teichen und kleinen Seen des Kathmandu Tales im mittleren Bergland, und in Teichen der Region von Koshi Tappu im nepalesischen Tiefland untersucht.

Temperatur, Leitfähigkeit und pH wurden vor Ort gemessen und Wasserproben für die chemische Analyse von Kationen und Anionen entnommen. In Gosainkunda und im Kathmandu Tal wurden Proben des Oberflächenwassers, und in Koshi Tappu wurden Proben des Oberflächen- und des Interstitialwassers genommen. Gleichzeitig wurde eine Untersuchung des Habitatcharakters der Seen und Teiche bezüglich der Substratbeschaffenheit und der Gewässervegetation, sowie der Uferregion bezüglich der Substratzusammensetzung, des Uferprofils, der terrestrischen Vegetation und der Landnutzung in unmittelbarer Umgebung durchgeführt.

Die Diversität und Artenzusammensetzung der Kieselalgen der Hochgebirgsseen, sowie der Teiche und Seen des mittleren Berglands und des Tieflands unterschieden sich deutlich entsprechend der unterschiedlichen Umweltbedingungen. Der Artenreichtum war am höchsten in den Gewässern des Kathmandu Tals, wo 213 Arten gefunden wurden, im Vergleich zu 119 Arten in den Teichen von Koshi Tappu und 77 Arten in den Hochgebirgsseen. Die Anzahl der vorhandenen Gattungen war in allen Regionen ähnlich und variierte zwischen 23 und 29. Die artenreichsten Gattungen unterschieden sich jedoch zwischen den Regionen. In den Seen von Gosainkunda gehörten die meisten Arten zu *Achnanthes* sensu lato, *Eunotia* und *Navicula* sensu lato, während die

artenreichsten Gattungen im Kathmandu Tal *Navicula* und *Gomphonema*, und in Koshi Tappu *Gomphonema*, *Navicula* und *Nitzschia* waren. Obwohl weltweit verbreitete Arten in allen drei Gebieten häufig waren, konnten zwischen 29 % und 51 % nicht bis auf Artniveau identifiziert werden, ein Hinweis darauf, daß viele der gefundenen Taxa möglicherweise ein eingeschränktes Verbreitungsgebiet haben.

Arten, die ein spezielles Habitat bevorzugten, wurden in allen Regionen gefunden. Die Kieselalgengemeinschaften in verschiedenen Mikrohabitaten der Gosainkundseen unterschieden sich deutlich voneinander und viele Arten, die auf Sandkörnern leben, waren typisch für das Epipsammon. In Koshi Tappu und im Kathmandu Tal waren viele motile Arten charakteristisch für das Epipelon. Die Unterschiede zwischen den Gesellschaften verschiedener Mikrohabitate waren geringer im Kathmandu Tal als in den beiden anderen Regionen. In Koshi Tappu und im Kathmandu Tal waren Artenzahl und Diversität am höchsten im Epipelon, im Gegensatz zur Region um Gosainkunda, wo die Artenzahl, Diversität und Evenness im Epilithon höher waren als im Epipelon.

Unterschiedliche Artenzusammensetzungen der Kieselalgengemeinschaften reflektierten Unterschiede im chemischen und im Habitat Charakter der Gewässer. In Gosainkunda unterschieden sich die Gemeinschaften im Herbst 2000 von denen im Frühjahr 2003. Säure tolerante Arten wie *Psammothidium* cf. *marginulatum* (Grunow) Bukhtiyarova & Round und *Tabellaria flocculosa* (Roth) Kützing waren häufiger im Frühjahr und säure empfindliche Arten wie *Psammothidium subatomoides* (Hustedt) Bukhtiyarova & Round und *Psammothidium* cf. *scoticum* (Flower & Jones) Bukhtiyarova & Round waren häufiger im Herbst. Dies spiegelte unterschiedliche Säuregehalte in Herbst und Frühjahr wieder, die durch atmosphärische Depositionen bedingt sein könnten.

Die Kieselalgengemeinschaften des Kathmandu Tals reflektierten Gradienten bezüglich der Wasserchemie und des Habitat Charakters, insbesondere Unterschiede in der aquatischen Vegetation, der Substratzusammensetzung, des Charakters der Uferregion sowie der umgebenden Landnutzung. *Achnanthidium minutissimum* (Kützing) Czarnecki war typisch in Gewässern mit höheren Kalzium Konzentrationen. Verschmutzungs tolerante Arten wie *Eolimna (Navicula) minima* (Grunow) Lange-Bertalot, *Nitzschia palea* (Kützing) W. Smith und *Gomphonema parvulum* Kützing waren häufig bei höheren Kalium, Chlorid, Natrium, Arsen, Nickel, Eisen und Aluminium Konzentrationen und indizierten vermutlich den Einfluss von Landwirtschaft, Oberflächenabfluß in städtischen Bereichen sowie atmosphärische Depositionen von Schadstoffen.

Die Zusammensetzung der Artengemeinschaften in Koshi Tappu reflektierte wasserchemische Gradienten sowie unterschiedliche Gewässervegetation, Teichsubstrate, Profile der Uferregion und Landnutzung als Folge von Landwirtschaft in den Einzugsgebieten. Gesellschaften des Epiphytons und des Epipelons reflektierten Gradienten in der Chemie des Oberflächenwassers, insbesondere Konzentrationen von Kalzium, Magnesium, Strontium und Natrium, und Epipelon zusätzlich Konzentrationen von Sulfat. Epiphytische Arten charakteristisch für höhere Natrium Konzentrationen waren *Gomphonema lagenula* Kützing, *Nitzschia* cf. *incognita* Krasske, *Gomphonema augur* Ehrenberg und *Navicula* cf. *minima* Grunow. *Gomphonema angustatum* (Kützing) Rabenhorst, *Gomphonema* cf. *affine* Kützing, *Nitzschia amphibia* Grunow und *Synedra ulna* v. *acus* Ehrenberg indizierten höhere Konzentrationen von Kalzium, Magnesium und Strontium. Epipelische Arten waren auch sensitiv gegenüber chemischen Gradienten im Interstitialwasser. *Diadesmis confervacea* Kützing, *Encyonema silesiacum* (Bleisch in Rabenhorst) D.G. Mann, *N.* cf.

minima und *G*. cf. *affine* waren typisch für höhere Konzentrationen von Phosphat und Silizium, und . *Achnanthes exigua* Grunow für höhere Konzentrationen von Kalzium und Magnesium.

Die Kieselalgengemeinschaften verschiedener Mikrohabitate in Teichen und Seen aus drei Regionen Nepals unterschiedlichen Charakters sind gute Indikatoren für Umweltveränderungen als Folge von landwirtschaftlicher Intensivierung, Industrialisierung und Verstädterung. Dieser Wandel wird sich in Zukunft beschleunigen mit zunehmender Beanspruchung von Wasserresourcen. Weitere Untersuchungen einer größeren Anzahl von Seen und Teichen über einen ausgedehnteren geographischen Raum könnte zur Erstellung einer Diatomeendatenbank führen, sowie zur Entwicklung von Methoden für die Gewässerüberwachung und deren ökologischer Bewertung, und damit letztlich zu besserem Umweltmanagement und Schutz stehender Gewässer in Nepal.

7. Appendix

Index of common or abundant diatom species

Kathmandu Valley

Achnanthes inflata (Kützing) Grunow

Achnanthes subhudsonis Hustedt

Achnanthidium minutissimum (Kützing) Czarnecki

Achnanthidium saprophilum (Kobayasi & Mayama) Round & Bukhtiyarova

Achnanthidium sp.1

Aulacoseira cf. c*rassipunctata* Krammer

Cocconeis placentula var. *euglypta* Ehrenberg

Cyclostephanos cf. *invisitatus* (Hohn & Hellerman) Theriot, Stoermer & Håkansson

Cyclotella atomus Hustedt

Cyclotella cf. *bodanica* var. *lemanica* O. Müller

Cyclotella ocellata Pantocsek

Cyclotella sp.1

Cymbella cf. *subleptoceros* Krammer

Diadesmis cf. *confervacea* Kützing

Diploneis cf. *boldtiana* Cleve

Eolimna (Navicula) minima (Grunow) Lange-Bertalot

Epithemia sorex Kützing

Eunotia bilunaris (Ehrenberg) Mills

Fragilaria capucina var.1

Fragilaria nanana Lange-Bertalot

Gomphonema cf. *angustatum* (Kützing) Rabenhorst

Gomphonema cf. *angustatum* var.1

Gomphonema cf. *angustatum* var.2

Gomphonema lagenula (Kützing) Frenguelli

Gomphonema cf. *minutum* (C.Agardh) C.Agardh

Gomphonema parvulum Kützing

Gomphonema cf. *pseudoaugur* Lange-Bertalot

Gomphonema cf. *rhombicum* Fricke

Navicula cryptocephala Kützing

Navicula cf. *fracta* Hustedt

Navicula heimansioides Lange-Bertalot

Navicula microcari Lange-Bertalot

Navicula subminuscula Manguin

Navicula veneta Kützing

Navicula sp.1

Nitzschia gracilis Hantzsch

Nitzschia palea (Kützing) W.Smith

Nitzschia palea cf. var. *debilis* (Kützing) Grunow

Nitzschia sinuata var. *delognei* (Grunow) Lange-Bertalot

Nitzschia sinuata var. *tabellaria* (Grunow) Grunow

Planothidium lanceolatum (Brébisson) Round & Bukhtiyarova

Pseudostaurosira brevistriata (Grunow) Williams & Round

Sellaphora seminulum (Grunow) D.G. Mann

Staurosira construens Ehrenberg var. *venter* Hustedt

Staurosira construens var.1

Staurosira cf. *elliptica* (Schumann) Williams & Round

Staurosirella pinnata (Ehrenberg) Williams & Round

Surirella cf. *roba* Leclercq

Koshi Tappu

Achnanthes exigua Grunow

Achnanthes hungarica (Grunow) Grunow

Achnanthidium minutissimum (Kützing) Czarnecki

Adlafia bryophila (Petersen) Lange-Bertalot

Amphora libyca Ehrenberg

Amphora montana Krasske

Amphora veneta Kützing

Anomoeoneis vitrea (Grunow) Ross

Caloneis bacillum (Grunow) Cleve

Craticula cf. *accomodiformis* Lange-Bertalot

Craticula cuspidata (Kützing) D.G. Mann

Craticula halopannonica Lange-Bertalot

Diadesmis confervacea Kützing

Encyonema silesiacum (Bleisch in Rabenhorst) D.G. Mann

Epithemia sorex Kützing

Eunotia bilunaris (Ehrenberg) Mills

Eunotia minor (Kützing) Grunow

Eunotia sp.1

Fragilaria cf. *bidens* Heiberg

Fragilaria cf. *tenera* (W. Smith) Lange-Bertalot

Gomphonema cf. *affine* Kützing

Gomphonema angustatum (Kützing) Rabenhorst

Gomphonema augur Ehrenberg

Gomphonema cf. *clavatulum* Reichardt

Gomphonema gracile Ehrenberg

Gomphonema lagenula (Kützing) Frenguelli

Gomphonema paludosum Reichardt

Gomphonema parvulum Kützing

Navicula cf. *antonii* Lange-Bertalot

Navicula cari Ehrenberg

Navicula cryptocephala Kützing

Navicula exilis Kützing

Navicula germainii Wallace

Navicula hustedtii Krasske

Navicula minima Grunow

Navicula cf. *minima* Grunow

Navicula perminuta Grunow

Navicula trivialis Lange-Bertalot

Navicula variostriata Krasske

Navicula viridula (Kützing) Ehrenberg

Nitzschia amphibia Grunow

Nitzschia dissipata (Kützing) Grunow

Nitzschia cf. *incognita* Krasske

Nitzschia linearis (Agardh) W. Smith

Nitzschia palea (Kützing) W.Smith

Nitzschia subacicularis Hustedt

Placoneis clementis (Grunow) E.J. Cox

Pinnularia subcapitata v. *subrostrata* Krammer

Rhopalodia gibba (Ehrenberg) O. Müller

Sellaphora pupula (Kützing) Mereschkowsky

Synedra (*Fragilaria*) *ulna* v. *acus* (Kützing) Lange-Bertalot

Synedra cf. *ulna* (Nitzsch) Ehrenberg

Gosainkunda

Achnanthes cf. *chlidanos* Hohn & Hellermann

Achnanthes distincta Messikommer

Achnanthes cf. *linearis* (W. Smith) Grunow

Achnanthes sp.2

Achnanthidium minutissimum (Kützing) Czarnecki

Anomoeoneis brachysira (Brébisson) Grunow

Aulacoseira cf. *alpigena* (Grunow) Krammer

Aulacoseira sp.1

Diatoma mesodon (Ehrenberg) Kützing

Encyonema minutum (Hilse in Rabenhorst) D.G. Mann

Eunotia bilunaris (Ehrenberg) Mills

Eunotia muscicola var. *tridentula* Nörpel & Lange-Bertalot

Eunotia nymanniana Grunow

Eunotia sp.1

Fragilaria cf. *delicatissima* (W. Smith) Lange-Bertalot

Fragilaria exigua Grunow

Navicula cf. *digitulus* Hustedt

Psammothidium bioretii (Germain) Bukhtiyarova & Round

Psammothidium cf. *marginulatum* (Grunow) Bukhtiyarova & Round

Psammothidium cf. *scoticum* (Flower & Jones) Bukhtiyarova & Round

Psammothidium subatomoides (Hustedt) Bukhtiyarova & Round

Pseudostaurosira brevistriata (Grunow) Williams & Round

Staurosira cf. *construens* Ehrenberg var. *venter* Hustedt

Staurosirella cf. *pinnata* (Ehrenberg) Williams & Round

“*Nepalia gosainkundensis*” manuscript name

Opephora olsenii Möller

Tabellaria flocculosa (Roth) Kützing

Kathmandu Valley: relative abundances

	P1sed	P1sto	P1mac	P2wal	P3wal	P4wal	P5sed	P5mac	P6sto
Achnsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Achnsubh	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Achnexig	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Achninfl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhelv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.0	0.0	1.2	0.0	0.0	0.6	0.0	0.0
Planlanc	1.0	0.0	0.2	0.4	0.0	0.0	0.2	0.0	0.0
Achnminu	29.9	14.1	65.3	0.4	59.1	1.1	1.1	10.0	0.2
Achnsapr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnsiam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnunda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphpell	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphmont	1.0	0.8	0.0	3.0	0.0	0.0	0.0	0.4	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aulacfcr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aulaital	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0
Coccpleu	0.0	0.0	0.0	0.0	1.4	0.5	2.4	1.8	0.0
Cyclatom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4
Cyclcfbl	0.0	0.0	0.0	0.0	0.0	0.0	32.3	0.0	0.0
Cyclocce	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyclsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0
Cycscfin	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0	1.8
Cymbcfsu	1.7	0.0	1.5	0.0	9.9	1.8	0.2	0.0	0.0
Cymbparv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymbsp2	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0
Diatmeso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplcfbo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encskram	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0
Encssubm	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0
Cymbsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	63.5	0.0	0.0	0.0
Eunobilu	0.2	0.0	0.2	0.0	0.0	0.0	4.0	5.9	0.0
Eunocfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Fragbrev	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragcagr	1.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Fragcav1	14.9	3.1	16.8	0.0	0.0	0.2	0.0	0.0	0.0
Staucove	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucov1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucoco	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.4	0.0
Staucov2	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0
Fragcfel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragnana	37.4	70.7	12.1	0.0	0.0	0.0	0.0	0.0	0.9
Staspinn	0.9	0.7	0.0	1.0	0.6	8.0	2.4	0.7	0.0
Fragulna	0.2	2.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Gompacum	0.2	0.0	0.4	0.0	0.0	0.0	0.3	0.0	0.0
Gompafaf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompaugu	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcav3	0.7	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0
Gompcfan	0.2	0.0	0.0	0.0	0.0	0.0	1.6	26.2	0.0
Gompcav1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.4	0.0
Gompcav2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Gompminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompparv	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.2
Gomplage	0.0	0.0	0.0	0.8	0.0	0.0	7.6	4.4	0.0
Gompcfgr	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppseu	0.5	0.0	0.0	1.0	0.0	0.0	2.7	3.7	0.0
Gomppsph	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Kathmandu Valley: relative abundances

	P1sed	P1sto	P1mac	P2wal	P3wal	P4wal	P5sed	P5mac	P6sto
Gompcfrh	0.0	0.0	0.0	0.0	0.4	0.0	2.6	1.8	0.0
Gompcfst	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfsu	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.0
Gomptrun	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlamusc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlasp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diadcfco	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0
Navicryp	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.7	0.4
Naviexil	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Navicffr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	1.7	0.2	0.6	0.0	0.0	0.0	0.0	0.7	0.0
Navilund	0.9	1.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	10.1	0.0	0.0	0.0	42.8
Navimini	0.3	0.8	0.0	2.4	0.0	0.0	0.0	0.4	5.1
Navinoth	0.2	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0
Naviobte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sellpupu	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.1	0.0
Naviscut	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Sellsemi	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.5
Navisubm	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	2.2
Navicftr	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
Navivene	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.5
NaviL16w	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NaviL9se	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.9
Nitzdiss	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
Nitzgrac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzpav1	0.0	2.2	0.0	2.0	0.0	0.0	1.9	2.6	0.0
Nitzpale	1.4	0.0	0.0	6.1	0.0	3.2	1.3	2.2	3.3
Nitzpalc	0.0	2.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Nitzrect	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzside	0.2	0.0	0.0	70.7	0.4	0.0	0.0	0.0	9.3
Nitzsita	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0
PinnL5se	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0
Suricfro	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Kathmandu Valley: relative abundances

	P7sed	P7mac	P8wal	P9sed	P9mac	P10sto	P11wal	P11mac	P12sed	P12sto
Achnsp1	0.0	0.0	44.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnsubh	0.0	2.1	0.0	3.1	0.0	0.7	0.0	0.0	4.0	15.3
Achnexig	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.3	0.0
Achninfl	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.0	0.0	0.0
Achnhelv	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	3.3	6.2
Achnminu	51.6	71.3	34.2	18.3	66.0	34.0	0.0	0.0	27.8	14.3
Achnsapr	7.7	2.9	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0
Achnrupe	0.0	0.0	0.0	1.0	1.3	0.0	0.0	0.0	0.7	1.8
Achnsiam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	1.0
Achnunda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	3.2
Amphpell	1.2	0.2	0.0	1.4	0.2	0.0	0.0	0.0	0.0	0.0
Amphmont	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Aulacfcr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aulaital	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccpleu	0.0	0.4	0.0	4.2	16.1	0.0	0.0	0.0	0.2	0.2
Cyclatom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyclcfbl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyclocce	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyclsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cycscfin	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymbcfsu	11.9	9.3	0.3	5.8	4.8	0.0	0.0	0.0	0.0	0.2
Cymbparv	3.3	2.5	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Cymbsp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diatmeso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.2
Diplcfbo	0.0	0.0	0.0	25.9	0.0	0.0	0.0	0.0	0.0	0.0
Encskram	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encssubm	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymbsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunobilu	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.2	0.2	0.2
Eunocfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragbrev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragcagr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragcav1	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.3	0.0
Staucove	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Staucov1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucoco	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Staucov2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragcfel	0.0	0.0	0.0	0.0	0.0	0.0	41.0	26.4	0.0	4.5
Fragnana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staspinn	1.8	0.5	0.0	2.1	1.3	0.1	0.0	0.0	0.0	0.0
Fragulna	0.3	0.0	0.0	0.0	0.2	0.1	0.0	0.6	0.0	0.0
Gompacum	0.3	1.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Gompafaf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompaugu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcav3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcav1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcav2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0
Gompminu	0.0	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompparv	0.3	0.4	0.0	0.2	0.0	16.6	0.2	1.8	0.5	1.8
Gomplage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfgr	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppsph	1.5	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0

Kathmandu Valley: relative abundances

	P7sed	P7mac	P8wal	P9sed	P9mac	P10sto	P11wal	P11mac	P12sed	P12sto
Gompcfrh	0.0	0.0	1.1	0.0	0.4	0.0	0.0	0.0	4.5	4.9
Gompcfst	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfsu	0.0	0.0	0.0	1.0	1.1	0.3	0.0	0.0	0.0	0.0
Gomptrun	3.0	1.4	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlamusc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7
Adlasp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diadcfco	0.0	0.0	0.0	0.0	0.0	0.0	41.0	65.5	0.2	0.7
Navicryp	6.2	1.6	0.0	0.0	2.0	0.1	0.4	0.0	3.5	0.2
Naviexil	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicffr	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	4.5
Navilund	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimini	0.6	0.9	0.0	2.9	1.3	3.8	0.0	0.9	6.6	29.0
Navinoth	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Naviobte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Sellpupu	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0
Naviscut	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sellsemi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Navisubm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicftr	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Navivene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NaviL16w	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NaviL9se	0.0	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	0.0	0.0	0.0	0.6	0.0	1.0	0.2	2.4	0.0	0.0
Nitzdiss	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	4.3	0.5
Nitzgrac	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0
Nitzcfla	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzpav1	1.5	0.5	0.0	1.0	0.0	21.9	0.0	1.1	3.3	0.7
Nitzpale	0.0	0.2	0.0	0.2	0.2	5.6	0.2	0.0	2.5	0.2
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzrect	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	2.5	0.0
Nitzside	0.3	0.0	0.3	1.2	0.0	0.4	0.0	0.0	0.0	0.0
Nitzsita	0.6	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0
PinnL5se	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suricfro	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	11.1	0.0

Kathmandu Valley: relative abundances

	P13wal	P14wal	P15sed	P15mac	P16wal
Achnsp1	0.0	0.0	0.0	0.0	0.0
Achnsubh	4.7	0.0	0.0	0.0	1.0
Achnexig	0.0	0.0	0.0	0.0	0.2
Achninfl	0.0	0.0	0.0	0.0	0.0
Achnhelv	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.0	0.0	0.0	1.0
Planlanc	1.1	0.0	0.0	0.2	0.0
Achnminu	2.6	88.9	0.0	4.2	59.7
Achnsapr	0.0	0.0	0.0	0.0	0.0
Achnrupe	0.0	0.0	0.0	0.0	0.0
Achnsiam	0.0	0.0	0.0	0.0	0.0
Achnunda	0.2	0.0	0.0	0.0	0.0
Amphpell	0.0	0.0	0.0	0.0	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0
Aulacfcr	0.0	0.0	10.0	0.0	0.0
Aulaital	0.0	0.0	0.0	0.0	0.0
Coccpleu	0.2	0.5	0.8	0.2	0.4
Cyclatom	0.0	0.0	0.0	0.0	0.0
Cyclcfbl	0.0	0.0	0.0	0.0	0.0
Cyclocce	0.0	0.0	14.5	0.0	0.0
Cyclsp1	0.0	0.0	0.0	0.0	0.0
Cycscfin	0.0	0.0	0.0	0.0	0.0
Cymbcfsu	0.0	0.0	0.0	0.2	0.0
Cymbparv	0.0	0.0	0.0	0.0	0.2
Cymbsp2	0.0	0.0	0.0	0.0	0.0
Diatmeso	0.4	0.0	0.0	0.0	0.0
Diplcfbo	0.0	0.0	0.0	0.0	0.0
Encskram	0.0	0.0	0.0	0.0	0.0
Encssubm	0.0	0.0	0.0	0.0	0.0
Cymbsp1	5.1	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.2	0.0	0.0
Epitsore	0.0	0.0	0.8	0.0	0.0
Eunobilu	0.0	0.0	0.0	0.0	0.0
Eunocfde	0.0	0.0	0.0	0.0	0.0
Fragbrev	0.0	0.0	18.9	0.0	0.0
Fragcagr	0.0	0.0	0.0	0.0	0.0
Fragcav1	0.6	7.3	0.0	0.0	0.2
Staucove	0.0	0.0	12.7	0.0	0.0
Staucov1	0.0	0.0	8.1	0.0	0.0
Staucoco	0.0	0.0	1.5	0.4	0.0
Staucov2	0.0	0.0	0.0	0.0	0.0
Fragcfel	0.0	0.0	0.0	0.0	0.0
Fragnana	0.0	0.5	0.0	0.0	0.0
Staspinn	0.0	0.0	13.7	0.8	0.4
Fragulna	0.0	0.0	0.0	0.2	0.0
Gompacum	0.0	0.0	0.0	0.0	0.0
Gompafaf	0.0	0.0	0.0	0.0	1.5
Gompaugu	0.0	0.0	0.0	0.0	0.0
Gompcav3	0.0	0.0	0.0	0.0	0.0
Gompcfps	0.0	0.0	0.0	0.0	0.0
Gompcfan	0.0	0.0	0.0	0.0	4.9
Gompcav1	0.0	0.0	0.0	0.0	0.0
Gompcav2	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0
Gompminu	0.0	0.0	0.0	0.0	0.0
Gompparv	0.2	0.0	0.0	0.0	0.0
Gomplage	0.0	0.0	0.0	4.4	2.9
Gompcfgr	0.0	0.0	0.0	0.0	0.0
Gomppseu	0.0	0.0	0.0	0.0	0.0
Gomppsph	0.0	0.0	0.0	0.0	0.0

Kathmandu Valley: relative abundances

	P13wal	P14wal	P15sed	P15mac	P16wal
Gompcfrh	0.0	0.0	0.0	0.4	0.0
Gompcfst	0.0	0.0	0.0	0.0	0.0
Gompcfsu	0.0	0.0	0.0	0.0	0.0
Gomptrun	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0
Adlamusc	0.6	0.0	0.0	0.0	0.0
Adlasp1	1.9	0.0	0.0	0.0	0.0
Diadcfco	0.0	0.0	0.2	0.0	0.0
Navicryp	0.0	0.0	0.0	0.4	2.1
Naviexil	0.0	0.0	0.0	0.0	0.0
Navicffr	0.0	0.0	0.0	0.0	0.0
Naviheim	65.0	0.0	0.0	0.0	0.0
Navilund	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0
Navimini	8.2	0.0	0.0	0.0	16.3
Navinoth	2.8	0.0	0.0	0.0	0.0
Naviobte	2.4	0.0	0.0	0.0	0.0
Sellpupu	0.0	0.0	0.0	0.0	0.0
Naviscut	0.0	0.0	1.9	0.2	0.0
Sellsemi	0.2	0.0	0.0	50.8	0.2
Navisubm	0.0	0.0	0.0	6.0	0.0
Navicftr	0.0	0.0	0.0	0.0	0.0
Navivene	0.0	0.0	0.0	0.0	0.0
NaviL16w	0.0	0.0	0.0	0.0	2.9
NaviL9se	0.0	0.0	0.0	0.0	0.0
Nitzamph	0.0	0.0	0.0	0.0	2.5
Nitzdiss	0.2	0.0	0.0	1.6	0.0
Nitzgrac	0.0	0.0	0.0	0.0	0.0
Nitzcfla	0.7	0.0	2.5	0.0	0.0
Nitzpav1	0.0	0.0	8.7	23.2	2.7
Nitzpale	0.9	0.0	3.9	2.6	0.6
Nitzpalc	0.0	0.0	0.0	0.0	0.0
Nitzrect	0.0	0.0	0.0	0.0	0.0
Nitzside	0.0	0.0	0.0	1.8	0.2
Nitzsita	0.0	0.0	0.0	0.0	0.0
PinnL5se	0.0	0.0	0.0	0.0	0.0
Suricfro	0.0	0.0	0.0	0.0	0.0

Kathmandu Valley: species codes

Achnsp1 = *Achnanthidium* sp.1
Achnsubh = *Achnanthes subhudsonis*
Achnexig = *Achnanthes exigua*
Achninfl = *Achnanthes inflata*
Achnhelv = *Achnanthes helvetica*
Achnhung = *Achnanthes hungarica*
Planlanc = *Planothidium lanceolatum*
Achnminu = *Achnanthidium minutissimum*
Achnsapr = *Achnanthidium saprophilum*
Achnrupe = *Achnanthes rupestoides*
Achnsiam = *Achnanthes siamlinearis*
Achnunda = *Achnanthes undata*
Amphpell = *Amphipleura pellucida*
Amphmont = *Amphora montana*
Amphvene = *Amphora veneta*
Aulacfcr = *Aulacoseira* cf. *crassipunctata*
Aulaital = *Aulacoseira italica*
Coccpleu = *Cocconeis placentula* v. *euglypta*
Cyclatom = *Cyclotella atomus*
Cyclcfbl = *Cyclotella* cf. *bodanica* v. *lemanica*
Cyclocce = *Cyclotella occelata*
Cyclsp1 = *Cyclotella* sp.1
Cycscfin = *Cyclostephanos* cf. *invisitatus*
Cymbcfsu = *Cymbella* cf. *subleptoceros*
Cymbparv = *Cymbella parviformis*
Cymbsp2 = *Cymbella* sp.2
Diatmeso = *Diatoma mesodon*
Diplcfbo = *Diploneis* cf. *boldtiana*
Encskram = *Encyonopsis krammeri*
Encssubm = *Encyonopsis subminuta*
Cymbsp1 = *Cymbella* sp.1
Encyminu = *Encyonema minutum*
Epitsore = *Epithemia sorex*
Eunobilu = *Eunotia bilunaris*
Eunocfde = *Eunotia* cf. *denticulata*
Fragbrev = *Pseudostaurosira brevistriata*
Fragcagr = *Fragilaria capucina* v. *gracilis*
Fragcav1 = *Fragilaria capucina* v.1
Staucove = *Stauroneis construens* v. *venter*
Staucov1 = *Stauroneis construens* v.1
Staucoco = *Stauroneis construens* f. *construens*
Staucov2 = *Stauroneis construens* v.2
Fragcfel = *Fragilaria* cf. *elliptica*
Fragnana = *Fragilaria nanana*
Staspinn = *Staurosirella pinnata*
Fragulna = *Fragilaria ulna*
Gompacum = *Gomphonema acuminatum*
Gompafaf = *Gomphonema affine* v. *affine*
Gompaugu = *Gomphonema augur*
Gompcav3 = *Gomphonema* cf. *angustatum* v.3
Gompcfps = *Gomphonema* cf. *pseudoaugur*
Gompcfan = *Gomphonema* cf. *angustatum*
Gompcav1 = *Gomphonema* cf. *angustatum* v.1
Gompcav2 = *Gomphonema* cf. *angustatum* v.2
Gompcfmi = *Gomphonema* cf. *minutum*
Gompminu = *Gomphonema minutum*
Gompparv = *Gomphonema parvulum*
Gomplage = *Gomphonema lagenula*
Gompcfgr = *Gomphonema* cf. *gracile*
Gomppseu = *Gomphonema pseudoaugur*
Gomppsph = *Gomphonema pseudophaerophorum*
Gompcfrh = Gomphonema cf. rhombicum
Gompcfst = *Gomphonema* cf. *stauroneiforme*
Gompcfsu = *Gomphonema* cf. *subclavatulum*
Gomptrun = *Gomphonema truncatum*
Gompsp1 = *Gomphonema* sp.1
Adlamusc = *Adlafia muscicola*
Adlasp1 = *Adlafia* sp.1
Diadcfco = *Diadesmis* cf. *confervacea*
Navicryp = *Navicula cryptocephala*
Naviexil = *Navicula exilis*
Navicffr = *Navicula* cf. *fracta*
Naviheim = *Navicula heimansioides*
Navilund = *Navicula lundii*
Navimicr = *Navicula microcari*
Navimini = *Eolimna minima*
Navinoth = *Navicula notha*
Naviobte = *Navicula obtecta*
Sellpupu = *Sellaphora pupula*
Naviscut = *Navicula scutelloides*
Sellsemi = *Sellaphora seminulum*
Navisubm = *Navicula subminuscula*
Navicftr = *Navicula* cf. *trivialis*
Navivene = *Navicula veneta*
NaviL16w = *Navicula* sp.L16 wall
NaviL9se = *Navicula* sp.L9sed
Nitzamph = *Nitzschia amphibia*
Nitzdiss = *Nitzschia dissipata*
Nitzgrac = *Nitzschia gracilis*
Nitzcfla = *Nitzschia* cf. *lacuum*
Nitzpav1 = *Nitzschia palea* v.1 (cf. v. *debilis)*
Nitzpale = *Nitzschia palea*
Nitzpalc = *Nitzschia paleacea*
Nitzrect = *Nitzschia recta*
Nitzside = *Nitzschia sinuata* v. *delognei*
Nitzsita = *Nitzschia sinuata* v. *tabellaria*
PinnL5se = *Pinnularia* sp.L5sed
Suricfro = *Surirella* cf. *roba*

Kathmandu Valley: habitat character

Categories: 1 = present, 2 ≥ 30%

	P1	P2	P3	P4	P5	P6	P7	P8
Pond dimensions								
Length (m)	400	30	25	35	30	200	150	20
Width (m)	300	20	15	10	5	150	30	10
Rip. Zone Width (m)	0.5	0.1	0.1	0.1	15	2	1	0.1
Bank Height (m)	2	1.5	0.5	0.5	0.2	1.5	1	1
Sustrate composition (%)								
Littoral								
Concrete	0	100	100	100	0	0	0	100
Boulders	0	0	0	0	0	0	0	0
Cobbles	25	0	0	0	0	30	0	0
Pebbles	25	0	0	0	0	50	0	0
Gravel	25	0	0	0	0	20	0	0
Sand	20	0	0	0	0	0	0	0
Silt,mud,earth	5	0	0	0	100	0	100	0
Riparian zone								
Concrete	0	100	100	100	0	0	0	100
Boulders	0	0	0	0	0	0	0	0
Cobbles	5	0	0	0	0	10	0	0
Pebbles	15	0	0	0	0	50	0	0
Gravel	50	0	0	0	0	30	0	0
Sand	20	0	0	0	0	10	0	0
Silt,mud,earth	10	0	0	0	100	0	100	0
Bank								
Concrete	0	100	100	100	0	0	0	100
Boulders	0	0	0	0	0	0	0	0
Cobbles	20	0	0	0	0	10	70	0
Pebbles	10	0	0	0	0	30	0	0
Gravel	40	0	0	0	0	20	0	0
Sand	20	0	0	0	0	20	0	0
Silt,mud,earth	10	0	0	0	100	20	30	0
Bank profile								
Natural								
Vertical, undercut	0	2	2	2	0	0	0	2
Vertical + toe	0	0	0	0	0	0	2	0
Steep	2	0	0	0	0	2	0	0
Composite	0	0	0	0	0	0	0	0
Gentle	0	0	0	0	2	0	0	0
Bank profile								
Artificial								
Resectioned	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	2	0
Reinforced part	0	0	0	0	0	1	0	0
Embanked	0	2	2	2	0	0	0	2
Poached	0	0	0	0	0	0	0	0

Kathmandu Valley: habitat character

Categories: 1 = present, 2 ≥ 30%

	P1	P2	P3	P4	P5	P6	P7	P8
Lake vegetation								
Emerg. herbs	2	0	0	0	0	0	1	0
Emerg. reeds, sedges	0	0	0	0	0	0	0	0
Rooted floating leaves	2	0	0	0	1	0	1	0
Free floating plants	0	1	0	0	0	0	1	0
Submerged plants	2	0	0	0	0	0	0	0
Filamentous algae	2	0	0	0	2	1	1	0
Bank vegetation (%)								
Bare	30	90	100	20	0	20	0	100
Short grass	40	0	0	80	50	20	30	0
Tall grass, herbs	30	10	0	0	50	20	60	0
Scrub	0	0	0	0	0	20	10	0
Trees	0	0	0	0	0	20	0	0
Trees, ass. features								
Trees	8	0	5	5	0	7	5	6
Shading	0	0	0	1	0	1	0	1
Riparian roots	1	0	0	0	1	1	0	0
Underw. roots	0	0	0	0	1	1	0	0
Fallen trees	0	0	0	0	0	1	0	0
Overh. boughs	0	0	0	0	0	1	0	0
Woody debris	1	0	0	0	0	1	0	0
Land use within 100m								
Urban settlement	1	2	1	1	0	1	1	1
Agriculture	1	0	0	0	0	0	1	0
Pasture	0	0	0	0	1	0	0	0
Rough grassland	0	0	0	0	1	0	1	0
Scrub	1	0	0	0	0	0	1	0
Broad leaved forest	1	0	1	1	0	1	1	1
Artificial features rip. zone								
Road, path	1	2	1	1	1	1	1	1
Weir, dam	1	2	2	2	0	0	1	1
Pier	0	0	0	0	0	0	0	0
Abstraction	1	0	0	0	0	0	0	0

Kathmandu Valley: habitat character

Categories: 1 = present, 2 ≥ 30%

	P9	P10	P11	P12	P13	P14	P15	P16
Pond dimensions								
Length (m)	25	250	15	400	30	200	100	200
Width (m)	15	250	15	20	10	100	100	150
Rip. Zone Width (m)	0.1	1.5	0.1	1	0.1	0.1	1.5	0.1
Bank Height (m)	0.2	1.5	0.5	2	0.7	0.7	1.5	1.5
Sustrate composition (%)								
Littoral								
Concrete	100	60	40	0	100	100	0	100
Boulders	0	0	0	20	0	0	0	0
Cobbles	0	0	10	10	0	0	0	0
Pebbles	0	30	10	10	0	0	0	0
Gravel	0	10	0	10	0	0	0	0
Sand	0	0	40	10	0	0	0	0
Silt,mud,earth	0	0	0	40	0	0	100	0
Riparian zone								
Concrete	100	30	100	0	100	100	0	100
Boulders	0	0	0	0	0	0	0	0
Cobbles	0	10	0	40	0	0	0	0
Pebbles	0	40	0	20	0	0	0	0
Gravel	0	20	0	20	0	0	0	0
Sand	0	0	0	20	0	0	0	0
Silt,mud,earth	0	0	0	0	0	0	100	0
Bank								
Concrete	100	100	100	0	100	100	0	100
Boulders	0	0	0	40	0	0	0	0
Cobbles	0	0	0	30	0	0	0	0
Pebbles	0	0	0	10	0	0	0	0
Gravel	0	0	0	10	0	0	0	0
Sand	0	0	0	10	0	0	0	0
Silt,mud,earth	0	0	0	0	0	0	100	0
Bank profile								
Natural								
Vertical, undercut	1	2	2	0	2	2	0	2
Vertical + toe	0	0	0	0	0	0	0	0
Steep	0	0	0	2	0	0	2	0
Composite	0	0	0	0	0	0	0	0
Gentle	0	0	0	0	0	0	0	0
Bank profile								
Artificial								
Resectioned	0	0	0	0	0	0	2	0
Reinforced whole	0	0	0	0	0	0	0	0
Reinforced part	0	0	0	0	0	0	0	0
Embanked	2	2	2	0	2	2	0	2
Poached	0	0	0	0	0	0	0	0

Kathmandu Valley: habitat character
Categories: 1 = present, 2 ≥ 30%

	P9	P10	P11	P12	P13	P14	P15	P16
Lake vegetation								
Emerg. herbs	0	0	0	0	0	0	0	0
Emerg. reeds, sedges	0	0	0	0	0	0	0	0
Rooted floating leaves	0	0	0	0	0	0	2	0
Free floating plants	0	0	1	0	0	0	0	0
Submerged plants	1	0	1	0	0	0	0	0
Filamentous algae	1	0	1	0	0	0	0	0
Bank vegetation (%)								
Bare	25	90	100	0	100	100	0	100
Short grass	25	0	0	0	0	0	70	0
Tall grass, herbs	25	10	0	70	0	0	20	0
Scrub	0	0	0	15	0	0	10	0
Trees	25	0	0	15	0	0	0	0
Trees, ass. features								
Trees	8	1	1	8	0	0	0	1
Shading	1	0	1	1	0	0	0	0
Riparian roots	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	2	0
Fallen trees	0	0	0	0	0	0	0	0
Overh. boughs	0	0	0	0	0	0	0	0
Woody debris	0	0	0	0	0	0	0	0
Land use within 100m								
Urban settlement	0	2	2	0	2	2	1	2
Agriculture	0	0	0	1	0	0	0	0
Pasture	0	0	0	0	0	0	1	0
Rough grassland	1	0	0	1	0	0	0	0
Scrub	1	0	0	1	0	0	0	0
Broad leaved forest	2	0	0	1	0	0	0	0
Artificial features rip. zone								
Road, path	1	1	1	0	0	1	1	1
Weir, dam	1	1	1	0	2	2	0	2
Pier	0	1	0	0	0	0	0	0
Abstraction	0	0	0	0	0	0	0	0

Kathmandu Valley: water chemistry

Conductivity in µS/cm, Na - Pb concentrations in mg/L

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
pH	7.8	8.8	8.0	8.5	7.3	8.8	8.0	7.8	8.4	9.7	6.8	7.8	7.5	8.1	7.0	9.9
Cond.	241.0	333.0	228.0	191.0	269.0	360.0	222.0	221.0	195.0	200.0	402.0	23.2	22.4	152.0	679.0	134.4
Na	6.1	24.5	2.1	10.3	18.2	25.3	1.5	1.3	2.1	22.6	16.8	4.4	4.3	6.4	56.9	10.2
K	4.2	27.7	0.8	1.1	34.9	13.5	0.7	0.7	1.0	11.3	8.2	0.7	0.6	6.1	59.1	8.7
Mg	7.9	6.2	5.1	3.2	5.5	10.1	3.2	3.0	3.1	2.5	8.1	0.5	0.5	3.6	17.6	2.2
Ca	41.2	38.0	50.1	32.9	16.8	45.0	52.4	51.2	47.5	17.5	68.6	2.7	2.4	25.6	50.4	15.5
F	0.12	0.08	0.00	0.08	0.16	0.07	0.01	0.00	0.01	0.18	0.06	0.01	0.00	0.45	0.74	1.23
Cl	5.9	21.4	0.4	2.2	37.0	24.4	0.3	0.2	0.3	24.4	11.5	0.3	0.2	5.4	94.8	5.2
Total N	0.36	1.50	0.31	0.02	0.20	0.89	0.03	0.23	0.10	0.06	2.20	0.10	0.05	0.03	12.65	0.32
PO_4	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	1.60	0.00	0.00	0.00	16.16	0.00
SO_4	4.99	2.70	2.51	3.76	0.08	12.17	0.88	0.91	0.94	4.43	11.26	0.39	0.18	1.05	37.67	3.17
Al	0.010	0.015	0.013	0.015	0.054	0.012	0.011	0.009	0.013	0.171	0.009	0.034	0.031	0.056	0.016	0.076
Fe	0.08	0.57	0.01	0.06	1.89	0.03	0.03	0.00	0.02	0.02	0.03	0.01	0.02	0.04	0.19	0.58
Mn	0.03	0.29	0.01	0.01	0.23	0.01	0.02	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.25	0.01
Sr	0.12	0.10	0.13	0.06	0.04	0.10	0.05	0.04	0.06	0.05	0.15	0.02	0.01	0.11	0.16	0.07
Ba	0.05	0.03	0.05	0.04	0.05	0.06	0.03	0.04	0.03	0.02	0.05	0.00	0.00	0.07	0.02	0.03
Ni	1.08	1.34	0.67	0.55	2.02	0.75	0.67	0.69	0.72	2.61	2.41	0.23	0.19	0.78	2.71	0.86
Zn	3.75	4.01	14.68	3.93	5.58	4.38	4.24	3.38	2.73	5.25	7.46	1.28	1.32	5.29	12.06	4.18
As	0.71	0.81	0.24	0.94	1.80	0.48	0.28	0.20	0.27	1.68	1.15	0.42	0.37	0.29	2.26	1.11
Pb	0.05	0.20	0.08	0.06	0.79	0.09	1.72	0.07	0.04	0.23	0.11	0.05	0.05	0.18	0.14	0.68

Koshi Tappu: relative abundances

	P1mac	P2mac	P3mac	P4mac	P5mac	P6mac	P7mac	P8mac	P9mac	P10mac	P11mac
Achnexig	0.4	2.2	0.0	0.0	0.0	3.1	0.0	0.0	0.3	0.0	2.0
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	11.7	0.0	0.0	0.0	18.8	0.0	0.8	0.5	1.0	0.0	0.0
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.9
Achnminu	1.9	43.5	88.0	81.7	0.0	4.7	0.6	0.0	5.6	7.0	0.5
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4
Amphliby	0.0	1.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.8	0.0	2.8	0.0	1.0	0.2	3.9
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	1.5	0.8	0.0	1.8	2.1	4.7	2.0	5.5	2.1	0.9	0.4
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcusp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	1.6	0.2	0.7	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.4
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	0.0	0.4	1.0	0.6	16.5	9.4	4.6	11.8	0.0	6.4	10.2
Eunobilu	2.1	2.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	0.2	0.0	0.0	0.8	0.0	0.2	0.0	0.7	0.0	0.0
Eunomono	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Fragcfbi	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	0.0	6.2	0.0	1.8	1.8	1.6	3.0	20.5	2.1	7.0	5.9
Gompangu	0.0	1.4	0.0	0.0	2.8	0.0	0.6	0.2	5.6	19.1	0.7
Gompaugu	3.8	2.6	0.2	1.5	0.8	1.6	1.2	5.5	0.7	2.0	2.9
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompgrac	15.1	0.0	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	1.0	0.2	0.0	0.0	1.3	0.0	1.4	3.9	2.8	2.4	1.6
Gompparv	3.8	0.2	0.0	0.2	2.1	9.4	0.4	0.0	2.1	10.3	9.4
Gomppseu	0.0	2.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	5.7	1.4	0.0	0.2	4.4	34.4	41.2	24.8	16.7	5.3	3.7
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P1mac	P2mac	P3mac	P4mac	P5mac	P6mac	P7mac	P8mac	P9mac	P10mac	P11mac
Navicari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Diadconf	6.3	0.0	0.0	0.0	0.3	0.0	0.8	0.0	0.7	0.2	1.8
Navicryp	2.5	0.6	0.0	1.3	0.0	0.0	0.0	0.0	0.3	1.3	0.2
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.0	0.4	2.9	0.0	0.3	0.0	0.0	0.0	0.0	0.2	0.0
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Navimini	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.2	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	9.8	4.8	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviviri	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	5.9	1.2	0.2	0.6	4.4	10.9	11.8	10.6	10.4	2.2	3.7
Nitzcfca	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	1.1	0.4	1.0	0.4	5.4	3.1	3.6	2.2	11.5	24.1	32.3
Nitzline	2.3	0.0	0.0	0.2	0.5	1.6	0.6	0.0	0.0	0.2	1.2
Nitzpale	16.1	13.5	0.0	4.3	16.2	12.5	8.2	4.8	19.4	6.6	1.4
Nitzpalc	1.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	5.9	0.0	0.4	0.2	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Pinusbsb	0.0	1.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	1.7	7.5	0.4	1.7	0.0	0.0	0.2	0.5	4.2	1.3	1.1
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	0.0	1.2	0.2	0.6	0.0	0.0	1.6	0.2	1.0	0.2	0.5
Selacfre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	1.7	6.3	4.3	1.7	14.7	1.6	2.8	0.7	5.9	2.4	10.7
Synecful	5.0	0.0	0.0	0.0	0.3	0.0	0.0	2.4	0.3	0.0	0.2

Koshi Tappu: relative abundances

	P12mac	P13mac	P14mac	P15mac	P16mac	P17mac	P18mac	P19mac	P21mac
Achnexig	0.2	0.5	0.2	0.8	0.2	2.5	0.2	1.1	0.0
Achncfch	0.0	4.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.0	4.4	7.3	4.5	0.0	0.0	12.4	0.0
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	1.2	3.3	0.0	8.1	1.2	1.5	90.3	1.3	65.0
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphliby	0.0	0.0	0.0	2.7	0.0	8.0	0.0	0.0	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	1.2	0.5	1.5	3.8	8.8	1.9	0.0	0.6	0.0
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0
Cratcusp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0
Encysile	14.1	1.2	4.2	0.4	1.1	2.7	0.4	2.8	0.2
Eunobilu	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.9	1.7
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.2	0.2	1.1	3.1	0.0	0.0	1.2	0.0	0.0
Eunomono	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0
Fragcfbi	0.0	0.2	0.0	0.0	4.6	16.1	0.2	3.7	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	5.4	2.1	8.6	4.2	2.0	3.6	0.2	4.1	0.0
Gompangu	1.4	0.0	2.4	0.0	0.3	7.3	0.0	3.5	0.4
Gompaugu	5.6	0.9	1.5	3.1	0.2	1.5	0.0	3.7	0.0
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	2.2	0.0	1.2	0.0	0.0	0.4	0.0
Gompgrac	0.0	0.0	0.0	0.8	0.3	0.0	0.0	0.0	11.8
Gompinsi	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	12.7	6.7	2.4	7.7	0.3	7.5	0.0	4.8	0.4
Gompparv	17.1	0.7	13.5	3.1	0.2	3.4	0.6	2.4	0.2
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.4
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	3.8	2.6	5.3	8.5	4.6	14.1	1.0	4.1	0.8
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	1.4	0.7	0.0	0.0	0.0	0.0	0.7	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P12mac	P13mac	P14mac	P15mac	P16mac	P17mac	P18mac	P19mac	P21mac
Navicari	0.0	1.6	2.4	0.4	0.0	0.0	0.0	1.3	0.0
Diadconf	0.2	0.0	4.2	0.0	0.0	0.0	0.0	1.1	0.2
Navicryp	0.2	0.2	0.0	0.0	0.0	0.6	1.2	2.4	0.6
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimini	0.0	0.7	2.0	3.8	0.0	0.0	0.0	1.5	0.2
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	1.9	0.4	0.4	0.0	0.0	0.0	0.2	0.0
Naviviri	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.8	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	11.8	19.3	8.4	5.8	53.8	8.4	1.8	4.4	0.8
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	6.2	2.3	1.8	8.1	0.0	8.8	0.0	16.3	1.4
Nitzline	0.6	0.7	0.4	0.4	0.0	0.0	0.0	0.7	0.0
Nitzpale	10.8	14.4	11.7	15.4	3.5	3.4	0.8	14.6	7.9
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.7
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	3.0	0.0	0.2	1.9	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Pinusbsb	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.0	0.0	0.0	0.8	0.0	0.0	0.0	1.3	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	0.0	0.2	3.1	1.5	0.8	0.8	0.2	0.6	0.0
Selacfre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	3.6	15.1	2.9	0.0	0.2	7.5	0.2	3.7	0.0
Synecful	0.0	0.0	0.2	4.2	0.0	0.0	0.0	0.4	0.0

Koshi Tappu: relative abundances

	P22mac	P23mac	P24mac	P25mac	P26mac	P28mac	P29mac	P31mac	P32mac
Achnexig	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
Achnminu	83.6	64.1	43.0	61.1	79.6	25.0	56.8	54.0	0.4
Achnrupe	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Amphliby	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	6.2	0.0	0.0	0.2	0.0	0.0
Anomvitr	0.0	0.0	15.7	1.3	0.0	6.8	8.5	0.0	0.0
Calobaci	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	4.6
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Cratcfac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cratcusp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	1.3	7.2	2.7	4.3	0.0	4.0	0.2	0.2	12.9
Eunobilu	0.2	2.9	3.0	0.0	1.5	0.0	1.7	0.2	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Eunointe	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	0.0	0.0	1.3	0.0	0.0	0.6	0.0	6.2
Eunomono	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	1.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Fragcfbi	0.9	0.0	0.0	9.2	0.0	0.4	0.0	0.0	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	0.2	1.3	1.2	1.3	2.0	0.7	2.6	0.5	17.7
Gompangu	0.0	0.0	0.7	0.2	0.4	0.0	0.0	0.0	8.0
Gompaugu	0.0	0.0	0.0	0.0	0.4	0.4	0.8	0.0	9.1
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2
Gompgrac	0.2	0.0	2.7	0.0	0.0	0.4	0.0	0.0	1.6
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.0
Gomplage	0.9	1.5	3.4	0.0	1.8	0.7	0.0	0.0	0.6
Gompparv	0.0	0.6	2.4	1.1	0.0	3.4	2.3	0.0	1.4
Gomppseu	0.0	0.6	0.0	0.2	0.0	0.2	0.0	0.0	0.0
Gompsubt	0.0	0.0	1.0	0.0	0.6	0.0	0.4	0.0	0.0
Gompsp1	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	0.0	0.0	0.3	1.9	0.0	3.1	1.3	2.5	3.6
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Navicfan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P22mac	P23mac	P24mac	P25mac	P26mac	P28mac	P29mac	P31mac	P32mac
Navicari	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Diadconf	0.0	0.2	0.8	0.2	0.0	0.0	0.0	0.0	2.2
Navicryp	1.7	10.1	3.0	1.9	0.9	24.9	3.6	0.2	0.0
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.0	0.0	0.0	0.4	0.0	0.0	0.2	2.5	0.2
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimini	0.0	0.0	0.0	0.0	0.0	0.2	0.0	1.1	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviviri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Nitzamph	1.7	0.0	0.3	2.3	0.0	0.5	1.1	0.7	3.0
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0
Nitzcfin	0.2	1.1	0.5	0.8	0.0	2.2	1.5	2.9	1.2
Nitzline	0.2	0.4	0.0	0.0	0.0	1.6	0.0	0.0	0.0
Nitzpale	6.2	1.1	11.2	2.8	5.3	16.0	14.0	14.5	3.2
Nitzpalc	0.0	0.4	0.0	0.0	0.0	0.0	0.8	0.2	0.4
Nitzsigm	0.0	0.0	0.0	0.0	0.4	0.0	1.1	0.0	0.0
Nitzsiv1	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinusbsb	0.0	0.0	0.2	0.2	0.2	0.5	0.0	0.0	0.2
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.0	0.0	0.0	0.6	0.0	0.5	0.0	0.2	11.7
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.6
Selacfre	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	0.0	5.3	1.5	0.0	5.9	1.3	1.3	0.0	6.0
Synecful	0.0	0.0	0.2	0.0	0.0	0.0	0.0	3.9	0.0

Koshi Tappu: relative abundances

	P33mac	P34mac	P35mac	P36mac	P37mac	P38mac	P39mac	P40mac	P41mac
Achnexig	0.0	0.0	0.0	0.4	0.4	0.2	0.6	5.6	0.0
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.0	0.0	0.2	0.0	0.0	3.6	0.2	2.0
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	50.5	0.0	0.7	0.0	0.0	4.0	0.4	0.4	0.0
Achnrupe	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Amphliby	0.9	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	2.2	1.9	0.9	0.0	5.0	4.3	1.3	2.3	1.1
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcusp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0
Encysile	8.9	0.6	3.1	4.2	6.3	2.2	13.6	2.3	10.3
Eunobilu	0.0	0.0	0.0	0.0	0.4	0.0	0.8	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	0.0	0.0	0.0	0.0	0.9	1.3	0.0	0.0
Eunomono	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Fragcfbi	0.9	0.0	0.0	11.2	0.0	0.0	0.0	4.3	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	3.5	4.3	40.6	17.6	8.1	3.4	13.2	17.1	8.9
Gompangu	2.6	4.3	0.0	0.0	0.0	0.7	0.6	7.7	0.2
Gompaugu	0.7	1.9	13.7	6.6	3.8	2.2	3.1	18.6	4.1
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Gompgrac	0.9	0.6	0.0	0.2	2.6	0.2	0.0	0.6	2.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	0.2	5.0	0.9	5.5	1.4	0.2	3.1	2.6	10.7
Gompparv	0.2	0.0	0.7	1.5	1.6	0.0	1.7	1.9	2.3
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	5.8	13.7	2.9	6.8	0.6	9.0	4.0	4.1	11.0
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P33mac	P34mac	P35mac	P36mac	P37mac	P38mac	P39mac	P40mac	P41mac
Navicari	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Diadconf	0.0	0.0	0.0	12.3	0.2	0.0	0.4	3.6	0.2
Navicryp	2.4	0.0	0.0	0.2	0.0	0.4	0.0	0.2	0.2
Navidign	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.4	0.0	0.2	0.2	0.6	0.0	0.0	0.2	0.0
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimini	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.8	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviviri	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	14.0	59.0	5.2	14.4	36.8	30.1	9.4	4.7	30.1
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Nitzcfin	0.0	0.0	11.7	4.7	8.5	0.2	18.4	2.4	0.2
Nitzline	0.0	0.0	0.0	0.8	0.4	0.2	1.2	0.9	0.0
Nitzpale	1.5	4.3	15.2	2.1	13.7	22.0	4.6	4.5	7.5
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinusbsb	0.0	0.0	0.0	0.6	0.0	0.0	0.8	0.4	0.2
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.4	0.0	0.0	0.0	4.0	0.4	4.0	7.7	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	0.0	0.6	2.7	1.7	1.4	2.0	0.4	2.1	0.2
Selacfre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	2.0	0.6	1.1	1.9	4.4	15.3	5.4	3.0	7.3
Synecful	0.0	0.6	0.0	0.0	0.0	0.0	0.2	0.0	0.0

Koshi Tappu: relative abundances

	P42mac	P43mac	P44mac	P45mac	P46mac	P47mac	P48mac	P49mac	P50mac
Achnexig	4.1	0.7	0.9	0.0	3.4	0.0	0.6	0.4	0.0
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.4	2.8	1.3	0.6	2.7	0.4	0.0	0.2
Achncfli	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	0.2	45.5	0.2	0.0	0.2	2.2	0.2	80.2	73.1
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphliby	1.2	0.7	0.0	0.0	1.4	0.0	0.0	0.4	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	4.9	3.3	0.7	1.6	0.8	1.1	0.2	0.9	2.1
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.5	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Cratcusp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	1.2	0.7	0.2	3.9	3.2	3.8	0.4	0.9	2.6
Eunobilu	0.0	21.3	0.0	0.0	0.0	0.0	1.4	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	6.2	0.0	0.0	5.4	0.5	0.4	0.2	1.5
Eunomono	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.0	0.6	0.0	3.8	0.0	0.0	0.0
Fragcfbi	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	1.0	1.9	1.5	3.2	2.2	11.3	4.0	3.2	1.5
Gompangu	0.7	0.0	1.3	1.6	7.4	2.2	3.2	0.9	0.2
Gompaugu	0.2	0.7	1.1	3.9	2.8	3.2	0.2	0.4	0.9
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	1.6	8.6	0.0	0.0	0.0
Gompgrac	0.0	0.0	0.0	0.3	0.0	0.0	0.8	0.0	0.7
Gompinsi	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	0.7	0.0	0.0	0.3	4.0	5.9	1.2	0.0	0.0
Gompparv	1.5	0.7	1.1	0.3	1.4	1.6	4.0	1.5	3.2
Gomppseu	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	18.3	1.1	10.0	1.0	10.6	6.5	37.6	0.0	3.9
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	0.0	1.1	0.0	1.6	1.6	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P42mac	P43mac	P44mac	P45mac	P46mac	P47mac	P48mac	P49mac	P50mac
Navicari	0.5	0.0	0.9	0.0	0.0	0.5	0.0	0.0	0.0
Diadconf	0.2	0.0	1.3	0.0	0.8	1.6	6.2	0.0	0.4
Navicryp	3.9	0.2	0.0	0.0	0.4	1.1	0.4	1.3	0.0
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.4
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimini	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Naviviri	3.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Nitzamph	2.9	6.7	14.8	17.8	25.3	9.7	2.2	5.8	1.9
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.7	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	1.7	0.2	11.5	18.1	0.4	5.9	2.2	0.0	0.0
Nitzline	2.2	0.0	0.9	0.3	1.4	0.0	0.0	0.0	0.2
Nitzpale	16.3	0.9	27.7	14.6	2.2	8.6	19.9	2.4	2.2
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0
Pinusbsb	0.2	0.4	0.2	0.0	0.4	0.0	0.2	0.0	0.0
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	1.2	0.2	3.1	6.1	5.0	9.7	0.4	0.0	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	6.6	0.4	2.2	17.2	3.0	1.1	0.8	0.2	0.4
Selacfre	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	22.9	3.2	12.6	4.9	9.6	7.0	12.5	0.9	0.0
Synecful	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2

Koshi Tappu: relative abundances

	P52mac	P53mac	P54mac	P56mac	P57mac	P58mac	P59mac	P62mac	P63mac
Achnexig	0.2	0.2	0.9	0.0	3.0	3.8	0.0	0.0	0.0
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	2.5	91.7	4.3	23.0	18.8	6.7	69.4	89.4	82.1
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Adlabryo	0.0	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.0
Amphliby	2.5	0.0	0.0	0.0	5.1	0.0	0.0	0.6	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	0.7	0.4	1.4	0.0	3.2	1.1	0.0	0.4	0.8
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.0	0.0	0.0	1.3	0.2	0.0	0.0	0.0
Cratcusp	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	9.7	0.2	1.8	0.0	1.3	2.5	7.9	0.6	0.0
Eunobilu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Eunomono	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.2	0.2	0.0	0.4	0.0	0.8	0.0	0.0	0.0
Fragcfbi	0.0	0.0	1.2	0.0	0.0	0.0	0.8	0.0	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	4.4	0.4	5.5	0.4	1.9	5.3	0.0	0.4	2.2
Gompangu	1.1	0.0	0.2	0.0	2.6	0.2	0.0	0.0	0.4
Gompaugu	4.4	0.0	2.7	0.2	0.2	2.5	0.0	0.0	0.0
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompgrac	1.6	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	0.7	0.0	1.4	0.0	1.3	10.9	0.0	0.0	0.0
Gompparv	3.5	0.0	0.0	0.0	3.9	1.5	0.0	0.0	0.4
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	2.3	0.0	4.3	0.4	15.8	23.4	0.0	0.0	0.0
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Navicfan	0.0	0.0	0.9	0.0	0.0	2.5	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P52mac	P53mac	P54mac	P56mac	P57mac	P58mac	P59mac	P62mac	P63mac
Navicari	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.2
Diadconf	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Navicryp	0.0	0.2	0.7	0.0	0.0	0.0	2.4	0.0	5.6
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Navimini	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviviri	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	4.9	5.9	2.8	5.8	28.4	19.8	0.0	2.5	4.8
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	47.8	0.0	41.7	0.0	0.4	0.2	0.8	0.6	0.2
Nitzline	4.7	0.0	1.1	0.2	0.2	0.6	0.6	0.0	0.0
Nitzpale	6.9	0.6	15.8	2.5	9.0	12.6	0.2	2.1	1.0
Nitzpalc	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinusbsb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.2	0.0	2.8	0.0	0.6	1.9	1.4	0.2	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	0.4	0.0	0.9	0.8	0.4	1.9	0.0	0.4	0.0
Selacfre	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	1.2	0.2	1.2	65.9	0.0	0.0	0.2	1.0	0.4
Synecful	0.0	0.0	0.2	0.0	0.8	0.6	0.0	0.0	0.2

Koshi Tappu: relative abundances

	P64mac	P65mac	P66mac	P67mac	P68mac	P69mac	P70mac	P71mac
Achnexig	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Achncfch	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0
Achnhung	0.0	1.6	0.0	4.5	14.4	0.0	0.0	4.2
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	1.2	0.0	0.0	0.4	3.4	67.1	3.7	0.2
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphliby	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	1.6	3.5	0.0	0.0	2.6	0.0	0.0	1.7
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcusp	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	2.7	2.3	1.3	0.4	4.1	0.4	3.2	2.1
Eunobilu	0.0	0.0	0.0	3.9	1.8	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Eunomino	7.0	0.0	0.0	0.0	4.3	0.0	0.0	1.2
Eunomono	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	1.3	0.0	0.0	1.5	0.0	0.0
Fragcfbi	0.2	0.0	0.0	0.2	0.6	0.0	0.0	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	28.0	6.6	8.3	0.2	4.1	1.5	1.2	9.6
Gompangu	0.4	0.0	0.3	0.2	4.7	0.0	26.8	0.0
Gompaugu	0.0	0.4	3.4	8.0	3.9	0.2	0.7	1.0
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompgrac	0.0	0.0	0.0	0.0	0.0	0.2	1.0	0.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	0.2	0.8	1.1	2.2	4.7	0.0	5.5	0.4
Gompparv	0.0	0.0	2.8	6.5	2.2	0.0	3.5	43.8
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.4	1.6	0.0	0.0	0.0	0.0	0.5	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfmi	0.2	3.9	0.8	3.4	1.2	0.4	14.4	0.2
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances

	P64mac	P65mac	P66mac	P67mac	P68mac	P69mac	P70mac	P71mac
Navicari	0.0	0.0	0.0	0.4	0.2	0.0	0.2	0.0
Diadconf	0.0	0.0	0.6	12.5	13.8	0.0	0.2	0.2
Navicryp	0.2	0.4	0.0	9.7	1.0	14.9	0.0	0.0
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimini	0.0	0.0	1.0	0.0	0.0	0.0	0.3	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Naviviri	0.0	0.0	0.0	0.0	2.2	0.2	0.0	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	39.7	18.4	3.2	3.9	12.0	8.0	21.2	5.2
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	1.0	5.9	58.2	9.1	0.8	0.0	1.8	10.0
Nitzline	1.0	13.7	2.3	6.7	0.4	0.0	0.3	1.2
Nitzpale	9.5	21.9	7.8	19.7	0.4	1.1	9.4	5.0
Nitzpalc	0.2	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Nitzcftr	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0
Placclem	0.0	0.8	0.2	0.0	0.0	0.0	0.0	0.0
Pinusbsb	0.2	0.8	0.0	0.9	1.2	0.0	0.2	0.2
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.2	0.8	0.0	0.2	5.7	0.0	0.2	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	1.9	13.7	0.2	0.0	0.8	0.4	3.5	0.0
Selacfre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	3.9	2.0	5.3	1.5	3.4	4.0	1.2	13.1
Synecful	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P2sed	P3sed	P5sed	P6sed	P7sed	P8sed	P11sed	P12sed	P13sed	P15sed
Achnexig	7.7	3.4	0.5	0.0	2.5	0.8	8.6	0.0	1.8	6.7
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.0	0.2	6.9	0.0	1.9	0.0	0.5	0.0	0.0	1.3
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	18.5	62.3	0.5	0.0	0.2	0.0	0.0	0.0	0.0	2.7
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Amphliby	5.9	1.6	0.0	0.0	1.3	0.8	0.0	0.5	0.4	8.0
Amphmont	0.0	0.0	0.0	19.6	0.8	3.8	0.3	0.0	0.4	0.4
Amphvene	0.0	0.0	0.0	0.0	0.2	0.0	1.2	0.0	0.0	0.0
Anomvitr	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	6.4	0.2	2.5	10.9	2.5	7.6	0.7	0.5	0.0	3.1
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Cratcusp	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	0.9	0.6	3.4	8.7	7.1	7.6	4.3	3.5	0.9	1.3
Eunobilu	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.4	0.8	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Eunomono	0.0	0.0	0.5	0.0	0.0	0.8	0.9	0.0	0.0	0.0
Eunosilv	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Fragcfbi	0.0	0.0	0.0	0.0	0.2	0.0	0.0	7.4	0.0	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	2.6	0.0	4.4	6.5	4.2	4.5	5.0	0.0	0.0	3.6
Gompangu	2.2	1.2	1.5	0.0	0.0	0.0	1.6	0.0	0.0	0.0
Gompaugu	1.8	0.2	4.9	4.3	1.0	0.8	1.0	3.0	0.0	0.4
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Gompgrac	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	0.0	0.4	2.0	4.3	2.3	8.3	2.1	2.0	5.3	3.6
Gompparv	2.0	2.0	1.0	2.2	3.1	0.0	4.7	3.5	0.4	0.0
Gomppseu	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.5	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Navicfmi	1.3	0.8	4.9	6.5	12.2	9.1	1.7	0.5	4.4	24.0
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Navirost	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	0.0	3.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P2sed	P3sed	P5sed	P6sed	P7sed	P8sed	P11sed	P12sed	P13sed	P15sed
Navicari	0.0	0.6	0.0	17.4	0.0	0.0	0.0	0.0	0.0	2.2
Diadconf	1.8	0.0	5.4	0.0	21.6	5.3	28.3	3.0	4.9	2.2
Navicryp	1.8	8.6	0.5	0.0	0.8	0.0	0.5	0.0	3.1	0.4
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.5	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Naviexil	0.7	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.4	1.3
Navigerm	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Navimini	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.9	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	2.0	0.0	1.9	0.0	0.0	0.0	0.0	2.2
Naviviri	1.3	1.0	0.0	0.0	0.8	0.0	0.3	2.5	0.4	1.8
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	1.3	3.2	23.6	0.0	23.1	33.3	17.1	11.4	11.6	6.2
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	0.0	1.0	0.0	0.0	0.0	0.0	0.0	14.9	14.7	0.4
Nitzline	0.0	0.0	6.4	0.0	0.2	0.8	0.2	19.3	2.2	0.0
Nitzpale	5.1	3.0	17.7	0.0	1.0	1.5	5.7	21.8	13.3	1.3
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinusbsb	6.8	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.8
Pinncfin	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.0	0.0	0.0	1.5	0.2	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	1.1	0.2	0.5	10.9	0.4	1.5	0.7	0.0	0.0	0.4
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Selapupu	8.8	6.6	1.5	0.0	5.2	2.3	6.4	2.0	0.0	19.6
Selacfre	1.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Stauance	0.2	0.0	0.0	0.0	0.0	0.8	0.2	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	1.5	0.4	3.0	4.3	0.2	0.0	3.4	0.0	34.7	0.0
Synecful	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P16sed	P17sed	P18sed	P19sed	P31sed	P32sed	P33sed	P34sed	P35sed	P36sed
Achnexig	2.8	15.3	4.9	6.4	0.5	1.1	8.3	17.8	4.5	7.8
Achncfch	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	4.0	0.0	0.0	5.3	0.5	0.0	0.0	0.0	0.0	0.6
Achncfli	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	0.0	2.3	37.7	0.5	13.5	0.0	6.7	0.0	0.0	0.0
Achnrupe	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.0	0.5	0.5	0.0	2.0	0.0	0.0	0.0
Amphliby	0.3	27.4	2.9	0.0	0.0	0.0	4.2	2.5	0.0	0.2
Amphmont	0.5	0.0	0.0	2.2	0.4	0.0	0.4	4.9	1.7	3.1
Amphvene	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Anomvitr	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Calobaci	4.0	1.3	1.8	0.7	0.0	5.7	2.2	5.5	2.1	1.2
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.5	1.1	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	2.6	0.0	0.5	0.9	2.0	0.0	0.0	0.0	0.0
Cratcusp	0.0	0.2	0.5	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	3.0	0.4	1.3	2.4	0.2	1.7	4.4	3.7	0.0	3.9
Eunobilu	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Eunomono	0.5	0.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosilv	0.0	0.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.2	0.0	0.0	0.0	0.6	0.0	0.0	0.4
Fragcfbi	0.3	0.4	0.2	1.5	0.2	0.0	0.2	0.0	0.0	0.2
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	5.3	2.1	2.6	2.1	0.0	1.7	1.8	1.2	1.2	2.9
Gompangu	0.0	3.6	2.6	1.0	0.0	2.0	3.4	0.0	0.0	0.2
Gompaugu	0.8	0.0	0.0	0.9	0.0	1.7	0.6	0.6	1.7	1.4
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Gompgrac	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.2
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	3.0	0.8	0.0	2.7	0.0	0.4	0.0	0.0	0.0	1.6
Gompparv	1.3	0.6	1.1	1.9	0.5	0.2	0.6	1.2	0.0	0.0
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.0	0.0	0.0	0.2	0.2	0.0	0.2	0.0	0.8	0.0
Navicfmi	3.3	0.4	1.1	5.5	0.4	23.9	18.6	8.0	0.4	10.7
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.2	0.0	0.2	0.9	0.2	0.0	0.0	0.2
Navicfan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3
Navibrem	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P16sed	P17sed	P18sed	P19sed	P31sed	P32sed	P33sed	P34sed	P35sed	P36sed
Navicari	0.3	0.0	0.4	0.3	0.4	0.0	0.0	0.0	0.0	0.0
Diadconf	2.0	4.7	1.1	27.5	0.0	19.8	2.4	38.0	1.2	13.8
Navicryp	0.8	0.6	6.4	3.8	1.4	1.5	3.0	0.0	0.8	0.0
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	19.1	0.0	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	1.5	0.6	2.4	0.9	1.1	0.4	4.2	0.6	0.0	0.4
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.4
Navimini	0.0	0.8	0.0	0.0	0.0	0.0	3.2	0.0	0.4	0.0
Navimimi	0.0	3.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.2	0.2	1.9	0.0	0.6	0.0	0.6	0.0	0.2
Naviviri	2.3	1.7	0.4	0.9	0.4	0.0	0.0	0.0	0.0	0.0
Neidsp1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	20.8	11.3	11.7	10.7	3.7	6.7	13.9	9.2	15.3	29.8
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	1.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.2	0.0
Nitzelon	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Nitzhant	0.8	0.2	0.0	0.2	0.2	0.0	0.0	0.0	1.2	0.0
Nitzcfin	0.0	0.2	0.0	0.3	1.6	0.6	0.0	0.0	2.1	0.2
Nitzline	0.0	0.6	0.5	0.7	0.0	1.1	0.2	0.0	0.0	0.6
Nitzpale	8.5	5.3	4.7	4.1	13.4	12.6	6.9	0.6	3.3	4.3
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	2.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Pinusbsb	4.0	0.0	0.0	0.5	0.0	0.7	0.0	0.6	0.0	0.6
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.4	2.9	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	1.2	0.0
Plancfde	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.0	0.2	0.2	0.2	0.4	0.4	0.8	0.0	0.0	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Selapupu	21.1	10.8	5.8	4.6	12.3	10.9	5.1	3.7	55.8	10.7
Selacfre	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Syneulac	3.5	0.8	0.0	0.2	0.0	0.0	2.0	0.0	0.4	0.4
Synecful	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P37sed	P38sed	P39sed	P40sed	P41sed	P42sed	P43sed	P44sed	P45sed	P46sed
Achnexig	5.5	22.3	2.5	20.4	0.8	33.3	5.0	2.3	22.9	8.7
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	0.6	0.0	3.1	0.0	0.8	0.0	0.2	0.0	0.0	2.5
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	0.0	1.6	0.5	0.7	0.0	0.0	25.0	0.0	0.0	0.6
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Amphliby	0.2	0.0	0.0	1.1	0.2	6.2	1.1	0.6	0.4	3.4
Amphmont	3.4	3.7	1.1	0.0	0.2	0.4	2.0	2.1	5.4	0.3
Amphvene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anomvitr	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.2	0.0	0.0
Calobaci	3.0	0.3	0.5	0.9	2.3	0.4	1.6	1.3	4.2	0.3
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.6	0.0	0.2	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Cratcusp	0.2	0.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crathalo	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.3
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	3.0	7.3	1.8	0.6	5.3	0.4	1.4	1.0	0.4	1.1
Eunobilu	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0
Eunomino	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomono	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.4	3.3	0.3
Eunosilv	0.0	0.0	0.0	0.0	1.4	0.0	0.5	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.2	0.0	0.0
Fragcfbi	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Fragcfte	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	0.4	2.6	2.9	1.1	1.6	0.0	0.7	2.5	2.5	0.8
Gompangu	0.9	0.0	1.1	0.0	1.8	0.0	0.4	0.0	0.4	1.7
Gompaugu	1.3	0.8	1.8	0.6	1.0	0.0	0.4	0.4	0.0	0.3
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.5	1.3	0.2	0.0	0.0	0.0	0.0	0.0
Gompgrac	0.0	0.3	0.7	0.0	0.6	0.0	0.5	0.0	0.0	0.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	1.1	0.3	2.2	0.7	4.5	0.0	0.0	0.8	0.8	0.3
Gompparv	0.4	0.5	0.7	0.0	4.9	1.1	0.7	1.7	0.8	0.6
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Lutimuti	0.4	0.3	0.4	0.0	0.0	0.0	0.2	0.4	0.0	0.0
Navicfmi	7.0	11.0	4.7	9.5	4.9	5.8	6.2	12.9	5.0	5.0
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.6	0.0	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.3
Navicfan	1.3	1.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P37sed	P38sed	P39sed	P40sed	P41sed	P42sed	P43sed	P44sed	P45sed	P46sed
Navicari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diadconf	1.1	0.0	26.9	21.2	12.1	1.1	0.0	26.3	4.6	2.0
Navicryp	0.0	0.0	0.7	5.0	0.6	4.7	5.1	1.0	0.0	0.6
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.2	0.0	0.0	0.0	1.4	0.0	0.0	1.1
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviexil	0.6	0.3	0.9	0.4	1.2	1.4	1.1	2.1	0.0	0.0
Navigerm	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	2.9	1.7
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navimicr	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.2	0.8	0.0
Navimini	0.0	0.0	0.9	0.0	0.0	1.1	0.0	3.3	0.0	0.6
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.9	0.3
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.6	0.3	0.0	0.2	0.0	1.1	0.0	0.4	0.0	0.0
Naviviri	0.9	0.0	3.5	1.3	0.0	13.8	0.5	0.2	0.0	8.4
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	37.1	10.5	18.4	8.3	22.9	2.9	25.5	20.3	10.4	13.7
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzelon	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzhant	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfin	2.6	1.6	1.1	0.0	0.4	0.4	0.7	0.4	0.4	0.6
Nitzline	3.4	1.0	0.0	0.0	3.7	0.0	0.0	0.4	2.5	1.1
Nitzpale	7.7	12.3	4.7	3.0	13.9	5.4	4.4	9.0	3.3	6.4
Nitzpalc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	0.0	0.0	0.9	7.1	0.0	0.0	0.2	1.3	2.1	0.8
Pinusbsb	0.2	1.8	0.2	0.2	0.6	0.7	0.0	0.2	0.8	2.8
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.2	0.0	0.2	0.0	0.2	0.0	0.9	0.0	0.0	0.0
Pinntriu	0.0	1.0	0.4	0.0	0.6	0.0	0.2	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.0	0.0	0.5	0.2	0.0	0.0	0.2	0.4	0.4	0.6
Selafust	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selapupu	8.5	13.4	7.8	9.6	8.2	13.8	6.2	3.1	20.8	24.9
Selacfre	0.0	0.0	0.2	0.0	0.2	0.0	1.1	0.0	0.0	0.0
Stauance	0.0	0.0	0.4	1.7	0.0	0.7	0.7	0.2	0.0	5.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	4.5	0.3	0.5	0.0	0.8	0.4	0.2	2.9	0.0	0.3
Synecful	0.0	0.0	1.6	0.0	1.0	0.0	0.0	0.0	0.4	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P47sed	P49sed	P53sed	P54sed	P56sed	P57sed	P58sed	P62sed	P63sed	P64sed	P65sed
Achnexig	14.5	5.9	2.3	8.0	1.7	4.7	1.5	1.5	3.0	3.9	3.0
Achncfch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnhung	4.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Achncfli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfma	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achnminu	0.0	46.6	66.0	2.0	9.2	0.0	0.0	83.3	40.5	0.0	0.0
Achnrupe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Adlabryo	0.0	0.4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Amphliby	0.0	1.3	1.2	0.0	0.4	7.9	0.0	0.4	0.0	1.4	0.0
Amphmont	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphvene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Anomvitr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calobaci	0.0	0.9	1.4	2.0	0.6	1.4	6.0	0.0	0.6	2.7	0.8
Calomola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calosili	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coccplac	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfac	0.0	0.0	0.0	0.0	0.2	0.5	0.4	0.4	0.9	1.8	1.3
Cratcusp	0.0	0.0	0.0	0.0	1.0	2.3	1.8	0.0	2.2	2.3	0.4
Crathalo	0.0	0.0	0.0	0.0	0.0	18.1	0.0	0.0	0.0	0.0	2.1
Cratminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratsp1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cymblata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitadna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitcfgo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epitsore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encysile	0.0	0.7	0.6	0.0	0.0	1.6	1.8	0.0	0.4	1.8	0.4
Eunobilu	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Eunoflex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunointe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomono	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.4	0.6	0.9	0.0
Eunosilv	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0
Eunosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragcfbi	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Fragcfte	0.0	0.0	0.0	0.0	56.9	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfaf	0.0	3.0	0.4	0.0	0.2	5.6	4.4	1.9	0.0	4.1	1.3
Gompangu	0.0	1.9	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0
Gompaugu	0.0	0.0	0.0	2.0	0.2	0.0	0.0	0.0	0.0	0.4	0.4
Gompcfat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcl	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0
Gompgrac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompinsi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompmacl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfmi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomppalu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gomplage	0.0	0.2	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0
Gompparv	0.0	1.5	0.4	0.0	0.4	2.7	6.4	0.0	0.6	3.1	0.0
Gomppseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsubt	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyrosp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hantelon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Lutimuti	0.0	0.0	0.2	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0
Navicfmi	0.0	0.6	0.0	8.0	0.6	4.7	7.3	1.1	4.1	2.2	1.3
Navisp61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviarct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navirost	0.0	0.0	0.0	2.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Navicfan	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navibrem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Koshi Tappu: relative abundances of epipelic diatoms

	P47sed	P49sed	P53sed	P54sed	P56sed	P57sed	P58sed	P62sed	P63sed	P64sed	P65sed
Navicari	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
Diadconf	12.9	0.4	0.0	0.0	0.0	4.3	4.0	0.0	0.0	0.7	0.0
Navicryp	0.0	7.4	0.0	0.0	0.0	0.5	0.0	0.0	22.4	0.0	0.0
Navidign	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navihust	0.0	0.0	0.0	0.0	0.6	0.7	0.7	0.0	0.0	0.0	0.0
Navicfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Naviexil	1.6	0.6	1.0	0.0	1.0	1.1	0.2	0.4	1.1	1.1	1.7
Navigerm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviheim	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navilanc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0
Navimicr	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	1.3	0.0
Navimini	0.0	0.4	0.0	2.0	0.0	0.5	0.0	0.0	0.9	0.0	0.0
Navimimi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navinoth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Naviperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitrid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navitriv	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navicfup	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navivari	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Naviviri	1.6	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.4	0.0
Neidsp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzacic	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzamph	8.1	10.8	8.4	4.0	7.3	22.6	12.4	5.3	9.1	28.2	5.1
Nitzcfca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzdiss	1.6	0.0	0.2	0.0	0.0	0.0	0.7	0.0	0.0	0.2	1.3
Nitzelon	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.4	0.4	0.0	0.0
Nitzhant	0.0	0.4	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.4
Nitzcfin	0.0	0.0	0.6	0.0	1.3	0.0	0.0	0.0	0.0	0.0	8.1
Nitzline	0.0	0.4	2.5	2.0	1.5	0.2	1.1	0.0	1.5	3.4	2.1
Nitzpale	3.2	3.3	4.7	18.0	2.7	3.2	2.4	0.6	6.5	10.6	44.1
Nitzpalc	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsigm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsiv1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzsbac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcfsl	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nitzcftr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Placclem	1.6	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Pinusbsb	1.6	0.2	0.0	0.0	0.2	0.0	0.7	0.0	0.0	0.0	0.0
Pinncfin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnlath	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinncfsa	0.0	0.0	0.6	0.0	1.5	0.9	0.2	0.4	0.9	0.7	0.4
Pinntriu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planfreq	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlanc	0.0	0.0	0.6	2.0	0.2	0.0	1.1	0.0	0.0	0.4	0.0
Plancfde	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhopgibb	0.0	0.0	0.2	0.0	0.0	0.2	0.9	0.0	0.0	0.0	0.0
Selafust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Selalaev	0.0	0.2	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0
Selapupu	12.9	3.7	8.8	48.0	9.6	6.3	36.1	3.8	4.3	24.2	22.9
Selacfre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stauprod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surisp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Syneulac	1.6	1.1	0.0	0.0	0.0	0.2	1.3	0.0	0.0	0.5	0.0
Synecful	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8

Koshi Tappu: species codes

Achnexig = *Achnanthes exigua*
Achncfch = *Achanthes* cf. *chlidanos*
Achnhung = *Achnanthes hungarica*
Achncfli = *Achnanthes* cf. *linearis*
Achncfma = *Psammothidium* cf. *marginulatum*
Achnminu = *Achnanthidium minutissimum*
Achnrupe = *Achnanthes rupestoides*
Adlabryo = *Adlafia bryophila*
Amphliby = *Achnanthes libyca*
Amphmont = *Amphora montana*
Amphvene = *Amphora veneta*
Anomvitr = *Anomoeoneis vitrea*
Calobaci = *Caloneis bacillum*
Calomola = *Caloneis molaris*
Calosili = *Caloneis silicula*
Coccplac = *Cocconeis placentula*
Cratcfac = *Craticula* cf. *accomodiformis*
Cratcusp = *Craticula cuspidata*
Crathalo = *Craticula halopannonica*
Cratminu = *Craticula minusculoides*
Cratsp1 = *Craticula* sp.1
Cymblata = *Cymbopleura lata*
Diplsp1 = *Diploneis* sp.1
Epitadna = *Epithemia adnata*
Epitcfgo = *Epithemia* cf. *goeppertiana*
Epitsore = *Epithemia sorex*
Encyminu = *Encyonema minutum*
Encysile = *Encyonema silesiacum*
Eunobilu = *Eunotia bilunaris*
Eunoflex = *Eunotia flexuosa*
Eunointe = *Eunotia intermedia*
Eunomino = *Eunotia minor*
Eunomono = *Eunotia monodon*
Eunosilv = *Eunotia silvae*
Eunosp1 = *Eunotia* sp.1
Fragcfbi = *Fragilaria* cf. *bidens*
Fragcfte = *Fragilaria* cf. *tenera*
Gompcfaf = *Gomphonema* cf. *affine*
Gompangu = *Gomphonema angustatum*
Gompaugu = *Gomphonema augur*
Gompcfat = *Gomphonema* cf. *augur* v. *turris*
Gompcfcl = *Gomphonema* cf. *clavatulum*
Gompgrac = *Gomphonema gracile*
Gompinsi = *Gomphonema insigniforme*
Gompmacl = *Gomphonema maclaughlinii*
Gompcfmi = *Gomphonema* cf. *minutum*
Gomppalu = *Gomphonema paludosum*
Gomplage = *Gomphonema lagenula*
Gompparv = *Gomphonema parvulum*
Gomppseu = *Gomphonema pseudosphaerophorum*
Gompsubt = *Gomphonema subtile*
Gompsp1 = *Gomphonema* sp.1
Gyrosp1 = *Gyrosigma* sp.1
Hantelon = *Hantzschia elongata*
Lutimuti = *Luticola mutica*
Navicfmi = *Navicula* cf. *minima*
Navisp61 = *Navicula* sp.61sed
Naviarct = *Navicula arctotenelloides*
Navirost = *Navicula rostellata*
Navicfan = *Navicula* cf. *antonii*
Navibrem = *Navicula bremensis*
Navicari = *Navicula cari*
Diadconf = *Diadesmis confervacea*
Navicryp = *Navicula cryptocephala*
Navidign = *Navicula digna*
Navihust = *Navicula hustedtii*
Navicfer = *Navicula* cf. *erifuga*
Naviexil = *Navicula exilis*
Navigerm = *Navicula germainii*
Naviheim = *Navicula heimansioides*
Navilanc = *Navicula lanceolata*
Navimicr = *Navicula microcari*
Navimini = *Navicula minima*
Navimimi = *Navicula minusculus* v. *minusculus*
Navinoth = *Navicula notha*
Naviperm = *Navicula perminuta*
Navitene = *Navicula tenelloides*
Navitrid = *Navicula tridentula*
Navitriv = *Navicula trivialis*
Navicfup = *Navicula* cf. *upsaliensis*
Navivari = *Navicula variostriata*
Naviviri = *Navicula viridula*
Neidsp1 = *Neidium* sp.1
Nitzacic = *Nitzschia acicularis*
Nitzamph = *Nitzschia amphibia*
Nitzcfca = *Nitzschia* cf. *capitellata*
Nitzdiss = *Nitzschia dissipata*
Nitzelon = *Nitzschia elongata*
Nitzhant = *Nitzschia hantzschiana*
Nitzcfin = *Nitzschia* cf. *incognita*
Nitzline = *Nitzschia linearis*
Nitzpale = *Nitzschia palea*
Nitzpalc = *Nitzschia paleacea*
Nitzsigm = *Nitzschia sigmoidae*
Nitzsiv1 = *Nitzschia sinuata* v.1
Nitzsbac = *Nitzschia subacicularis*
Nitzcfsl = *Nitzschia* cf. *sublinearis*
Nitzcftr = *Nitzschia* cf. *tropica*
Placclem = *Placoneis clementis*
Pinusbsb = *Pinnularia subcapitata* v. *subrostrata*
Pinncfin = *Pinnularia* cf. *interruptiformis*
Pinnlath = *Pinnularia latarea* v. *thermophila*
Pinncfno = *Pinnularia* cf. *nobilis*
Pinncfsa = *Pinnulatia* cf. *saprophila*
Pinntriu = *Pinnularia triundulata*
Planfreq = *Planothidium frequentissimum*
Planlanc = *Planothidium lanceolatum*
Plancfde = *Planothidium* cf. *delicatulum*
Rhopgibb = *Rhopalodia gibba*
Selafust = *Sellaphora fusticulus*
Selalaev = *Sellaphora laevissima*
Selapupu = *Sellaphora pupula*
Selacfre = *Sellaphora* cf. *rectangularis*
Stauance = *Stauroneis anceps*
Staucons = *Stauroneis conspicua*
Stauprod = *Stauroneis producta*
Surisp1 = *Surirella* sp.1
Syneulac = *Synedra ulna* v. *acus*
Synecful = *Synedra* cf. *ulna*

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P1	P2	P3	P4	P5	P6	P7	P8	P9
Pond dimensions									
Length (m)	60	50	40	40	40	50	50	50	50
Width (m)	25	15	10	40	15	50	50	30	40
Pond area	1500	750	400	1600	600	2500	2500	1500	2000
Rip. Zone Width (m)	4	2	2	1.5	1	1.5	1.5	1.5	1.5
Bank Height (m)	0.5	2.5	2.5	2	0.5	1	1	1	1
Substrate composition (%)									
Littoral									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	30	0
Silt,mud,earth	50	75	50	50	80	50	90	60	50
Leaves, plants	50	25	50	50	20	50	10	10	50
Riparian zone									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	30	0
Silt,mud,earth	50	70	30	50	80	70	50	40	40
Leaves, plants	50	30	70	50	20	30	50	30	60
Bank									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	25	50	10	30	10	20	30	30	30
Leaves, plants	75	50	90	70	90	80	70	70	70
Bank profile									
Natural									
Vertical, undercut	0	0	0	0	0	0	0	0	0
Vertical + toe	0	0	0	0	0	0	0	0	0
Steep	0	2	2	2	2	1	0	2	1
Composite	1	0	0	0	0	2	1	1	1
Gentle	2	0	0	0	0	0	0	0	0
Artificial									
Resectioned	0	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	0	0	0
Reinforced part	0	0	0	0	0	0	0	0	0
Embanked	0	1	2	2	2	2	2	2	2
Poached	0	0	0	0	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P1	P2	P3	P4	P5	P6	P7	P8	P9
Lake vegetation									
Emerg. herbs	1	1	2	2	1	1	1	0	1
Emerg. reeds, sedges	1	0	1	1	0	1	1	1	1
Rooted floating leaves	2	1	1	2	1	1	0	1	1
Free floating plants	1	0	0	0	1	1	1	1	1
Submerged plants	2	1	2	1	1	1	1	1	0
Bryophytes	0	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0	0
Bank vegetation (%)									
Bare	0	0	0	10	30	0	0	0	0
Short grass	0	40	10	80	30	40	50	50	80
Tall grass, herbs	0	20	70	10	30	10	20	40	18
Scrub	90	0	15	0	0	10	0	0	0
Trees	10	40	5	0	10	40	30	10	2
Trees, ass. features									
Trees	0	4	1	1	1	4	3	3	1
Shading	0	1	0	0	0	1	0	1	0
Riparian roots	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	0	0	0	0	0	0	0
Overh. boughs	0	1	0	0	0	0	0	0	0
Woody debris	0	1	0	0	0	1	0	1	0
Land use wider catchment									
Village	0	0	1	0	1	1	1	1	1
Roads	0	0	0	0	0	0	0	0	0
Agriculture	0	1	1	1	1	1	1	1	1
Pasture	1	0	0	0	0	1	1	1	1
Rough grass	2	1	1	2	2	1	1	2	2
Scub	1	1	1	0	0	1	0	1	1
Broad leaved forest	0	1	1	1	0	0	0	0	0
Land use within 100 m									
Urban settlement	0	0	0	0	0	0	0	0	0
Isolated houses	0	1	0	0	0	0	1	0	0
Agriculture	1	1	1	1	1	1	1	1	1
Pasture	0	0	0	0	0	0	0	0	0
Rough grassland	2	1	1	0	1	1	1	1	2
Scrub	1	1	1	1	0	0	0	0	0
Broad leaved forest	0	0	0	0	0	0	0	0	0
Artificial features riparian zone									
Road, path	0	1	0	0	0	0	0	0	0
Weir, dam	0	1	1	1	1	1	1	1	1
Management, use									
Removal lake veg.	0	1	0	0	1	1	1	1	0
Removal riparian vegetation	0	1	1	1	1	1	1	1	1
Removal bank vegetation	0	1	1	1	1	1	1	1	1
Fish pond	0	0	1	1	1	1	1	1	1

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P10	P11	P12	P13	P14	P15	P16	P17	P18
Pond dimensions									
Length (m)	60	250	70	70	60	60	60	50	25
Width (m)	50	70	70	50	40	40	60	30	20
Pond area	3000	17500	4900	3500	2400	2400	3600	1500	500
Rip. Zone Width (m)	1	1.5	1	1.5	1.5	1.5	2	2	2
Bank Height (m)	1	1	1	1	1	0.5	1.5	1.5	1
Substrate composition (%)									
Littoral									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	65	0	0	0	0	0	0
Silt,mud,earth	20	50	30	100	70	90	90	95	25
Leaves, plants	80	50	5	0	30	10	10	5	75
Riparian zone									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	20	20	80	98	10	50	90	10	10
Leaves, plants	80	80	20	2	90	50	10	90	90
Bank									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	20	20	50	30	10	20	50	5	5
Leaves, plants	80	80	50	70	90	80	50	95	95
Bank profile									
Natural									
Vertical, undercut	0	0	0	1	0	0	1	0	0
Vertical + toe	0	0	0	1	0	2	2	1	1
Steep	2	1	1	1	1	0	0	1	1
Composite	0	2	2	1	2	0	0	1	1
Gentle	0	0	0	0	0	0	0	1	1
Artificial									
Resectioned	0	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	0	0	0
Reinforced part	0	0	0	0	0	0	0	0	0
Embanked	2	2	2	1	2	1	2	2	1
Poached	0	0	0	0	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P10	P11	P12	P13	P14	P15	P16	P17	P18
Lake vegetation									
Emerg. herbs	1	1	1	1	1	1	1	1	2
Emerg. reeds, sedges	2	0	0	0	1	0	0	0	0
Rooted floating leaves	2	1	1	0	1	0	0	0	1
Free floating plants	1	1	1	1	1	1	1	0	0
Submerged plants	1	2	1	0	0	0	0	0	1
Bryophytes	0	0	0	0	0	0	0	0	0
Filamentous algae	0	2	0	0	0	0	0	1	0
Bank vegetation (%)									
Bare	0	0	0	10	0	0	10	0	0
Short grass	50	40	20	10	10	40	55	80	60
Tall grass, herbs	20	30	5	5	40	10	5	2	20
Scrub	20	30	30	45	25	20	10	3	0
Trees	10	0	45	30	25	30	20	15	20
Trees, ass. features									
Trees	1	0	8	4	4	5	5	5	3
Shading	0	0	1	1	1	1	1	1	0
Riparian roots	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	0	0	0	1	1	0	0
Overh. boughs	0	0	1	0	1	0	1	0	0
Woody debris	0	0	1	0	0	1	0	0	0
Land use wider catchment									
Village	0	0	0	0	0	1	1	1	1
Roads	0	0	0	0	0	0	0	0	0
Agriculture	0	1	1	1	1	1	1	1	1
Pasture	1	1	1	1	1	1	1	1	1
Rough grass	1	0	1	1	1	1	1	1	1
Scub	1	1	1	1	1	1	1	1	1
Broad leaved forest	0	1	1	1	1	1	1	1	1
Land use within 100 m									
Urban settlement	0	0	0	0	0	0	0	0	0
Isolated houses	0	0	0	0	0	1	0	0	1
Agriculture	0	1	1	1	1	1	1	0	1
Pasture	1	1	0	1	1	1	1	0	1
Rough grassland	1	0	1	1	1	1	1	1	1
Scrub	0	0	1	1	1	1	1	0	0
Broad leaved forest	0	0	1	1	1	0	0	0	1
Artificial features riparian zone									
Road, path	1	1	1	1	1	0	0	0	0
Weir, dam	1	1	1	1	1	1	1	1	1
Management, use									
Removal lake veg.	0	0	0	1	1	1	1	1	0
Removal riparian vegetation	1	1	0	1	0	1	1	1	1
Removal bank vegetation	1	1	0	1	0	1	1	1	1
Fish pond	1	1	0	1	1	1	1	1	1

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P19	P21	P22	P23	P24	P25	P26	P28	P29
Pond dimensions									
Length (m)	100	25	70	100	450	250	25	500	80
Width (m)	70	15	40	50	80	50	10	100	30
Pond area	7000	375	2800	5000	36000	12500	250	50000	2400
Rip. Zone Width (m)	5	0.5	1	2	4	4	3	5	1.5
Bank Height (m)	1	0.5	0.5	0.5	0.5	0.5	1	3	3
Substrate composition (%)									
Littoral									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	10	90	30	5	30	50	80	10	5
Leaves, plants	90	10	70	95	70	50	20	90	95
Riparian zone									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	10	30	10	20	20	50	30	10	5
Leaves, plants	90	70	90	80	80	50	70	90	95
Bank									
Boulders	0	0	0	0	0	0	0	50	20
Cobbles	0	0	0	0	0	0	0	0	70
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	40	0	0	20	20	20	20	0	0
Leaves, plants	60	100	100	80	80	80	80	50	10
Bank profile									
Natural									
Vertical, undercut	0	0	0	0	0	0	0	0	0
Vertical + toe	0	0	0	0	0	0	0	0	0
Steep	0	0	1	0	0	0	0	2	2
Composite	1	1	2	1	1	1	1	0	0
Gentle	2	2	0	2	2	2	2	1	0
Artificial									
Resectioned	0	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	0	2	0
Reinforced part	0	0	0	0	0	0	0	0	0
Embanked	1	0	0	0	0	0	0	0	2
Poached	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P19	P21	P22	P23	P24	P25	P26	P28	P29
Lake vegetation									
Emerg. herbs	1	0	1	1	1	1	1	2	2
Emerg. reeds, sedges	2	0	0	0	0	1	1	1	1
Rooted floating leaves	0	0	0	0	2	2	0	1	2
Free floating plants	1	0	0	1	2	1	1	1	2
Submerged plants	2	0	2	2	2	2	1	2	2
Bryophytes	0	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	1	1	0
Bank vegetation (%)									
Bare	10	0	0	0	0	0	0	30	70
Short grass	10	0	0	0	10	0	0	0	15
Tall grass, herbs	60	90	90	60	60	20	60	55	15
Scrub	10	10	10	30	10	40	20	15	0
Trees	10	0	0	10	20	40	20	0	0
Trees, ass. features									
Trees	5	0	1	3	7	7	5	1	0
Shading	0	0	1	1	1	1	1	0	0
Riparian roots	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	0	0	0	0	0	0	0
Overh. boughs	0	0	0	1	0	0	0	0	0
Woody debris	0	0	0	1	0	0	0	0	0
Land use wider catchment									
Village	1	0	0	0	0	0	0	0	0
Roads	0	0	0	0	1	1	1	1	1
Agriculture	1	0	0	0	0	0	0	0	0
Pasture	1	0	0	0	0	0	0	0	0
Rough grass	1	2	2	2	1	1	1	2	2
Scub	1	1	1	1	1	1	1	1	1
Broad leaved forest	1	1	1	1	1	1	1	0	0
Land use within 100 m									
Urban settlement	0	0	0	0	0	0	0	0	0
Isolated houses	1	0	0	0	0	0	0	0	0
Agriculture	1	0	0	0	0	0	0	0	0
Pasture	1	0	0	0	0	0	0	0	0
Rough grassland	1	2	2	2	1	1	2	2	1
Scrub	1	1	1	1	1	1	1	1	0
Broad leaved forest	0	0	0	1	1	1	1	0	0
Artificial features riparian zone									
Road, path	1	0	0	0	1	0	1	1	1
Weir, dam	1	0	0	0	0	0	0	1	0
Management, use									
Removal lake veg.	1	0	0	0	1	0	1	0	0
Removal riparian vegetation	0	0	0	0	1	0	1	0	0
Removal bank vegetation	1	0	0	0	1	0	1	1	1
Fish pond	1	0	0	0	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P31	P32	P33	P34	P35	P36	P37	P38	P39
Pond dimensions									
Length (m)	150	30	30	50	50	80	70	50	17
Width (m)	7	5	8	15	25	40	20	20	8
Pond area	1050	150	240	750	1250	3200	1400	1000	136
Rip. Zone Width (m)	4	1	1	1	1	2	1	0.5	1.5
Bank Height (m)	0.5	1.5	1.5	1.5	1	1	1	1	0.5
Substrate composition (%)									
Littoral									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	40	30	5	0	0	0	0	0
Silt,mud,earth	90	20	10	90	100	50	90	90	70
Leaves, plants	10	40	60	5	0	50	10	10	30
Riparian zone									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	5	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	20	0	0	0	0	0	0
Silt,mud,earth	70	10	10	90	90	30	80	90	10
Leaves, plants	25	90	70	10	10	70	20	10	90
Bank									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0
Silt,mud,earth	40	30	10	50	30	20	5	20	5
Leaves, plants	60	70	90	50	70	80	95	80	95
Bank profile									
Natural									
Vertical, undercut	0	0	2	0	0	0	1	1	0
Vertical + toe	0	0	2	2	2	1	1	1	1
Steep	0	2	0	1	1	1	1	2	0
Composite	1	0	0	0	0	1	1	0	2
Gentle	2	0	0	0	0	0	0	0	1
Artificial									
Resectioned	2	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	0	0	0
Reinforced part	1	0	0	0	0	0	0	0	0
Embanked	0	2	2	2	2	2	2	2	1
Poached	0	0	0	0	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P31	P32	P33	P34	P35	P36	P37	P38	P39
Lake vegetation									
Emerg. herbs	1	1	2	1	1	2	1	2	2
Emerg. reeds, sedges	1	0	0	0	0	0	0	0	0
Rooted floating leaves	1	0	1	1	0	1	1	0	0
Free floating plants	0	2	0	1	0	1	0	1	1
Submerged plants	0	1	1	0	0	1	0	0	2
Bryophytes	0	0	0	0	0	0	0	0	0
Filamentous algae	0	1	0	0	0	0	0	0	0
Bank vegetation (%)									
Bare	25	0	0	20	0	10	0	0	0
Short grass	0	50	20	40	40	20	15	15	5
Tall grass, herbs	30	35	50	30	30	60	70	40	95
Scrub	15	10	5	0	10	5	5	5	0
Trees	30	5	25	10	20	5	10	40	0
Trees, ass. features									
Trees	4	1	3	3	3	1	3	8	0
Shading	1	1	1	0	0	0	0	1	0
Riparian roots	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	0	0	0	0	0	0	0
Overh. boughs	1	0	1	1	1	0	1	0	0
Woody debris	0	0	0	0	1	0	1	1	0
Land use wider catchment									
Village	0	1	1	1	1	1	1	1	1
Roads	2	0	0	0	0	0	0	0	0
Agriculture	0	2	2	1	1	1	1	1	2
Pasture	0	0	0	1	0	0	1	0	0
Rough grass	1	1	1	1	1	1	1	1	0
Scub	0	1	0	1	1	1	1	1	0
Broad leaved forest	1	0	0	1	1	1	1	1	0
Land use within 100 m									
Urban settlement	0	0	0	0	0	0	0	0	0
Isolated houses	0	0	0	0	0	0	0	0	1
Agriculture	0	2	2	0	1	0	1	1	2
Pasture	0	0	0	0	0	0	0	0	0
Rough grassland	2	1	1	1	1	1	1	1	0
Scrub	0	0	1	0	1	1	0	0	0
Broad leaved forest	1	0	0	1	0	0	0	1	0
Artificial features riparian zone									
Road, path	1	0	0	0	0	0	0	0	0
Weir, dam	1	1	1	1	1	1	1	1	1
Management, use									
Removal lake veg.	1	0	0	1	1	1	1	1	1
Removal riparian vegetation	1	1	1	1	1	1	1	1	0
Removal bank vegetation	1	1	1	1	1	1	1	1	0
Fish pond	0	0	1	1	1	1	1	1	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P40	P41	P42	P43	P44	P45	P46	P47	P48
Pond dimensions									
Length (m)	35	60	70	25	50	30	15	35	100
Width (m)	25	6	50	15	10	30	12	25	40
Pond area	875	360	3500	375	500	900	180	875	4000
Rip. Zone Width (m)	0.5	1	2	1	1	1	2	1.5	2
Bank Height (m)	1.5	0.5	1.5	1.5	1	1	1	1.5	1
Substrate composition (%)									
Littoral									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	40	60	10	0	0	10	5	0	0
Silt,mud,earth	10	10	60	80	60	40	55	60	20
Leaves, plants	50	30	30	20	40	50	40	40	80
Riparian zone									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	60	60	0	0	0	0	5	0	0
Silt,mud,earth	10	10	50	20	30	20	15	40	10
Leaves, plants	30	30	50	80	70	80	80	60	90
Bank									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	5	0	0
Silt,mud,earth	50	30	40	20	20	10	15	10	10
Leaves, plants	50	70	60	80	80	90	80	90	90
Bank profile									
Natural									
Vertical, undercut	0	0	2	1	1	0	0	0	0
Vertical + toe	0	0	1	1	0	0	1	1	0
Steep	2	1	0	2	2	2	1	1	1
Composite	1	2	0	1	0	1	1	1	1
Gentle	0	0	0	0	0	0	0	0	1
Artificial									
Resectioned	0	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	0	0	0
Reinforced part	0	0	0	0	0	0	0	0	0
Embanked	2	2	2	2	2	2	2	2	2
Poached	0	0	0	0	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P40	P41	P42	P43	P44	P45	P46	P47	P48
Lake vegetation									
Emerg. herbs	1	1	0	2	0	2	0	1	1
Emerg. reeds, sedges	0	1	0	1	0	0	0	0	0
Rooted floating leaves	2	1	0	2	0	1	1	1	1
Free floating plants	2	2	2	0	2	1	2	1	2
Submerged plants	2	1	0	1	1	2	2	1	2
Bryophytes	0	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0	0
Bank vegetation (%)									
Bare	20	0	25	0	10	0	10	10	5
Short grass	5	20	50	20	55	65	60	30	40
Tall grass, herbs	25	25	20	50	20	15	20	35	45
Scrub	5	10	0	10	10	10	0	15	5
Trees	45	45	5	20	5	10	10	10	5
Trees, ass. features									
Trees	4	3	1	3	1	3	3	5	1
Shading	1	1	1	1	0	1	1	1	0
Riparian roots	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	0	0	0	0	0	0	0
Overh. boughs	1	0	1	1	0	1	0	1	0
Woody debris	0	0	0	0	0	1	1	1	0
Land use wider catchment									
Village	1	1	1	1	1	1	1	1	1
Roads	0	0	0	0	0	0	0	0	0
Agriculture	1	1	1	1	1	1	1	1	1
Pasture	0	1	1	1	1	1	1	1	1
Rough grass	1	1	1	1	1	1	1	1	1
Scub	1	1	1	1	1	1	1	1	1
Broad leaved forest	1	1	1	1	1	1	1	1	1
Land use within 100 m									
Urban settlement	0	0	0	0	0	0	0	0	0
Isolated houses	0	0	0	0	0	0	1	1	1
Agriculture	0	0	1	1	1	1	1	1	1
Pasture	0	0	0	1	1	1	0	0	0
Rough grassland	1	1	1	1	1	1	1	1	1
Scrub	1	1	0	1	1	1	1	1	1
Broad leaved forest	1	1	0	1	0	0	0	0	0
Artificial features riparian zone									
Road, path	0	0	0	0	0	0	0	0	0
Weir, dam	1	1	1	1	1	1	1	1	1
Management, use									
Removal lake veg.	1	1	1	1	1	1	1	1	0
Removal riparian vegetation	1	1	1	1	1	1	1	1	0
Removal bank vegetation	1	1	1	1	1	1	1	1	1
Fish pond	1	1	1	1	1	1	1	1	1

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P49	P50	P52	P53	P54	P56	P57	P58	P59
Pond dimensions									
Length (m)	40	60	70	70	30	40	30	27	1000
Width (m)	25	30	50	30	30	30	10	10	200
Pond area	1000	1800	3500	2100	900	1200	300	270	200000
Rip. Zone Width (m)	1.5	2	3	2	1	4	3	1	5
Bank Height (m)	1.5	2	2.5	2.5	2	3	2	2	7
Substrate composition (%)									
Littoral									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	30	80	10	5	0	0
Silt,mud,earth	50	10	10	50	15	80	90	90	10
Leaves, plants	50	90	90	20	5	10	5	10	90
Riparian zone									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	25	35	5	5	0	0
Silt,mud,earth	10	30	10	50	5	65	75	80	0
Leaves, plants	90	70	90	25	60	30	20	20	100
Bank									
Boulders	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	10
Pebbles	0	0	0	0	0	0	0	0	10
Gravel	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	20	0	0
Silt,mud,earth	20	30	10	5	20	40	10	10	10
Leaves, plants	80	70	90	95	80	60	70	90	70
Bank profile									
Natural									
Vertical, undercut	1	0	0	1	0	0	0	0	0
Vertical + toe	1	0	1	1	2	1	0	1	0
Steep	1	2	1	1	2	1	1	1	0
Composite	1	0	2	1	0	1	2	1	2
Gentle	1	0	0	0	0	0	0	0	0
Artificial									
Resectioned	0	0	1	0	0	0	0	0	0
Reinforced whole	0	0	1	0	0	0	0	0	0
Reinforced part	0	0	1	0	0	0	0	0	2
Embanked	2	2	2	2	2	2	2	2	0
Poached	0	0	1	1	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P49	P50	P52	P53	P54	P56	P57	P58	P59
Lake vegetation									
Emerg. herbs	2	0	0	0	1	1	1	1	1
Emerg. reeds, sedges	1	0	1	1	1	0	1	1	0
Rooted floating leaves	1	1	0	1	0	0	0	0	0
Free floating plants	0	0	2	0	0	0	0	0	0
Submerged plants	1	2	2	1	0	0	1	0	2
Bryophytes	0	0	0	0	0	0	0	0	0
Filamentous algae	0	1	0	0	0	0	0	0	0
Bank vegetation (%)									
Bare	5	20	5	0	5	25	15	5	20
Short grass	25	32	20	60	0	10	35	10	10
Tall grass, herbs	45	28	30	30	85	30	25	60	45
Scrub	5	5	15	10	5	5	5	5	23
Trees	20	15	30	0	5	30	20	20	2
Trees, ass. features									
Trees	5	3	4	0	1	7	5	5	1
Shading	1	0	1	0	0	1	1	1	0
Riparian roots	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	1	0	0	0	0	0	0
Overh. boughs	0	0	1	0	0	0	0	0	0
Woody debris	1	0	1	0	0	1	0	1	0
Land use wider catchment									
Village	1	1	1	1	1	1	1	1	0
Roads	0	0	0	0	0	0	0	0	1
Agriculture	1	1	1	1	1	1	1	1	0
Pasture	1	1	1	1	1	1	1	1	0
Rough grass	1	1	1	1	1	1	1	1	1
Scub	1	1	1	1	1	2	2	2	1
Broad leaved forest	1	1	1	1	1	2	2	2	0
Land use within 100 m									
Urban settlement	0	0	0	0	0	0	0	0	0
Isolated houses	1	1	1	0	0	0	0	0	0
Agriculture	1	1	1	0	0	0	0	0	0
Pasture	1	1	1	2	0	1	1	1	0
Rough grassland	1	1	1	1	1	1	1	1	1
Scrub	1	1	1	1	1	1	1	1	1
Broad leaved forest	1	1	1	1	1	1	1	1	0
Artificial features riparian zone									
Road, path	0	0	0	0	0	0	0	0	1
Weir, dam	1	1	1	1	1	1	1	1	1
Management, use									
Removal lake veg.	0	1	1	1	1	1	1	1	0
Removal riparian vegetation	1	1	1	1	1	1	1	1	1
Removal bank vegetation	1	1	1	1	1	1	1	1	1
Fish pond	1	1	1	1	1	1	1	1	1

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71
Pond dimensions										
Length (m)	50	40	50	40	60	50	60	20	50	70
Width (m)	30	30	40	40	50	40	30	7	20	25
Pond area	1500	1200	2000	1600	3000	2000	1800	140	1000	1750
Rip. Zone Width (m)	1.5	2.5	1.5	2	5	2.5	3	0.5	1	2.5
Bank Height (m)	2.5	2.5	2.5	2	1	0.5	1	2	1	1
Substrate composition (%)										
Littoral										
Boulders	0	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0	0
Silt,mud,earth	90	20	95	100	10	0	30	60	40	0
Leaves, plants	10	80	5	0	90	100	70	40	60	100
Riparian zone										
Boulders	0	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0	0
Silt,mud,earth	60	70	90	95	5	0	20	60	40	0
Leaves, plants	40	30	10	5	95	100	80	40	60	100
Bank										
Boulders	0	0	0	0	0	0	0	0	0	0
Cobbles	0	0	0	0	0	0	0	0	0	0
Pebbles	0	0	0	0	0	0	0	0	0	0
Gravel	0	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0	0
Silt,mud,earth	25	40	10	30	0	0	10	30	0	0
Leaves, plants	75	60	90	70	100	100	90	70	100	100
Bank profile										
Natural										
Vertical, undercut	0	0	0	0	0	0	0	0	0	0
Vertical + toe	0	0	0	0	0	0	2	2	2	0
Steep	1	1	1	1	0	0	1	2	1	2
Composite	2	2	2	2	2	2	0	0	1	0
Gentle	0	0	1	0	2	2	0	0	0	0
Artificial										
Resectioned	0	0	0	0	0	0	0	0	0	0
Reinforced whole	0	0	0	0	0	0	0	0	0	0
Reinforced part	0	0	0	0	0	0	0	0	0	0
Embanked	2	2	2	2	1	1	2	2	2	2
Poached	1	0	1	1	0	0	0	0	0	0

Koshi Tappu: habitat character

Categories: 1 = present, 2 ≥ 30%

	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71
Lake vegetation										
Emerg. herbs	1	0	1	0	2	2	2	2	2	2
Emerg. reeds, sedges	0	0	0	0	1	1	1	1	1	2
Rooted floating leaves	0	0	0	0	1	1	0	0	0	0
Free floating plants	0	0	0	0	2	2	2	0	1	2
Submerged plants	1	1	0	0	2	2	1	1	0	2
Bryophytes	0	0	0	0	0	0	0	0	0	0
Filamentous algae	0	2	0	0	0	0	0	0	0	0
Bank vegetation (%)										
Bare	25	15	10	30	0	0	5	15	0	0
Short grass	25	10	60	45	45	15	15	5	40	10
Tall grass, herbs	30	25	20	5	25	40	40	30	40	30
Scrub	20	45	5	5	25	40	20	20	20	30
Trees	0	5	5	15	5	5	20	30	0	30
Trees, ass. features										
Trees	1	1	1	3	1	3	6	7	0	6
Shading	0	1	0	1	1	0	1	1	0	1
Riparian roots	0	0	0	0	0	0	0	0	0	0
Underw. roots	0	0	0	0	0	0	0	0	0	0
Fallen trees	0	0	0	0	0	0	0	0	0	0
Overh. boughs	0	0	0	0	0	0	0	0	0	0
Woody debris	0	0	0	0	0	0	0	0	0	0
Land use wider catchment										
Village	1	1	1	1	1	0	1	0	1	1
Roads	0	0	0	0	0	0	0	0	0	0
Agriculture	1	1	1	1	1	0	1	2	1	1
Pasture	1	1	1	1	1	1	1	0	1	1
Rough grass	1	1	1	1	1	1	1	1	1	1
Scub	1	1	1	1	1	1	1	1	1	1
Broad leaved forest	1	1	1	1	1	1	1	1	1	1
Land use within 100 m										
Urban settlement	0	0	0	0	0	0	0	0	0	0
Isolated houses	0	1	0	1	1	1	0	0	0	0
Agriculture	0	1	0	0	1	0	1	2	1	1
Pasture	1	1	1	1	1	1	0	0	1	0
Rough grassland	1	1	1	1	1	1	1	1	1	1
Scrub	1	1	1	1	1	2	1	1	1	1
Broad leaved forest	0	1	1	1	0	0	1	1	0	1
Artificial features riparian zone										
Road, path	0	0	0	0	0	0	0	0	0	0
Weir, dam	1	1	1	1	1	1	1	1	1	1
Management, use										
Removal lake veg.	1	1	1	1	0	0	0	0	1	0
Removal riparian vegetation	1	1	1	1	0	0	1	1	1	0
Removal bank vegetation	1	1	1	1	1	1	1	1	1	1
Fish pond	1	1	1	1	1	0	1	1	1	0

Koshi Tappu: surface water chemistry

Conductivity in µS/cm, Na - Zn concentrations in mg/L

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
pH	7.44	7.7	8.8	7.9	7.8	7.8	8	8.4	8.1	7.9	8.2	8.2	8.6	7.4	7.9	7.9	8.6	7.9
Cond.	266	310	207	245	257	280	265	253	255	218	182	209	240	250	251	293	261	259
Na	3.6	3.6	3.4	3.3	3.5	3.9	3.8	3.8	3.9	3.2	3.3	3.8	4.0	4.2	3.9	3.8	3.0	3.1
K	5.7	9.2	5.1	4.8	7.4	6.3	5.2	5.9	5.6	4.8	3.8	4.4	5.0	3.9	6.2	7.3	8.4	8.0
Mg	5.1	13.0	11.7	7.9	6.9	7.1	5.6	6.3	5.4	4.2	4.3	4.1	4.8	4.5	4.6	7.0	8.0	12.6
Ca	41.1	37.6	20.6	31.3	31.8	36.1	35.6	33.1	34.3	29.4	23.5	27.4	34.1	34.9	36.4	41.5	35.5	29.4
F	0.11	0.11	0.09	0.12	0.10	0.12	0.10	0.11	0.11	0.10	0.10	0.10	0.11	0.13	0.12	0.10	0.07	0.08
Cl	0.7	1.4	0.5	0.4	0.9	0.6	0.4	0.5	0.4	0.3	0.2	0.5	0.4	0.2	0.5	0.8	0.6	0.7
NO3	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
PO4	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SO4	7.11	7.42	8.28	4.44	12.40	12.14	9.40	8.18	9.36	10.65	6.34	19.45	16.05	21.50	10.96	24.72	14.67	6.42
Si	4.5	2.4	0.8	0.5	2.8	0.4	4.3	6.3	4.4	3.5	1.7	2.3	1.0	5.0	2.7	4.9	1.8	1.1
Al	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.046	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fe	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mn	0.25	0.25	0.01	0.01	0.00	0.01	0.00	0.02	0.01	0.29	0.03	0.04	0.01	0.54	0.01	0.00	0.01	0.03
Sr	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.09	0.06	0.05	0.05	0.05	0.06	0.05	0.06	0.07	0.07	0.07
Ba	0.03	0.03	0.02	0.03	0.02	0.04	0.03	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.04	0.04	0.04	0.02
Zn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Koshi Tappu: surface water chemistry

Conductivity in µS/cm, Na - Zn concentrations in mg/L

	P19	P21	P22	P23	P24	P25	P26	P28	P29	P31	P32	P33	P34	P35	P36	P37	P38	P39
pH	7.7	7	9.6	9.5	7.5	9.4	7.5	7.5	8	7.7	7.3	7.7	7.9	7.9	8.1	9	7.8	7.4
Cond.	240	74	83	100	102	85	108	100	116	119	224	272	303	298	295	240	318	276
Na	3.6	1.5	1.6	1.7	1.9	1.6	1.6	3.1	3.6	3.4	2.8	3.1	4.0	4.5	4.2	4.3	3.8	4.4
K	5.0	2.0	1.8	4.1	2.6	1.1	4.3	2.2	2.4	2.4	0.9	5.7	7.8	8.0	7.4	7.4	9.8	6.0
Mg	6.3	2.7	2.5	2.7	2.9	2.5	3.3	3.1	3.6	3.8	5.5	9.5	12.3	10.2	10.8	10.0	11.1	8.0
Ca	34.9	8.6	9.3	11.8	13.6	10.9	13.5	12.0	14.1	14.7	37.7	39.3	39.8	41.0	41.0	30.7	44.5	39.9
F	0.11	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.08	0.07	0.10	0.09	0.12	0.14	0.13	0.13	0.13	0.11
Cl	0.2	0.1	0.1	0.5	0.2	0.0	0.2	0.5	0.4	0.6	0.1	0.4	1.2	1.0	0.7	1.1	0.7	0.6
NO3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.48	0.01	0.10	0.01	0.01	0.01	0.01
PO4	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
SO4	7.65	5.21	6.80	4.20	2.22	2.34	1.72	6.94	6.55	6.62	4.68	10.25	19.73	23.41	13.34	12.86	15.08	16.45
Si	1.5	0.1	0.2	0.1	1.3	0.6	0.4	2.6	2.9	2.5	3.4	0.7	0.8	6.5	1.3	4.1	3.6	1.9
Al	0.005	0.005	0.022	0.007	0.005	0.009	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fe	0.05	0.10	0.01	0.08	0.14	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mn	0.06	0.01	0.00	0.01	0.05	0.00	0.04	0.01	0.04	0.02	0.02	0.03	0.36	0.02	0.07	0.00	0.03	0.07
Sr	0.07	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.09	0.08	0.08	0.07	0.09	0.08
Ba	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.04	0.02	0.03	0.04	0.03
Zn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Koshi Tappu: surface water chemistry

Conductivity in µS/cm, Na - Zn concentrations in mg/L

	P40	P41	P42	P43	P44	P45	P46	P47	P48	P49	P50	P52	P53	P54	P56	P57	P58	P59
pH	7.7	7.8	7.7	7.9	8	7.8	7.8	8.1	7.5	7.9	8.5	8.5	8.1	8.1	8.6	8.4	8	10.1
Cond.	275	257	293	317	324	382	375	355	254	284	224	217	350	304	260	334	339	114
Na	3.9	3.8	3.0	3.1	4.1	4.8	6.1	4.8	3.3	3.1	4.2	3.3	4.3	3.5	3.1	3.8	3.6	3.0
K	6.4	4.9	0.8	8.8	8.7	9.1	4.4	8.8	0.8	8.9	7.5	5.2	10.7	7.3	5.9	8.6	7.2	1.9
Mg	8.5	6.7	7.6	9.5	12.5	11.8	17.1	11.2	6.0	13.1	6.8	6.3	10.6	7.8	7.0	11.1	8.5	2.8
Ca	40.6	39.8	49.6	46.8	44.6	57.1	51.0	51.3	42.2	34.0	26.7	31.4	50.0	47.1	40.3	50.2	53.9	10.9
F	0.12	0.13	0.13	0.13	0.11	0.13	0.19	0.12	0.12	0.08	0.17	0.16	0.22	0.09	0.10	0.10	0.13	0.07
Cl	0.5	0.2	0.5	0.8	1.1	1.1	0.3	1.4	0.0	0.9	0.7	0.3	0.5	0.8	0.6	0.6	0.5	0.5
NO3	0.01	0.01	0.01	0.85	0.01	0.01	0.01	0.01	0.01	0.10	0.01	0.01	0.07	0.01	0.01	0.65	0.01	0.01
PO4	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SO4	9.12	7.57	13.08	13.04	19.58	10.25	15.19	14.48	7.84	9.07	32.20	4.31	27.06	15.54	21.37	34.60	26.05	7.49
Si	1.9	1.3	1.7	0.8	2.5	4.3	1.9	2.1	2.0	0.5	2.2	3.4	3.8	4.2	1.7	3.3	3.7	1.4
Al	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.020
Fe	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.11	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mn	0.07	0.17	0.00	0.04	0.00	0.13	0.04	0.10	0.00	0.03	0.09	0.06	0.00	0.10	0.01	0.02	0.16	0.00
Sr	0.07	0.07	0.07	0.08	0.08	0.10	0.10	0.10	0.07	0.07	0.07	0.08	0.15	0.07	0.07	0.11	0.12	0.04
Ba	0.03	0.02	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.05	0.03	0.03	0.04	0.05	0.00
Zn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Koshi Tappu: surface water chemistry

Conductivity in µS/cm, Na - Zn concentrations in mg/L

	P62	P63	P64	P65	P66	P67	P68	P69	P70	P71
pH	8.1	8.8	8.4	8.6	7.5	7.4	7.6	7.8	8	9.2
Cond.	313	289	343	308	209	234	309	331	341	173
Na	4.1	3.0	3.6	3.6	3.5	3.5	3.7	4.6	5.1	3.5
K	11.3	10.1	9.7	8.1	3.0	12.7	3.3	7.5	8.9	4.5
Mg	11.1	12.1	9.8	7.6	4.6	4.5	7.9	13.7	8.6	6.6
Ca	40.6	34.8	51.1	47.1	31.8	30.0	49.6	43.4	48.7	21.6
F	0.21	0.10	0.13	0.11	0.12	0.12	0.13	0.19	0.18	0.17
Cl	0.7	0.6	0.7	1.0	0.1	1.9	0.1	0.6	0.8	0.3
NO3	0.01	0.13	0.01	0.47	0.01	0.05	0.01	0.01	0.01	0.01
PO4	0.01	0.01	0.01	0.01	0.01	0.09	0.01	0.01	0.01	0.01
SO4	17.07	36.73	23.84	18.01	9.27	3.33	8.70	3.24	40.02	2.11
Si	1.7	2.1	4.7	3.9	1.9	1.5	3.0	0.1	2.1	1.8
Al	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fe	0.01	0.01	0.01	0.01	0.05	0.05	0.01	0.01	0.01	0.01
Mn	0.00	0.01	0.01	0.01	0.05	0.15	0.04	0.04	0.40	0.06
Sr	0.12	0.08	0.11	0.08	0.05	0.05	0.08	0.10	0.08	0.06
Ba	0.04	0.01	0.05	0.04	0.02	0.03	0.03	0.03	0.02	0.01
Zn	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Koshi Tappu: interstitial water chemistry

Na - Zn concentrations in mg/L

	P2	P3	P5	P6	P7	P8	P11	P12	P13	P15	P16	P17	P18	P19	P31	P32	P33	P34
Na	7.3	6.0	5.1	7.6	6.6	4.1	5.0	6.3	5.5	5.5	4.6	3.9	4.1	5.8	4.7	3.2	5.2	4.7
K	9.6	6.1	7.5	6.5	6.1	6.1	4.2	4.9	5.6	6.7	7.4	8.5	8.6	6.5	3.3	1.4	6.6	7.9
Mg	12.0	11.0	6.5	6.3	6.2	6.1	4.2	3.8	4.6	4.3	6.8	7.7	12.7	6.6	4.1	5.1	10.8	11.2
Ca	38.6	28.1	38.2	41.9	47.9	40.4	31.4	29.5	36.6	39.1	47.4	42.0	45.7	46.2	17.3	40.3	52.2	40.5
F	0.13	0.09	0.10	0.13	0.11	0.12	0.12	0.11	0.11	0.12	0.11	0.07	0.06	0.09	0.08	0.11	0.08	0.11
Cl	2.4	1.7	1.7	2.4	1.3	0.9	1.2	1.6	1.1	1.3	1.3	1.1	1.4	1.1	1.3	0.4	0.9	1.3
NO_3	0.03	0.03	3.01	0.03	0.03	0.03	0.45	2.20	0.03	0.03	0.08	0.03	0.03	0.03	0.72	0.03	0.03	0.03
PO_4-Sol	0.34	0.15	0.26	0.75	0.58	0.74	0.19	0.19	0.31	0.08	0.18	0.18	0.12	0.35	0.04	0.14	0.15	0.45
SO_4	11.05	9.96	5.25	4.79	3.98	4.58	7.22	19.88	11.16	10.89	15.84	7.26	2.84	4.00	8.58	6.00	5.02	8.41
Si	4.4	2.0	5.3	7.6	8.9	11.0	2.7	2.4	2.9	3.1	7.3	3.8	4.5	5.4	3.4	3.4	3.0	4.7
Al	1.428	0.788	0.286	0.137	0.287	0.292	0.136	0.034	0.279	0.057	0.181	0.033	0.155	0.423	1.121	0.056	0.125	0.574
Fe	1.51	0.83	1.01	1.59	2.44	1.93	0.43	0.18	1.93	0.14	2.71	0.85	1.75	2.54	0.55	0.09	0.29	2.28
Mn	0.82	0.39	4.21	6.09	3.12	1.49	0.54	0.29	1.51	0.32	2.12	1.04	1.08	1.45	0.04	0.04	0.60	6.10
Sr	0.07	0.07	0.06	0.06	0.07	0.09	0.05	0.05	0.06	0.06	0.08	0.07	0.09	0.08	0.05	0.07	0.09	0.09
Ba	0.07	0.10	0.07	0.17	0.27	0.10	0.12	0.13	0.12	0.34	0.14	0.14	0.09	0.19	0.03	0.08	0.13	0.12
Zn	0.06	0.43	0.02	0.06	0.13	0.01	0.02	0.04	0.05	0.05	0.06	0.02	0.03	0.03	0.02	0.02	0.03	0.03

Koshi Tappu: interstitial water chemistry

Na - Zn concentrations in mg/L

	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45	P46	P47	P49	P53	P54	P56	P57
Na	7.5	6.0	5.5	4.4	5.6	5.1	5.2	3.7	3.9	5.2	5.5	6.9	5.8	4.2	5.8	4.1	4.0	4.7
K	8.8	8.9	11.0	10.1	9.5	7.8	5.7	1.7	10.6	10.2	8.8	5.7	9.5	9.3	12.6	6.7	7.0	10.1
Mg	9.6	10.5	9.6	9.8	7.9	7.9	6.1	7.0	9.1	11.2	12.0	15.2	10.6	12.9	10.0	6.5	7.1	11.5
Ca	43.9	53.7	36.6	47.4	44.5	44.0	39.0	47.2	52.4	54.1	56.3	55.1	49.3	34.2	45.8	35.9	39.7	50.8
F	0.13	0.12	0.12	0.13	0.10	0.11	0.14	0.12	0.13	0.11	0.12	0.13	0.11	0.08	0.21	0.05	0.11	0.08
Cl	2.1	1.5	3.1	1.0	2.5	1.1	1.0	0.7	1.5	1.7	1.3	0.8	1.9	1.2	2.0	1.0	1.1	0.9
NO_3	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	1.16	0.95	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
PO_4-Sol	0.35	0.68	0.31	0.23	0.61	0.56	0.17	0.17	0.07	0.85	0.23	0.32	0.38	0.20	0.12	0.08	0.22	0.70
SO_4	10.29	5.37	3.37	5.52	4.57	6.74	10.87	10.69	5.03	3.69	4.11	7.11	6.68	2.56	23.35	7.42	11.20	8.33
Si	8.1	10.9	6.5	5.3	7.4	3.8	2.5	2.8	4.5	9.0	5.9	5.8	6.8	3.2	4.9	5.1	4.3	7.1
Al	0.335	0.325	0.633	0.199	0.415	0.121	0.335	0.144	0.261	0.234	0.229	0.143	0.058	0.067	0.112	0.027	0.244	0.136
Fe	1.36	2.28	1.59	0.70	5.13	1.07	0.52	0.71	2.42	3.04	1.65	2.33	2.16	0.67	0.59	0.28	1.77	2.20
Mn	2.19	4.52	2.25	2.08	3.42	2.27	2.25	1.09	4.65	7.93	2.02	1.92	3.15	0.41	1.41	0.52	1.67	5.10
Sr	0.09	0.09	0.07	0.09	0.09	0.08	0.06	0.07	0.09	0.08	0.10	0.11	0.10	0.08	0.14	0.08	0.08	0.12
Ba	0.81	0.17	0.09	0.09	0.12	0.21	0.13	0.09	0.16	0.14	0.15	0.15	0.14	0.13	0.14	0.08	0.10	0.14
Zn	0.03	0.03	0.01	0.01	0.03	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01

Koshi Tappu: interstitial water chemistry

Na - Zn concentrations in mg/L

	P58	P62	P63	P64	P65
Na	4.2	5.2	4.6	5.1	5.1
K	7.2	12.7	11.3	11.2	9.1
Mg	6.6	12.0	12.2	10.7	7.9
Ca	40.3	70.3	43.0	56.1	50.7
F	0.12	0.17	0.09	0.12	0.11
Cl	1.0	1.2	1.3	1.4	1.6
NO_3	0.03	0.03	0.03	0.03	0.13
PO_4-sol	0.29	0.20	0.16	0.17	0.12
SO_4	8.37	6.94	16.41	13.55	20.01
Si	5.7	5.6	3.4	6.1	4.3
Al	0.161	0.261	0.096	0.115	0.062
Fe	3.14	5.52	0.31	0.93	0.26
Mn	1.77	2.02	0.43	1.60	0.48
Sr	0.10	0.17	0.09	0.12	0.09
Ba	0.14	0.22	0.10	0.15	0.08
Zn	0.02	0.04	0.01	0.01	0.01

Gosainkunda lakes 2000: relative abundances of diatom taxa on stones

	L1sto	L2sto	L3/2sto	L4sto	L5sto	L6sto	L7sto
Achnlate	0.0	0.0	0.3	0.0	0.0	0.0	1.6
Achnbior	0.4	0.2	0.0	0.3	0.0	0.0	0.0
Achncari	0.0	1.0	0.0	0.0	0.7	0.0	0.0
Achnsp4	3.5	2.2	2.5	5.0	6.7	0.0	1.3
Achndist	1.0	0.5	0.6	2.1	4.1	0.4	1.6
Achncfli	11.6	18.7	4.0	13.1	0.0	16.9	21.9
Achncfma	6.0	3.2	0.6	8.8	4.1	1.7	8.2
Achnminu	12.7	32.8	26.1	10.2	7.0	65.0	31.7
Achncfre	0.0	0.0	1.2	0.0	0.0	0.0	0.0
Achncfsc	3.9	2.0	0.9	2.2	7.4	0.9	2.4
Achnsuba	0.6	1.0	11.5	8.7	13.5	0.0	2.9
Achnsp2	2.9	1.9	0.0	0.7	12.0	0.6	0.8
Anombrac	6.7	1.7	0.3	2.4	0.4	1.3	0.5
Aulasp1	9.1	5.1	3.7	27.2	15.5	2.1	8.7
Aulasp2	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Cymbsp2	0.2	0.2	0.0	2.2	0.0	0.0	0.0
Diathyem	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Diatmeso	0.0	0.9	0.0	1.7	0.4	0.0	0.5
Encyminu	0.6	0.5	8.1	0.5	1.7	0.6	2.4
Eunobilu	1.9	4.1	0.0	2.8	0.0	0.0	0.0
Eunomino	0.0	0.3	0.0	0.0	0.0	0.4	0.0
Eunomutr	1.3	4.3	0.6	1.7	0.9	0.4	0.8
Eunonyma	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Eunosuba	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Eunosp1	2.3	3.6	0.0	1.9	0.0	0.8	0.0
Eunosp2	1.7	0.3	0.0	0.0	0.0	0.0	0.5
Pseubrev	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Staucfcv	0.6	0.3	16.5	2.4	9.4	0.0	0.0
Fragcfde	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Fragexig	14.8	1.0	2.5	0.2	3.1	1.5	4.0
Staucfpi	0.0	0.0	5.9	0.2	0.6	0.0	0.0
Fragtene	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Frusrhcr	3.1	0.2	0.0	0.3	0.4	0.0	0.0
Gompcfcy	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Gompgrac	0.4	0.0	0.0	0.0	0.0	1.9	0.5
Gompparv	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Gomppaex	0.8	3.1	2.2	0.2	0.4	0.0	0.0
Gompsp1	0.0	1.0	1.2	0.0	0.0	0.0	0.0
Navisp3	1.0	1.2	2.5	1.0	5.4	0.8	0.8
Navimedi	2.3	0.2	0.0	0.0	0.0	0.0	0.0
Navicfob	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Navisemi	0.0	0.3	2.2	0.0	0.0	0.0	0.0
Navicfse	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Navicfsc	0.0	1.5	0.0	0.2	0.0	0.4	0.0
NaviD79	0.0	1.2	0.0	0.0	2.4	0.0	0.0
Neidsp1	1.5	0.5	0.0	0.5	0.0	0.0	0.0
Nepagosa	2.7	0.0	0.9	0.0	0.0	0.4	6.6
Nitzperm	0.6	0.2	0.0	0.0	1.8	0.0	0.0
Sellpupu	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Stendeli	0.6	0.0	0.0	0.2	0.0	0.0	0.0
Tabefloc	1.7	2.2	1.6	1.7	0.2	1.1	0.5

Gosainkunda 2000: species codes

Achnlate = *Achnanthidium latecephalum*

Achnbior = *Psammothidium bioretii*

Achncari = *Achnanthes carissima*

Achnsp4 = *Achnanthes* (cf. *chlidanos)* sp.4

Achndist = *Achnanthes distincta*

Achncfli = *Achnanthes* cf. *linearis*

Achncfma = *Psammothidium* cf. *marginulatum*

Achnminu = *Achnanthidium minutissimum*

Achncfre = *Achnanthes* cf. *rechtensis*

Achncfsc = *Psammothidium* cf. *scoticum*

Achnsuba = *Psammothidium subatomoides*

Achnsp2 = *Achnanthes* sp.2

Anombrac = *Anomoeoneis brachysira*

Aulasp1 = *Aulacoseira* sp.1

Aulasp2 = *Aulacoseira* sp.2

Cymbsp2 = *Cymbella* sp.2

Diathyem = *Diatoma hyemalis*

Diatmeso = *Diatoma mesodon*

Encyminu = *Encyonema minutum*

Eunobilu = *Eunotia bilunaris*

Eunomino = *Eunotia minor*

Eunomutr = *Eunotia muscicola* v. *tridentula*

Eunonyma = *Eunotia nymanniana*

Eunosuba = *Eunotia subarcuatoides*

Eunosp1 = *Eunotia* sp.1

Eunosp2 = *Eunotia* sp.2

Pseubrev = *Pseudostaurosira brevistriata*

Staucfcv = *Staurosira* cf. *construens* v. *venter*

Fragcfde = *Fragilaria* cf. *delicatissima*

Fragexig = *Fragilaria exigua*

Staucfpi = *Staurosirella* cf. *pinnata*

Fragtene = *Fragilaria tenera*

Frusrhcr = *Frustulia rhomboides* v. *crassinervia*

Gompcfcy = *Gomphonema* cf. *cymbelliclinum*

Gompgrac = *Gomphonema* cf. *gracile*

Gompparv = *Gomphonema parvulum*

Gompexil = *Gomphonema parvulum* v. *exilissimum*

Gompsp1 = *Gomphonema* sp.1

Navisp3 = *Navicula* (cf. *digitulus)* sp.3

Navimedi = *Navicula mediocris*

Navicfob = *Navicula* cf. *obsoleta*

Navisemi = *Sellaphora seminulum*

Navicfse = *Sellaphora* cf. *seminulum*

Navicfsc = *Navicula* cf. *schmassmanii*

NaviD79 = *Navicula* sp.D79

Neidsp1 = *Neidium* sp.1

Nepagosa = *Nepalia gosainkundensis*

Nitzperm = *Nitzschia perminuta*

Sellpupu = *Sellaphora pupula*

Stendeli = *Stenopterobia delicatissima*

Tabefloc = *Tabellaria flocculosa*

Gosainkunda lakes 2003: relative abundances of diatom species

	L1sto	L1san	L2sto	L2san	L3/1sto	L3/1san	L3/2sto	L3/2sed	L3/2mac	L4sto	L4sed
Achnbior	1.7	4.5	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.6	0.0
Achnsp4	1.7	29.5	1.3	1.8	1.1	12.9	6.1	7.0	1.5	5.3	5.8
Achndefl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achndist	5.0	2.8	2.6	6.2	1.1	8.8	10.2	4.4	0.0	5.8	3.2
Achncfkr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achncfli	10.9	0.0	10.5	3.3	2.8	0.6	3.2	0.0	0.0	0.0	0.0
Achncfma	16.0	40.6	10.1	13.3	3.4	27.4	40.1	73.5	3.6	7.8	1.2
Achnminu	17.6	0.3	47.9	62.7	65.4	22.1	15.2	0.0	72.6	5.0	24.3
Achncfsc	1.7	8.2	0.0	3.8	2.0	2.1	0.0	10.8	1.2	1.4	4.1
Achnsuba	0.0	0.0	0.9	4.4	0.3	0.0	2.9	0.0	0.3	3.3	5.6
Achnsp2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4
Amphliby	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anombrac	7.6	0.3	2.8	0.9	0.0	1.5	0.9	1.5	0.0	1.4	0.0
Aulacfal	0.0	0.0	0.0	0.0	1.1	0.0	3.8	0.3	0.6	46.0	9.4
Aulacfit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aulasp1	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfdi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfsv	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diathyem	0.0	0.0	0.0	0.0	0.3	0.9	0.0	0.0	0.0	1.1	0.0
Diatmeso	0.8	0.0	0.0	0.3	1.4	0.6	0.6	0.0	0.0	5.0	0.0
Encycfkr	0.0	0.3	1.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encycflu	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	0.8	0.0	0.7	0.0	7.3	2.9	1.2	0.0	2.1	1.9	0.6
Encysile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunocfca	0.0	1.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.6	0.0
Eunoinci	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunonaeg	0.0	0.0	0.0	0.0	0.3	3.2	0.3	0.0	0.0	0.0	0.0
Eunocfna	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunomino	0.8	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Eunomutr	5.9	0.9	2.9	0.9	0.3	1.8	0.6	0.0	1.2	0.8	0.0
Eunonyma	12.6	3.7	0.0	0.0	0.0	0.0	0.6	1.7	0.0	0.3	0.0
Eunocfpt	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosp1	1.7	0.0	0.2	0.0	0.3	1.8	0.0	0.0	0.3	0.8	0.0
Fragbrev	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucfcv	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	31.3
Fragexig	2.5	0.0	2.0	0.0	0.0	0.0	1.2	0.0	0.0	1.4	0.0
Fragdeli	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Fragcfde	0.0	0.0	0.0	0.6	3.4	3.2	0.0	0.0	9.4	0.0	0.0
Staucfpi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Fragpseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompcfcy	0.0	0.0	2.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompaex	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Gompcfgr	0.0	0.0	0.0	0.0	2.3	0.9	0.0	0.0	0.0	0.6	0.0
Gompparv	0.0	0.0	0.0	0.0	0.8	0.3	1.2	0.0	0.9	0.0	0.0
Navicfmi	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sellsemi	0.0	0.0	1.1	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0
Navisp3	0.8	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.3	6.1	4.7
Neidcfal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nepagosa	0.0	0.0	0.2	0.0	3.9	0.3	1.2	0.0	0.0	0.0	0.0
Nitzperm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Opepolse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opopcfol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnsubg	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Planlabi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucfan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stendeli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suricfli	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tabefloc	0.8	0.0	6.6	1.2	1.1	4.1	6.1	0.3	4.9	1.1	0.0

Gosainkunda lakes 2003: relative abundances of diatom species

	L5sto	L5san	L5sed	L6sto	L7sto	L7sed	L8sto	L8sed	L9sto	L9sed	L9mac	L10sto
Achnbior	0.3	1.2	0.0	0.0	0.0	0.3	1.2	0.0	0.6	0.0	0.0	1.0
Achnsp4	11.5	13.1	6.2	1.9	4.4	37.9	12.4	2.4	6.9	53.6	5.1	12.7
Achndefl	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Achndist	7.4	16.9	2.2	0.0	4.4	21.7	0.3	0.3	0.0	0.0	0.0	1.0
Achncfkr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0
Achncfli	0.3	0.0	0.0	17.8	13.9	1.2	0.0	0.0	3.2	0.0	6.0	5.9
Achncfma	7.4	16.0	3.1	3.7	9.4	16.8	38.1	0.0	26.5	36.8	20.6	4.9
Achnminu	7.1	2.6	5.0	44.9	14.7	3.4	4.7	6.8	2.0	0.0	0.9	8.8
Achncfsc	2.7	5.8	5.6	0.0	1.9	11.0	2.9	0.0	0.0	0.0	0.3	2.0
Achnsuba	3.3	10.8	3.1	0.0	0.0	0.0	3.2	1.5	1.4	0.0	0.0	0.0
Achnsp2	7.1	2.6	5.3	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Amphliby	0.9	0.0	0.0	0.0	0.0	0.0	1.5	4.2	0.0	0.0	0.0	0.0
Anombrac	0.6	0.6	0.0	0.0	8.3	0.6	0.6	0.3	10.7	0.9	25.3	1.0
Aulacfal	15.1	17.8	51.4	11.2	3.1	0.6	5.0	0.6	2.3	0.6	6.3	3.9
Aulacfit	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aulasp1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cratcfdi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0
Cratcfsv	0.0	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.9	0.0	0.0	1.0
Diathyem	2.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Diatmeso	3.6	0.6	0.6	2.8	2.8	0.0	0.3	0.0	0.0	0.3	0.3	24.5
Encycfkr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0
Encycflu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Encyminu	3.6	1.7	0.3	0.9	0.8	0.0	1.8	7.1	0.0	0.0	0.0	1.0
Encysile	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0
Eunocfca	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	5.5	2.5	0.6	0.0
Eunoinci	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	2.0
Eunonaeg	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Eunocfna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Eunomino	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Eunomutr	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0	11.5	0.9	7.3	20.6
Eunonyma	0.0	0.0	0.0	1.9	0.6	0.3	0.0	0.0	2.9	0.6	1.3	0.0
Eunocfpt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eunosuba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0
Eunosp1	0.3	0.3	0.0	0.0	0.6	0.0	0.0	0.0	8.4	0.0	7.3	6.9
Fragbrev	1.5	0.0	0.0	0.0	0.0	0.0	4.4	7.1	0.0	0.0	0.0	0.0
Staucfcv	7.1	3.5	3.1	0.0	1.1	0.0	2.7	2.1	0.3	0.0	0.0	0.0
Fragexig	3.6	0.0	1.6	0.9	8.6	0.9	0.9	1.2	0.0	0.0	0.0	0.0
Fragdeli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fragcfde	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staucfpi	1.2	2.0	0.9	0.0	0.0	0.0	5.9	3.0	0.0	0.0	0.0	0.0
Fragpseu	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
Gompcfcy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompaex	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Gompcfgr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gompparv	0.3	0.0	0.0	1.9	0.0	0.3	0.0	0.9	0.0	0.0	0.0	0.0
Navicfmi	0.3	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Sellsemi	0.6	0.0	0.9	0.0	0.0	0.0	0.9	0.0	2.0	0.0	0.6	0.0
Navisp3	6.8	2.6	6.9	0.0	1.4	0.0	2.7	9.2	0.0	0.0	0.6	0.0
Neidcfal	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nepagosa	0.0	0.0	0.0	6.5	8.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Nitzperm	0.0	0.9	0.3	0.0	1.1	0.0	0.6	0.9	0.3	0.0	0.3	0.0
Opepolse	0.0	0.0	0.0	0.0	0.0	0.0	7.4	45.5	0.0	0.0	0.0	0.0
Opopcfol	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pinnsubg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planlabi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
Staucfan	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Stendeli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0
Suricfli	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tabefloc	0.3	0.3	0.0	5.6	0.8	0.3	0.0	0.0	1.2	0.0	16.8	1.0

Gosainkunda 2003: species codes

Achnbior = *Psammothidium bioretii*
Achnsp4 = *Achnanthes* (cf. *chlidanos)* sp.4
Achndefl = *Achnanthes deflexum*
Achndist = *Achnanthes distincta*
Achncfkr = *Achnanthes* cf. *kranzii*
Achncfli = *Achnanthes* cf. *linearis*
Achncfma = *Psammothidium* cf. *marginulatum*
Achnminu = *Achnanthidium minustissimum*
Achncfsc = *Psammothidium* cf. *scoticum*
Achnsuba = *Psammothidium subatomoides*
Achnsp2 = *Achnanthes* sp.2
Amphliby = *Amphora libyca*
Anombrac = *Anomoeoneis brachysira*
Aulacfal = *Aulacoseira* cf. *alpigena*
Aulacfit = *Aulacoseira* cf. *italica*
Aulasp1 = *Aulacoseira* sp.1
Cratcfdi = *Craticula* cf. *dissociata*
Cratcfsv = *Craticula* cf. *sverirschopkae*
Diathyem = *Diatoma hyemalis*
Diatmeso = *Diatoma mesodon*
Encycfkr = *Encyonopsis* cf. *kriegeri*
Encycflu = *Encyonema* cf. *lunatum*
Encyminu = *Encyonema minutum*
Encysile = *Encyonema silesiacum*
Eunocfca = *Eunotia* cf. *carolina*
Eunoinci = *Eunotia incisa*
Eunonaeg = *Eunotia naegelii*
Eunocfna = *Eunotia* cf. *naegelii*
Eunomino = *Eunotia minor*
Eunomutr = *Eunotia muscicola* v. *tridentula*
Eunonyma = *Eunotia nymanniana*
Eunocfpt = *Eunotia* cf. *paludosa* v. *trinacria*
Eunosuba = *Eunotia subarcuatoides*
Eunosp1 = *Eunotia* sp.1
Fragbrev = *Pseudostaurosira brevistriata*
Staucfcv = *Staurosira* cf. *construens* v. *venter*
Fragexig = *Fragilaria exigua*
Fragdeli = *Fragilaria delicatissima*
Fragcfde = *Fragilaria* cf. *delicatissima*
Staucfpi = *Staurosirella* cf. *pinnata*
Fragpseu = *Fragilaria pseudoconstruens*
Gompcfcy = *Gomphonema* cf. *cymbelliclinum*
Gompaex = *Gomphonema parvulum* v. *exilissimum*
Gompcfgr = *Gomphonema* cf. *gracile*
Gompparv = *Gomphonema parvulum*
Navicfmi = *Navicula* cf. *minuscula*
Sellsemi = *Sellaphora seminulum*
Navisp3 = *Navicula* (cf. *digitulus)* sp.3
Neidcfal = *Neidium* cf. *alpinum*
Nepagosa = *Nepalia gosainkundensis*
Nitzperm = *Nitzschia perminuta*
Opepolse = *Opephora olsenii*
Opopcfol = *Opephora* cf. *olsenii*
Pinnsubg = *Pinnularia subgibba*
Planlabi = *Planothidium lanceolata* ssp. *biporoma*
Staucfan = *Stauroneis* cf. *anceps*
Stendeli = *Stenopterobia delicatissima*
Suricfli = *Surirella* cf. *linearis*
Tabefloc = *Tabellaria flocculosa*

Habitat character

Categories: 1 = present, 2 ≥ 30%

Gosainkund lakes 2000

	L1	L2	L3/2	L4	L5	L6	L7
Sustrate composition (%)							
Littoral							
Boulders	20	45	5	40	5	20	20
Cobbles	40	45	25	40	20	35	40
Pebbles	30	10	20	15	25	35	20
Gravel	10	0	30	5	25	10	20
Sand	0	0	20	0	25	0	0
Silt,mud,earth	0	0	0	0	0	0	0
Bank profile							
Vertical, undercut	0	0	0	0	0	0	1
Vertical + toe	0	0	1	0	0	0	0
Steep	1	0	1	0	0	1	1
Composite	1	1	1	1	1	1	1
Gentle	2	2	1	2	2	1	0
Land use within 100 m							
Isolated houses	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0
Pasture	0	0	0	0	0	0	0
Rough grassland	1	1	2	1	2	1	1
Scrub	0	0	0	0	0	0	0
Broad leaved forest	0	0	0	0	0	0	0
Alpine tundra	2	1	1	1	2	2	1
Boulder fields	2	2	1	2	2	2	2

Gosainkund lakes 2003

	L1	L2	L3/1	L3/2	L4	L5	L6	L7	L8	L9	L10
Sustrate composition (%)											
Littoral											
Boulders	25	0	5	5	25	5	25	20	5	5	30
Cobbles	30	5	20	20	40	25	25	30	20	50	40
Pebbles	25	20	10	20	30	30	20	20	15	30	20
Gravel	15	40	20	30	25	20	10	10	20	5	10
Sand	5	35	40	30	0	20	20	20	35	10	0
Silt,mud,earth	0	0	5	5	25	0	0	0	5	0	0
Bank profile											
Vertical, undercut	0	0	0	0	0	0	0	0	0	0	0
Vertical + toe	0	0	0	0	0	0	0	1	0	0	0
Steep	0	1	2	0	0	1	1	1	0	1	1
Composite	1	1	1	2	1	1	1	1	2	1	1
Gentle	2	2	0	1	2	1	1	0	1	1	1
Land use within 100 m											
Isolated houses	0	0	1	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0
Pasture	0	0	0	0	0	0	0	0	0	0	0
Rough grassland	1	1	2	2	2	2	1	2	2	1	1
Scrub	0	0	0	0	0	0	0	0	0	0	0
Broad leaved forest	0	0	0	0	0	0	0	0	0	0	0
Alpine tundra	2	2	1	2	2	2	2	1	2	2	2
Boulder fields	2	2	1	1	2	2	2	1	1	2	2

Water chemistry

Conductivity in µS/cm, Na - SO_4 concentrations in mg/L

Gosainkunda lakes 2000

	L1	L2	L3/2	L4	L5	L6	L7
pH	7.2	7.2	7.6	7.2	7.4	7.4	7.6
Cond	3.1	6.7	8.6	12.3	11.5	6.8	9.1
Na	0.0	0.2	0.3	0.4	0.4	0.2	0.3
K	0.3	0.0	0.3	0.2	0.4	0.2	0.1
Mg	0.1	0.1	0.2	0.2	0.2	0.1	0.2
Ca	0.3	0.6	0.9	1.1	1.1	0.6	0.9
Cl	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Total N	0.06	0.04	0.05	0.10	0.09	0.06	0.07
SO_4	0.24	0.81	1.42	1.81	1.88	0.65	1.20

Gosainkunda lakes 2003

	L1	L2	L3/1	L3/2	L4	L5	L6	L7	L8	L9	L10
pH	6.9	6.1	7.3	7.1	6.2	6.2	6.5	6.5	7.4	6.9	6.4
Cond	5	5	10	9	11	7	7	10	9	6	5
Na	0.2	0.4	0.4	0.4	0.3	0.2	0.2	0.4	0.3	0.2	0.2
K	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Mg	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1
Ca	0.5	0.9	1.1	1.0	1.0	0.8	0.8	1.1	0.9	0.6	0.5
Cl	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Total N	0.10	0.08	0.13	0.09	0.10	0.14	0.12	0.09	0.14	0.12	0.10
SO_4	0.35	0.89	1.16	1.21	1.18	0.72	0.68	1.21	0.87	0.38	0.29

Declaration

The work contained in this thesis is the result of my own investigations, except where due acknowledgement is made to other sources.

This work has not already been accepted in candidature for any degree, and is not being concurrently submitted in candidature for any other degree to any other university.

In agreement with my supervisor Prof. Dr. Walter Traunspurger, University of Bielefeld, and my external supervisor Dr. Ingrid Jüttner, National Museum Wales, the second (Diatoms in ponds and small lakes of the Kathmandu Valley, Nepal – relationships with chemical and habitat characteristics) and third chapters (Diatoms in lowland ponds of Koshi Tappu, Eastern Nepal – relationships with chemical and habitat characteristics) of the thesis have been submitted for publication to *Archive for Hydrobiology* and *International Review of Hydrobiology*, respectively, the former is published in May issue and the latter is in press.

For the second chapter I participated in planning the field work, carried out the field work in collaboration with my external supervisor, carried out the laboratory work except the chemical analysis of the water samples, which was carried out by Gary Jones, Natural History Museum, London. I performed the qualitative and quantitative analysis of the diatoms samples, carried out the statistical analysis subject to advice from my external supervisor, except for the calculation of species richness, which was carried out by P.D. James Chimonides, Natural History Museum, London, and compiled the manuscript subject to advice from my external supervisor. Mapping was provided by P.D. James Chimonides, Natural History Museum, London. In total my contribution to this chapter was 80 %. My external supervisor contributed 10 %, Gary Jones and P.D. James Chimonides contributed 5 % each.

For the third chapter I participated in planning the field work, carried out the field work in collaboration with my external supervisor, carried out the laboratory work except the chemical analysis of the water samples, which was carried out by Gary Jones, Natural History Museum, London. I performed the qualitative and quantitative analysis of the diatom samples, carried out the statistical analysis subject to advice from my external supervisor, except for the cluster analysis and the calculation of species richness, which was carried out by P.D. James Chimonides, Natural History Museum, London, and compiled the manuscript subject to advice from my external supervisor. Mapping was provided by P.D. James Chimonides, Natural History Museum, London. In total my contribution to this chapter was 75 %. My external supervisor and P.D. James Chimonides contributed 10 % each, Gary Jones contributed 5 %.

28|07|2006

Bishnu Simkhada, Candidate

Miss Bishnu Simkhada
83/8 Ganga Jamuna Marga
Balaju, P.O.Box: 13863
Kathmandu, Nepal
00977 1 4350754

Current address:

25 Avery House,
Skipton Road,
Birmingham
B16 8JW
Email: Bishnu.Simkhada@hotmail.com
Phone: 0044 (0) 7946624214, 0044 (0)1212422190

SUMMARY OF QUALIFICATIONS

Five years of PhD research work in "Diatoms as Indicators of Environmental Change in Lakes and Ponds of the Lowlands, Middle Hills and High Himalayas of Nepal" conducted at National Museum of Wales Cardiff. Three years and eleven months Technical assistant at Natural History Museum, London. Seven Years of teaching and research at Tribhuvan University, Tri-Chandra college, Department of Chemistry, Kathmandu, Nepal. Three years of science teaching at secondary school of Kathmandu, Nepal.

Education:

2001 - 2006:	PhD research: "Diatoms as indicators of environmental change in lakes and ponds of the lowlands, Middle Hills and High Himalayas of Nepal".
1989 - 1991	M.Sc. Chemistry, First class, Tribhuvan University, Central Department of Chemistry, Kathmandu, Nepal.
1986 – 1988	B. Sc. Chemistry, Botany, Zoology, First Class, Tribhuvan University, Amrit Science College Kathmandu, Nepal.
1983 – 1985	I. Sc. physics, chemistry, biology, Padma Kanya Campus, Nepal.

Work Experience:

08/2001 – 06/2005:	Technical Research Assistant, Department of Entomology, Natural History Museum, London.
05/2001 – 08/2001:	Volunteer diatom research, Department of Botany, Natural History Museum London.
06/1997 – 12/2000:	Lecturer in chemistry, Tribhuban University, Tri-Chandra Multiple College, Kathmandu, Nepal.
	Visiting Lecturer in chemistry, Biswaniketan Science Campus, Tripureshwar, Kathmandu, Nepal.
	Visiting lecturer in Chemistry, National Institute of Technical Sciences, Balaju, Kathmandu, Nepal.
05/1993 – 05/1997:	Assistant lecturer in chemistry, Tribhuvan University, Tri-Chandra Multiple College, Kathmandu, Nepal.

02/1995 – 05/1996 Science Department Head, Bhanubhakta Memorial Secondary School, Panipokhari, administration and teaching management.

02/1993 – 01/1995 Senior Science Teacher, Bhanubhakta Memorial Secondary School.

Publications

SIMKHADA B. & JÜTTNER I. (2006) Diatoms in ponds and small lakes of the Kathmandu Valley, Nepal- relationships with chemical and habitat characteristics, *Archive for Hydrobiology*. **166** (1) 41 – 65.

SIMKHADA B. JÜTTNER, I. & CHIMONIDES.P.J.: Diatoms in lowland ponds of Koshi Tappu, Eastern Nepal - relationships with chemical and habitat characteristics, *International Revue of Hydrobiology*, in press.

Training/Seminars:

- **21st – 23rd October 2005**:
Presented talk at the British Diatomists' Meeting 2005, Gregynog Hall, Newtown.
- **12th October 2005**
Presented talk at the Departmental Seminar of BIOSYB, National Museum of Wales, Cardiff.
- **22nd – 24th October 2004:**
Presented talk at "British Diatomists' Meeting", Bristol University.
- **31st October – 2nd November 2003**
Poster presentation at British Diatomists' Meeting, organised by Essex University.
- **9th – 11h September 2003**
Poster presentation at British Ecological Society Annual Meeting & AGM, Manchester Metropolitan University.
- **23rd -29th September 2002**
Poster presentation at the NATO Advanced Research Workshop, use of humates to remediate polluted environments: from theory to practice, Zvenigorod, Russia.
- **6th – 10th March 2002Poster**
Poster presentation in the international seminar "the International Year for Mountain", Kathmandu 2002
- **11/1999 – 12/1999**
Regional training course in analytical chemistry, IIT, Madras, India.
- **05/1999**
Regional Training programme in chemistry of natural products, Department of Chemistry, Tribhuvan University, Kathmandu, Nepal.
- **06/1997**
Workshop on phytochemical and basic analytical techniques. Department of Chemistry, Tribhuvan University, Kathmandu, Nepal.
- **01/1996 – 11/1996**
Technical Instructors Trainer Trainee at Technical Instructors Trainer Training Institute, Bhaktapur, Nepal.

Member of professional organisations:

British Ecological Society,
International Diatom Research Society,
British Federation of Women Graduate,
Nepal Chemical Society

Training Awards:

Award for "**ACADEMIC ACHIEVEMENT**", Award for "**BEST DEMONSTRATION**", Award for "**MOST HELPFUL**" awarded by Technical Instructor Trainer Training Institute.

Gedruckt auf alterungsbeständigem Papier. Printed on non-ageing paper.