Research to Application, Department of Biotechnology, New Delhi, 2003.
10. Chaturvedi, S., WTO, Biosafety Regulatory Regime and Trade in Genetically Modified Goods: Options before developing countries – An Indian Perspective in *Asian Biotechnology and Development Review* (eds Panchamukhi, V. R. and Dhar, B.), Multiplexus, New Delhi, 2002, pp. 41–64.
11. Bruce, G. (ed.) The Jordan Report accelerated development of vaccines, NIAID, NIH, Washington, 1998.
12. Vogel, G., *Science*, 2002, **297**, 175.
13. Holden, C. and Vogel, G., *Science*, 2002, **297**, 923–925.

ACKNOWLEDGEMENTS. My position at IISc is sustained by the Distinguished Biotechnologist Award of the DBT. Till recently, I was supported by an Emeritus Scientist Scheme of the CSIR.

G. Padmanaban is in the Department of Biochemistry, Indian Institute of Science, Bangalore 560 012, India
e-mail: geepee@biochem.iisc.ernet.in

Food plants and feeding habits of Himalayan ungulates

Anjali Awasthi, Sanjay Kr. Uniyal, Gopal S. Rawat and S. Sathyakumar

A review of information available on the food plants and feeding habits of Himalayan ungulates revealed that of the 12 alpine ungulate species only four have been studied in detail. Analyses of the compiled data on food plants show that a total of 140 wild plant species are palatable to different ungulate species. However, information on palatability of many other plant species is lacking. The information on the food plants of domestic ungulates is also scarce. Based on whatever information is available it was found that out of 140 plant species, 13 are common in the diet of wild and domestic ungulates. Some of the recent studies have given some indications of a competition existing between wild and domestic Himalayan ungulates for food, hence it becomes imperative to study their feeding habits and document their food plants.

The Himalayan region sustains a diverse array of wild and domestic ungulates[1], besides a large number of small herbivores[2]. A perusal of the literature on the food and food habits of Himalayan ungulates reveals that out of the total 12 wild ungulate species inhabiting the subalpine and alpine zones of Himalaya, only four have been studied. Majority of the work on feeding ecology of ungulates is restricted to temperate and sub-alpine regions, while a few studies have been done in the trans-Himalaya. Besides direct observations, faecal pellet analysis that was initiated in the western countries in the early 20th century, has been widely used to assess the feed composition of ungulates. It involves the microhistological analyses of dung and its comparison with the reference slides of food plants available in the study area. Though it has a limitation of differential digestion, it is one of the best methods to document the diet of wild animals. Initially Schaller[3] reported the feeding patterns of different mountain ungulates but did not provide their detailed dietary profile. It has been found that different ungulate species have varying food and feeding habits. Some are purely grazers such as kiang and Himalayan tahr, others such as serow mostly browse while species such as musk deer are mixed feeders (graze and browse). Later, Green[4], Mishra and Johnsingh[5] and Ilyas[6] studied the diet of temperate and sub-alpine ungulates. Green[4] found that the Himalayan musk deer (*Moschus chrysogaster*) avoided graminoids and thrived on poorer quality diets such as lichens and mosses during winters. Brown oak (*Quercus semecarpifolia*) and *Gaultheria nummularia* (tinglu) also formed important diet components during winter when most of the forbs were under snow. Mishra and Johnsingh[5], on the other hand, found that the proportion of graminoids was high in the diet of goral (*Nemorhaedus goral*) for all seasons (92.2% in winters and 98.3% in summers). Similar results were obtained by Ilyas[6]. However, information on the diet composition and food plants of most of the Himalayan ungulates such as tahr (*Hemitragus jemlahicus*), Tibetan argali (*Ovis ammon*), shapu (*Ovis orientalis*) and kiang (*Equus hemionus kiang*) is virtually lacking. Recently, Manjrekar[7] conducted a detailed study on the feeding ecology of Himalayan ibex (*Capra ibex sibirica*) in the trans-Himalaya region. Food habits of bharal (*Pseudois nayaur*) and domestic livestock formed a part of another study carried out by Mishra[8] in the trans-Himalayan region. Both the studies revealed seasonal food selectivity by these animals. Manjrekar[7] found that ibex had highest food selectivity in spring (Preference index = 10.79) and least in winters (Preference index = 0.98). Fruits of wild rose (*Rosa webbiana*) accounted for *ca.* 24% of the diet of ibex in winters. Mishra[8] found that all the ungulate species had a diverse diet in summer compared to winter, when resources become even scarcer. Both the studies have emphasized on the need for studies on the dietary overlap between different ungulate species. Though some of the food habit studies have been carried out on the mountain ungulates of Nepal and Tibet[9–11], information on this aspect is lacking from the alpine ranges of Indian Himalaya.

Perusal and analyses of the pooled data on the botanical composition of diet (Table 1) shows that a total of 140 wild plant species are palatable to different ungulate species, which constitutes *ca.* 9% of the alpine flora of the Western Himalaya[12]. It was also revealed that of the total 44 families of documented food plants, most of the highly consumed food plants belonged to families Rosaceae and Asteraceae (14 each), followed by Fabaceae (13) and Polygonaceae (10).

Table 1. List of palatable plant species documented in different studies (Green 1987, Sundriyal 1989, Negi *et al.*, 1993, Manjrekar 1997, Ilyas 2001, Mishra 2001) done in Indian Himalaya

		Wild			Domestic								
Family	Plant species	Ibex	Bh	MD	Gral	Yak	Hor	Don	Dzomo	Sheep	Goat	Cow	Buffalo
Liliaceae	*Allium* sp.	–	–	–	–	–	+	+	–	+	+	–	–
Apiaceae	*Bupleurum falcatum*	+	–	–	–	–	–	–	–	–	–	–	–
	Bupleurum longicaule	–	–	–	–	–	+	–	–	+	–	–	–
	Ferula jaeschkeana	+	–	–	–	–	–	–	–	–	–	–	–
	Heracleum sp.	–	–	–	–	+	–						–
	Heracleum thomsonii	–	+	–	–	–	–	+	+	+	–	+	–
	Selinum vaginatum	–	–	+	–	–	–	–	–	–	–	–	–
	Seseli trilobum	+	–	–	–	–	–	–	–	–	–	–	–
	Trachydium roylei	–	–	–	–	–	+	–	–	+	+	+	+
Asteraceae	*Ainsliaea aptera*	–	–	+	+	–	–	–	–	–	–	–	–
	Artemisia maritima	+	–	–	–	–	–	–	–	–	–	–	–
	Cirsium wallichii	–	–	–	–	–	–	–	–	–	+	–	–
	Cousinia thomsonii	–	+	–	–	+	+	+	–	+	–	–	–
	Gerbera kunzeana	–	–	+	–	–	–	–	–	–	–	–	–
	Jurinaea dolomiaea	–	–	–	–	–	+	–	–	–	–	–	–
	Launaea secunda	–	–	–	+	–	–	–	–	–	–	–	–
	Leontopodium himalayanum	+	–	–	–	–	–	–	–	–	–	–	–
	Scorzonera sp.	–	+	–	–	–	–	–	–	–	–	–	–
	Senecio alatus	–	–	+	–	–	–	–	–	–	–	–	–
	Tanacetum gracile	+	–	–	–	–	–	–	–	–	–	–	–
	Tanacetum longifolium	–	–	–	–	–	–	–	–	+	+	–	–
	Taraxacum officinale	–	–	–	–	–	+	–	–	+	+	–	–
	Tragopogon gracilis	+	–	–	–	–	–	–	–	–	–	–	–
Balsaminaceae	*Impatiens scabrida*	–	–	–	+	–	–	–	–	–	–	–	–
Berberidaceae	*Berberis vulgaris*	–	–	+	–	–	–	–	–	–	–	–	–
Boraginaceae	*Arnebia euchroma*	+	+	–	–	–	–	–	–	–	–	–	–
	Eritrichium canum	+	–	–	–	–	–	–	–	–	–	–	–
	Lindelofia anchusoides	+	–	–	–	+	+	–	+	+	+	+	–
	Lindelofia sp.	+	–	–	–	–	–	–	–	–	–	–	–
	Lindelofia stylosa	+	–	–	–	–	–	–	–	–	–	–	–
Caryophyllaceae	*Arenaria serpyllifolia*	+	–	–	–	–	–	–	–	–	–	–	–
	Stellaria alsine	–	–	–	–	–	–	–	–	–	–	–	+
	Stellaria micropetala	–	–	–	–	–	–	–	–	+	+	+	+
	Silene sp.	+	–	–	–	–	–	–	–	–	–	–	–
Chenopodiaceae	*Eurotia ceratoides*	–	+	–	–	+	+	+	–	–	–	+	–
Coriariaceae	*Coriaria nepalensis*	–	–	–	+	–	–	–	–	–	–	–	–
Cornaceae	*Swida oblonga*	–	–	–	+	–	–	–	–	–	–	–	–
Crassulaceae	*Rhodiola heterodonta*	+	–	–	–	–	–	–	–	–	–	–	–
	Rosularia alpestris	+	–	–	–	–	–	–	–	–	–	–	–
Cyperaceae	*Carex infuscata*	–	+	–	–	+	+	+	+	+	+	+	–
	Carex melanantha	–	–	–	–	+	+	+	+	+	+	+	–
	Carex sp. 1	–	+	–	–	+	+	+	–	+	+	–	–
	Carex sp. 2	–	–	–	–	+	–	–	–	+	+	–	–
	Kobresia duthiei	–	–	–	–	–	+	–	–	+	+	–	–
	Kobresia nitens	–	–	–	–	–	–	–	–	+	+	+	+
	Kobresia royleana	–	–	–	–	+	+	–	–	–	–	–	–
Dipsacaceae	*Dipsacus inermis*	–	–	+	–	–	–	–	–	–	–	–	–
Ephedraceae	*Ephedra gerardiana*	+	–	–	–	–	–	–	–	–	–	–	–
Ericaceae	*Cassiope fastigiata*	–	–	–	–	–	–	–	–	–	+	–	–
	Gaultheria nummularioides	–	–	+	–	–	–	–	–	–	–	–	–
	Gaultheria trichophylla	–	–	+	–	–	–	–	–	–	–	–	–
	Rhododendron anthopogon	–	–	–	–	–	–	–	–	–	+	–	–
	Rhododendron campanulatum	–	–	+	–	–	–	–	–	–	–	–	–
Euphorbiaceae	*Euphorbia stracheyi*	–	–	–	–	–	+	–	–	+	+	–	–
Fabaceae	*Astragalus candolleanus*	+	–	–	–	–	–	–	–	–	–	–	–
	Astragalus densiflorus	+	–	–	–	–	–	–	–	–	–	–	–
	Astragalus grahamianus	–	–	–	–	–	+	–	–	+	+	–	–
	Astragalus prostratus	+	–	–	–	–	–	–	–	–	–	–	–
	Astragalus spp.	+	–	–	–	–	–	–	–	–	–	–	–
	Caragana sp.	–	–	–	–	–	–	–	–	–	+	–	–
	Cicer microphyllum	+	–	–	–	+	–	–	–	–	–	–	–

contd...

Table 1. *contd...*

Family	Plant species	Wild			Domestic								
		Ibex	Bh	MD	Gral	Yak	Hor	Don	Dzomo	Sheep	Goat	Cow	Buffalo
	Flemingia strobilifera	–	–	–	+	–	–	–	–	–	–	–	–
	Indigofera heterantha	–	–	–	+	–	–	–	–	–	–	–	–
Ranunculaceae	*Oxygraphis polypetala*	–	–	–	–	–	+	–	–	+	+	+	+
	Oxytropis cachemiriana	+	–	–	–	–	–	–	–	–	–	–	–
Fagaceae	*Quercus leucotrichophora*	–	–	–	+	–	–	–	–	–	–	–	–
	Quercus semecarpifolia	–	–	+	–	–	–	–	–	–	–	–	–
Gentianaceae	*Gentiana argentea*	–	–	–	–	–	–	–	–	+	–	–	–
	Swertia cordata	–	–	+	–	–	–	–	–	–	–	–	–
Geraniaceae	*Geranium pratense*	+	–	–	–	–	–	–	–	–	–	–	–
	Geranium wallichianum	–	–	–	–	–	–	–	–	+	–	–	–
Juncaceae	*Juncus elegans*	–	–	–	–	–	–	–	–	–	+	–	+
	Juncus himalensis	–	–	–	–	–	+	–	–	–	–	–	–
Lamiaceae	*Calamintha umbrosa*	–	–	–	+	–	–	–	–	–	–	–	–
	Hyssopus officinalis	+	–	–	–	–	–	–	–	–	–	–	–
	Nepeta discolor	–	–	–	–	–	–	–	–	–	–	+	–
	Nepeta podostachys	+	–	–	–	–	–	–	–	–	–	–	–
	Origanum vulgare	–	–	–	+	–	–	–	–	–	–	–	–
	Plectranthus striatus	–	–	–	+	–	–	–	–	–	–	–	–
	Thymus serpyllum	+	–	–	–	–	–	–	–	–	–	–	–
Liliaceae	*Lloydia serotina*	+	–	–	–	–	–	–	–	–	–	–	–
	Trillium govanianum	–	–	+	–	–	–	–	–	–	–	–	–
Linaceae	*Linum perenne*	+	–	–	–	–	–	–	–	–	–	–	–
Myrsinaceae	*Myrsine africana*	–	–	–	+	–	–	–	–	–	–	–	–
Oleaceae	*Jasminum humile*	–	–	+	–	–	–	–	–	–	–	–	–
Onagraceae	*Epilobium angustifolium*	–	–	–	+	–	–	–	–	–	–	–	–
	Epilobium royleanum	–	–	–	–	–	–	–	–	+	+	+	+
	Epilobium sp.	+	–	–	–	–	–	–	–	–	–	–	–
Osmundaceae	*Osmunda claytoniana*	–	–	–	–	–	–	–	–	–	+	–	–
Papilionaceae	*Trifolium repens*	–	–	–	–	–	+	–	–	+	–	–	–
Pinaceae	*Abies pindrow*	–	–	+	–	–	–	–	–	–	–	–	–
Plantaginaceae	*Plantago major*	–	–	–	–	–	+	–	–	+	+	–	–
Poaceae	*Agrostis munroana*	–	–	–	–	–	+	–	–	+	–	–	–
	Agrostis stolonifera	–	–	–	–	–	–	–	–	–	–	+	+
	Arundinaria sp.	–	–	+	–	–	–	–	–	–	–	–	–
	Danthonia cachemyriana	–	–	–	–	–	+	–	–	+	+	+	+
	Elymus longe-aristatus	–	+	–	–	+	+	+	+	+	+	+	–
	Festuca olgae	–	+	–	–	+	–	–	+	–	+	–	–
	Leymus secalinus	–	+	–	–	+	+	+	+	+	+	+	–
	Poa pratensis	–	–	–	–	–	+	–	–	+	–	–	–
	Stipa orientalis	–	+	–	–	+	+	+	+	+	+	+	–
Polygonaceae	*Aconogonum tortuosum*	+	–	–	–	–	–	–	–	–	–	–	–
	Bistorta vivipara	–	–	–	–	–	+	–	–	+	–	–	–
	Koenigia nepalensis	–	–	–	–	–	–	–	–	+	–	–	–
	Persicaria amphibia	–	–	–	–	–	+	–	–	+	–	–	–
	Polygonum amplexicaule	–	–	+	–	–	–	–	–	–	–	–	–
	Polygonum aviculare	+	+	–	–	–	–	–	–	–	–	–	–
	Polygonum filicaule	+	–	–	–	–	–	–	–	–	–	–	–
	Polygonum macrophyllum	–	–	–	–	–	–	–	–	–	–	–	+
	Polygonum polystachyum	–	–	+	–	–	–	–	–	+	+	–	–
	Rumex nepalensis	–	–	–	–	–	–	–	–	+	–	–	–
Primulaceae	*Primula denticulata*	–	–	–	–	–	+	–	–	+	+	–	–
Ranunculaceae	*Thalictrum foetidum*	+	–	–	–	–	–	–	–	–	–	–	–
	Thalictrum minus	+	–	–	–	–	–	–	–	–	–	–	–
Rosaceae	*Cotoneaster duthieanus*	+	–	–	–	–	–	–	–	–	–	–	–
	Cotoneaster microphyllus	–	–	+	–	–	–	–	–	–	–	–	–
	Fragaria vesca	–	–	+	–	–	–	–	–	–	–	–	–
	Geum elatum	–	–	–	–	–	+	–	–	+	+	+	+
	Potentilla atrisanguinea	+	–	–	–	–	–	–	–	+	+	+	+
	Potentilla cuneata	+	–	–	–	–	–	–	–	–	–	–	–
	Potentilla nepalensis	–	–	–	–	–	+	–	–	+	+	–	–
	Potentilla sp.	–	–	–	–	–	–	–	–	+	+	–	–
	Rosa webbiana	+	+	–	–	–	–	–	–	–	–	–	–

contd...

Table 1. *contd...*

Family	Plant species	Wild			Domestic								
		Ibex	Bh	MD	Gral	Yak	Hor	Don	Dzomo	Sheep	Goat	Cow	Buffalo
	Rubus ellipticus	–	–	–	+	–	–	–	–	–	–	–	–
	Rubus nutans	–	–	+	–	–	–	–	–	–	–	–	–
	Rubus paniculatus	–	–	–	+	–	–	–	–	–	–	–	–
	Rubus pedunculosus	–	–	+	–	–	–	–	–	–	–	–	–
	Sibbaldia parviflora	–	–	–	–	–	–	–	–	+	+	+	+
	Galium aparine	–	–	–	+	–	–	–	–	–	–	–	–
	Galium sp.	–	–	+	–	–	–	–	–	–	–	–	–
Rutaceae	*Skimmia laureola*	–	–	+	–	–	–	–	–	–	–	–	–
Salicaceae	*Salix lindleyana*	–	–	–	–	–	–	–	–	–	+	–	–
Saxifragaceae	*Bergenia ligulata*	–	–	–	+	–	–	–	–	–	–	–	–
	Parnassia nubicola	–	–	–	–	–	–	–	–	+	+	+	+
	Saxifraga diversifolia	–	–	–	–	–	–	–	–	+	+	+	+
Scrophulariaceae	*Pedicularis longiflora*	–	–	–	–	–	+	–	–	–	–	–	–
Thymelaeaceae	*Daphne papyraceae*	–	–	–	+	–	–	–	–	–	–	–	–
Valerianaceae	*Valeriana hardwickii*	–	–	–	+	–	–	–	–	–	–	–	–
Violaceae	*Viola canescens*	–	–	–	+	–	–	–	–	–	–	–	–
Vitaceae	*Parthenocissus himalayana*	–	–	–	+	–	–	–	–	–	–	–	–

Bh, Blue sheep (Bharal); md, Musk deer; Gral, Goral, Hor, Horse; Don, Donkey).

However, information on palatability of many other plant species is lacking because food habits of many other ungulates is not yet known. Proportion of forbs dominated the diet of ungulates of Greater Himalaya while proportion of graminoids dominated in the diet of trans-Himalayan ungulates. This could be due to the variation in floral composition of Greater and trans-Himalaya[13–17]. Each region also has distinct plant formations determined by elevation, drainage, precipitation, sunlight and other factors[18]. This also affects the food availability and its consumption by the ungulates. Sedge meadows along moist slopes, stream and lake banks, dominated by species of *Carex* and *Kobresia* are known to support livestock and wild ungulates during dry season[19] but Schaller[11] has reported that certain grasses and sedges such as *Carex* and *Kobresia* were avoided by most of the ungulates during winter when the digestibility was low and fibre content was high. Nutritive quality of plant species, which is an important factor for forage selection by the ungulates, has not been studied systematically and hence the information available is scarce and dispersed.

The information on the food plants of domestic animals is also very scanty. Based on the works of Sundriyal[20], Negi *et al.*[21] and Mishra[8] it can be stated that 13 plant species out of the total of 140 palatable species are common in the diets of wild and domestic ungulates. These plant species belonged to 9 different families, of which the maximum number of species belonged to family Poaceae. Domestic livestock had a wide dietary spectrum, i.e. the number of species consumed was more (44%, of the total 140 palatable species) compared to that of ibex and bharal (35%). This would certainly result in the dietary overlap between them. Dietary overlap amongst domestic and wild ungulates in alpine areas, where food resources are already scarce and the growth season for vegetation is limited, would lead to competitive exclusion of the latter. Competition in spring/summer may actually not exist but in autumn and winter when wild ungulates move to lower altitudes (where livestock graze during summer), they have to survive on the scanty and less nutritious resources leftover by the livestock.

Hence it becomes imperative to study the food habits of wild as well as domestic ungulates and document their diet composition to assess the spatial and temporal patterns of dietary overlap in the alpine regions of Greater and trans-Himalayan regions of India. In the Indian alpine region, where overstocking and overgrazing due to migratory livestock has raised concerns amongst ecologists and conservationists[22–25], such studies become even more important. Keeping this in view, a study has recently been initiated by the Wildlife Institute of India in collaboration with the University of Tromsø (Norway) to study the food habits of wild and domestic ungulates of the Western and trans-Himalayan regions of India. The study is expected to fill some of these gaps in information. This will not only provide updated information on the food and feeding habits of wild and domestic ungulates in the region but will also generate information on the niche separation and/or competition for food between wild and domestic ungulates and a plant reference database for future studies, thus contributing to the overall goal of resource management and wild-life conservation in the Himalayan region.

1. Rodgers, W. A., Proceedings of the National Range Land Symposium, Jhansi, 1988, pp. 404–420.
2. Anonymous, First Annual Technical Report, Wildlife Institute of India, International Snow Leopard Trust, 2001.
3. Schaller, G. B., *Mountain Monarchs: Wild Sheep and Goats of the Himalaya*, The University of Chicago Press, Chicago, 1977, p. 425.
4. Green, M. J. B., *J. Wildlife Manage.*, 1987, **51**, 880–892.
5. Mishra, C. and Johnsingh, A. J. T., *J. Zool. (London)*, 1996, **240**, 573–580.
6. Ilyas, O., Ph D thesis, Aligarh Muslim University, 2001, p. 259.
7. Manjrekar, N., Ph D thesis, Saurashtra University, Rajkot, 1997, p. 123.
8. Mishra, C., Doctoral thesis, Wageningen University, Netherlands, 2001, p. 131.
9. Green, M. J. B., M Sc thesis, University of Durham, 1978, p. 151.
10. Harris, R. B. and Miller, D. J., *Mammalia*, 1995, **59**, 197–212.
11. Schaller, G. B., *Wildlife of the Tibetan Steppe*, The University of Chicago Press, Chicago, 1998, p. 373.
12. Rau, M. A., *High Altitude Flowering Plants of Himalaya*, Botanical Survey of India, Calcutta, 1975, p. 234.

13. Kachroo, P., Sapru, B. L. and Dhar, U., *Flora of Ladakh: An Ecological and Taxonomic Appraisal*, Dehra Dun, 1977, p. 172.
14. Naithani, B. D., *Flora of Chamoli*, New Delhi, 1984, vols 1, 2, p. 796.
15. Aswal, B. S. and Mehrotra, B. N., *Flora of Lahul-Spiti (A Cold Desert in North West Himalaya)*, BSMS Publications, Dehra Dun, 1994, p. 761.
16. Singh, S. K. and Rawat, G. S., *Flora of Great Himalayan National Park, Himachal Pradesh*, BSMS Publications, Dehra Dun, 1999, p. 304.
17. Gaur, R. D., *Flora of the District Garhwal North West Himalaya (with ethnobotanical notes)*, Trans Himalayan Publications, Srinagar, Garhwal, 1999, p. 811.
18. Rawat, G. S., *Parks*, 1998, **8**, 27–36.
19. Rawat, G. S. and Adhikari, B. S., Report submitted to the ICIMOD, Nepal and Wildlife Institute of India, Dehra Dun, 2002, p. 32.
20. Sundriyal, R. C., *Environ. Ecol.*, 1989, **7**, 247–249.
21. Negi, G. C. S., Rikhari, H. C., Ram, J. and Singh, S. P., *J. Appl. Ecol.*, 1993, **30**, 383–394.
22. Rawat, G. S. and Uniyal, V. K., *Environ. Conserv.*, 1993, **20**, 164–167.
23. Sathyakumar, S., Ph D thesis, Saurashtra, University, Rajkot, 1994, p. 244.
24. Fox, J. L., Nurbu, C., Bhatt, S. and Chandola, A., *Mt. Res. Dev.*, 1994, **14**, 39–60.
25. Kala, C. P. and Rawat, G. S., *Trop. Ecol.*, 1999, **40**, 69–74.

ACKNOWLEDGEMENTS. We thank the Director, Wildlife Institute of India for facilities and encouragement. We also thank Dr J. L. Fox, Dr Y. V. Bhatnagar and two unknown referees for their valuable suggestions and comments.

Anjali Awasthi, Sanjay Kr. Uniyal, Gopal, S. Rawat and S. Sathyakumar are in the Wildlife Institute of India, P.O. Box #18, Chandrabani, Dehradun 248 001, India*
**For correspondence.*
e-mail: awasthy_9@yahoo.com

SCIENTIFIC CORRESPONDENCE

Emergence of a *Microcystis* bloom in an urban water body, Kandy lake, Sri Lanka

Restoration and management of eutrophic water bodies located in urban centres are priorities in the socio-economic agenda of local governments, urban councils, city missions, etc. A variety of bottom-up and top-down strategies have been tested (e.g. diversion of effluent outfalls, dredging, aeration, chemical treatment, bio-manipulation, watershed management, etc.) around the world, and there are success stories and failures[1,2]. Failures in restoration and sustainable management of eutrophic, urban water bodies, especially in developing countries are primarily linked with poor knowledge of hydraulic balance, limnological processes and dynamics of particular aquatic systems, and disturbances in the watershed or within the water body triggered by human activities. Trophic evolution and subsequent eutrophication is fundamentally a chronological phenomenon[3]. However, sudden outbreaks of algal blooms in eutrophic water may be linked with other unknown factors[4]. Silva and Schiemer[5] emphasize the human factor as the fourth dimension of reservoir limnology in the tropics. Hydraulic balance is rigorously manipulated in the tropics, resulting in sudden changes in limnological processes and dynamics[6]. Shallow man-made water bodies in monsoon Asia show a distinct annual trophic shift from mesotrophic to eutrophic, resulting from rainfall-bound filling and progressive water release to meet the demand in the command area[7].

A chronic cyanobacteria species, *Microcystis aeruginosa* which had some toxin-producing strains (L. P. Jayatissa, pers. commun.) emerged as a bloom and formed into a thick scum with the onset of the southwest monsoon in May 1999, in an aesthetic urban water body popularly known as the Kandy lake located in the tourist capital of Sri Lanka. The emergence of this bloom in the Kandy lake has become a major socio-political issue because of its very location, adjoining the world-famous Buddhist Temple, Dalada Maligawa where the sacred tooth relic of Lord Buddha is preserved. The unique characteristics of this water body and its watershed, and limnological structure and dynamics observed since 1997 to the dry season of 2002 are highlighted here to justify the most likely scenario for the sudden emergence of a *Microcystis* bloom. Some appropriate and important strategies that could be implemented for the restoration and management of eutrophic water bodies of this nature which are common in south and southeast monsoonal Asia, are also discussed.

The Kandy lake (7°18′N; 80°39′E) located at 510 m msl was constructed by the last King of the Sinhalese monarchy between 1810 and 1812 by forced labour, to enhance the panoramic beauty of the royal palace complex and the surrounding temples. It is 18 ha in area and 13 m in maximum depth and has a capacity of 0.348 MCM within a perimeter of 3.25 km. Kandy, the second largest city and also known as the hill capital of Sri Lanka, is presently renowned as one of the key heritage cities in the world because of its cultural legacy, archaeological importance and aesthetic value. Located adjoining the most esteemed religious centre, fishing and bathing are prohibited in the lake and the lake water is neither used for irrigation nor for other domestic purposes. Two small brooks feed the lake, and water spills over only during the rainy season (October–December). Evaporation losses are high during the dry months (February–March). Further, the lake which has two morphologically distinct basins (deep and shallow), has no prominent littoral zone and the entire perimeter is surrounded either by public roads or cement and concrete walls. Erosion and subsequent transport of sediment have resulted in substantial siltation of about 1.5 m