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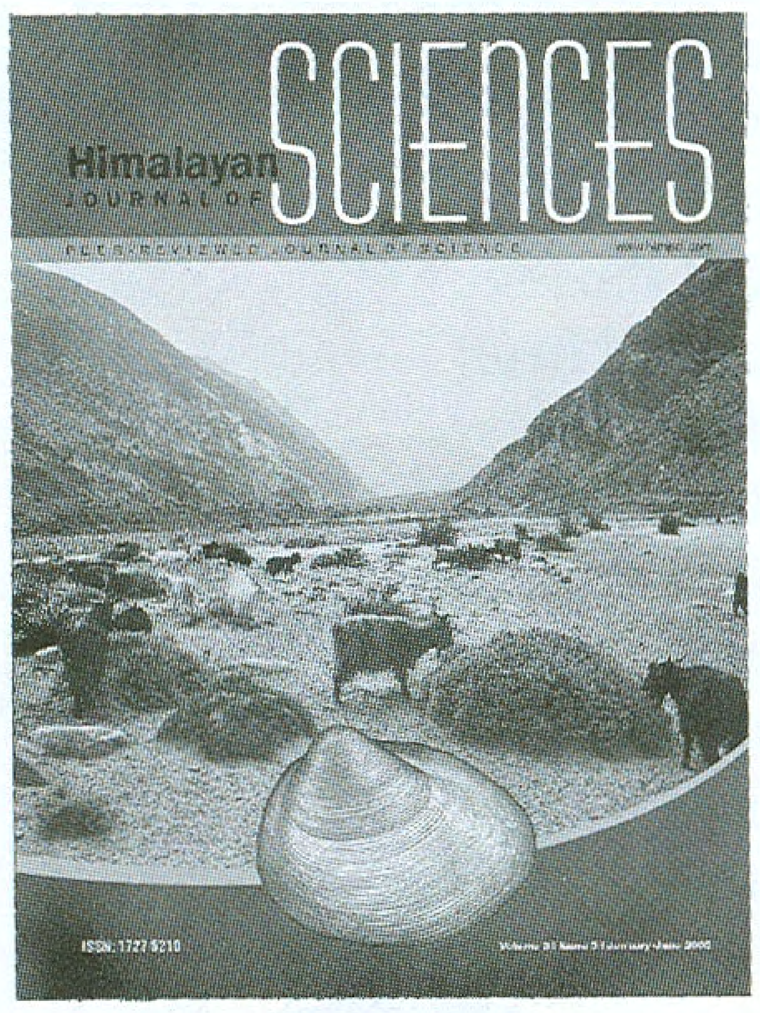

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Cover image
Diverse vegetation at 3800 masl in the Kaligandaki Gorge, Mustang, Western Nepal. Photo courtesy of RP Chaudhary
Below: *Pisidium (Afropisidium) clarkeanum.* Story on Page 63

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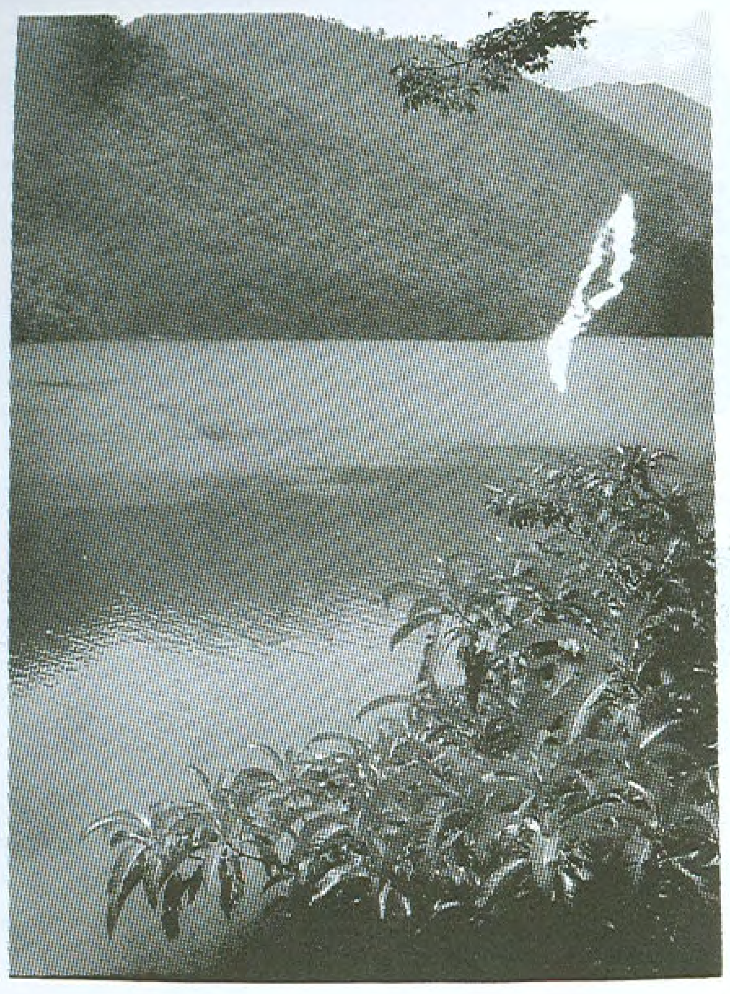

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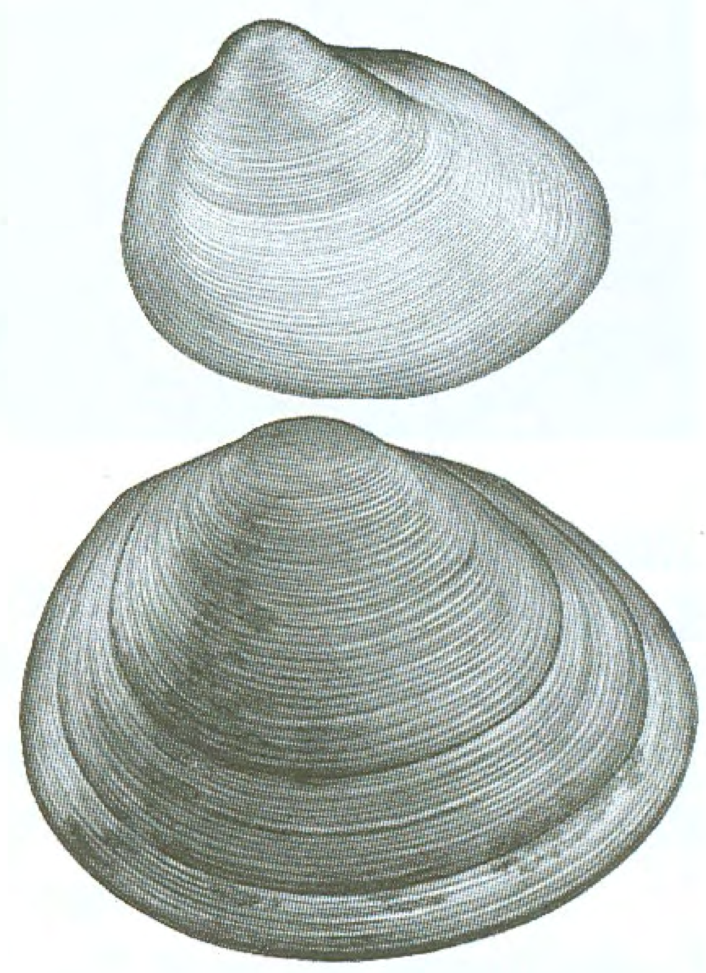

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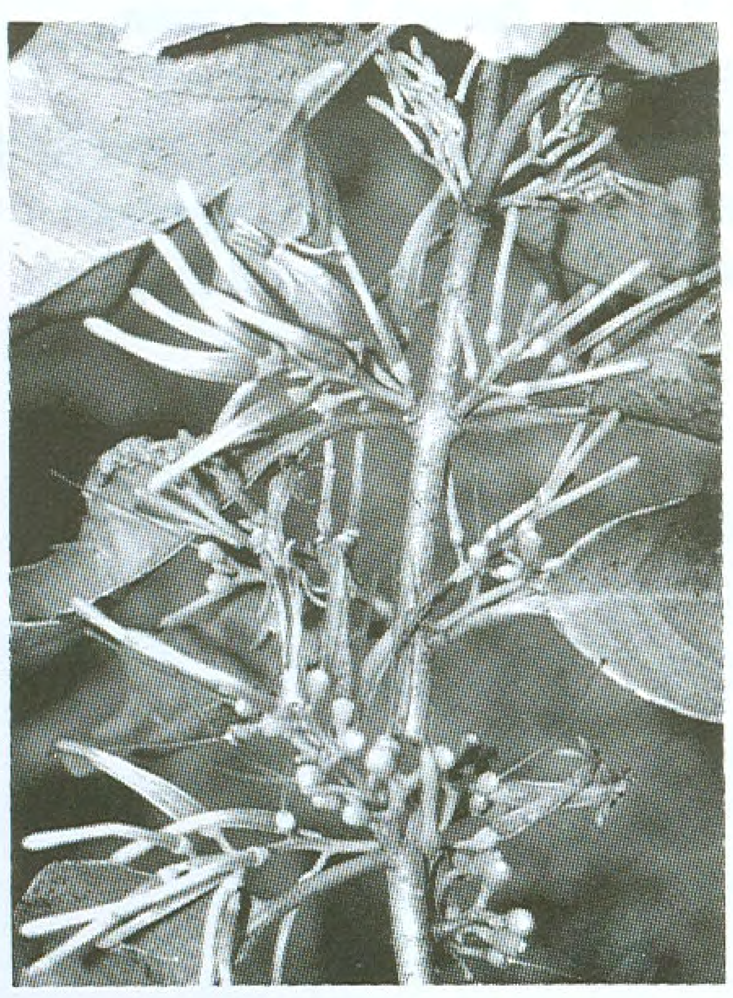

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Plagiarism: *Ke Garne ?*

Academic fraud must have consequences

A few days ago, as we were rushing to press with an issue that has been plagued by unforeseeable delays, we found that one of our articles contained plagiarized material.

"Tut-tut," you say. "A purloined phrase... an undocumented source? Where's the harm? Everybody does it!"

Purloined phrase? Not quite. One of the sources cited for apparently minor points was in fact looted: page after page was lifted verbatim, along with the major conclusions, which were simply grafted onto the article that we were about to publish.

And where's the harm? Well, forgive our petulance, but we wasted hours and hours of our time on a 36-page manuscript, reviewing, revising, and eventually exposing it. The cover, contents, and layout of this entire issue had to be redone. All of which is trivial compared to the fiasco narrowly averted. Had we actually published the article, we would have directly injured the original author (and his publisher), whose intellectual property and professional stock-in-trade were stolen; we would have brought disrepute on ourselves and our journal; and we would have been exposed to legal and financial repercussions, including the danger of diminished support from those on whom the ultimate success of the journal depends.

An even greater loss is now incurred by us all through the thwarted dissemination of important information and ideas. The article in question applied findings pertinent to one group of endangered fish, whose genetic diversity and is threatened by captive breeding and realease, and proposed that the same might be true of a group of Himalayan fish. Such applications of published scholarly research represent the best-case scenario for our journal, our readers, and our society; yet we are no choice but to withdraw the article.

Everybody does it? Academic dishonesty is certainly rampant, and probably nowhere more than in Nepal, where political, commercial, and legal corruption have a solid schooling in our educational system. All the more reason to take a stand and do something about it.

First of all, we will review and clarify our guidelines for contributors, in order to minimize the likelihood of inadvertent plagiarism. Second, we are considering a policy of public exposure of all those who use or attempt to use the *Himalayan Journal of Sciences* to perpetrate intellecual fraud. Third, we are taking steps to organize a symposium of publishers, academics, and legal experts in order to develop strategies for dealing with a problem that undermines our institutions and threatens our future, as well as other forms of scientific misconduct.

We invite your input and collaboration. ■

It wasn't your typical fish story. This wasn't a fisherman exaggerating the size of the one that got away — it was a case of massive plagiarism. Fortunately, HJS editors caught it before the story went to print, but we paid a price in time, money, and goodwill. Now we have to think seriously about what we can do to protect ourselves from intellectual dishonesty. We invite your suggestions and your collaboration.

Nepalese malacology trails behind

"Catch up!"

Prem B Budha

Mollusks of the world are, in general, more thoroughly documented than other invertebrates. This is the case for the Himalayas as well – except in Nepal. A scant 139 species have been reported from Nepal, but the new sightings reported every year and the high percentage of endemism (94.6 for terrestrial and 47.8 for aquatic mollusks) both suggest that a focused and accelerated study of these creatures is warranted. However, inauspicious externalities indicate that, for the foreseeable future, progress is unlikely to exceed the proverbial snail's pace.

In terms of biological diversity, the Himalayan region is one of the world's richest ecosystems (Pei and Sharma 1998) and has been identified as a "biodiversity hotspot." Although Nepal constitutes only about 0.09% of the world's land area, it harbors a remarkable number of faunal species: 4.5% of all mammals, 9.5% of birds, 1.2% of amphibians, 2.03% of reptiles and 6.8% of butterflies and moths. China, which is 65 times greater in area than Nepal, is home to only 12.5% of the world's mammals, 6.3% of the birds, 9.1% of the amphibians and 18.8% of the reptiles. Similarly, India is 16 times greater than Nepal, but can claim only 8.6% of the mammals in the world, 13.3% of the birds, 4.3% of the amphibians and 7.2% of the reptiles (Pei 1996).

Unlike many other invertebrates, mollusks throughout most of the world are taxonomically a relatively well-known group. There are databases for Eastern Himalayan mollusks (covering Assam, Darjeeling, Arunachal, Meghalaya, and Burma) and also for Western Himalaya species (including those of Jammu, Kashmir, Himachal Pradesh and Gahrwal). No such database exists for mollusks of the Nepal Himalaya. Inadequate data and information management is considered a significant threat to Nepal's biodiversity conservation (MFSC 2002). Sporadic reports on the phylum from Nepal Himalaya are scattered in articles and dissertations throughout the world and not readily accessible to researchers; they have yet to be included in Nepal's biodiversity databases. Nonetheless, the existing databases reveal that the Himalayan region as a whole is rich in endemic mollusks: 94.6% of the terrestrial species and 47.8% of the freshwater species found in the eastern and central Himalayas are found *only* in the regions (Dey and Mitra 2000). Much taxonomic work remains to be done, particularly in Nepal, where we may expect to discover numerous endemic species of both terrestrial and freshwater mollusks, as well as new species, in the many unexplored and isolated microhabitats within the severely compressed bioclimatic zones (from tropical to nival) generated by the extreme altitudinal gradient (60 to 8848 masl in a country that is on average only 193 km wide). Without complete information on this important zoogeographic region, the world database of malacofauna remains woefully incomplete.

Taxonomic expertise is an indispensable foundation for estimation of global biodiversity and formulation of conservation policy (Golding and Timberlake 2002). The Seventh International Malacological Congress in 1980 recommended that governments, universities, museums and conservation agencies be urged to promote research on the taxonomy of mollusks (IUCN 1983). Article 7 of the Convention on Biological Diversity (CBD), which Nepal ratified in 1993, stipulates the importance of identification and monitoring of species and assemblages. Decision II/8 of the second meeting of the Conference of the Parties to the CBD identified the lack of taxonomists as a significant impediment to the implementation of the Convention at the national level. More recently, a workshop of the South Asian Loop of BioNet-International (SACNET) was held in Bangladesh (2003 June 15-20) in conjunction with the third regional session of the Global Biodiversity Forum (GBF) for South Asia; again, the participants emphasized the taxonomic impediment to implementation of the CBD for the whole region. Sadly, even two decades after the first wake-up call, taxonomic expertise on mollusk is shockingly poor in Nepal.

Taxonomic work in Nepal has proceeded at the proverbial mollusk's pace due to lack of advanced tools, trained staff, research infrastructure, logistic support and incentives for researchers. According to published resources, *Pupilla eurina* was the first mollusk reported from Nepal; Benson identified it as *Pupa eurina* in 1864 (Gude 1914). In 1909, more than four decades after the first report, Preston (1908) identified *Limnaea (Gulnaria) simulans* from a Nepalese specimen in the collection of the Indian Museum, Calcutta. Subba Rao (1989) details 285 species of freshwater mollusks collected in India, Pakistan, Bangladesh, Burma, Sri-Lanka and other adjoining countries. In Rao's handbook, the malacofauna of Nepal is represented by only two species – *Bellamya nepalensis* and *Lymnaea andersoniana*. Recently, Dey and Mitra (2000) reviewed 689 species of freshwater and land mollusks found in the Himalayas; again, Nepal's mollusks are almost entirely absent, with only two species mentioned – *L. andersoniana* and *Pupilla eurina*. Scientists from other regions have carried out taxonomic research on mollusks during short expeditions to Nepal. They have identified many new taxa and their work indicates that Nepal is a promising area for further biodiversity and taxonomic research. In the literature survey, I found 139 species of mollusks (83 terrestrial and 56 freshwater) reported so far from Nepal, and new finds have been recorded every year. The discovery of two new genera of terrestrial mollusks: *Ranibania* (Schileyko and Kuznetsov 1996) and *Nepaliena* (Schileyko and Frank 1994), and eight new terrestrial species: *Hemiphaedusa martensiana* (Nordsieck 1973), *H. kathmandica* (Nordsieck 1973), *Laevozevrinus nepalensis* (Schileyko and Frank 1994), *L. mustangensis* (Kuznetsov and Schileyko 1997), *Himalodiscus aculeatus* (Kuznetsov 1996), *Pupinidius tukuchensis* (Kuznetsov and Schileyko ➡

1997), *Anadenus nepalensis* (Wiktor 2001) and *Limax (Limax) seticus* (Wiktor and Bössneck 2004) indicate that Nepal is rich in endemic terrestrial mollusk taxa. Nesemann and Sharma (2003) reported 45 species of aquatic mollusks (25 gastropods and 20 bivalves) from lowland (Terai) regions of Nepal; none of them are endemic. However, further study of freshwater mollusk taxonomy is required in order to more accurately assess Nepal's endowment. Recently several works have been undertaken to remedy the data deficiency of this important phylum (Subba and Ghosh 2001, Nesemann *et al*. 2001, Budha 2002, Nesemann and Sharma 2003 and Subba 2003).

Mollusks have significant economic value for the poor people and indigenous communities in Nepal and neighboring countries. Various freshwater bivalves and snails are used as a source of cheap animal protein, and the shells are used in traditional art. Lime produced from bivalve shells is mixed with chewing tobacco. Terrestrial slugs have been used in traditional treatments for body pain, fractured bones, and general health, as well as in dietary supplements to improve the yield of dairy cows (Budha 2002). Twenty ethnic groups in Bangladesh consume snail meat (Jahan and Rehaman 2000), and in India the shells are used in the manufacture of buttons, ornaments and lime. Four species of mollusks in Bihar and seven in Mizoram have been used by people as food (Subba Rao and Dey 1986). Shellfish are also useful in improving vision and in controlling diarrhea and gastric disorder (Suba Rao 1989). In addition, mollusks are also useful indicator for biological assessment of water quality monitoring (Nesemann and Sharma 2005, this issue paper, page 57-65). Some snails and slugs also act as intermediate hosts for parasites of domestic and wild animals. *Lymnaea sp.* is a causative agent for human schistosomiasis, and many countries have given high priority to its control (WHO 1993). Likewise, certain invasive land snails have also emerged as pests, causing substantial losses of vegetable crops in various regions of Nepal (Raut 1999). There are, however, no data available on specific shellfish-dependent ethnic groups, mollusk-harvesting practices, or impact on human health.

The systematic deposition of voucher specimens in scientific institutions and access to these collections can stimulate interest in taxonomy among young scientists. Such resources are lacking in Nepal. The primary institution for maintaining records of voucher specimens, the Natural History Museum in Swayambhu (Kathmandu), has no collection of Nepalese mollusks. Only 20-25 species of freshwater and land mollusks are represented in the museum of the Central Department of Zoology, Tribhuvan University in Kirtipur, and these have not been authoritatively identified or competently preserved. One auspicious development is the deposition of 56 authentically identified species of freshwater mollusks from Nepal at Kathmandu University (KU), Dhulikhel (Nesemann 2005, personal communication).

Clearly the need for a database on mollusk diversity within Nepal is urgent. To fill this information gap, I offer the following recommendations:

- The Natural History Museum and the universities of Nepal should undertake the proper deposition of voucher specimens of Nepalese malacofauna.
- Research institutes and conservation organizations should offer research opportunities for young taxonomists.
- The collection of baseline information on mollusks, including spatial diversity, distribution and ethno-malacology, should be established as a national research priority. ■

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Himalayan misconceptions and distortions: What are the facts?

Himalayan Delusions: Who's kidding who and why — Science at the service of media, politics and the development agencies

Jack D Ives

EDITOR'S NOTE: Jack Ives' article, drawn from his new book *Himalayan Perceptions*, is a cautionary tale that might almost be read as a gloss on Peter Weingart's "Moment of truth for science" (see page 11-14). Ives begins by recounting the life and times of the "Theory of Himalayan Environmental Degradation," a grossly exaggerated but convenient "theory of everything" that suited almost everybody's agenda — from the media (always hungry for neatly packaged disaster scenarios), to the politicians (happy to point fingers conveniently away from their own failings), to the developers (ready and willing to focus their energies in the pleasant hills of Nepal rather than the steamy lowlands of Bangladesh and India), to the scientists (eager for fame and funding). True to Weingart's prediction, there was a scientific reaction to the alarmist theories: the Mohonk Conference successfully rallied a generation of "montologists" to investigate critically the bases for predictions of Himalayan deforestation and subcontinental flooding. As a result, the theory was effectively debunked. Unfortunately, it seems to rear its head now and then — most notably in China. And, even more unfortunately, there seems to be a ready supply of successor theories. One media favorite is the impending catastrophic collapse of glacial lakes swollen by glaciers retreating in the face of global warming. Let's hope that Weingart's optimism is justified: melting glaciers and glacial lake outburst floods (GLOFs) obviously deserve scientific attention. The question is, will the media and politicians pay any attention at all if researchers predict something less than a super-catastrophe?

It is more from carelessness about truth than from intentional lying
that there is so much falsehood in the world.
— Samuel Johnson 1778

This paper is a modified version of Chapter 10 of my recently published book: *Himalayan Perceptions: Environmental change and the well-being of mountain peoples* (Ives 2004). The original chapter title: *What are the facts? Misleading perceptions, misconceptions, and distortions,* is intended to draw attention to what I regard as one of the major problems facing effective development and the relief of poverty characteristic of much of the Himalayan region. Mistaken, or deliberately constructed self-serving policies have been exacerbated by false or misunderstood reporting and exaggeration since the beginnings of 'foreign aid' shortly after the end of World War II. My discussion is presented to *The Himalayan Journal of Sciences* because of the on-going urgency and because the book itself, published in hard cover edition in London and New York, has an unfortunately high price such that it will likely find only modest distribution in South and Central Asia.

The aim is to address the confusion brought about by a combination of lack of academic rigour in the early stages of the propagation of the myth of Himalayan environmental degradation, aid agency and news media carelessness, and the unsubstantiated basis for some of the policies of regional governments. Thompson and Warburton's (1985) now famous challenge, *what are the facts?* was originally introduced as part of the refutation of the then widely accepted view that deforestation in the Himalaya by poor farmers was responsible for increased flooding in Gangetic India and Bangladesh. Nevertheless, even with the great increase in research across many disciplines and inter-disciplines since about 1990, their own provocative response to the question remains relevant: 'What would you like the facts to be?'

Central government agencies in India, Thailand, China, and Nepal, for instance, certainly appear to want the 'facts' to support their policies that are frequently based upon the assumption that 'ignorant' mountain minority farmers are devastating the forests and so causing serious downstream environmental and socio-economic damage. The Government of Bhutan largely fabricates its perception of 'truth'. And there has been a continual flow of news media and environmentalist publication to the effect that death and destruction on a large scale are imminent, whether the result of unwise resource extraction by mountain people or due to global forces, such as climate warming. Is it all part of a game? If so, it is a very serious and dangerous game.

This paper examines the larger issues of how Himalayan perceptions have arisen, how many have been misleading, misconceptions, even seemingly deliberate distortions. In contrast, many commentaries and recommendations have been eminently reasonable and have contributed to the eventual inclusion of Chapter 13 in Agenda 21 following the

1992 Rio de Janeiro *Earth Summit.* This in turn was the vital turning point that led to the United Nations designation of 2002 as the *International Year of Mountains*. It is appropriate, therefore, to go back to the origins of the Theory of Himalayan Environmental Degradation and to work forward from there.

The theory of Himalayan environmental degradation

This topic is introduced here to set the stage for examination of the way in which perceptions of Himalayan development and environmental stability have been, and are being distorted. Other scholars, or developmental practitioners, or environmentalists may select alternate starting points. However, the GTZ-UNESCO conference of December 1974 in Munich can be regarded as the initiation of a worldwide discourse on environmental problems of the Himalaya. The formal topic in Munich was *The Development of Mountain Environment* and it brought together a diverse group of participants – diverse nationalities, disciplines, and professions. The impacts of the 1972 Stockholm Conference on the Human Environment had only recently been felt. Similarly, the then recent winding down of the International Biological Programme (IBP) had begun to influence the formulation of the UNESCO MAB–Progamme, Project–6, and had demonstrated the applicability of computer modelling.

The Munich participants were presented with a series of well-intentioned, if disturbing, scenarios. Many were based on apparently first-hand experience in the Himalaya, others were derived from experience elsewhere, and yet others depended upon rational thought arising from formal conventional education, or a combination of the above. The participants were alerted informally to GTZ's plans for providing funds to establish an international mountain research and development institution; that it would probably have been headquartered in Tehran because the Shah of Iran of that time had indicated that he would provide many more millions of dollars.

A feeling of dire emergency was generated at the conference, together with a sense of opportunity. Something must be done to save the world's mountains; mountain regions in the developing countries were most seriously at risk; and the Himalaya warranted special attention. A Munich Manifesto was deliberated and unanimously approved. There were suggestions that a 'Club of Munich' should be formed to imitate environmentally the Club of Rome, proceedings were published, and press releases were initiated. Nevertheless, the proceedings (Müller-Hohenstein 1974) were eminently constructive and constrained. A request was made for accentuated mountain research linked to development policy and the creation of a scholarly publication outlet for the results of such research. The need for informing United Nations agencies, national governments, and world opinion at large was underlined. Frank Davidson (in Müller-Hohenstein 1974: 186) urged establishment of an independent mountain research institution with appropriate links to United Nations agencies and universities and, taking cause from the widely recognized contributions of *Oceanography*, recommended consideration for establishment of *mountainology* (to become *montology* – Oxford Dictionary 2002 edition). Very little of the informal discussions about an environmental crisis in the Himalaya appeared in the proceedings. The closest, yet oblique reference appears in the summary report of the proceedings:

> But these mountain regions are seriously and increasingly affected by processes of deforestation, soil erosion, improper land use, and poor water management. Overuse of mountain environments has a widening impact on the plains with downstream floods, the siltation of dams and harbours and on the damage of crops and of homesteads.
>
> (Müller-Hohenstein 1974: 5)

Thirty years later, following a considerable increase in mountain research (both academic and applied) and much wider recognition of the importance of mountain regions, the general statements emanating from the Munich Conference read as eminently rational. But in terms of the last three decades of melodramatic recounting by the news media of Himalayan deforestation causing catastrophic flooding in Gangetic India and Bangladesh, Eric Eckholm's statement in the Munich proceedings is revealing:

> If deforestation in Nepal and Kashmir threatens the survival of three-quarters of a billion people in South Asia, and indirectly will affect the political and economic well-being of people in Tokyo, New York, and Munich, then these facts should be in the newspapers every week in all of these countries. But I read several newspapers every day, and have followed the accounts of many major devastating floods over the last few years, and I have discovered that *the news accounts never mention deforestation as a cause of the flooding*. The collective knowledge of the minds in this room, if distilled in the proper form, would horrify and astound millions of people and hopefully goad them into the needed actions. The question is: How will we help them find out before it's too late.
>
> (my emphasis)
> Müller-Hohenstein 1974: 131

Thus it is reasonable to conclude that the Munich Conference of 1974 served indirectly, rather than directly, as the flashpoint for propagating widespread acceptance of the notion of imminent environmental catastrophe in the Himalayan region*. The innumerable literature references to Eckholm's paper in *Science* (1975) and to his book (1976) show how the assumptions, portrayed with such skill and intellectual appeal in these two publications, dominated mountain environment and development thought over the next 15 years; and the catastrophe discourse has remained highly influential in many areas of government and institutional decision making to the present time.

Despite earlier cautious reaction to the deforestation/ landslide /downstream flooding scenario (Ives 1970) I recall being swept up by the sense of urgency in Munich. Nevertheless, the seeds were sown for eventual publication of the journal *Mountain Research and Development* in 1981, and for the establishment in 1982 of the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu.

Following the Munich Conference, however, it appeared that writers, academics, agency personnel, and politicians were seeking to out-perform each other by moving progressively through repetition to hyperbole. No new 'facts' were needed, only the repetition and enlargement of existing 'facts'. Thompson et al. (1986) argued that these 'facts' were precisely what the agency personnel required in seeking to enlarge their development budgets and to expand and prolong their presence in Nepal, long regarded as one of the most attractive locales for appointment of expatriate bureaucrats by donor agencies (how that situation has changed when today's events are considered!)

The now notorious World Bank (1979) prediction of total loss of accessible forest cover in Nepal by 2000 was very powerful. The 'State of India's Environment: A Citizen's Report' (1982) spoke with great authority in similar terms, as did the World Resources Institute (1985) and the Asian Development Bank (1982). Likewise, internationally respected foresters and environmentalists raised the spectre of Khumbu forest devastation, perceived as a necessary part of the struggle for establishment of the Sagarmatha National Park. It should be noted, however, that the Khumbu was a special case for it was there that the imminent disaster scenario had unfolded early and independently of the Munich Conference and only later merged with the general demand for mountain forest protection as a prime approach to averting environmental disaster. All of the foregoing were powerful institutional forces that drove the complex of assumptions for which the short-hand term *Theory of Himalayan Environmental Degradation* was coined.

During the first 10–15 years following the Munich Conference the majority of academic publications concerned with the Himalayan region, or parts of it, both echoed and replenished the news media campaign and the *myth* of Himalayan environmental degradation became firmly embedded in world opinion. However, after about 1983, first a trickle, and then a flow of academic publications began to discredit the *myth* although, for the most part, the news media continued on course, as did many of the vested interests of the region. The process of Himalayan environmental discourse and its split into two opposing streams will be illustrated by a selection of short quotations, citations, and comments.

Academic and research publications

There were innumerable references in scholarly and research publications that advanced and reinforced the Theory:

Eckholm (1975 *Science,* 189: 764–70: referred to above)
Rieger (*in* Lall and Moddie 1981: 351–76)

These papers provide a parallel discourse to Eckholm (1976) except that Rieger (1981), in particular, develops a series of computer simulations demonstrating relations between population growth, deforestation, soil erosion, and downstream impacts. However, Rieger's approach does foresee a much longer time interval for total elimination of all Himalayan forests.

Ives and Messerli (1981: 229–30–based on an initial reconnaissance for field work in the Kakani area, Nepal):

Loss of soil and loss of agricultural land through gullying and landsliding are occurring more rapidly than the local people with their existing resources can replenish. This is true without considering the deterioration to be anticipated by projecting the current rate of population growth into the future.

To be somewhat redeemed by the following:

It is also believed that involvement of the local people in every planning stage and incorporation of their experience will prove critical.

Karan and Iijima (1985: 81):

One-fourth of the forests of the country has been cut in the past decade. If this trend persists, the remaining forest area may be denuded in another twelve to twenty years.

Karan and Iijima (1985: 84):

The Kulu Valley, formerly a picturesque scene of deodar trees, some forty-five meters high . . . is now almost barren.

This statement should be compared with other interpretations of the Kulu landscape that emphasize the excellent degree of preservation of the Kulu Valley forests (reviewed in Ives 2004, Chapter 3: 113).

Myers (1986):

This paper is also a parallel statement to those of Eckholm (1975) and Rieger (1981).

Literature on deforestation in the Khumbu Himal, Nepal

Blower (1972, cited in Mishra 1973: 2):

. . . depleting forests of the Khumbu . . . since destruction would result in disastrous erosion leading to enormous economic and aesthetic loss to the country.

Lucas et al. (1974) wrote that the members of the New Zealand mission:

. . . saw too much evidence of incipient erosion to feel other than a sense of deep concern for the future.

Fürer-Haimendorf (1975: 97–8):

Forests in the vicinity of the villages have already been seriously depleted, and particularly near Namche Bazar whole hillsides which were densely forested in 1957 are now bare of tree growth and the villagers have further and further to go to collect dry firewood.

Speechly (1976: 2):

. . . forest areas in the proposed Sagarmatha National Park are, as a result of a combination of influences, in a depleted state, such that if present pressure of use is continued, severe environmental damage will result.

Hinrichsen et al. (1983: 204):

. . . more deforestation [has occurred in the Khumbu] during the past two decades than during the preceding 200 years.

In contradiction to the above, Charles Houston (1982, 1987), as a member of the 1950 Mount Everest reconnaissance from the south, had revisited the Khumbu in 1981. He wrote that, with the exception of a thicket of dwarf juniper at Pheriche there was:

as much or more forest cover than there was in 1950 and I have the pictures to prove it.

International agencies

World Bank (1979):

Nepal has lost half of its forest cover within a thirty-year period (1950–80) and by AD 2000 no accessible forests will remain.

Asian Development Bank (1982):

. . . distinct danger that all accessible forests, especially in the Hills, will be eliminated within less than 20 years. (ADB 1982, Vol. 1, p. 12)

On page 63 of ADB Volume 2, the alarm is somewhat heightened by the prediction of forest elimination within 14 years.

World Resources Institute (1985):

. . . a few million subsistence hill farmers are undermining the life support of several hundred million people in the plains.

United Nations Environment Programme was reported to have commented on the seriousness of the threat of deforestation in *The Bangladesh Observer*, Dhaka, 2 June 1990 under the headline *Deforestation in the Himalaya Aggravating Floods*. The article was reporting on an address to the National Seminar on Environment and Development by Dr Mustafa K. Tolba, Executive Director of UNEP, organized by the Environment and Forestry Ministry, UNDP and UNEP. It quoted Dr Tolba as stating that:

. . . the chronic deforestation in the Himalayan watersheds was already complicating and compounding seasonal floods in Bangladesh.

And added the comment that 700,000 people died in Bangladesh in 1970 because of flooding.

News media reportage

Sterling (1976 *Atlantic Monthly,* 238 [4]: 14–25 – one of the earliest and most melodramatic reports):

Between 1976 and 1986 most of the world's newspapers were predicting imminent disaster in the Himalaya and on the plains of the Ganges and Bramhaputra. The coverage ranged from *The Times*, London, to almost every local newspaper in the Western World, and in India, Nepal, Pakistan, and China. The coverage extended to leading periodic magazines, such as *Newsweek* and *Atlantic Monthly* and the conservationist literature. Television coverage was also extensive world-wide. Examples are restricted to the more recent period following 1986.

Farzend Ahmed in *India Today*, under the title *Bihar Floods: Looking Northwards*, 15 October 1987:

Each time north Bihar is devastated by floods, the state Government performs two rituals. It holds neighbouring Nepal responsible and promises to implement a master plan for flood control . . . Nepal is invariably held guilty because most of the rivers . . . originate there before flowing into the Ganga. The Bihar Government maintains that Nepal's non-cooperation lies at the root of the annual cycle of human misery . . . This time the chorus of accusation reached fever pitch when Prime Minister Rajiv Gandhi . . . demanded to know what preventative measures had been taken. . . Predictably, the [response] referred to the hill kingdom's lack of cooperation. The Nepal-bashers also scored a major victory at the Second National Water Resources Council meeting in New Delhi last fortnight. State Irrigation and Power Minister Ramashray Assad Singh managed to have the national water policy draft amended to say that the solution to Bihar's flood problems lay beyond its borders.

Begley et al. 1987 in *Newsweek,* under the title *Trashing the Himalayas – that once fertile region could become a new desert:*

Dense alpine forests once covered the lower slopes of Mount Everest, and the Khumbu Valley below the mountain used to blush dark green from its carpet of junipers. But that was the Everest of 1953, when Sir Edmund Hillary and Tenzing Norgay became the first men to conquer the highest peak on earth. Today the forest at Everest's base is 75 percent destroyed, replaced by a jumble of rocks interspersed with lonesome trees. All the Khumbu's junipers have fallen to axes . . . The degradation of the Himalayas is not confined to the tall peaks. In Pakistan, India, Nepal and Tibet, deforestation has eroded fertile top-soil from the hills, triggering landslides and clogging rivers and reservoirs with so much silt that they overflow when they reach the plains of the Ganges. . . At the rate trees are being felled for fuel and cropland, the Himalayas will be bald in 25 years . . . Although a significant fraction of the erosion stems from nature . . . most of the damage is man-made.

New York Times: 9 September 1988:

United Nations expert Tom Enhault, director of projects in Bangladesh–asserted that the environmental havoc wreaked by the destruction of the Nepalese forests have done the most damage [referring to the flooding of 1987 and 1988]. . . he also blamed over-grazing.

Sunday Star–Bulletin: Honolulu, 11 September 1988:

Bangladesh flood disaster blamed on deforestation

Flooding on a massive scale may soon become the norm . . . remarkable collapse of the Himalayan ecosystem.

A. Atiq Rahman, director Institute of Advanced Studies, Dhaka, stated 'the main environmental problem is the widespread and growing deforestation of the Indian and Nepalese mountains.' . . . B. M. Abbas, Bangladesh's leading authority on water control and for many years Minister of Water Resources said 'For so many years I have told people that trends in the mountains would destroy us.' Hassan Saeed stated that there had been 1,451 deaths and that 700,000 flood refugees had been forced to find shelter in Dhaka.

Dawn: Sunday magazine, Islamabad, 4 October 1992:

Minister for Environment and Urban Affairs, Anwar Saifullah Khan said 'the destructive power of the floods has increased manifold as a result of deforestation which has been continuing unabated in the Northern Areas of the country.'

Sacramento Bee: Sunday 1 August 1993:

Bangladesh has renewed demands that India and Nepal agree to control the powerful rivers that flow through their countries. Officials in Bangladesh say the flooding has killed at least 150 people and displaced 7 million people.

World Tibet Network News: Beijing, 28 August 1998, under the headline: *Asian Disasters Blamed Partly on Shrinking Forests: Deforestation Leads to Floods:*

Floods kill more than 2,000 people along China's Yangtze River and 370 others along the Ganges and Jamuna in Bangladesh . . . Rain across the region has been much heavier than normal this year, but World Watch Institute President, Lester Brown, said recently that a 'human hand lurks behind the floods. That hand often wields the ax or chain-saw, denuding the highlands that feed Asia's great river systems and sending greater volumes of water and silt to compound the catastrophes downstream. The forests that once absorbed and held huge quantities of monsoon rainfall, which could then percolate slowly into the ground are now largely gone. The result is much greater runoff into the rivers.

Apart from the interspersed explanatory remarks, no further comment will be added to the quotations introduced above, with a single exception. This is because the statement in the

Islamabad magazine *Dawn* (4 October 1992), attributed to Environment and Urban Affairs Minister, Anwar Saifullah Khan, is especially out-of-step with reality. The cause of the devastating floods, to which the Minister refers, has been assessed by Hewitt (1993). He was present in Northern Pakistan during the event and was able to obtain many observations on the extent of the damage and subsequently to analyze the records of relevant climate stations throughout the region. The cause was, without doubt, unusual and excessive rainfall. Furthermore, even prior to the opening of the Karakorum Highway and the accelerated and illegal logging, total forest cover of Northern Pakistan was such a minute percentage of total land area that, even if complete removal of trees had been accomplished by 1992, impact on flood magnitude would have been imperceptible.

The political implications of the official statements, however, warrant careful attention. For instance, Bihar and New Delhi authorities and politicians blame Nepal for downstream disasters due to assumed mountain deforestation; Bangladeshi authorities blame India and Nepal; the Chinese government blames the irresponsible and illegal logging by minority peoples in the upper watersheds of the Yangtze. Herein lies part of a possible explanation for institutional adherence to the Theory up to the presence. This will be discussed further below.

How was the academic tide turned?

Academics undertaking research in the Himalayan region began to reverse the tide of support for the concept of an environmental super-crisis in the early- to mid-1980s. Increasingly since 1989 the Theory of Himalayan Environmental Degradation has come to be regarded as an insupportable myth and today, while some confusion and misunderstanding remains, there is little support within academia for the totality of the notion of Himalayan environmental collapse in the form in which it originated in the 1970s. So, how was the tide turned?

A large part of the explanation is that several research groups and individuals began detailed studies about the same time (late–1970s to1980) and became aware of each other's work. The 'coming together' was greatly facilitated by emergence of the quarterly journal *Mountain Research and Development*, that in turn led to organization of the Mohonk Conference on the Himalaya–Ganges Problem in May 1986. From that point most of the linkages in the eight-point scenario that was constructed to illustrate the Theory came under increasingly critical investigation. Comparatively little rigorous environmental research had been carried out in the Himalayan region prior to about 1980. The foregoing account of the alarmist discourse in both the academic and popular literature was based upon supposition and emotion that entered policy formulation. It also entered the environmental and development politics of the region and, in turn, encouraged even greater commitment to the 'cause' of addressing Himalayan environmental degradation. Examination of many of the reports prepared for aid agencies and local governments was particularly revealing – successive consultants simply reproduced the conclusions of their predecessors. There were exceptions, although the 'white noise' was almost overwhelming.

For the United Nations University (UNU) research team in Nepal, the tide turned on entering Balami/Chhetri/Tamang villages with Nepalese students and Western university field workers. Johnson, Olson, and Manandhar (1982) quickly learned how well the villagers understood landslide mechanics and witnessed their ability to manage, even to propagate landslides themselves for constructive agricultural use. The research team was able to analyze the complexities of the environmental–socio-economic situation; year-round research with the subsistence agricultural systems helped to explode the myth, and it became apparent that it had been based upon reports of 'experts', prepared in Kathmandu's best hotels, heavily dependent on earlier reports by other 'experts' also based on Kathmandu hotels but preferably not during the summer monsoon, the peak season for landslides, leeches, and maximum discomfort for field travel.

By 1983 the research progress of the UNU team was sufficiently advanced for a public review of early results to be organized in Kathmandu. This, together with the regular publications scheduled through *Mountain Research and Development*, became one element in the turning of the tide. There were others equally effective. Most important were the Nepal–Australian Forestry Project and the involvement of the East–West Center, Honolulu. The Australian foresters and their Nepalese graduate students appreciated the 'truth' from living and working with the indigenous mountain farmers (Bajracharya 1983; Mahat et al. 1986a, 1986b, 1987). Hamilton's basic forest ecology led him to attack the notions that forests act as a sponge for excessive rainfall and that 'deforestation' is necessarily bad. He argued that the very term 'deforestation' had been abused to the point of it being reduced to the level of emotion; finally, there was his 'rain on the plain' motif (Ives 2004, Chapter 5:190). Intellectually, one of the most satisfying contributions was Thompson and Warburton's (1985) adaptation of Fürer-Haimdendorf's (1975) 'careful cultivators and adventurous traders' phrase leading to 'uncertainty on a Himalayan scale'. All of these separate strands came together as the 'Mohonk Process' (Thompson 1995; Forsyth 1996).

The answer to the question 'how was the academic tide turned?' is that the very melodrama seems to have aided in prompting the first phase of rigorous research in the Himalaya by scholars who had no restricting vested interests.

But are these the 'facts' and what are the next steps? It appears that as specific myths are identified and explained, modified, or demolished, or used to good effect (Thompson 1995), new ones spring up to take their place.

Some current myths on a Himalayan scale

A series of examples, or case studies, are introduced to illustrate the problem of misrepresentation. It is unlikely that proof can be obtained to demonstrate a causal relationship between popular reporting and policy formulation, or the reverse. It is also difficult to determine how particular exaggerations are manufactured because the news media as the channel of communication between the field research and sometimes casual observation, and popular presentation is rarely a direct line. Nevertheless, the following examples are offered because the degree of misinformation appears to be both extensive, widespread, and continuing. They are introduced, not so much because of their inherent importance, but as examples that could be multiplied many times over. They could be dismissed as part of a phenomenon that pervades all spheres of world society. Reporting on global warming, the world economy, international terrorism, or almost any disaster has become comparable to the campaign speeches politicians tend to make at election time. It has also been understood for several decades now that 'green' movements have felt compelled to exaggerate in order to compete for attention with the possible bias of well- ➡

financed campaigns of big business and industry. Regardless, the examples of 'latter-day myths' are set forth because their pervasiveness tends to clutter the sustainable development landscape and perpetuate the Himalayan scale of uncertainty.

The cause of flooding in Bangladesh

The infamous 1979 World Bank prediction of a nearly treeless Nepal within 20 years has been referred to in different contexts and its re-introduction here may be criticized as out-dated and over-used. Yet it forms a good starting point as a frequently argued explanation for flooding in Bangladesh. Two decades later, in response to the severe flooding of 1998, the *Basler Zeitung*, amongst numerous major newspapers, published the following on 15 September 1998:

> The severe floods in eastern India and Bangladesh are not the result of a natural disaster, but of ruthless exploitation of the forests which has been practiced over many centuries in the Himalayas.

The Canadian Broadcasting Corporation (CBC-TV) produced a documentary for its Newsworld programme on 21 March 2000. The topic was the cyclone of the previous September that caused extensive damage and loss of life in Orissa, India. Amidst dramatic film footage, the commentator warned the viewers that:

> . . . conditions will deteriorate further in the future because the sea level is rising as a result of deforestation in the Himalayas.

Following the Bangladesh flooding of 1998, the news media were awash with hyperbole. Yet the following quotation from the *Bangladesh Daily Star* should provoke a reflective pause:

> *Have no fear, the children are enjoying diving in the River Jumuna.*

The melodrama is surely recognizable as such, yet the fact remains that the governments of India, China, and Thailand, for instance, have all legislated logging bans on their upper mountain watersheds. Their prime justification is that large-scale commercial logging, as well as that of the mountain minority peoples, is causing extensive environmental, economic, and social losses downstream. The linkage with the Three Gorges Dam in China is a prime cause-effect assumption. The danger herein is that, even if the logging bans can be enforced, actual deforestation in the upper watersheds has not been shown scientifically to propagate downstream devastation. Although some kind of control over logging is certainly needed, in the form of consistently applied forest laws and effective forest management, the Government's policy represents an example of trying to solve a problem by confronting an assumed yet unproven cause. It is certain, however, that upstream losses are occurring. However, much of the loss is in the form of considerable hardship placed on the shoulders of the very poor people whose livelihoods depend on the forests and a shift in forest pressure onto the village community forests and the forest reserves of neighbouring countries. Neither can the widespread illegal and legal commercial logging be ignored.

The above commentary is not intended to denigrate the importance of mountain forests since they are vital to the survival of viable mountain agriculture and also have an important aesthetic value. In addition, given good management practices, they are vital for their commercial products.

Meltdown in the Himalaya

'Meltdown!' is the title of one of four papers published by the *New Scientist* as part of its celebration of the International Year of Mountains–2002 (Pearce 2002: 44–48). The core of this presentation is an explanation for the undoubted increase in flash flooding that is occurring when glacier lakes in the Himalaya (and elsewhere) break through their end moraine dams to produce destructive mudflows/debris flows/floods for many kilometres downstream. These glacial lake outburst floods (jökulhlaup – Icelandic, or GLOFS) are a topic of widespread current interest (Mool et al. 2001a and b).

There is no question that they represent a serious threat. Nevertheless, Pearce (2002) quotes John Reynolds, an experienced geotechnical consultant, as predicting that:

> . . . the 21st century could see hundreds of millions dead and tens of billions of dollars in damage . . .

from the outbreak of glacier lakes world-wide, but principally in the Himalaya and Andes. There is also the prediction that the downstream extent of such outburst floods could extend for hundreds of kilometres, cross the borders of Nepal and Bhutan, and cause extensive damage to the large Indian cities on the Ganges flood plain.

There is a factual base for Pearce's reported predictions. Two recent surveys have identified the initiation and growth of about 3,000 such lakes in Bhutan alone (Mool et al. 2001a) and about 2,000 in Nepal (Mool et al. 2001b), of which 44 have been designated as dangerous, although a majority were little more than tiny ponds. Outburst floods that have occurred have barely penetrated more than 50–75 kilometres downstream. There is no intention here, however, to deny that GLOFs are dangerous, nor to imply that serious efforts to mitigate their potential effects are not needed. But it would remain an understatement to suggest that Pearce's reporting represents an exaggeration.

Rolwaling, Nepal, and the threat from Tsho Rolpa glacial lake

The history of formation and the mechanics of development of potentially dangerous glacial lakes, including Tsho Rolpa, have been described in some detail by several authors (see Ives 2004, Chapter 6). Here emphasis is placed on socio-economic and psychological consequences that arose in 1997 from reactions to a report that Tsho Rolpa was on the brink of a catastrophic outbreak. The discussion is taken from a published blow-by-blow account by Gyawali and Dixit (1997) and personal comments (Gyawali 22 November 2003).

Concerns for the safety of the inhabitants of Rolwaling valley were expressed by the lake survey team in 1996, and the Government of Nepal requested a more detail examination of the end moraine that forms the dam for the expanding lake. This was undertaken in May 1997 by Reynolds Geo-Science Ltd., in collaboration with the Nepal Department of Hydrology and Meteorology (DHM), funded by the British Government. Following the field survey, a seminar was held in Kathmandu to facilitate public and government review. The report presented by the consultants was cited as eminently cautious and responsible. However, following the seminar, oral presentation to the news media appears to have created the impression that a catastrophic flood was about to be released momentarily. This produced panic amongst the public and government departments and amongst many of the inhabitants living below the lake all the way down to the frontier with India. The panic prompted the local Member of Parliament to demand immediate government action. It was considered that such a flood would directly affect 4,000 people in 600 households of 18 villages. The warden of the Kosi Tappu Wildlife Reserve in the Terai reported that 175 km^2 of the reserve would be destroyed with the loss of 200 wild buffaloes, 400 species of birds, as well as crocodiles, deer, wild boar, snakes, dolphins and other precious animals. It was also contended that the flood would wash away the Kosi Barrage threatening enormous losses in Bihar, India.

The Royal Nepal Airline Corporation (RNAC) suspended flights to the lower area, villagers were evacuated, and workers at the Khimti hydro-electricity project, as well as 90 per cent of the people of Kirnetar, began to evacuate. Police and army posts were set up in the Rolwaling valley.

Many more details of the panic are provided in Gyawali and Dixit (1997) who also estimated considerable personal loss on the part of many people who were induced to leave their homes. Yet the villagers living near Tsho Rolpa, who had observed the seasonal fluctuations in the lake level for years refused to move 'asking the police not to speak nonsense' (Gyawali and Dixit 1997: 24).

RNAC resumed its regular flights on 13 July 1997. By the end of July the flood level of the Tama Kosi, into which the Rolwaling drainage empties, had fallen to almost winter flow conditions and the people who had fled their homes began to return. The results of the affair in Kathmandu included widespread journalistic charges that the rumour of a possible Tsho Rolpa outburst flood had aided expatriate consultants and Department of Hydrology and Meteorology officials to prepare an outrageously expensive proposal for artificial lowering of the lake level for their own financial benefit (Gyawali and Dixit 1997: 33).

The discussion illustrates the severe problem of how authorities should react to potentially lethal mountain hazards that are notoriously difficult to predict with any precision. It underlies the need, not only for extensive survey and monitoring of hazardous mountain phenomena, but also for the establishment of a responsible review and reporting mechanism. In the Tsho Rolpa case by far the most serious losses were caused by the panic reaction to what appears to have been a rumour. Glacial lake outburst floods do occur, as the carefully surveyed case of Dig Tsho of August 1985 illustrated. Following that event, the Government remained lethargic for nearly a decade; by 1997 it appears that the reaction had moved to the opposite extreme – one of panic.

On a related theme *The Times* of London (21 July 2003), reporting on an international meeting held at the University of Birmingham, noted that 'Himalayan glaciers could vanish within 40 years because of global warming . . . 500 million people in countries like India could also be at increased risk of drought and starvation.' Syed Hasnain is quoted as affirming that 'the glaciers of the region [Central Indian Himalaya] could be gone by 2035'.

According to Barry (1992: 45) the average temperature decrease with height (environmental lapse rate) is about 6^{o}C/km in the free atmosphere. The dry adiabatic lapse rate (DALR) is 9.8^{o}C/km. If it is assumed that the equilibrium line altitude (comparable with the 'snow line') in the Central Himalaya is about 5,000 masl and it will need to rise above 7,000 m if all the glaciers are to be eliminated, then the mean temperature increase needed to effect this change would be about 12–18^{o}C. Given that degree of global warming, summers in Calcutta would be a little uncomfortable.

The Khumbu and Sagarmatha National Park

As indicated earlier, myths tend to be self-perpetuating. In practice their longevity is often encouraged by vested interests of one form or another. Sagarmatha National Park is perhaps the most likely location in the entire greater Himalayan region for such perpetuation. Conflicting reports and stories here began with Byers's disagreement with the claims for extensive deforestation by Fürer-Haimendorf and the New Zealand foresters as part of the campaign to ensure the gazetting of the world's highest national park (Byers 1986, 1987, 1997; Ives and Messerli 1989: 59–65).

Byers's most recent work indicates the persistence of healthy forests throughout the Sagarmatha National Park area and little change since the 1950s, very long-term indigenous landscape modification, and significant disturbance of the subalpine juniper belt along the approaches to the Mount Everest base camp. The successful reforestation in the vicinity of the park headquarters was certainly an improvement in the park-like landscape although it risks distracting attention from the serious damage in the upper treeline belt. It was with considerable interest, therefore, that Paul Deegan (February 2003) requested review of a manuscript dealing with the dangerous loss of forest cover in the Himalaya, especially in Sagarmatha National Park. The manuscript was sent for critical comment to Alton Byers and Stan Stevens, active current researchers in the Khumbu. The result was a much more balanced account that was submitted by Deegan to *Geographical*, the London-based monthly magazine. Press deadlines did not permit the author, let alone the informal reviewers, to read the final edited version. The ensuing article was published in the March 2003 issue under an editorially imposed title: *Appetite for Destruction.* Essential passages accredited to Byers in the original submission had been eliminated and the tone of the conclusions substantially altered. Upon publication, Deegan protested and alerted his informal reviewers to his disappointment. The editor promised to redress the situation by inclusion of the following statement in the June issue of the magazine.

> Correction: During the editing process, text was removed from Paul Deegan's article on forest-related issues in Nepal . . . that highlighted the difference between healthy forest cover below the treeline in Nepal's Sagarmatha National Park and the clearing that is taking place in the alpine zone. Extensive research by Dr. Alton Byers has shown that not only did the forest cover below the forest treeline remain constant between mid-1950s and the 1980s, but it has increased over the past 20 years.

This article, however, brings another aspect into focus that does involve unfortunate environmental destruction. Fear of Maoist Insurgency activity had prompted Nepalese military personnel to eliminate '[t]housands of young trees around the park headquarters . . . to give army personnel clear fields of fire in the event of a rebel attack.' (Deegan 2003:34). Seth Sicroff, who was chairing a conference at Namche, was asked to check the details directly and replied: 'Mendelphu Hill (site of SNP headquarters) has been trashed . . . trees cut, foxholes and trenches dug, barbed wire everywhere.' (Seth Sicroff pers. comm. 20 May 2003). Nevertheless, Deegan's article, does serve to identify illegal tree felling south of the park boundary by local mountain people as well as provide a firmly documented example from the park itself (Mendelphu Hill) as an act sponsored by government authorities, regardless of whether or not such an act is justifiable in light of the insurgency threat.

The foregoing discussion requires some qualification. Cutting of trees south of the national park boundary in Pharak has been observed for several decades. This has been reported by Stevens (1993, 2003), Ortner (2000), and others. During the 1979 UNU reconnaissance, considerable numbers of porters carrying heavy timbers toward Namche were noted. Similarly, firewood was being carried, not only to the Mount Everest View luxury hotel above Namche, but also for use in the new trekking lodges that were springing up throughout the area. Additionally, illegal cutting was occurring within the park, especially for firewood and construction timber. Nevertheless, this cutting, while likely to be damaging in the long-term if continued unabated, had not been sufficient to cause even local *deforestation* (i.e. clear cutting), nor to affect the area's hydrological regime and cause accelerated soil erosion. In relation to the pre-1950 landscape changes it was insignificant.

Lake Sarez, Pamir Mountains: Prediction of a flood of 'biblical proportions'

Lake Sarez began to accumulate behind a massive earthquake-induced landslide in 1911. By 1998 the upper course of the Murghab River had formed a lake 62 km long and with a volume of about half that of Lake Geneva. Soviet scientists had been monitoring the lake for several decades but with the collapse of the Soviet Union observations had ceased. Understandably, the government of the newly independent Tajikistan began to express its concern about the possibility of the dam collapsing leading to catastrophic drainage of the lake. Since the lake surface stands at 3,200 masl and the landslide dam is more than 500 m high, it was eminently reasonable to examine the prospects for a 'worst-case scenario' evaluation. Based on research by staff of the United States Geological Survey on landslides, mudflows, and the dangers of landslide dams (Schuster 1995) the United States Army Corps of Engineers produced a computer simulation. This predicted that if total failure of the dam were to occur (by any measure, a worst case) then the impacts would be profound. According to the computer simulation any total lake outburst would produce a very high speed (100s km/hr) mudflow varying with the topography of the valley below and the availability of loose slope material, and would eventually extend over 2,000 kilometres to the Aral Sea. Five million lives would be at risk in four different Central Asian countries, together with untold destruction of property. Nevertheless, it is emphasized that this was a computer simulated model of the *worst case scenario* of the type that is frequently set up in such circumstances to provide a basis for field test and not a vehicle for public alarm.

At the urgent request of the Government of Tajikistan, the UN International Strategy for Disaster Reduction (ISDR), based in Geneva, and the World Bank formed a team of experts to investigate the actual nature of the Lake Sarez hazard. With close support, including scientific and military personnel, from the Government of Tajikistan, the team of geophysicists, engineers, geologists, and geographers examined all aspects of the hazard during June 1999 (Alford and Schuster 2000, Alford et al. 2000). In brief, the unanimous conclusion was that the worst-case scenario was such a remote possibility that it could be discounted. Nevertheless, because the mountain slopes above the lake were highly unstable, and also subject to frequent earthquakes, there were inherent secondary hazards. The most likely event, although there was insufficient data available for real-time prediction, would be a large rockfall/landslide hitting the lake surface and generating a seiche wave to over-top the dam. This, in turn, would splash down the steep outer slope of the dam into the Bartang Gorge and imperil the 32 villages that are strung along the floor of the gorge for more than 120 kilometres as far as the confluence with the Pianj River. In view of this, recommendations were made for the installation of fully automatic lake-level monitoring, slope stability monitoring, and advanced warning systems. In addition, a series of 'safe havens' were proposed, to be located above estimated flood levels and stocked with food and supplies for use in an emergency. Installation is proceeding at time of this writing (August 2003).

So far only verifiable facts have been introduced. However, knowledge of the perceived hazard constituted by Lake Sarez was sufficiently widely known that the UN/World Bank team of experts organized a press conference on their return to Geneva. More than 20 eminent news media were represented. Pains were taken to diffuse the relevance of the worst-case scenario; in fact all team members who made presentations emphasized that discussion of such a disaster could be dismissed as wild speculation, if not irresponsible. The facts, as reiterated above, were set forward together with a plea for consideration of the Mountain Tajiks living in the Bartang gorge who already had to contend with a great range of 'normal' natural hazards and, in any event, needed food relief support from the Aga Khan Rural Support Programme to survive there.

It was unfortunate, therefore, that two inflammatory reports appeared (Pearce, *New Scientist*, 19 June 1999; Burke, *The Observer*, 20 June 1999) prior to the Geneva press conference. Each article cited as its main source Scott Weber of the 'UN Department for Humanitarian Affairs' and 'who organized the expedition' [to survey the degree of hazard posed by Lake Sarez]. Some of the more inflammatory phrases include: 'Scott Weber said . . . they [the research team] had found an enormous disaster waiting to happen.'; 'Five million people could die.'; 'When the natural dam which holds back the water breaks – which experts say could be at any moment – a wave as high as a tower block will blast a trail of destruction a thousand miles through the deserts and plains once crossed by the fabled Silk Road and now covered in farms, fields and cities.'; 'we don't know when it could go, but it could go at any time.' Many details were added to include information on the high seismicity of the region, the recent civil war in Tajikistan, and problems of establishing an early warning system. In contrast, all the news media who were represented at the Geneva press conference reflected the calm assessment of the Lake Sarez team. To underline the exaggerated nature of the reports published by *The Observer* and *The New Scientist* the response obtained from an interview (aided by local interpretation) with an elderly widow is reproduced. Her home is located close to the junction of the Bartang and Pianj rivers. When asked to what extent she feared the possibility of a flood from Lake Sarez, she replied:

> My parents were living in this house when the 1911 earthquake and landslide occurred and I was born here in 1932. Neither they nor I worried about Lake Sarez. I intend to stay here until I die. If Allah decides that the dam will burst, so be it; but I don't think he will.

After the mission report was presented, the Government of Tajikistan accepted the recommendations and plans went ahead for design and installation of the monitoring and warning systems. All seemed calm. Then, in early April 2003, an alarm was sounded on a Russian website (www.strog.ru):

> In Central Asia an accident on a planetary scale is expected. . . . Today, Uzbek scientists have deciphered space images from the Japanese film-making system *Aster* using the satellite *Terra*. They discovered that Lake Sarez has overtopped the dam that is now being destroyed as if cut by a giant circular saw.

The ensuing prediction referred to a 100 metre-high mudflow destroying cities for 2,000 kilometres downstream to the Aral Sea with 600,000 to five million lives lost (translated loosely from the Russian by the United States Embassy in Dushanbe). Tense reaction reverberated throughout Central Asia and all the way to Washington DC, as well as to members of the 1999 evaluation team. Sober, authoritative responses calmed the possibility of panic, although the post-1999 Lake Sarez Risk Mitigation Project planned to send a reconnaissance mission to the lake. No recent information has appeared and the very absence of news certifies that there has been no flood 'of biblical proportions' with the loss of millions of lives, and that the April alarm was false.

There is need here for a pause to reflect on the possible events that may have occurred had the 1999 evaluation mission to Lake Sarez not made a responsible assessment. One of the serious risks envisaged at that time was the prospect of governmental over-reaction to the hazard that could prompt a forced, and unnecessary, evacuation of the 32 small villages along the Bartang Gorge together with all the hardship that would entail, even to the collapse of an important, if poverty-stricken mountain culture (Alford and Schuster 2000: 83–90).

A final anecdote

This series of anecdotes and commentaries intended to illuminate the regrettable misunderstandings created by the manner in which the Himalayan–Ganges Problem has been reported is brought full circle by returning to the coverage of the serious 1987 and 1988 floods in Bangladesh. Piers Blaikie (pers. comm. 24 June 2003) recalled his interview with the BBC in preparation for the Nine O'clock News programme. When he expressed his conviction that the Theory of Himalayan Environmental Degradation had no factual basis, this caused the interviewer's face to fall. She responded, 'Oh, but I have already had all the upstream/downstream diagrams prepared.' Thus, when the actual news was broadcast the accompanying cartoons showed hectares of trees felled and rising flood waters. All mention of Blaikie's explanation of the socio-economic management of the floods and the lack of any relationship between deforestation in the Himalaya and flooding downstream had been eliminated. He relates that the TV image of his face was seen to jump a little where the section of the film track that explained his opposition to the Theory had been edited out.

Conclusion

The aim of this discussion has been to highlight the misrepresentation and exaggeration that have been perpetrated for decades and are still being generated today. It is firmly believed that such misrepresentation inhibits urgently required definition of some of the many problems that do beset the region. The single biggest obstruction that dominated the development of thought during the 1970s and 1980s was the widespread assumption that linked increase in mountain rural populations with massive deforestation, soil erosion, and damaging downstream consequences. Some of the real underlying problems that have persisted for decades have been exacerbated by lack of adequate attention or by attempts to solve perceived problems that did not exist, or were of less importance. Although Thompson et al. (1986) expressed doubt that the 'uncertainty' could be dispelled and thus should be accepted as part of the Himalayan scene, it is believed that an attempt should be made to reduce the level of uncertainty as far as possible. Hence the need to ask how the misunderstandings arose and why they have been carried into the present century when, at the same time, the academic perceptions have changed significantly.

This discussion is not intended to minimize the profound complexity of the greater Himalayan region and of its many problems. It would be a disservice to imply that deforestation is not occurring in some specific areas, or that soil depletion and landsliding are unimportant. But these considerations should not be exaggerated and generalized to characterize the entire region, nor should they be articulated to a single simplistic and unsubstantiated cause. This only serves to deflect attention from the extent of poverty, mistreatment of poor minority peoples, and the cruel and self-destructive violent conflicts that are engulfing large parts of the region and so may forestall any attempt at resolution. Nor is it the intention to blame the news media for a large share of the misinformation. Although many elements of the news media are certainly culpable, it is bilateral aid agencies, United Nations institutions, governments, NGOs, and non-rigorous scholars that frequently have failed to show real determination to separate cause and effect, whether intentionally or not. In practice this adds additional weight to the widespread suppression, or at least lack of adequate concern about the well-being of large numbers of poor, and frequently minority, mountain people. ■

This article is slightly rephrased version of Chapter 10 (What are the facts? Misleading perceptions, misconceptins and distortions) from Jack D Ives's recent book "Himalayan Perceptions: Environmental change and the well-being of mountain peoples", page 211–228, Routledge Taylor and Francis Group, London and New York. Published with the permission of Routledge Taylor and Francis Group.

Note

* While there had been earlier warnings of perceived environmental degradation in Nepal (Kaith 1960; Skerry et al. 1991), they had not entered the mainstream discourse. In addition, alarm had been expressed concerning the Himalaya and other Asian mountain areas within India, China, and Thailand.

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Adaptation strategies against growing environmental and social vulnerabilities in mountain areas

Narpat S Jodha

This paper deals with the strategies adopted by the Hindu Kush Himalayan (HK-H) mountain communities in response to adverse natural and human induced circumstances. The quality of life and growth options in mountains (including hills) are deeply rooted in mountain specificities (e.g., fragility, marginality, diversity). Hence, the disregard of these mountain specificities while using mountain resources reduces communities' options and makes them more vulnerable to environmental and economic distresses. The paper first introduces the concept of vulnerability and the traditional low-intensity system of resource use. It then deals with the decline of such traditional systems due to the intensification of resource use caused by the integration of the relatively isolated mountain areas into mainstream economies. The paper concludes with a call for introduction of macro level policies to: (i) Minimize the vulnerability potential of globalization and global environmental change and (ii) Enhance local capacities to withstand and adapt to the changes promoted by these global processes. This discussion covers larger part of the present paper.

Vulnerability of an entity refers to its inability to withstand the stress caused by change. While environmental vulnerability is rooted in the biophysical features of a region or an ecosystem (e.g., mountain areas) and the responses of biophysical features when disturbed by natural forces or manipulated though human interventions (Kasperson et al. 1995). The social (socio-economic) vulnerability is linked to the nature and range of livelihood options available to the people. Thus, fewer the usable options, greater is the vulnerability of a group. The inability of a community to effectively tackle the natural and socio-economic circumstances results in reduced range of options (Blaikie and Brookfield 1987).

In fragile resource zones, such as the mountains, the process and factors generating environmental and social vulnerabilities tend to reinforce each other. Hence, policies aiming to address vulnerability will be successful only when they:

a. Consider specific biophysical features of mountain areas and their imperatives
b. Look at the imperatives as factors affecting mountain ecosystem's ability to withstand stresses, especially those caused by human interventions
c. Identify the livelihood affecting circumstances created by the natural features of mountain areas and human adaptations to risky and limited range of options created by them
d. Enhance aforementioned range of options by overstepping the limits imposed by vulnerability-creating circumstances of mountain ecosystems
e. Look at the whole dynamics of human (economic) processes accentuating the vulnerability enhancing incentives

As a part of this we look in to the factors and processes associated with global environmental change and economic globalization, which have created new set of circumstances accentuating vulnerabilities in mountain areas; and required strategies against them.

Vulnerability enhancing features and adaptations in mountain area

Due to their biophysical conditions, mountain areas are characterized by high degree of fragility, marginality, limited accessibility, diversity, specific niche resources/products, and specific human adaptation mechanisms. Their causative factors are indicated in **Table 1**. The way these features influence the nature – society interaction (i.e., the type and intensity of human activities and the nature's responses there to) in terms of resource degradation, followed by yet another round of human action (e.g., further resource use intensification to meet scarcity), and nature's responses (e.g., further degradation) shape the interactive links between environmental and socio-economic vulnerabilities.

Due to their fragility (caused by slope, altitude, sensitivity to seismic activities etc.), the vulnerability of the Hindu Kush Himalayan (HK-H) mountains is easily amplified by natural forces such as mass wasting, flush floods, glacier melting, earthquakes etc. However, this paper primarily focuses on natural vulnerabilities which create socio-economic vulnerabilities and in turn become aggravated by the latter (by side effects of efforts to overcome the socio-economic vulnerabilities). In such situations, efforts to enhance sustenance options result in to reduced options.

Risky and limited range of options

In the context of socio-economic vulnerability, the mountain circumstances can be seen as the cause of risky and limited range of earning and sustenance options for mountain communities. Thus, due to fragility, some mountain areas cannot withstand the activities involving high resource use (which is often associated with increase in productivity) and creation of infrastructure (which could catalyze resource use intensification). Because of relative isolation, mountain communities are unable to fully harness "niche opportunities", which could enhance the range of earning options. Inaccessibility and isolation restrict the access and hence, the reliance on external support and force the mountain communities to depend on the limited options and local resources.

Furthermore, these circumstances (i.e., isolation, etc.) make mountain communities less prepared and weaker while interacting and exchanging with mainstream economies/ societies. Once integrated with the latter, they acquire

TABLE 1. Mountain specificities and their indicative vulnerability related imperatives

Limited accessibility	
Product of	• Slope, altitude, terrain, seasonal hazards, and so on (and lack of prior investment to overcome them)
Manifestations and implications (i.e., promoting vulnerability and poverty-circumstances)	• Isolation, semi-closeness, poor mobility, high cost of: mobility, infrastructural logistics, support systems, and production/exchange activities • Limited access to, and dependability of, external support (products, inputs, resources, experiences) • Detrimental to harnessing niche and gains from trade, invisibility of problems/ potentials to outsiders
Imperative (appropriate responses, adaptation approaches to reduce vulnerability and poverty)	• Local resource centred, diversified production/consumption activities fitting to spatial and temporal opportunities and constraints • Local regeneration of resources, protection, regulated use, recycling etc. • Low-weight/volume and high-value products for trade • Nature and scale of operations as permitted by the degree of accessibility/ mobility and local availability of resources • Development interventions with a focus on: Decentralization and local participation: reduction of inaccessibility with sensitivity to other mountain conditions (e.g., fragility) and changed development norms and investment yardsticks
Fragility and marginality	
Product of	• Combined operations of slope/altitude, and geologic, edaphic, and biotic factors; biophysical constraints (create socio-economic marginality)
Manifestations and implications (i.e., vulnerability and poverty promoting circumstances)	• Resources vulnerable to rapid degradation, unsuited to intensification, use of costly inputs; low carrying capacity • Limited, low productivity, high risk production options; little surplus generation or reinvestment and subsistence orientation preventing high cost-high productivity options, disregard by 'mainstream' societies • High overhead cost of resource use, infrastructural development; leading to permanent under-investment or selective investment for exploiting niche for mainstream economy • People's low resource capacity preventing use of costly options for resource upgrading and production • Socio-political-marginality of communities and their disregard by 'mainstream' societies
Imperatives (i.e., appropriate responses, adaptation approaches to reduce vulnerability and poverty	• Upgrading resources (e.g., by terracing) and regulation of usage • Focus on low intensity, high stability in resource use • Diversification involving a mix of high and low intensity uses of land, a mix of production and conservation measures with low cost • Local regeneration of resources, recycling, regulated use, dependence on nature's regenerative processes and collective regulatory measures/institutions • Different norms for investment to take care of high overhead costs • Special focus on more vulnerable areas and people and their demarginalisation/empowerment
Diversity and niche	
Product of	• Interactions between different factors ranging from elevation to soils and climatic conditions, as well as biological and human adaptations to them, uniqueness of environmental resources and human responses
Manifestations and implications (i.e., potential for vulnerability and poverty reducing activities)	• A basis for spatially and temporally diversified and interlinked activities conducive to sustainability, strong location specificity of production and consumption activities limiting the scope for large-scale operation • Potential for products, services, activities with comparative advantages
Imperatives (i.e., appropriate responses, adaptation approaches to harness vulnerability poverty-reducing opportunities)	• Small-scale, interlinked, diversified production/consumption activities differentiated temporally and spatially for fuller use of environment • diversified and decentralized interventions to match diversity • Equitable external market links; infrastructural development and local capacity building to guide the mountain development interventions and harness the opportunities

Source: Table adapted from Jodha (1998) and based on evidence and inferences from over 60 studies referred to by Jodha and Shrestha (1993)

marginality status vis-à-vis the mainstream society, with several negative implications for mountain communities such as the over exploitation of mountains' niche for mainstream economies and the transfer of mountain niche at unfavorable terms of trade for mountain areas (Jodha 1998).

Diversity (and the consequent diversification of resource use) is an important factor responsible for health and stability of mountain environment as well as sustenance options for the mountain communities. However, by restricting the scope for several high pay off, option promoting activities requiring larger scale and specialization, it tends to reduce the range of options and increases vulnerability. This way, the natural vulnerabilities lead to social vulnerabilities (in terms of reduced range of livelihood options). **Table 2** briefly summarises the relevant details.

TABLE 2. Mountain features shaping the vulnerability related circumstances and the conditions generally associated with high economic performance or enhanced adaptation options against vulnerability

	Conditions/processes conducive to increased adaptation options						
	Option-enhancing production factors				Option-enhancing external links		
Vulnerability enhancing/ reducing mountain features	Resource-use intensification	Input absorption capacity	Infrastructure facility	Scale-economies	Surplus generaion/trade	Replicating external experiences	Attracting external attention/ support
Limited Accessibility: Distance, semi-closeness, high cost of mobility and operational logistics, low dependability of external support, or supplies	(-)[a]	(-)	(-)	(-)	(-)	(-)	(-)
Fragility: Vulnerable to degradation with intensity of use, low productivity/pay-off options	(-)	(-)	(-)		(-)	(-)	(-)
Marginality: Limited, low pay-off options; resource scarcities and uncertainties, cut off from the 'mainstream'		(-)	(-)	(-)	(-)	(-)	(-)
Diversity: High location specificity, potential for temporally and spatially inter-linked diversified products/activities	(+)[a]	(+)		(-)	(+)	(-)	(-)
Niche: Potential for numerous, unique products/ activities requiring capacities to harness them	(+)	(+)		(+)	(+)	(-)	(+)
Human adaptation mechanisms: traditional resource management practices-folk agronomy, diversification, recycling, demand rationing, etc.	(+)	(+)		(-)		(+)	(-)

a (-) and (+) respectively indicate "extremely limited" and "relatively higher degree" of convergence between imperatives of mountain features and the conditions associated with high degree of livelihood options/adaptation options. To enhance the earning opportunities as adaptations options against vulnerabilities the degree of convergence indicated by (+) has to be increased. This would involve (i) enhanced accessibility, (ii) upgrading and development of fragile/marginal lands or evolve high pay off activities suited to them; (iii) demarginalisation and empowerment of mountain communities; (iv) harnessing of niche and high pay off diversified activities with equitable local gains and (v) build upon indigenous knowledge combined with R&D based scientific measures to evolve resource management usage systems with high returns. All this needs greater understanding of mountain situation. **Source**: Table adapted from Jodha (1997) applicable to different sectors in mountain areas

Traditional two-way adaptation system

The mountain people are acquainted with the above circumstances (except perhaps the side effects of increased physical and economic integration of mountain areas with the mainstream economies), and through trials and errors over the generations have evolved several practices and measures to promote and enhance the range of survival and growth options. Historically mountain communities have tried to reduce bio-physical as well as socio-economic vulnerabilities by means of a two way adaptation process:

- Adjusting their demands to restrictions imposed by mountain circumstances;
- Adapting mountain conditions to their needs through practices such as terracing to cultivate on fragile slopes (Jodha 1998).

These patterns are still visible in remote and isolated mountain areas.

The process of change: Resource use intensification and weakening of traditional adaptations

While the two way adaptation process helped reduce vulnerabilities in the subsistence economic context, it was largely supply driven (i.e.,, demand was adjusted to supply conditions). Hence, it faced a gradual decline once resource use system and production processes became demand driven (when the mountain areas were integrated with the mainstream economies). As a result, mountain resources were exposed to serious degradation and depletion through inappropriate intensification and over extraction induced by increased demands. In most areas, this degradation led to a reduction in the range of local resource-based earning options. The major consequences of the integration with mainstream economies (as summarized under **Table 3**) are briefly noted below. For details see Jodha (1998).

(a) Integration and impacts on coping mechanisms

While integration with mainstream economies have led to a various gains including availability of growth opportunities, several indicators show that it has also led to a decline in traditional coping mechanisms. This is a serious problem communities where equally dependable alternative options have not been created.

(b) Shift from supply-driven to demand-driven resource use systems

The most important consequence of improved links between mountain communities and the mainstream economies is the shift of resource use/production systems from being supply-driven-to being demand-driven. Accordingly, the integration process has promoted increased resource extraction in order to meet external and internal demands. This change has made the mountain areas more vulnerable both environmentally as well as in a socio-economical context. The process applies to both traditional farming systems as well to larger resource extraction system for niche-resources (forest, mineral, hydropower etc.), to meet the mainstream systems' demands. Loss of resource regenerative practices, diversification measures, combining production and conservation needs etc. are well known unsustainability and vulnerability promoting responses to

TABLE 3. Vulnerability related impacts of closer integration of mountain areas into mainstream economies*

Positive impacts	
Enhanced range of livelihood options helping in adaptations to vulnerability through:	• Increased access to external supplies, markets, employment (productive migration), social transfers (welfare and relief), investable resources etc. • Increased internal production cum exchange opportunities through investments, technologies infrastructural facilities etc. • Scope for harnessing unique opportunities (niche resources) and gains from trade. • Increase in local capacities to harness new opportunities.
Negative side effects	
Enhanced risks of increased environmental and social (economic) vulnerabilities through:	• Increased pressure of internal and external demand on mountain resources, over extraction. • Strong extractive focus of development policies and market forces on selective niche-resources/products of mountains (e.g., timber, mineral, hydropower etc.) exposing mountains to greater environmental degradation, reduced resource regeneration and productivity. • Resource exploitation to primarily meet the needs of mainstream economy, ignoring the local social and environmental concerns and by-passing the non-niche resource areas/activities. • Imposition/extension of externally evolved inappropriate technological and institutional interventions: (i) Promoting indiscriminate resource intensification, and narrow specialization, and (ii) Marginalizing the traditional resource use practices and institutional arrangements designed to guard against environmental/economic risks. • Marginalization of mountain communities and their concerns with little participation in mainstream decisions/actions about mountains. • Increased high land - low land economic links with unfavorable terms of trade for mountains. • Persistent poverty and low skills/capacities and resources to benefit from development interventions; and widening intra-mountain area disparities i.e., between accessible and less accessible areas.

* Uneven but increased integration of mountain areas with mainstream economy through physical infrastructure, market, development intervention, and administrative controls. **Source:** Table based on evidence observations, and inferences from over 40 studies from different countries of HK-H region.

increasing demands by ignoring the natural limits to supply.

(c) Marginalization of traditional sources of resilience

Integration also led to marginalization and disappearance of several indigenous knowledge systems, folk agronomic practices, collective risk sharing arrangements and several locally evolved and enforced institutional arrangements that have been safeguarding against vulnerability promoting processes. This resulted from external interventions (of technological and institutional nature) in mountain areas without sufficient understanding and consideration of mountain specific conditions. Most of them emerged as side effects of mountain development without mountain perspective. Particularly, since 1950s, when state assumed the responsibility of welfare and development, the external interventions and plain-based experiences were imposed on mountain areas, which in most cases disrupted the traditional adaptation practices and measures without providing effective substitutes (Jodha 2002).

Adaptation options in the changed context

Despite the fact that traditional adaptations against vulnerabilities have been marginalized, integration has resulted in generating new coping strategies and adaptation options against vulnerabilities, particularly in mountain areas with better access and high production potential.

As far as natural disasters are concerned, degree of vulnerability has been reduced because external support and supplies means that communities no longer have to fend for themselves. Besides, the subsidies and support systems for production activities have also helped in enhancing sustenance and development options. Himachal Pradesh in India, Ninang and Kunming areas in China, Ilam district in Nepal and Northern territories Pakistan are same examples of places where earnings through various production and marketing activities have substantially increased. A number of sources of vulnerabilities rooted in limited accessibility, marginality, fragility etc. are also controlled in many areas though infrastructural development, resource-development, improved market links, new technologies and income enhancing activities.

However, the access and use of new potential adaptation options are not uniformly available to all mountain areas. Consequently, intra-mountain and inter-community differentiations have significantly increased. The remote and marginal areas have not benefited in terms of enhanced options (Jodha 2001a)

More importantly, a number of new options have increased mountain communities' dependence on external support and charity; their access and control over local natural resources has declined.

Besides, new options invariably involve intensification of resource use and over-extraction of mountain niche and their supplies to downstream economy with unfavorable terms of trade to mountains. Consequently, one observes a range of emerging indicators of unsustainability of existing patterns of resource use. Thus unless sensitized to mountain conditions, the present approaches promoting adaptations against vulnerabilities may enhance the extent of the latter. Some indicators of the same are already visible in many areas (Jodha et al. 1992). The current trends indicating resource use intensification driven by economic globalization and global environmental change may accentuate the loss or unreliability of newly promoted adaptation options, as discussed below.

New sources of growing vulnerabilities and needed adaptation strategies

As mentioned in previous discussion, a major shift is evident when one compares the traditional and present day source and adaptation to vulnerability. While the local (community-level) perceptions and practices were responsible for the assessment and defenses against vulnerabilities in the past, it is now macro-level, with external links and intervention becoming more important in promoting both vulnerabilities and the options against them. Furthermore, the external factors acted as yet another contextual variable, to which local communities had to adapt. As a result of the above shifts, the macro-level public policies have become an important locus for identification and promotion of adaptation strategies against vulnerabilities in mountain areas. This becomes clear once one looks at the sources of growing vulnerabilities associated with economic globalization and global environmental change.

In the following paragraphs, we will discuss the role of global environmental changes in accentuating vulnerabilities as well as its repercussions in the context of the Hindu Kush Mountains. The discussion draws upon the issues and analysis elaborated by Jodha (2000, 2001b).

Global environmental changes: Skewed perspectives

There are two types of global environmental changes namely 'systemic type' and 'cumulative type' (Turner et al. 1990, Kasperson and Kasperson 2001, Kasperson et al. 1995). Broadly speaking, a systemic change is one that, while taking place in one locale, can affect changes in systems elsewhere. The underlying activity need not be widespread or global in scale, but its potential impact is global in that it influences the operation and functioning of the whole system. Emissions of CO_2 from limited activities that have impacts on the great geosphere-biosphere system of the Earth and causing global warming offer a prime example. The cumulative type of change refers to localized but widely replicated activities where changes in one place do not affect changes in other distant places. When accumulated, however, they may acquire sufficient scale and potential to influence the global situation in various ways. Widespread deforestation, extractive land-use practices, ground water pollution/depletion, biodiversity loss etc. and their potential impacts on the global environment serve as examples. Both types of changes are the products of nature-human interactions and are linked to each other in several ways.

However, despite several uncertainties and information gaps especially in the regional contexts, mainly due to domination of the discourse by natural science groups working on climate change and the high noise potential of issues debated (e.g., dooms-day predictions), the 'systemic type' of environmental change has received greater attention and resource allocation for research and policy advocacy in the global fora. Thus, until recently, the 'cumulative type', despite more concrete evidence, certainties of impacts and possibilities of well-focused remedial/adaptive measures, received limited attention. This has led to 'skewed perspectives' on the whole subject of global environmental change (Jodha 2001b). The major consequence of this imbalance has been the lesser attention to more practical and concrete options to address global environmental issues.

Cumulative environmental change

While the mountain areas are subject to both types of changes, due to elevation related features, the impacts of systemic changes is more readily visible (e.g., through glacier melting due to warming; upward shift of certain plant species; distortion of flowering seasons for fruits such as hill apples etc.). However, for the reasons stated above and their greater visibility to communities, the cumulative type of changes should get greater attention, especially in the short run. In the place-based contexts these changes not only more readily expose the communities to higher risks and vulnerabilities, but they get further reinforced by people's efforts (through resource use intensification etc.) to face the emerging risks and scarcities.

In short, the environmental risks and vulnerabilities of a system, such as a mountain ecosystem, can be understood in terms of instability or destruction of (a) natural resources, (b) their productivity potential, and (c) largely invisible processes represented by the biophysical functions and flows categorized as regeneration, variability-flexibility, resilience, nature's cycles, or energy and material flows. The environmental risks and people's vulnerabilities in terms of reduced adaptation options can be identified with a negative change in any of the three categories of variables. Ultimately, however, the extent and nature of environmental risk and vulnerabilities relate to disruptions in the biophysical functions and flows (which in mountain regions are very much linked to imperatives of mountain specificities (see **Table 1**).

Traditionally, the mountain communities would guard against such risks and vulnerabilities through folk agronomic and institutional practices such as diversified farming. These adaptations involved various other practices – such as product recycling, flexible consumption patterns, transhumance and migration – that directly or indirectly facilitated regulation of pressure on resources and, hence, proved conducive to the operation of biophysical processes for environmental stability. However, these land-extensive, non-extractive features of traditional systems are incompatible with the resource-use intensification forced by rising internal and external demands on mountain resources.

Inappropriate intensification of resource use disrupts the above functions and exposes the environment to serious degradation. This process manifests the cumulative type of global environmental change. It's more popularly understood or projected components are deforestation, overgrazing, extension of cropping to steep and fragile slopes, landslides and mudslides, periodic flash floods, soil erosion, disappearance of vital biophysical resources, and reduced resource productivity. Some of these have been documented as emerging indicators of unsustainability in HK-H region.

The levels of environmental instability, risks and vulnerabilities, which are already quite serious, are further accentuated with the impacts of global systemic change (e.g. global warming), and economic globalization.

Impacts of systemic changes

Compared to the information on cumulative changes, there is a dearth of details on the potential systemic changes affecting mountain areas. With full recognition of the limitations of the regional information on systemic changes (e.g., their conjectural nature and associated uncertainties of predicted change scenarios), however, a few possibilities may be stated. Accordingly, the potential changes in the Hindu Kush-

Himalayas resulting from global warming, as summarized by different studies (Topping et al. 1990, ICIMOD 1993, IPCC 2001) include the following:

(i) Forests may have both quantitative and qualitative changes. Some of the species may disappear; others may move spatially. This may accentuate the already known current negative trends relating to forest areas. The resulting reduced biodiversity may influence both biophysical functions and flow governing environmental stability, thereby making the economy and survival strategies of people more vulnerable to risks.
(ii) The region may have higher rainfall (convective, high-intensity rains), which may cause increased runoff, flash floods, soil erosion, and mud- and landslides, and could influence overall farming systems. This will adversely affect people's survival strategies as well as the basic biophysical functions of the area.
(iii) Increased warming would lead to increased snow-melting and consequent disturbance to hydrological cycles, seasonality of flows of water, and related impacts on land use and cropping intensities, disturbing the already threatened diversity and sustainability of mountain resource use. The environmental risks will, thus, be further accentuated.
(iv) To the potential changes one may add a few more possibilities. They include probable changes in the specific mountain conditions (such as fragility, diversity, or niches) and in their interrelationships; these changes may generate new constraints and opportunities, influencing the comparative advantages of mountains and their links with other regions, and perspectives of public interventions in mountain areas. At the microlevel, the agricultural systems covering all land-based activities may undergo several changes, including disturbance to well-adapted cultivars and management practices, product and income flows, and people's strategies for coping with risks (Jodha 1989, 1995). These changes, in turn, may influence resource-use patterns, with implications for environmental stability.

The above changes may result in increased compulsions or incentives for resource-use intensification, which may accelerate the already observed cumulative changes and their impacts on vital biophysical processes and flows; thereby affecting the adaptation options against vulnerability. **Table 4** presents some possibilities of current trends in resource degradation (cumulative changes) likely to be accentuated by systemic changes. The impacts of the combined two types of changes on biophysical processes and nature's flows are indicated by the capital letters in **Table 4**.

Environmental change and social vulnerabilities

The final consequence of the changes mentioned above is reflected in reduced livelihood options for mountain communities and hence increased extent of vulnerabilities (see **Table 5**).

The socio-economic vulnerabilities at the operational level, are revealed by reduced range, viability, flexibility, dependability, and pay-offs of production and resource-use options to satisfy human needs. These problems may arise owing to the breakdown or infeasibility of diversified, resource-regenerative practices as well as to the degradation of the natural resource base. On the institutional side, a different degree of socio-economic vulnerability is exhibited by the slackening of resource-management/protection systems, reduced access to resources, the reduced range and quality of group activities, and the marginalisation of collective sharing systems as well community's collective stakes in local resources. Some of these problems arise from disruptions in environmental and natural-resource situations while others cause such disruptions, as when socio-economic adjustments to environmental change create further negative changes in the environmental situation at secondary or tertiary levels. **Table 6** indicates these possibilities, which relate mainly to the predominant activity (i.e., agriculture) of mountain communities. Such formulation, however, can be present with respect to other activities.

Fuller understanding of risks and their processes may help identify and evolve adaptation measures. Framework and perception to address these and associated issues are elaborated for different regions in two very comprehensive volumes on the subject (Kasperson et al. 1995, Kasperson and Kasperson 2001). However, that falls outside the scope of this paper.

Economic globalization and vulnerabilities

Economic globalization with primacy to market friendly and market driven processes is spreading to all countries and regions. Though promoted as means to global growth and prosperity, the process also carries risks. The participants unprepared for the changes are likely to encounter more risks and limited gains in the process. The mountain communities like HKH, due to their specific biophysical conditions and marginalization, fall under the above category. Due to disregard of the mountain imperatives while designing and implementing development efforts, the efforts have not led to substantial progress. Insensitivity of market processes to the imperatives of mountain conditions, while integrating mountain areas into wider economic systems may further the pattern of neglect. Besides, the rapid erosion of traditional coping strategies of mountain communities in the face of market driven technological and institutional changes, their inability to effectively participate in the same change process, and the reduced economic role and capacity of the state (due to market friendly economic reforms) to extend welfare and development support to them is going to make the communities more vulnerable.

Market and related changes are not new to mountain communities. But globalization differs from the past changes in terms of:
(i) Unprecedented primacy accorded to market and marginalization of the state and communities in economic and related decisions and processes
(ii) Reinforcement of the role of inter-connectedness of economic transaction (specially trade flows involving resources, products and services) globally helping the more competitive entities
(iii) Facilitative and speed promoting integrative role of information technology
(iv) The power accorded to formal institutions such WTO, which promotes global perspectives at the cost of local concerns.

With such features empowering the market forces, and also due to the spread of economic globalization to mountain areas, the nature and extent of vulnerabilities are rapidly changing. Even when most of the mountain products do not get into global trade, globalization influences mountain areas through major shifts in policies, programmes, priorities etc. adopted by the state in response to the incentives, obligations and compulsions created by market friendly arrangements promoted by agencies such as WTO, World Bank, IMF etc. at

TABLE 4. Potential accentuation of cumulative environmental change under the impacts of systemic environmental changes

Current problem (cumulative type of change) likely to be accelerated by systemic change	Potential key manifestation of systemic change (impacts of global warming)		
	Vegetation changes: forest size, location, composition, growth cycle, biodiversity, interactive processes	*Increased convective rains*: floods, runoff, soil erosion, changes in growing season, hydrological cycle	*Warming-led snow melt*: increased water flows, soil erosion, changes in hydrology mountains and flood plains
Deforestation, vegetation degradation, reduced diversity	X (R, F, N, S)[a]		X (R, N, F)
Soil erosion, landslides and mudslides, floods		X (N, F, S)	X (N, F)
Changes in land-use pattern, reduced diversity of farming systems, increased resource-use intensity and degradation	X (R, F, N)	X (S, N)	
Increased vulnerability of people's survival strategies to environmental instability due to resource degradation and disruption	X (R, F)	X (R, F, S)	X (R, S)

a, biophysical processes and flow likely to be affected; R, regeneration; F, flexibility, variability; N, resilience; S, energy and material flows.
Source: Adapted from Jodha (2001)

TABLE 5. Environmental change and socio-economic impacts promoting vulnerabilities in mountain areas

Environmental changes and underlying factors or responses to change	Socio-economic impacts/vulnerabilities[a]			
	Reduced: feasibility of traditional production systems, regeneration, resilience	Reduced range/quality of livelihood options; control, access to resources	Increased external dependency, subsidy marginalization unequal exchange	Reduced collective sharing (options) low resilience, breakdown of group action culture
Physical degradation of land resources (W, S)[b]	X	X	X	X
Reduced variability, flexibility of production factors (V, W)	X	X	X[p]	
Increased "ecological" subsidization through chemical, physical, biological inputs (V, W)			X[p]	X[p]
Vicious circle of resource degradation, overextraction-degradation (W, S)	X	X	X	
Niche, technology, market-induced overextraction, reduced resource availability/access (V, W, S)		X	X[p]	X[p]

a: Details presented in the Table largely relate to agriculture dominated by stagnant production system but the items indicated by *p* apply to progressive agricultural areas as well; b: The capital letters stand for worsening of the situation due to internal scarcities and external pressures with regard to the following resources likely to be affected by environmental degradation: W, water; V, vegetation; S, soil. Source: Adapted from Jodha (1995)

global level. The consequent emergence of micro-level changes creates the circumstances that adversely affect the range and quality of options against vulnerability available to mountain communities. The specific processes and impacts (summarized under **Table 6**) are elaborated below. They are largely based on an exploratory study on impacts of globalization on fragile mountain areas and communities in selected areas of five countries in HK-H region (Jodha 2001b).

(a) Ignoring links between environmental and socio-economic vulnerabilities

There are visible incompatibilities between the mechanisms and driving forces of globalization and imperatives of mountain. While globalization calls for resource intensification, narrow specialization and over extraction for profitability, mountain imperatives call for diversified and interlinked activities which combine production and conservation concerns. This Vulnerability-wise incompatibility has the following implication:

While the changes promoted by globalization may result in economic gains, they disregard activities which promote environmental sustainability and stable economic options. Thus, the promoted options against economic vulnerability may promote environmental vulnerability. Since the new options differ significantly from traditional options, a decline in the range of time-tested options against vulnerability is imminent, especially when globalization is considered.

(b) Decline of social transfers and support systems

The vulnerability is further accentuated by the loss of welfare and development support due to the norms encouraged by WTO such as privatization, deregulation and structural reforms, which reduce the role of state and public sector. The net result is reduced employment and income as well as support through R&D and infrastructure related services in mountain areas.

(c) Erosion of niche-opportunities

'Niche' refers to resources activities/products having comparative advantage to mountain areas/people. Production of off-season vegetables; fruits NTFPs and seeds etc. are some examples. As shown by recent evidence from HKH countries, trade liberalization has led to the loss of 'niche' as a number of these products are produced in massive green houses in plains. Similarly a number mountain products (e.g., fruits and flowers) are losing to competition from these products from distant countries due to trade liberalization.

Finally, profitability and selectivity-based intensive exploitation as a result of globalization adversely affects the mountains' niche. This is because the products are partly results

TABLE 6. Potential vulnerability enhancing factors associated with globalization in mountain context and approaches to adapt to them

Potential factors	Elaborations/Examples
(a) Visible incompatibilities between driving forces of globalization and imperatives of specific features of mountain areas (fragility, diversity, etc.)	(i) Market driven selectivity, resource use intensification and over exploitation induced by uncontrolled external demand versus (ii) fragility-marginality induced balancing of intensive and extensive resource uses; diversification of production systems, niche harnessing in response to diversity of resources **Consequence:** Environmental resource degradation loss of local resource, diversified livelihood options; increased external dependence.
(b) Accentuation of negative side effects of past development interventions under globalization due to their common elements (approaches, priorities, etc.) with adverse effects on mountain areas	Common elements between the past public interventions and market driven globalization: (i) Externally conceived, top-down, generalized initiatives (priorities, programs, investment norms) with little concern for local circumstances and perspectives, and involvement of local communities (ii) Indiscriminate intensification at the cost of diversification of resource use, production systems and livelihood patterns causing resource degradation (e.g., deforestation, landslide, decline in soil fertility, biodiversity) (iii) General indifference to fragile areas/people excepting the high potential pockets creating a dual economy/society; over-extraction of niche opportunities (timber, mineral, hydropower, tourism) in response to external (mainstream economy) needs, with very limited local development **Consequence:** Environmental degradation and marginalisation of local resource use systems, practices, and knowledge etc., likely to be enhanced due to insensitivity of market to these changes and gradually weakened public sector
(c) Globalization promoting erosion of provisions and practices imparting protection and resilience to marginal areas/ people (including disinvestment in welfare activities)	(i) Traditional adaptation strategies based on diversification, local resource regeneration, collective sharing, recycling, etc., likely to be discarded by new market-driven incentives and approaches to production, resource management activities (ii) Shrinkage of public sector and welfare activities (including subsidies against environmental handicaps, etc.) depriving areas/people from investment and support facilities (except where externally exploitable niche opportunities exist) **Consequence:** Likely further marginalisation of the bulk of the mountain areas and people.
(d) Loss of local resource access and niche-opportunities through the emerging "exclusion process"	Niche resources/products/services with their comparative advantage (e.g., timber, hydropower, herbs, off-season vegetables, horticulture, minerals, tourism etc.) and their likely loss under globalization through: i) Market-driven over extraction/depletion due to uncontrolled external demand ii) Focus on selective niche, discarding diversity of niche, their traditional usage systems, regenerative practices, indigenous knowledge iii) Transfer of "niche" to mainstream prime areas through market-driven incentives, green house technologies, infrastructure and facilities (e.g., honey, mushrooms, flowers produced cheaper and more in green house complexes in the Punjab plains compared to naturally better suited Himachal Pradesh, India) iv) Acquisition and control of access to physical resources: forest, water flow, biodiversity parks, tourist attractions by private firms through sale or auction by government, depriving local's access, destroying customary rights and damaging livelihood security systems. **Consequence:** Loss of comparative advantages to fragile areas or access to such gains for local communities
(e) Adapting to globalization process, possible approaches to loss minimization	i) Sharing gains of globalization through partnership in primary and value adding activities promoted through market; building of technical and organizational capacities using NGOs and other agencies including market agencies to promote the above ii) Promotion of local ancillary units (run by locals) to feed into final transactions promoted by globalization; this needs institutional and technical infrastructure and capacity building iii) Provision for proper valuation of mountain areas resources and compensation for their protection, management by local people for use by external agencies iv) Enhance sensitivity of market-driven initiatives to environment and local concern to be enforced by international community and national governments v) All the above steps need local social mobilization, knowledge generation and advocacy movements; and policy-framework and support **Consequence:** If above steps are followed, there are chances of influencing the globalization process and reducing its negative repercussion for mountain areas/people

Source: Adapted from Jodha (2000)

of diversified and interlinked resource use systems that helps in maintaining the organic integrity, as well as health and productivity of the natural resource-base. Market driven patterns of resource use are insensitive to this aspect and hence selectively focus on individual component disintegrating the total system.

(d) Exclusion process

Mountain communities are losing their livelihood options and adaptation strategies against vulnerabilities due to an emerging "exclusion" process (i.e., making people resourceless and optionless). As a part of economic liberalization, privatization and deregulation promoted under globalization, the governments favour market agencies, especially those that can bring in foreign direct investment (FDI). As a part of this process, in HKH region, governments have acquired the community (and private lands) and given it to business firms in the name of promoting development. There are also other emerging trends showing communities deprived of their intellectual property rights.

Another facet of "exclusion process" is people's inability to participate in highly paying activities promoted by globalization. This applies mainly to those who are not well equipped or prepared to participate effectively in globalization-led changes or those who are unable to adapt quickly to the change.

Potential opportunities

Despite wide-spread criticism of economic globalization for its vulnerability-promoting effects, there are some potential opportunities to build adaptation strategies against the vulnerabilities. These opportunities include:

- Improved trade opportunities for mountain product such as specialty organic food and herbs
- Services such as mountain tourism, which will grow faster in the times to come
- Surable gainful opportunities for associating mountain people as ancillary partners with low land market agencies to harness opportunities created by globalization.

There are several scattered success stories indicating the above possibilities (Jodha 2002). The availability of investable funds and technologies for relating biophysical constraints in mountain areas is another possibility offered by globalization process.

However, the key constraint is the lack of knowledge about such possibilities and skills to harness them. Put differently, to begin with one should focus on "identification of options"- to minimize negative effects and harnessing of positive opportunities created by globalization. These options could form a part of regionally differentiated integrated coping strategy for mountain areas to wisely and effectively adapt to globalization. To build such a strategy, focused research in different mountain area is a first step. Guided by this concern ICIMOD has recently initiated work on "Globalization and Fragile Mountains" covering areas in five countries of HKH region.

Adaptation strategies against enhanced vulnerabilities

Basic considerations for adaptation strategies

The first important factor to be understood while evolving such strategies is that most of the present adaptation-option reducing circumstances are primarily rooted in the external, macro-level decisions and action (e.g., those promoting economic globalization and unintentionally encouraging and permitting environmental degradation). Hence, the adaptation strategies (which will create micro-level options) have to have strong elements of macro-policies and support systems.

Secondly, since one of the root causes of (option reduction) vulnerability promotion is indiscriminate intensification of resources, this has to be supplemented by high pay-off (high option generating) diversified, interlinked, and equitable natural resource use systems. This would call for focus on specific priorities and provisions at macro-policy levels, which can help build complementarities between diversification and intensification.

Third, sensitivity towards and involvement of community level stakeholders in the policy-programme interventions to

TABLE 7. Indicative steps/measures to enhance adaptation options against vulnerabilities caused by cumulative type of global environmental change

Adaptation areas	Operational steps
Amending Incentive Structures that promote demand pressure and over extraction of environmental resources and services (ERS)	• Assessment, valuation and realistic costing of environmental resources and services • Based on (a), (ERS) users pay to the protectors/conservators of ERS (e.g., low landers compensating uplanders) • Curtail "free riding" tendencies and practices
Recognition and space for place-based (micro-level) perspectives, practices in global discourse on ERS	• To reduce disconnects between supply and demand side stakeholders in ERS • To ensure on ground awareness and help concrete focus and action on option-reducing ERS usage systems • To promote local responsibilities of global stakeholders
Sensitivity towards and involvement of communities in ERS related policy-programmes	• To help build bottom up participatory strategies and approaches to ERS issues • Identify spatially differentiated steps to regulate ERS
Change focus of technological and institutional interventions regarding ERS issues	• To promote complementarities between extensive and intensive types of resource use • Upgrade, modify, and integrate components of traditional ERS management systems in to modern ones

TABLE 8. Indicative steps/measures to enhance adaptation options against vulnerabilities caused by economic globalization processes

Adaptation areas	Operational steps
Mechanisms to help mountain people share gains of Globalization	• Share in primary and value adding activities based on mountain-located opportunities promoted by globalization • Partnership with external market agencies • Equitable terms of trade (compensation for mountain) • Land product/services under highland – lowland economic links
Strengthening and local participation in harnessing of mountain niche	• Complement nature-endowed niche with human made niche facilities • Ancillary role in harnessing of key resources (e.g., hydropower, NTFPs etc.) by external agencies
Arresting exclusion process	• Partnership in enterprises based on assets taken from local people • Adequate compensation for unavoidable exclusion (i.e., loss of assets, opportunities due to global process)
Integration of mountain economies with rest of the world on equal terms	• Capacity building • Partnership with external agencies
Global advocacy and concessions	• With special problems of mountains, provision for special window (exceptions to WTO rules) to help mountain areas • International concern and mobilization/dialogue supporting mountains for their contributions to global commons (fresh water, biodiversity, hydropower helping downstream communities and economies)

enhance adaptation options against vulnerabilities is a crucial requirement, because it is the "place-based" situation that finally reflects the operational dimension of the problems and relevance and effectiveness of the planned solutions.

Finally, an important step in designing adaptation strategies is to look at the potential opportunities associated with the risk or vulnerability promoting changes. This is specifically, so in the case of economic globalization which carries both risks and potential opportunities for mountain areas and communities, as alluded to earlier.

Specific areas for identification of options against vulnerabilities

Given the broad framework of basic considerations mentioned above some steps may be suggested to help reduce the vulnerability promoting (option reducing) impacts of global environmental change (cumulative type ones) and economic globalization. They are summarized in **Tables 7** and **8**. Even though scattered evidence on these aspects is already emerging (Jodha 2000), but systematic research on the indicated measures and their implementations will go a long way in enhancing livelihood options for mountain communities to adapt to emerging vulnerabilities more (Jodha 2000) effectively. ■

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Participatory fisheries management for livelihood improvement of fishers in Phewa Lake, Pokhara, Nepal

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This paper deals with the participatory fisheries management program, aimed at and successful in livelihood improvement of fisher community known as 'Pode' or 'Jalari' living near Phewa Lake, Pokhara, Nepal. The community, traditionally depending on fishing activities for their livelihood, led a nomadic life along the rivers and lakes, carrying cast nets to feed their families. In the early 1960s, when the fish catch declined due to over fishing, the Pode's only source of livelihood was threatened. Meanwhile, the Fisheries Development Center, now Agriculture Research Station (Fisheries), was established in Pokhara in 1962 with the objective of assisting the poorest fishing communities through cage fish culture and open water fisheries. To begin with, each family was enabled to buy a single 50 m^3 cage in order to start farming fish; the loans were underwritten by the local Agriculture Development Bank. The total fish production from Phewa Lake in 2001 was estimated at 98 mt (224 $kgha^{-1}$: 52 mt from cage culture and 46 mt from open water recapture fisheries). The income from fish production is shared among local fisher families; it has brought substantial changes in the livelihood of the fisher community. A few years ago, it was difficult to find a literate member of the Pode community, but these days many children attend school and some even college. The community has realized the importance of lake resources and devised a code of conduct for sustainable fishery. The improvement on livelihood of fisher community is attributable to the combination of participatory fisheries management with their traditional skill on fish handling as well as their easy access. Apart from supporting in livelihood of poor communities, participatory fisheries management also contributes in maintaining ecological balance of aquatic ecosystems.

Key words: 'Pode', sustainable fishery, Phewa, cage culture, livelihood

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Small scale fishers, especially those on inland waters, are among the poorest of the rural poor in developing countries facing apparently insurmountable obstacles in the existing economic and social power structures as they attempt to better themselves (Berkes et al. 2001). However, a participatory approach can overcome these obstacles (Jiggins and de Zeeuw 1992, Van de Fliert et al. 1999). Ideally, a participatory approach to fishery creates an integrated development strategy by fostering new relationships, ways of thinking, and structures and processes (Campbell and Salagrama 2000). The participatory approach paradigm in research and development completely differs from the conventional top-down approaches, and is an essential part of Sustainable Livelihood (SL) programs (FAO 2000). It is a customer-focused program where the targeted group participates in the entire process, learning about the situation, identifying problems, discussing alternatives, selecting solutions, designing and implementing activities, evaluating and disseminating results (Chat 2000). In these processes, target groups share their traditional knowledge to identify problems and solutions, ensuring the poor and uninformed will not be excluded from development opportunities. This also creates a forum where outsiders can work with the community and help to improve their specific capacities (Chat 2000).

Nepal is rich in water resources, and fishing is a long-standing tradition. The communities involved in fishing activities are mostly Tharu, Majhi, Malaha, Danuwar, Kewat, Bote, Mushar, Mukhiya, Darai, Kumal, Dangar, Jalari, Bantar, Rai and other poverty-laden ones. Swar (1980) estimated there were about 80,000 fishers; however, it is estimated that there has recently been a three- to five-fold increase in the fishing population due to the increasing population and deepening poverty in Nepal (Gurung 2003a).

As a result of lack of appreciable management, most water bodies of Nepal are over-fished and environmentally degraded threatening the biodiversity and livelihood of traditional communities (Bhandari 1998, Karki and Thomas 2004). In this article, we present an example of sustainable participatory fishery management practices which has been successful in improving the livelihood of the fishers' community substantially around Phewa Lake (Pokhara, Nepal).

Beginning of the participatory approach to fishery

The Agriculture Research Station (Fisheries), Pokhara, established in 1962 to improve the livelihood of poor people through sustainable fishery, is a major stakeholder of this participatory approach. Its relation with local fishers was strengthened in 1972 when the caged fish culture program was initiated with the cooperation of the Food and Agriculture Organization (FAO), the United Nations Development Program (UNDP) and Ministry of Agriculture and Co-operatives, His Majesty's Government of Nepal. To organize the local fishers, mainly nomadic Jalari, in a forum where issues on participatory fisheries management could be discussed, a fisheries association known as Matsya Byawasayi Samitee Kaski was founded. Fewa Matsya Byawasayi Samitee (FMBS), Nepali version of 'Phewa Committee of Fishers' was established as a wing of this organization. The District Agriculture Development Office and the Agriculture Development Bank of Kaski are also the main stakeholders in their joint effort.

At first the fisher families were trained to manage cage fish culture in the lake. Later, unsecured loans were offered for cage material and fingerlings (Swar and Pradhan 1992, Gurung and Bista 2003). The FMBS later formulated code of conduct for gill net operation (the cage fish culture in the lake), marketing and loan repayment systems. The major strategies adopted in the participatory approach were community mobilization for resource management and conservation, and fish stocking enhancement.

TABLE 1. Cage fish culture production rate (kg·m^{-3}·y^{-1}) in Phewa Lake

Year	Production rate	Source
1979	5.5	Pradhan and Shrestha (1979)
1980	3.4	Wagle (2000)
1985	3.4	Swar and Pradhan (1992)
1990	1.33	Sharma (1990)
1998	5.0	Wagle (2000)
2000	3.5	Present study
2001	4.3	Present study
2002	4.4	Present study

TABLE 2. Family number, cage holding and fish harvest from cage fish culture in Phewa Lake

Year	Number of families	Number of cages	Fingerlings stocked	Fish harvest	
				Number	Weight (kg)
2000	56	213	107500	63500	37274
2001	58	227	144500	68100	47000
2002	58	253	127000	75900	48300

Source: Fish Grower's Association, Phewa Lake, Pokhara

Characteristic features of Phewa Lake

Phewa Lake is situated at the southwestern edge of Pokhara Valley (28° 1' N, 82° 5' E, alt. 742 m) with a watershed area of approximately 110 km^2 (Ferro and Swar 1978). The total surface area of the lake was estimated at 500 ha by Ferro and Swar (1978), while Rai et al. (1995) reported 523 ha. More recently, Lamichhane (2000) estimated 443 ha of water surface area with a maximum depth of 23 m. Phewa Lake is fed by two perennial streams: Harpan Khola and Andheri Khola, as well as several seasonal streams.

The lake has a single outlet, where water is diverted for irrigation and hydropower generation. About 1700 wooden plank boats and other craft are operating in the lake, mainly for tourism services. It is estimated that 16% of Pokhara's total income is generated through tourism (Oli 1997), and the shorelines of Phewa Lake, especially the western side, comprise one of the most popular tourist spots, with many hotels and restaurants.

Several studies have revealed the mesotrophic status of Phewa Lake (Ferro 1980, 1981/82, Fleming 1981, Nakanishi et al. 1988, Rai 1998, Davis et al. 1998). Presently, the lake is facing severe environmental problems as a result of nutrient loading from agriculture, landslides, and rapid urbanization in the surrounding area. Sewage from the surrounding settlements is directed into the lake (Lamichhane 2000), and the volume

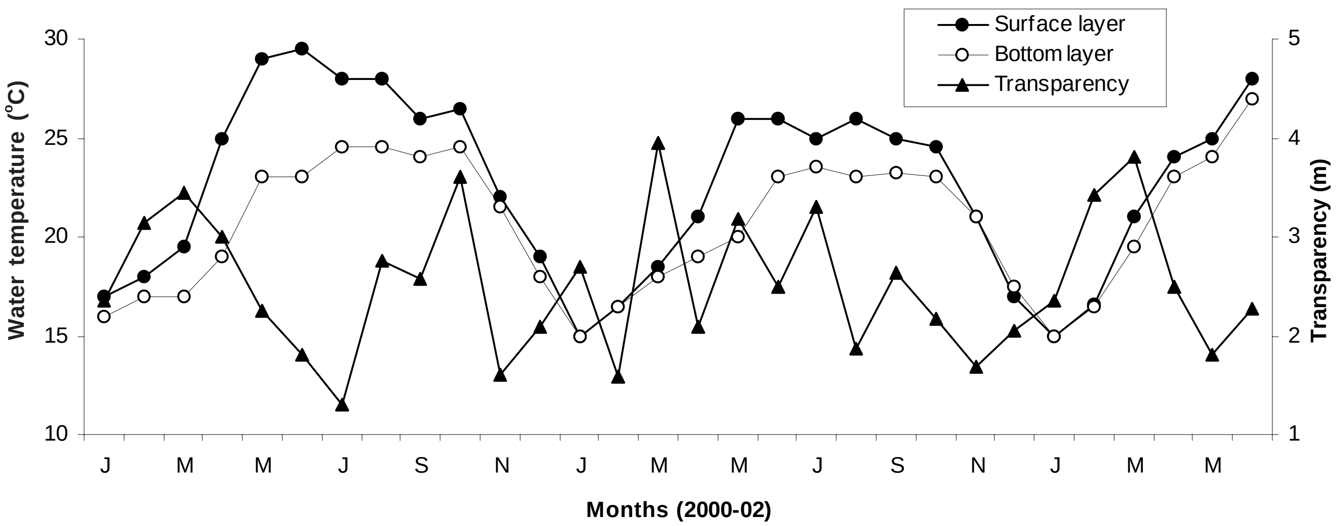

FIGURE 1. Seasonal changes in water temperature and transparency in Phewa Lake

continues to rise dramatically in response to increased tourism (Oli 1997). The recent trend is toward rapid eutrophication (Oli 1997, Lamichhane 2000, Rai 2000). However, the lake is also seasonally oligotrophic due to heavy rainfall in its wider catchment area (Rai 2000). Phewa Lake receives as much as ten times more run-off during the monsoon season that the rest of the year (Ferro 1981/82). The lake is now infested with a floating macrophyte, the water hyacinth, *Eichhornia crassipes,* and blue green algae indicating enriched nutrient loading into the lake.

Phewa Lake's water temperature ranges between 15 and 29° C and transparency varies between 1.2 to 4.1 m (**Figure 1**). In the study period, the lowest transparency was recorded in July 2000 due to monsoon siltation, and the highest in March 2001, probably due to the low productivity of the water in winter.

Cage fish culture in Phewa Lake

Fish in the cages at Phewa Lake exclusively depend on plankton that contains nitrogen (N) and phosphorus (P). These two nutrients are major elements responsible for eutrophication. Since fish becomes the food for humans, N and P are displaced from the lake to the land (Pradhan and Pantha 1995). Therefore, the subsistence cage farming is often cited as an environment friendly livelihood approach.

Cage fish culture of plankton feeder fish in nylon or polyethylene knot-less floating cages of approximately 5 m x 5 m x 2 m is a popular method of fish production in the lake (Swar and Pradhan 1992, Gurung 2001). Silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*) are reared at the rate of 10 fish m^{-3}. The farmer stocks 25 g fingerlings in 25–35 mm mesh cage and they become harvestable at 500–1000 g in 12–15 months (Rai 2000). Cages may yield 1.33–5.5 kg of fish per cubic meter per year, depending on the trophic status of the lake (**Table 1**), excluding losses of 10–20% due to mortality and escape.

Fish production from cage culture was 37 mt in 2000, while in 2002 it reached to 48.3 mt (**Table 2**). In addition, 6–8 mt of fish are produced annually in experimental cages by the Fisheries Research Station, Pokhara. In 2001, the total cage fish production was estimated to be 52 mt.

Monetary income from 4–5 cages was adequate to cover all expenses of a typical fisher family comprising 5 members for a year (Swar and Pradhan 1992). To begin with, each family was given a single cage, which only provided partial support for the family (Sharma 1990), but the number of cages was increased later (**Table 2**). The supply of quality fingerlings became the main bottleneck. This was resolved when a fish hatchery constructed in Pokhara under the aegis of HMG Nepal and Japan International Cooperation Agency (JICA) (Gurung and Bista 2003)

Now some fishers owning as many as 16 cages are producing about 3000–4000 kg of marketable fish per annum (**Table 2, 3**). The annual income of these fishers comes to approximately 200–300 thousand Nepalese rupees, equivalent to US $2850–4280 at the current exchange rate of 70 NR = US$ (Gurung and Bista 2003). The fishers now pay 30–50 thousand Nepalese Rupees annually as an income tax to the District Development Committee after the fish harvest. Most families now own their land, have houses with toilets, gas stove, and TV; a few also possess motorbikes. With the increased income and improving livelihood, community members are able to send their children to school; at present, a dozen students are ready to attend university. A few years ago, it was difficult to find a single literate member of the community (Gurung and Bista 2003).

Open water fishery

Fishing is the traditional occupation of Pode or Jalari in Pokhara, capture fishery using gill nets of mesh size up to 200 mm was widely adopted during the 1960s (Rajbanshi et al. 1984, Swar and Gurung 1988). Since 1975, the participatory approach has been encouraging the fisher community to utilize their

TABLE 3. Number of production and nursery cages hold by fisher's family in Phewa Lake

Number of families	Number of cages owned by each family
5	15–20
10	10–15
34	5–9
8	1–4

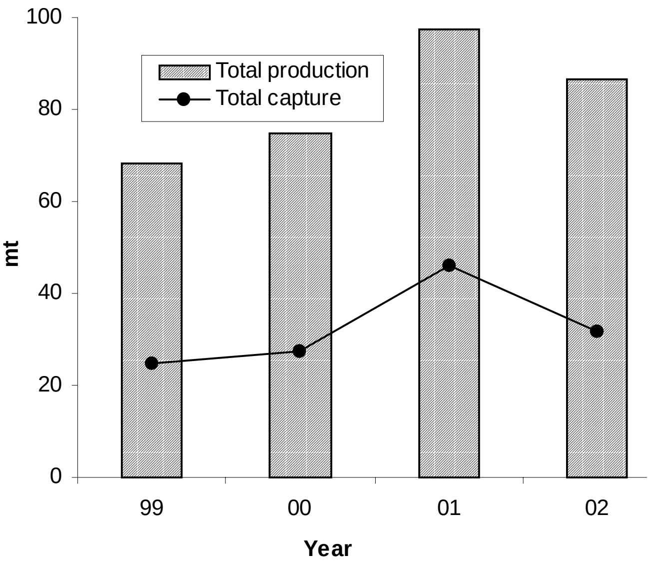

FIGURE 2. Total fish production and contribution of total captured fishery in Phewa Lake (Source: FMBS, Pokhara)

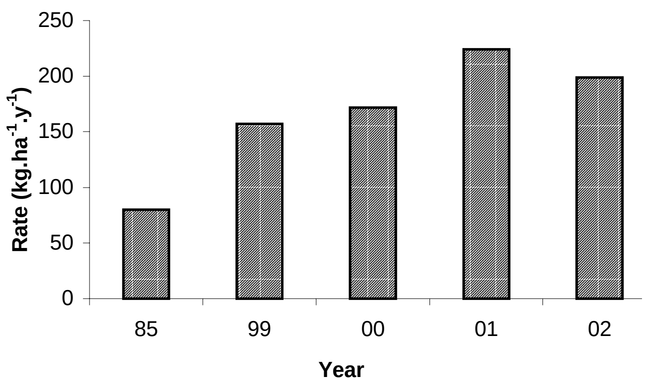

FIGURE 3. Annual fish production rate of Lake Phewa

traditional skills and helping them earn livelihood easily. This requires releasing (restocking) finger sized baby fish (fingerling) into the lake and re-catching later (recapture) when they grow bigger (Swar and Gurung 1988, Shrestha et al. 2001) using fishing devices like gill net, cast net, line, hook etc.

The main native species that form the basis of Phewa Lake fishery are *Tor* spp, *Acrossocheilus hexagonolepis, Labeo dero, Cirrihina reba, Mastacembelus armatus, Barilius* spp., and *Puntius* spp. (Ferro 1980, Bista et al. 2002). The fishery in Phewa Lake is comprised of exotic and indigenous fishes with substantial contribution of the former (Wagle and Bista 1999). The native and exotic fish species contributing to capture fishery are listed in **Table 4**. Their contribution is ranked as high, medium and low on the basis of annual abundance in catch statistics.

The total annual fish production ranged from 65 to 98 mt in Phewa Lake between 1999 and 2002, out of which 46 mt were captured in 2001 and 31 mt in 2002 (**Figure 2**). Wagle and Bista (1999) reported a 50.7 mt fish catch in Phewa Lake which included a 20% augmentation of the recorded catch to account for unrecorded harvest.

The total fish production in Phewa Lake reached about 98 mt in 2001 (**Figure 2**) contributing up to 219 $kg \cdot ha^{-1} \cdot y^{-1}$ (**Figure 3**). Mean fish production rate from reservoirs in Asia was estimated to be 20 $kg \cdot ha^{-1} \cdot y^{-1}$ (De Silva 1988) suggesting that Phewa Lake is much more productive than average Asian reservoir.

Market channeling

Pokhara city is a traditional market for fish products; however, market channeling must be improved. Given the national consumption rate of 1.5 kg per capita (Gurung 2003a) and Pokhara's population of about 300,000, approximately 1.5 mt of fish can be easily sold every day in the local market. Only a small portion of the total fish production of Pokhara valley is marketed in adjacent districts and Kathmandu, mostly during winter when yield surpasses local consumption. In summer, when fish catch is low, fish is supplied to Pokhara from outside sources.

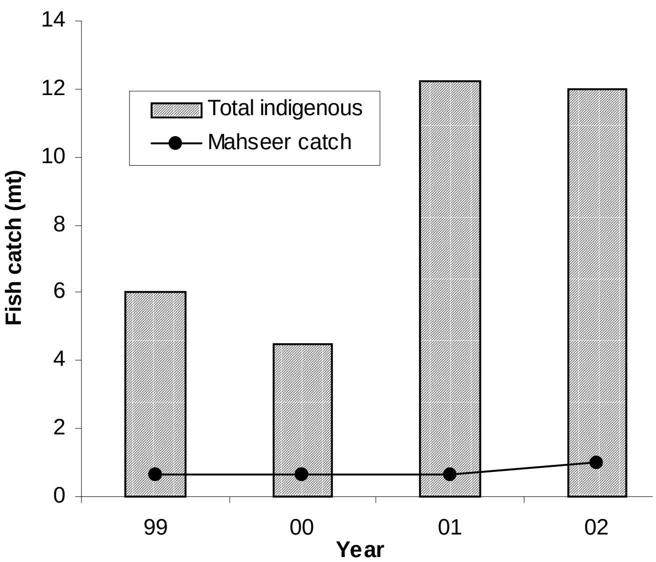

FIGURE 4. Total indigenous fish catch and contribution of *T.* spp (Mahseer) in Phewa Lake

Market arrangement for cage cultured fish and loan repayment

A multi-stakeholder body that includes FMBS, Agriculture Research Station (Fisheries), Agriculture Development Office and local fish-marketers determine the wholesale price of fish. The FMBS determines the turn for marketing each owner's fish. Fish are harvested early in the morning and brought to the office premises located nearby the lake around 6 AM, where, farmers are given a coupon to specify what was delivered, and the fish is turned over to a contractor for marketing. The contractor returns to the fisheries office to pay for the fish after selling it. The fishers are then paid according to the coupon

TABLE 4. Fish species and their contribution in capture fishery of Phewa Lake

Scientific name	Local name	Contribution*
Tor putitora (Hamilton)	Sahar	Low
Tor tor (Hamilton)	Sahar	-
Acrossocheilus hexagonolepis (McClelland)	Katle	Low
Cirrihina reba (Hamilton)	Rewa	Medium
Mastacembelus armatus (Lacepede)	Chuche bam	Low
Xenentodon cancila (Hamilton)	Dhunge bam	Medium
Channa gachua (Hamilton)	Bhoti	Low
Channa striatus (Bloch)	Bhoti	Low
Barilius barna (Hamilton)	Lam Fageta	High
B. bola (Hamilton)	Fageta	High
B. vagra (Hamilton)	Faketa	High
Barilius bendelisis (Hamilton)	Fageta	High
Mystus bleekeri (Day)	Junge	Low
Puntius sophore (Hamilton)	Bhitte	High
P. sarana (Hamilton)	Kande	High
P. titius (Hamilton)	Bhitte	High
P. ticto (Hamilton)	Bhitte	High
Nemacheilus rupicola (McClelland)	Gadela	Low
Garra annaldalei (Hora)	Buduna	Low
Clarias batrachus (L.)	Magur	Low
Psilorynchus pseudochenesis (Menon & Dutta)	Tite	Low
Cirrhinus mrigala (Hamilton)	Naini	Low
Catla catla (Hamilton)	Bhakur	Low
Labeo rohita (Hamilton)	Rohu	Medium
Aristichthys nobilis (Richardson)	Bighead carp	High
Hypophthalmichthys molitrix (Valenciennes)	Silver carp	High
Ctenopharyngodon idella (Valenciennes)	Grass carp	Low
Cyprinus carpio (L.)	Common carp	Low

tendered. If they have to pay loan, 50% amount of earning is deducted for repayment. In order to secure the best price, many fishers deliver their live product.

Market arrangement for recaptured fish

The marketing of recaptured fish (caught after being restocked; restocking is the act of releasing baby fish into the lake to increase fish population) is well organized. Women fisher themselves sell smaller fish weighing less than 2 kg each collected near the shoreline in the local market. A contractor may purchase recaptured fish larger than 2 kg each, which are collected every morning and brought to a chilling center located at the southern edge of the lake, where fresh, processed fillet and smoked products are sold.

Conservation initiative

A substantial quantity of Mahseer (*Tor* spp.) and other native fish were caught every year during '60s in Phewa Lake (Ferro 1980). However, the population was largely depleted and the catch fishery of Mahseer declined sharply, contributing less than 1.4 $mt \cdot y^{-1}$ (**Figure 4**).

There are 23 native fishes reported in Phewa Lake. The abundance of some fish has changed over time. For instance, *Channa* spp. and *Clarias batrachus* have been appeared more frequently in catches, which was not the case earlier. Katle *(Acrossocheilus hexagonolepis)* populations have decreased noticeably. Until 1960s, people catched a mahseer as big as 40 kg (personal communication with local fishers), but now only smaller individuals ($\leq$10 kg) are caught. Mahseer is vulnerable during spawning season, when they migrate towards shallow inlet stream for breeding. To protect these spawners, the fisher community has formed groups on their own initiative to patrol inlet streams during the breeding season (monsoon) and suppress illegal fishing (Gurung 2003b). Women's groups have also been mobilized, and they have proven more effective than their male counterparts at controlling fishing. It appears that few traditional fishers indulge in non-conventional techniques such as the use of electricity, explosives and poisons. Instead, these practices are more typical of urban people visiting the Phewa Lake area. Recently, the fisher community has also been engaged in manual removal of water hyacinth and other invasive macrophytes from the lake.

Code of conduct for sustainable fisheries management

Citizens of both developed and developing countries have a stake in environment, for both their health and that of their children (Downes and Brennan 1998). They now understand that environmental protection and sustainable use of resources such as lake and forest are fundamental to long-term prosperity (Downes and Brennan 1998, FAO 2002). Accordingly, the fisher community in close cooperation with other stakeholders has formulated the following code of conduct:

i. Fishing zone: Fishing in lake by any means is prohibited around 100 m of the Ratna Mandir, Fisheries Research Center, the *Barahi* temple and the inlet stream of Harpan Khola.

ii. Fishing method: Fishing using explosive, chemicals and battery operated electric rods are prohibited. Fishing by hook and line, gill net, and cast net are allowed, except in restricted areas and monsoon seasons. However, gill nets with mesh smaller than 100 mm is not allowed in the offshore of the lake.

iii. Fish culture areas: Cages for fish culture can only be set at three locations in the lake. The permitted sites are *Khapaudi,* in front of Fisheries Research Center and *Sedi* Area.

Lessons learned

The lessons learned from the participatory fisheries approach in recent decades are:

- Participatory programs in a community, which comprises socially deprived and ethnic minorities takes a long time to become self-sustaining in the mainstay of the society.
- The participatory approach to fishery can only be sustainable if the income generated is substantial and adequate to support the involved families.
- Deprived communities are inclined to depend on their stakeholder for various needs in addition to technical support
- The quality of twine, cage and net materials available in Pokhara for fish farming is very poor. In the near future attempts should be made to initiate local production of quality gear for fishing and fish farming.

Implications

The successful application of the participatory fisheries program of Phewa Lake has been implemented in other lakes of Pokhara Valley, Kulekhani Reservoir in Makawanpur District, and some parts of mid and far western development regions of the country. In Kulekhani area, community displaced by the construction of the Kulekhani hydropower dam has been resettled and provided a source of income and employment through cage fish culture and capture fisheries management. Besides the hydropower reservoirs, hundreds of shallow lakes, swamps, wetlands and inundated areas exist in southern plains (Bhandari 1998). In such waters implementation of participatory fishery managements can improve the livelihood of local communities and protect aquatic environments.

Costa-Pierce (1998) argued that cage aquaculture in Indonesian Reservoir is neither environmentally nor socially sustainable. The cage aquaculture was originally guaranteed to the displaced people by provincial legislation, and they were supposed to be granted exclusive control of production and marketing. However the rewards of cage culture have been usurped by the politically powerful and consolidated in the hands of the urban rich. On the other hand, management of the extensive cage fish farming system in Phewa Lake is fully controlled by the fisher community; it is essential that this system be maintained. Recent reports indicate that tourism activities can adversely affect the ecology of pristine ecosystems through the loading of nutrients into the water column (King and Mace 1974, Liddle and Scorgio 1980, Hadwen et at. 2003). Such studies have not been yet carried out in Nepal, though Phewa Lake is under intense pressure from tourism development (Oli 1997, Lamichhane 2000). Since tourism is one of the most lucrative economic sectors fostering around Phewa Lake, adequate attention must be paid to sustainable management of the lake ecosystem so that tourism and fishery may develop ➡

synergistically rather than adversarially.

Conclusions

The threats to sustainability of Phewa Lake are sedimentation, eutrophication and heavy infestation of water hyacinth. If these are controlled, the life of the lake could be improved and lengthened. It is anticipated that fishers can contribute to the sustainable management of Phewa Lake, if they are allowed to participate fully and share their skills and traditional knowledge. Since, the participatory management of natural resources in Phewa Lake has been proved to be an important avenue for sustainable livelihood enhancement of poor, it is anticipated that several other water bodies could be wisely managed to bring deprived fisher communities into the mainstream of society. ■

Acknowledgements
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Illustrated checklist of pea clams (Mollusca: Bivalvia: Sphaeriidae) from Nepal

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The pea clams (Sphaeriidae) of Nepal are represented by 11 taxa. The highest diversity is found in the mid-altitudinal range between 795 and 1570 masl. Pea clams are poorly represented in the high Himalaya and the Terai. Faunal associations are with the Palaearctic and Oriental regions and with Central Asia. Most pea clams are useful indicator species and, owing to their high abundance and long life span, they are useful in monitoring the water quality of streams.

Key words: *Pisidium*, *Musculium*, pea clam, indicator species, Sphaeriidae, Nepal

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At present, 11 taxa (10 species and one subspecies) of pea clams are found in Nepal. Sphaeriids range from 70 to 2750 masl, whereas the Corbiculidae, Unionidae and Amblemidae are mainly restricted to the Terai, below 200 masl elevation. In the mid-altitudes pea clams are a dominant part of the macrozoobenthic communities of running water. Most species are useful indicator organisms for biological water quality. The average life span ranges from one to two or three years. The activity period of two highly specialized taxa is confined to temporary bodies of water and coincides with the 3 to 4 monsoon months of June to Sept. All other species are found throughout the year. All taxa are briefly characterized by figures. Four sphaeriids were not recorded by Nesemann et al. (2001) and represent new records for Nepal. Additional remarks for identification are given.

Methodology

The study area is situated between the Kali Gandaki and Kosi River Systems (27°35'– 28°50' N, 83°45'– 85°40' E). Field work was carried out from September 2003 to April 2005. Pea clams were collected qualitatively using nets of varying mesh size (1 mm, 500 µm, 150 µm), washed where appropriate, and examined under a stereomicroscope. Living specimens were fixed in 70% ethanol and presumably preserved in the same medium and empty shells were dried. Specimens were deposited in the reference collections of Kathmandu University Museum and the Vienna Natural History Museum (Naturhistorisches Museum Wien), Austria. In order to study seasonal variation, frequent sampling was carried out in selected cites within the middle Mountains of the Central Zone and the Terai region in the Eastern Zone. In making identifications, we relied primarily on a reference collection provided by Dr. Alexei Korniushin, Kiev, Ukraine. Sketches were produced by H. Nesemann. The biological water quality assessment is based on the Nepalese Biotic Score NEPBIOS method, following Sharma (1996). The four water quality classes and their recommended uses are: Class I, excellent, recommended for drinking; Class II, good, drinking possible after treatment; Class III, fair, hazardous; Class IV, bad, unsuitable for any human use except as a receptacle for sewage.

Descriptions

Family Sphaeriidae (= in part: Pisidiidae)
Genus *Musculium* Link, 1807

1. ***Musculium indicum*** (Deshayes, 1854)
(= *Sphaerium indicum*)

Distribution: Gangetic River basin in northern India (Prashad 1922) and Nepal (Nesemann et al. 2001).
Occurence in Nepal: Common in streams of the upper Bagmati River basin in the Kathmandu Valley, in the Punyamata Khola, lower Ashi Khola and Cha Khola. Additional populations were found recently in the Phewa Tal and Begnas Tal. Only recorded from 790 masl to 1600 masl.
Ecology: *M. indicum* lives abundantly in the lower reaches of small or medium-sized midhill streams, where a rich amount of organic matter and detritus is found. It can also be found in small eutrophic ponds and temporary paddy fields. Its occurrence correlates closely with intensive agriculture and natural bodies of shallow water, which are warm in summer. It is largely absent from upstream headwaters, springs and forest streams.
Indicator value: This species tolerates a wider range of organic pollution than all other Sphaeriidae (Sharma 1996). It can be found in spring pools of water quality class I-II, in eutrophic streams of class II and even in critically polluted running waters of class II-III to III, when there is enough oxygen due to high water current and turbulence. It usually lives in association with other *Pisidium*-species under betamesosaprobic conditions. In more polluted zones (e.g. the Bosan Khola north of Kirtipur and the middle reach of Bishnumati in Kathmandu Valley), *M. indicum* is present in large quantities while other sphaeriids are absent.

2. ***Musculium goshaitanensis*** **nov. spec.**

New to the fauna of Nepal: *Musculium goshaitanensis* nov. spec. is confined to temporary waterbodies of the Punyamata between Shree Khandapur and Dhulikhel. It is known only from elevations of 1450–1470 masl.
Ecology: Records to date have been confined to paddy fields. It occurs abundantly as the sole sphaeriid or sympatrically with *Pisidium clarkeanum dhulikhelensis* nov. subspec. Abundance is low and it primarily occurs in dark black mud, which is low in oxygen. Its activity period is June through October. Diapausis of juveniles occurs in soil at a depth of ≥50 cm from the end of October to mid-June.
Indicator value: Lives in low oxygen conditions sufficient for only a meager level of biological activity.
Description and differential diagnosis: *Musculium goshaitanensis* nov. spec. differs from *Musculium indicum* in the following characters: shell more elongated, adult length usually ≥10 mm (8–9.5 mm in *M. indicum*); caps always present; thin-shelled and fragile, periostracum color gray to dark red-brown with numerous dark concentric growing lines (yellow to gray-blue without dark concentric growing lines in *M. indicum*); inner shell surface dark and glossy (white to yellowish-blue in *M. indicum*); hinge has thin and prolonged anterior and posterior lateral teeth; minute cardinal teeth with short curved triangular C2.

Genus *Pisidium* Pfeiffer, 1821
Subgenus *Jenyns,* 1832 (= *Casertiana* Fagot, 1892)

3. ***Pisidium (Euglesa) atkinsonianum*** Theobald, 1876

Distribution: Ganga and Brahmaputra River basins. Darjeeling, Sikkim (Prashad 1925), Meghalaya (Subba Rao et al. 1995, coll. of H. N. 2002), Nepal (Nesemann et al. 2001).
Occurrence in Nepal: *P. atkinsonianum* is known from nine localities in the Kathmandu Valley, including the Bosan Khola (Dudh Pokhari, Simpani), Godavari Khola, Bishnumati Khola and upper Bagmati River in the Shivapuri hills where it ranges from 1300 to 1680 masl. It is abundant from the Punyamata Valley from Nala, Banepa, Dhulikhel to Panauti where it was recorded from twenty-five localities and from three localities of the Roshi Khola downstream from Panauti from 1430 to 1550 masl. The only known populations in the Cha-Khola watershed are in four springs at Khasre and Rohini Bhanjyan at 1785 masl and 2065 masl.
Ecology: *P. atkinsonianum* is closely related to *P. casertanum* and replaces the latter species in large parts of the central and eastern Himalaya. It is largely confined to flowing water and occurs in small- to medium-sized streams, being almost absent from forest-streams and stagnant water bodies. Very large forms are found in slightly eutrophic water and agricultural irrigation channels. It is often associated with *Musculium indicum* in the lower reaches and *Pisidium annandalei* in the upper reaches of the same streams.
Indicator value: *P. atkinsonianum* tolerates a wider range of organic pollution than other *Pisidium* species and is able to exploit habitats rich in detritus and fine organic material. It is usually found in Class I-II to II-III water, indicating mainly betamesosaprobic conditions, it occurs only rarely in Class I environments. It is locally abundant, and very often the dominant bivalve species with densities reaching several hundred individuals per square meter. *P. atkinsonianum* is therefore a good indicator species for low to moderate pollution.

4. ***Pisidium (Euglesa) casertanum*** Poli, 1791

Distribution: Widely distributed in the Palaearctic and Nearctic region, it also occurs in some parts of South America, Africa and Australia and is the most widely distributed species of freshwater mollusc in the world (Clarke 1981). In Asia, *P. casertanum* is found in the upper Indus River basin in Kashmir (Prashad 1925, Subba Rao 1989), in China (Tibet) and eastwards to the Amur River basin (Zeissler 1971). In Southeast Asia, Brandt (1974) reported one locality in Thailand.
New to the fauna of Nepal: Kavre District, Banepa, small springstream to the lower Chandeshwari Khola, 0.5 km SE of Chandeshwari, 8. 1. 2005, elevation 1615 masl.
Ecology: The species was found abundantly in a very small natural cold stream in dense mixed *Rhododendron* forest. The water temperature was 11° C on 10th January, 2005. The microhabitat was fine mud and leaf litter in very shallow pools. No other bivalves occur so far upstream. *P. casertanum* lives in association with the prosobranch gastropod *Tricula montana* and the potamid crab *Himalayapotamon* spec. (sensu Brandis and Sharma 2004).
Indicator value: This predominantly holarctic species of temperate regions is known in Nepal only from this uppermost headwater with constant low temperature and no anthropogenic pollution, with Class I water quality.
Remarks: *P. casertanum* is distinguished from the closely allied *P. atkinsonianum* by the following characters: small size, maximum length usually 3.0 to 3.7 mm; thick-shelled, surface with fine irregular striations; periostracum yellowish to redbrown in the posterior half; hinge more curved than in *P. atkinsonianum*; anterior and posterior teeth rather thick; cardinal teeth C2 and C3 distinctly curved; umbones more prominent and more shifted posteriorly than in *P. atkinsonianum*.

Subgenus *Odhneripisidium* Kuiper, 1962

5. ***Pisidium (Odhneripisidium) annandalei*** Prashad, 1925

Distribution: Oriental region including some Mediterranean parts of southeast Europe (Zeissler 1971), Sicily, southern Italy and Greece. From Israel to Southeast Asia and India (Subba Rao 1989), Bihar (Prashad 1925), Meghalaya (coll. of H.N. 2002), Nepal (Nesemann et al. 2001), Thailand and Indonesia (Brandt 1974).
Occurrence in Nepal: Two localities in the southwest Kathmandu Valley (Central Zone), Bosan Khola with Dudhpokhari and Simpani, twenty localities in the Punyamata Valley, numerous localities in the Ashi Khola and Cha Khola watershed. Occurs from 795 to 2065 masl.
Ecology: *P. annandalei* is restricted to springs, springstreams and small to medium-sized hillstreams. Coldwater tolerant, it is relatively abundant in headwaters and upstream stretches. A large form was found at high density in the spring pool of Goshaikunda north of Banepa (1645 masl) surrounded by *Pinus roxburghii* forest, where the water temperature was stable at around 11° C; no other bivalve species were recorded at this locale. In another spring pool between Kathmandu University and Shree Khandapur (1490 masl) where the water temperature ranges from 11–15° C, the eudominant *P. annandalei* occurs sympatrically with several *Musculium indicum* specimens.
Indicator value: Although *P. annandalei* is widely distributed from unpolluted oligosaprobic zones (Class I) to betamesosaprobic organically polluted zones (Class II and II-

III), it is the most useful indicator species for drinking water quality assessment. High abundance is only found in water quality Class I and I-II, where *P. annandalei* reaches its largest size and is often the sole bivalve present. With increasing organic pollution and eutrophication, this species is successively replaced by other *Pisidium* and *Musculium* species. In the organically polluted zones of the lower Dhobi Khola and lower Goshaitan Khola near Dhulikhel (1450 masl), which may have water quality Class II-III during spring, a very dense population of sphaeriids can be observed. The dominant taxa are *Musculium indicum* and *Pisidium atkinsonianum*, whereas *P. annandalei* is present in only small numbers.

6. ***Pisidium (Odhneripisidium) prasongi*** Kuiper, 1974

Distribution: Southeast Asia: Thailand (Brandt 1974), South Asia: Nepal. *P. prasongi* appears to be a more widely distributed species, previously overlooked due to its minute size, or mistaken for immature *P. annandalei*.
New to the fauna of Nepal: Western region, Kaski District, Pokhara Valley, Sano Tal Khola 0.75 km NW of Khapaudi, 14. 11. + 1. 12. 2004, Khahare Khola near Bhakunde Bagar, 1. 12. 2004, Khanjare Khola W of Sano Tal, 2. 12. 2004, Central region, Kavre District, Mahadevsthan, lower Ashi Khola 0.5 km SW of Dhaitar, 4. 1. 2005. *P. prasongi* occurs in a very limited altitudinal range between 795 and 815 masl.
Ecology: Recorded from only four streams in Nepal; it is abundant in three localities of the Phewa Tal watershed. Sano Tal Khola is a small cold midhill stream (16º C) with mixed water from a stream and eutrophic lake. Here *P. prasongi* occurs in a dense population only in 150 m long stretch where the stream enters into the wide Harpan-Khola-Phewa Tal floodplain. After the stream mixes with the confluence of Sano Tal, this species is associated with *P. nevillianum* and *P. clarkeanum*. Khahare and Khanjare Khola are two geothermal springstreams (22º C) with highly diversified benthic invertebrate communities. In the Ashi-Khola watershed only a few specimens of *P. prasongi* were collected together with *Musculium indicum* and *P. nevillianum*. Elsewhere this stream is predominantly colonized by *P. annandalei*.
Indicator value: This species is confined to running water and found in unpolluted to slightly polluted waters of water quality Class I-II to II. *P. prasongi* replaces *P. annandalei* below 800 masl. Although *P. prasongi* is locally abundant, its very limited distribution severely restricts its utility in biological water quality monitoring. Since it is highly localised within Nepal, the occurrence of *P. prasongi* may indicate a unique habitat type within Nepal.
Remarks: *P. prasongi* is distinguished from the closely allied *P. annandalei* by the following characters: small size, maximum length usually 2.0 to 2.2 mm; thin shell; oval outline; shell surface with fine regular striations and pale periostracum; hinge: anterior and posterior teeth shorter and less swollen than in *P. annandalei*; cardinal teeth C2 and C3 curved.

7. ***Pisidium (Odhneripisidium) kuiperi*** Dance, 1967

Distribution: India: Sikkim (Dance 1967), Nepal (Nesemann et al. 2001).
Occurence in Nepal: Hitherto, this species was known only from the upper Bhageri Khola at Godawari, southern Kathmandu Valley at 1555 masl. A second locality was recently found (24, 25. 10. 2003) in the small effluent stream of the Dhumba Tal near Jomson, Mustang District, upper Kali Gandaki watershed.
Ecology: In Mustang *P. kuiperi* lives abundantly in the fine dark brown mud of slow-running stretches of the stream within acidophilic Juncaceous vegetation. It is accompanied by the Lymnaeids *Galba truncatula* and *Radix hookeri* at 2700 masl.
Indicator value: Both localities in Nepal are unpolluted waters of water quality Class I-II.
Remarks: In outward appearence live specimens are similar to *P. casertanum* in size, shape, periostracum color and concentric striations, but differ by in the ligament pit in subgeneric level.

Subgenus *Afropisidium* Kuiper, 1962

8. ***Pisidium (Afropisidium) ellisi*** Dance, 1967

Distribution: Sikkim (India), Nepal.
New to the fauna of Nepal: Kavre District, Banepa, three springstreams to the lower Chandeshwari Khola, 0.8 km E of Chandeshwari, 15. 1. 2005, elevation 1585–1650 masl; Rohini Bhanjyan, springstream of Cha-Khola, 26. 3. 2005, elevation 2065 masl; Kaphalbot, springstream of Ashi-Khola, 7. 4. 2005, elevation 1765 masl.
Ecology: Specimens were collected in small natural cold streams in dense mixed and oak forest. The microhabitat is fine red-brown mud in very shallow pools, where the pea clams are found on the sediment surface. *P. ellisi* usually lives in association with large numbers of *P. annandalei*. Other bivalves found in these waters are *P. casertanum* and *P. atkinsonianum*. Additional taxa in this assemblage are the prosobranchia *Tricula montana* (Pomatiopsidae), two Spring Spire Snails (*Erhaia* spec. new to the Fauna of Nepal), the Potamid crab *Himalayapotamon* spec. (sensu Brandis and Sharma 2004) and the Red Algae *Batrachospermum moniliforme* (Rhodophyceae: Nemaliomales).
Indicator value: Xenosaprobic to oligosaprobic condition of natural oak-forest springs. Water quality Class I. Among all pea clams, *P. ellisi* is the best indicator of high quality water.
Remarks: *P. ellisi* can be identified by the following characters: very small shell, length 1.6–1.8 mm (Chandeshwari), 2.0 mm (Cha-Khola); external ligament prominent and long; the anterior lateral teeth much closer to the cardinal teeth than the posterior laterals; periostracum yellowish-brown with fine concentric striation; most shells dark in appearance having been stained black or brown by the sediment.

9. ***Pisidium (Afropisidium) clarkeanum*** G.& H. Nevill, 1871

Distribution: A widely distributed species in South and Southeast Asia, known from India (Prashad 1925, Subba Rao 1989, Nesemann et al. 2003), Nepal (Nesemann et al. 2001), Myanmar, Thailand and Laos (Brandt 1974).
Occurrence in Nepal: Terai in Western, Central and Eastern regions (15 localities): Jhapa, Morang, Sunsari and Rautahat Districts. Midhills, Kavre District: Mahadevsthan, lower Ashi Khola near Kunta (798 masl). Kaski District: Phewa Tal, Sano Tal and Begnas Tal (795 masl), Phusre Khola, Orlan Khola, Khudi Khola, Deura Khola, Chyanladi Khola and Gaduwa Khola. This species is found mostly in warm subtropical lowland waters from 70 to 140 masl. It also occurs at mid-altitudes whenever the local climate and hydrology (geothermal springs of Pokhara Valley) provide suitable microhabitats.
Ecology: In the Gangetic plain and Terai *P. clarkeanum* is abundant in slowly running streams and rivers; it is occasionally found in the littoral zone along the shores of lakes and large ponds where it prefers lentic areas with a soft muddy bottom. In the mid-altitudinal range, it is very often found sympatrically

with *P. nevillianum*, but is usually less abundant than the latter species. By comparison with *P. nevillianum*, *P. clarkeanum* is restricted mainly to lentic microhabitats, preferring sediments such as mud enriched with detritus or silt.
Indicator value: *P. clarkeanum* is a very good indicator for mesosaprobic conditions with moderate organic pollution. It is dominant in betamesosaprobic to alphamesosaprobic waters with water quality Class II or II-III.

10. ***Pisidium (Afropisidium) clarkeanum dhulikhelensis* nov. subspec.**

Distribution: Nepal, Kavre District, endemic to the upper Punyamata Valley.
New to the fauna of Nepal: This is considered to be a distinct subspecies of *P. clarkeanum*. It is confined to temporary waterbodies of the Punyamata between Panauti and Banepa. *P. clarkeanum dhulikhelensis* nov. subspec. is known only from elevations between 1430 and 1495 masl.
Ecology: This is a highly specialized species able to exploit the temporary aquatic habitats of paddy fields where it may occur at very high densities and is often the sole bivalve species present, although it may occur with *Musculium goshaitanensis* nov. spec. Other bivalves cannot survive permanently in such habitats, although they are occasionally carried into paddy fields with flood waters. *P. clarkeanum dhulikhelensis* nov. subspec. lives in association with the fairy moss *Azolla pinnata* var. *africana*. Life span: Activity period June to October. Diapausis of juveniles in soil depth of ≥50 cm from end of October to mid-June.
Indicator value: The presence of *Pisidium clarkeanum dhulikhelensis* indicates a fairly good oxygen level in water and sediment, equivalent to a betamesosaprobic situation of water quality Class II.
Description and differential diagnosis: *P. clarkeanum dhulikhelensis* nov. subspec. can be distinguished from *P. clarkeanum* sensu stricto by the following characters: thin tumid shell with colorless pale periostracum; oval outline (subtrigonal in *P. clarkeanum*), prominent umbones always with distinct caps, more central than in *P. clarkeanum* hinge more elongated with thin teeth; P2 always curved, C2 always prominent and closer to a 2 than in the nominate subspecies.

TABLE 1. Zoogeographical comparison of different Eurasian Sphaeriidae fauna

<table>
<tr><th>Subgenus</th><th colspan="3">Species/subspecies</th></tr>
<tr><td></td><td>(West-) Palaearctis</td><td>Nepal</td><td>Thailand</td></tr>
<tr><td>Pisidium s. str.</td><td>amnicum</td><td></td><td></td></tr>
<tr><td rowspan="12">Euglesa</td><td colspan="3">casertanum</td></tr>
<tr><td>cas. ponderosum</td><td>atkinsonianum</td><td></td></tr>
<tr><td>globulare</td><td></td><td></td></tr>
<tr><td>henslowanum</td><td></td><td></td></tr>
<tr><td>supinum</td><td></td><td></td></tr>
<tr><td>milium</td><td></td><td></td></tr>
<tr><td>nitidum</td><td></td><td></td></tr>
<tr><td>pulchellum</td><td></td><td></td></tr>
<tr><td>personatum</td><td></td><td></td></tr>
<tr><td>lilljeborgi</td><td></td><td></td></tr>
<tr><td>pseudosphaerium</td><td></td><td></td></tr>
<tr><td>obtusale</td><td></td><td></td></tr>
<tr><td rowspan="2">Neopisidium</td><td>moitessierianum</td><td></td><td></td></tr>
<tr><td>conventus</td><td></td><td></td></tr>
<tr><td rowspan="3">Odhneripisidium</td><td>tenuilineatum</td><td colspan="2">annandalei</td></tr>
<tr><td>stewarti (subfossil)</td><td colspan="2">prasongi</td></tr>
<tr><td></td><td>kuiperi</td><td>sumatranum</td></tr>
<tr><td rowspan="4">Afropisidium</td><td rowspan="4"></td><td>ellisi</td><td></td></tr>
<tr><td colspan="2">nevillianum</td></tr>
<tr><td colspan="2">clarkeanum</td></tr>
<tr><td>cl. dhulikhelensis</td><td>javanum</td></tr>
<tr><td rowspan="2">Musculium</td><td>lacustre</td><td>indicum</td><td></td></tr>
<tr><td>transversum</td><td>goshaitanensis</td><td></td></tr>
<tr><td rowspan="2">Sphaerium</td><td>corneum</td><td></td><td></td></tr>
<tr><td>scaldianum</td><td></td><td></td></tr>
<tr><td>Sphaeriastrum</td><td>rivicola</td><td></td><td></td></tr>
<tr><td>Cyrenastrum</td><td>solidum</td><td></td><td></td></tr>
<tr><td rowspan="2">Nucleocyclas</td><td>nucleus</td><td></td><td></td></tr>
<tr><td>ovale</td><td></td><td></td></tr>
<tr><td>TAXA</td><td>25</td><td>11</td><td>7</td></tr>
</table>

11. ***Pisidium (Afropisidium) nevillianum*** Theobald, 1876

Distribution: South and Southeast Asia: India (Prashad 1925, Subba Rao 1989, Nesemann et al. 2003), Bangladesh (Brandt 1974, Subba Rao 1989), Nepal (Nesemann et al. 2001), Thailand (Brandt 1974).
Occurrence in Nepal: Terai in Central and Eastern regions (20 localities). Adittional records from Terai: Bishazari Tal (coll. P. B. Budha, TU Kirtipur), from midhills in Central region (Kavre District): Cha Khola, Ashi Khola. Midhills in Western region (Kaski District): Phewa Tal, Begnas Tal, Sano Tal, Gaduwa Tal, Orlan Khola, Khudi Khola, Deura Khola, Chyanladi Khola, Gaduwa Khola and Tal Khola. *P. nevillianum* is found at elevations between 75 and 920 masl.
Ecology: This is a subtropical species requiring high water temperatures during the summer and monsoon; it also needs organic matter and detritus to flourish. *P. nevillianum* is very

common across a wide range of streams and small rivers and is a dominant species in larger lakes in the midhills. High densities were observed in agricultural irrigation channels, where *P. nevillianum* is usually accompanied by *P. annandalei*. Unlike *P. clarkeanum*, *P. nevillianum* is predominantly found in lotic microhabitats. It prefers sediments with a mud and sand mixture or even pure sand.

Indicator value: *P. nevillianum* lives mainly under betamesosaprobic conditions. Due to its wide range and abundance, it is a very useful indicator for water quality class II. It also occurs in slightly polluted midhill irrigation channels (together with *Odhneripisidium* species) of Class I-II and occasionally in Terai in critically polluted zones of Class II-III, wherever the water current provides enough oxygen.

Zoogeographical comments

The Eurasian continent is sharply divided by the Alpine/ Himalayan mountain range system (Banarescu 1992) into the northern Palaearctic and southern Oriental region. The faunal composition of Sphaeriidae in the Nepalese mid-altitudinal range is a mixture of both regions and can be described as a transitional zone, although all running waters are part of the Gangetic watershed. *Afropisidium* originates from the Oriental region, whereas *Odhneripisidium* is centred in Central Asia. From the Palaearctic region *Musculium* has invaded the southern Himalayan midhills. The predominantly palaearctic *Euglesa*, although highly diverse, is poorly represented in Nepal. The ecological niches of European *Euglesa* are partially occupied in Nepal by *Odhneripisidium*, *Afropisidium* and *Musculium*. Two pea clams *P. (O.) kuiperi*, *P. (A.) ellisi* are endemic to the Central Himalayan region in Nepal and Sikkim. The only widespread species in Europe and Asia is *Pisidium casertanum*. In contrast to the temperate zones of the Palaearctic, where *P. casertanum* is very common, it is rare in South and Southeast Asia, where it is limited to a few cold water habitats. Two pea clams *M. goshaitanensis* n. sp. and *P. (A.) clarkeanum dhulikhelensis* n. subspec. are endemic to Punyamata Valley, obviously evolved with an ancient pleistocene lake. ■

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Plates on the next pages

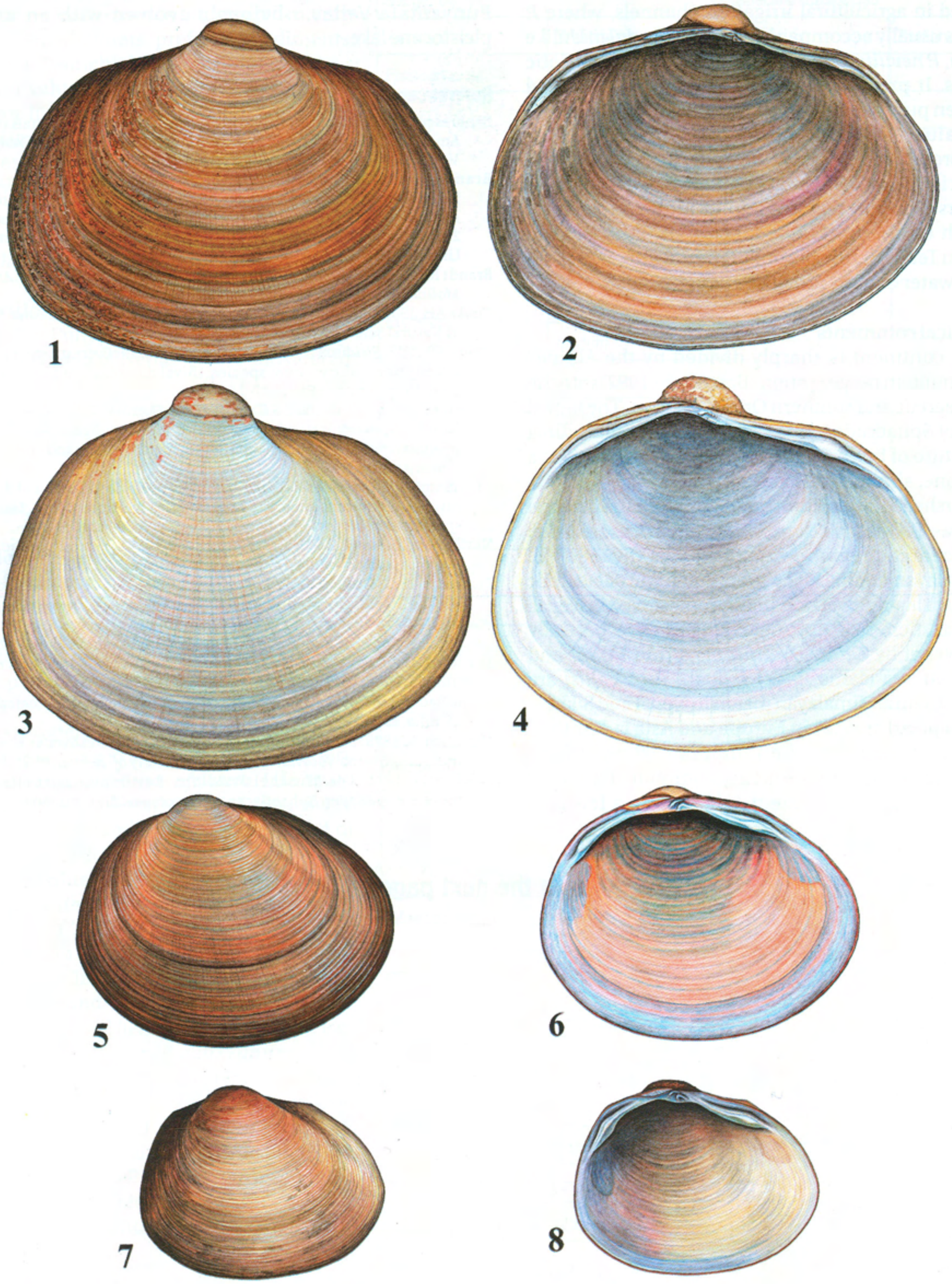

PLATE I. Musculium and Euglesa

1 and 2: *Musculium goshaitanensis*, Kavre, Dhulikhel, Paddy-field near Dhobi-Khola, length 10.3 mm, Holotype, Natural History Museum Vienna, Mollusca Collection No. 103317

3 and 4: *Musculium indicum*, Kavre, Dhulikhel, Dhobi-Khola, length 9.6 mm, Natural History Museum Vienna, Mollusca Collection No. 103311

5 and 6: *Pisidium (Euglesa) atkinsonianum*, Kavre, Dhulikhel, Dhobi-Khola, length 5.8 mm, Natural History Museum Vienna, Mollusca Collection No. 103306

7 and 8: *Pisidium (Euglesa) casertanum*, Kavre, Banepa, Chandeshwari Khola watershed, small spring-stream, length 3.8 mm, Natural History Museum Vienna, Mollusca Collection No. 103304

Note: All figures are in the same scale.

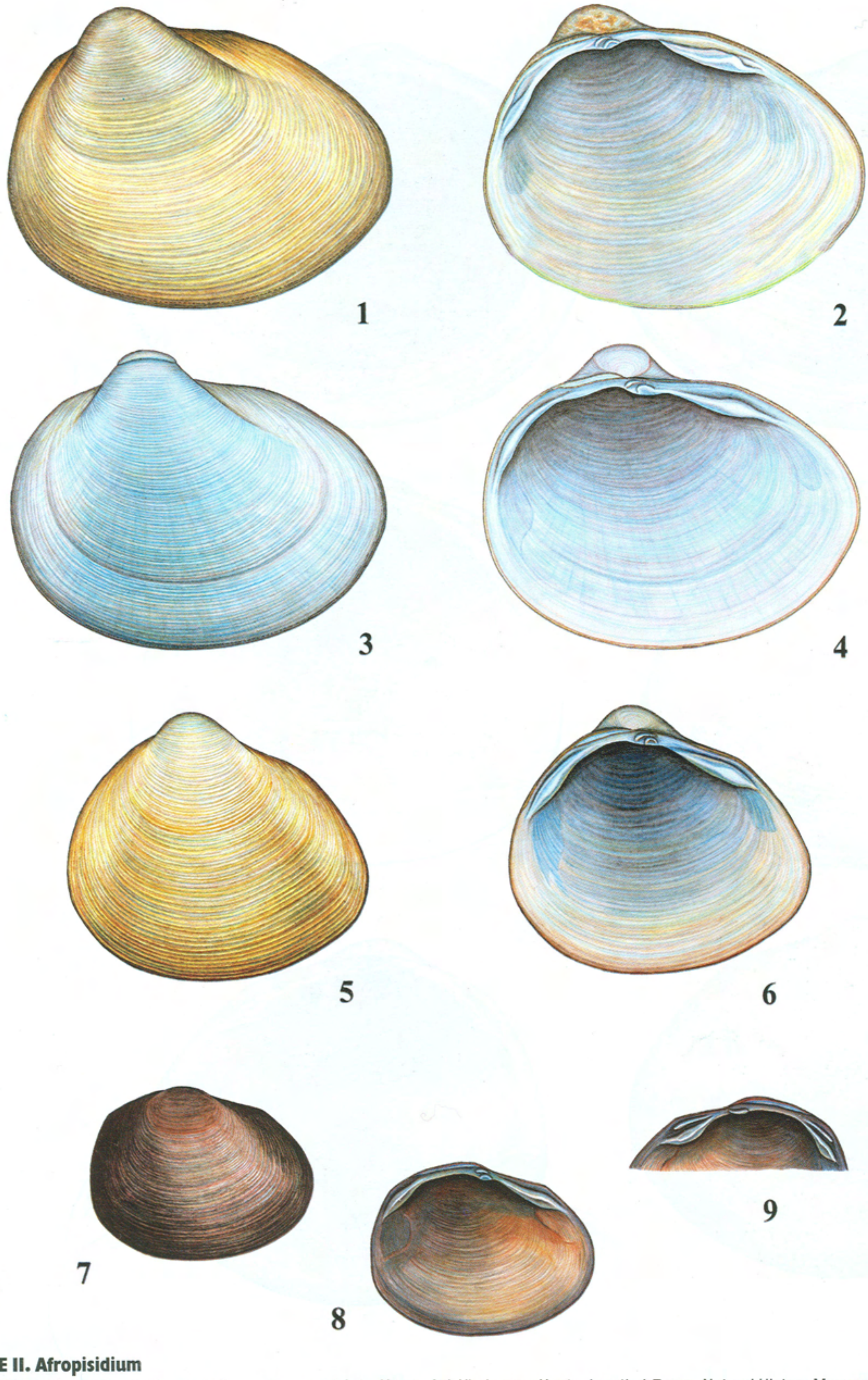

PLATE II. Afropisidium

1 and 2: *Pisidium (Afropisidium) clarkeanum* sensu stricto, Kavre, Asi-Khola near Kunta, length 4.7 mm, Natural History Museum Vienna, Mollusca Collection No. 103305

3 and 4: *Pisidium (Afropisidium) clarkeanum dhulikhelensis*, Kavre, Dhulikhel, Paddy-field near Dhobi-Khola, length 4.7 mm, Holotype, Natural History Museum Vienna, Mollusca Collection No. 103313

5 and 6: *Pisidium (Afropisidium) nevillianum*, Kavre, Asi-Khola near Kunta, length 3.9 mm Natural History Museum Vienna, Mollusca Collection No. 103307

7–9: *Pisidium (Afropisidium) ellisi*, Kavre, Banepa, Chandeshwari Khola watershed, small spring-stream, length 2.0 mm, Natural History Museum Vienna, Mollusca Collection No. 103308

Note: All figures are in the same scale.

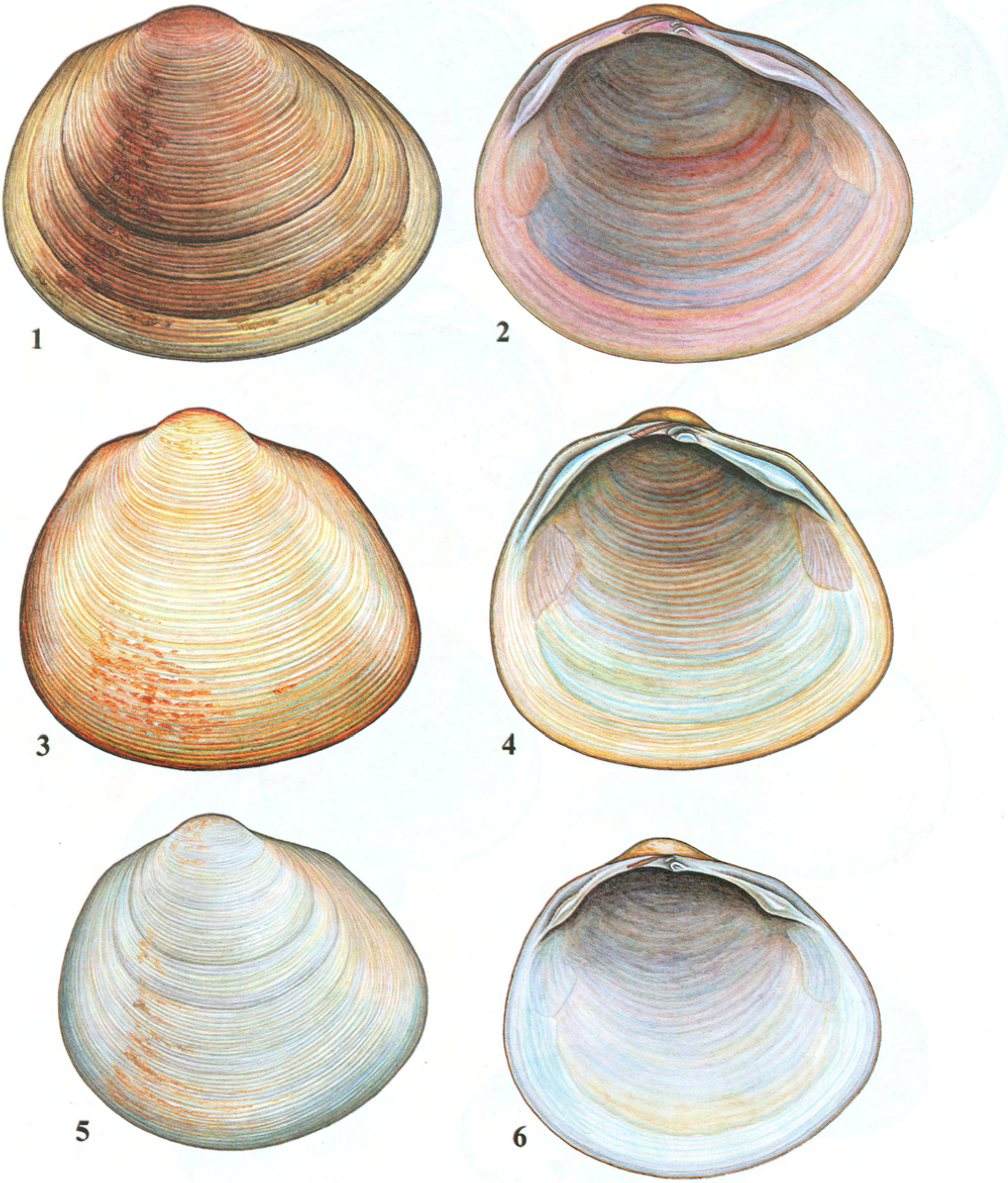

PLATE III. Odhneripisidium

1 and 2: *Pisidium (Odhneripisidium) kuiperi*, Mustang, Dhumba Tal effluent near Jomson, length 3.6 mm, Natural History Museum Vienna, Mollusca Collection No. 103309
3 and 4: *Pisidium (Odhneripisidium) annandalei*, Kavre, Dhumba Tal Asi-Khola 2.5 km upstream of Dhaitar, length 2.5 mm, Natural History Museum Vienna, Mollusca Collection No. 103310
5 and 6: *Pisidium (Odhneripisidium) prasongi*, Kaski, Sano Tal-Khola near Phewa Tal, length 2.1 mm, Natural History Museum Vienna, Mollusca Collection No. 103303.
Note: All figures are in the same scale.

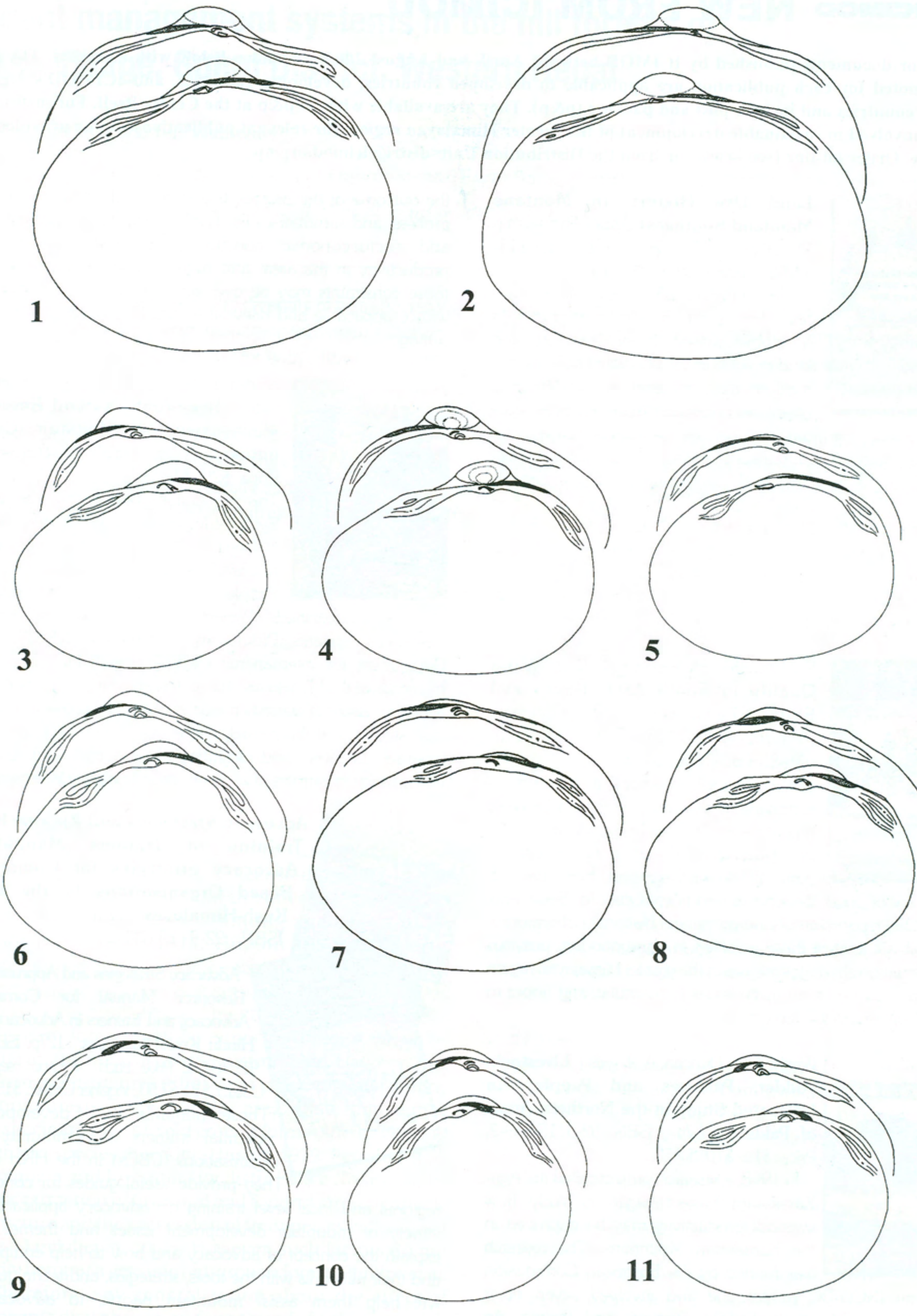

PLATE IV. Sphaeriidae characters of hinge

1: *Musculium indicum*
2: *Musculium goshaitanensis*
3: *Pisidium clarkeanum*
4: *Pisidium clarkeanum dhulikhelensis*
5: *Pisidium ellisi*
6: *Pisidium nevillianum*
7: *Pisidium atkinsonianum*
8: *Pisidium casertanum*
9: *Pisidium kuiperi*
10: *Pisidium annandalei*
11: *Pisidium prasongi*

Note: Figures not in the same scale.

Composition, distribution and diversity of tree species under different management systems in the hill forests of Bharse Village, Gulmi District, Western Nepal

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Species composition, distribution and diversity of tree species were compared in three forest stands in the Bharse area, Gulmi District, Nepal. These forests have distinct management systems and are used for different purposes: Raiker (RK) for controlled-cutting, Raniban (RB) for cattle grazing, and Thaple (TL) for both cutting and cattle grazing. The total density of trees in RK was higher (2640 ha^{-1}) than that in RB (2533 ha^{-1}) and TL (1875 ha^{-1}). However, the largest basal area (105 m^2ha^{-1}) was found in RB while RK and TL were calculated at 72 m^2ha^{-1} and 58 m^2ha^{-1}, respectively. The distribution of species showed clump behavior in the grazing forests whereas mixed (clump and regular) distribution occurred in the controlled-cutting forest. Trees with small diameter size were more in the controlled-cutting forest (RK) than the forests used for grazing and/or cutting (RB and TL). Species richness was highest in forest opened for cattle grazing. However, values of tree species diversity and evenness were higher in the controlled-cutting forest than in the forests with grazing and/or cutting. One might conclude that controlled cutting is more effective than grazing and/or cutting in conserving the diversity of tree species.

Key words: Trees, distribution, composition, diversity, management system, hill forest, Nepal

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The structure of tree species diversity in hill forests varies greatly from place to place due to variation of altitude, orientation of slope, nature of soil, and type and intensity of disturbance (Stainton 1972, Vetaas 2000). Natural disturbances such as forest fire, landslide, volcanic activity, and climatic change, determine forest dynamics and tree diversity (Burslem and Whitmore 1999, Masaki et al. 1999). They can also affect tree population and can modify interactions among species in plant communities (Connell 1978, Huston 1994). Similarly, anthropogenic disturbance may regulate the regeneration dynamics, structure and floristic composition of forest (Ewel et al. 1981, Hong et al. 1995). The effect of anthropogenic disturbance on forests may be either positive or negative, depending on the intensity of the disturbance. However, the disturbance intensity may differ from place to place among the existing forests in a particular area. Disturbance may increase species richness in old growth forest (Sheil 1999) and may maintain species diversity (Huston 1979, Petraitis et al. 1989). Frequent and low intensity disturbance (for example, grazing, or extraction of firewood and fodder) strongly affects forest structure and the succession of tree species in the forest (Ramirez-Marcial et al. 2001). However, such factors do not necessarily hamper a genuine old-growth forest (Phillips et al. 1997). Therefore, any generalization about the effect of anthropogenic disturbance on forest needs further research and discussion.

Species composition of forests has been documented for Nepal over several decades (Hara 1966, Shrestha 1982). Anthropogenic disturbances in the form of deforestation for diverse purposes (collection of timber and firewood, expansion of agriculture land and human settlement) have been a serious issue for sustainable development since the 1970s (World Bank 1978, Bishop 1990). Most previous studies have focused on the socio-economic and environmental impact of decline in forest cover. The ecological changes associated with human-induced disturbance of forests in the hill forests of Nepal have, however, received relatively little attention (Khatry-Chhetry 1997, Acharya 1999). This study analyzes the impact of human-induced disturbance under three different forest management systems in terms of species composition, distribution pattern, and diversity.

Study area

Within the Bharse area (1400–2572 masl), we selected three forest stands: Raiker, Raniban, and Thaple (hereafter RK, RB, and TL, respectively) (**Table 1**). The forest cover in this area has remained virtually unchanged since the 1960s, though the disturbance intensity among the forest stands has varied (Gautam and Watanabe 2004a). A low degree of disturbance characterizes RK whereas the RB and TL have been known to moderate and high levels of disturbances, respectively.

We surveyed 55 plots, each covering 50 m^2. These forest patches lie on the southern slope of the Satyabati Range. The highest summit of this mountain ridge attains 2572 masl, and the area is characterized by steep slopes (>30°). Annual rainfall is 2500–3000 mm. Snowfall occasionally occurs during winter seasons on the top of the Satyabati Range. The predominant forest tree species are *Quercus* species at higher altitude and *Schima-Castanopsis* species at lower.

The forests selected for this study have been managed by local people since 1952 (Budhathoki 1955, Gautam 2005). RK has been used only for timber cutting, for which the management committee collects a fee. RB is open for cattle grazing but the collection of forest products of any kind is prohibited. In some places, however, evidence of tree-cutting (stumps) and lopping was observed. TL is used for both cutting (fodder, firewood and timber) and cattle grazing. Therefore, TL, though located farther from settlements, has more intense disturbance than RK and RB.

Methodology

The number of sampled plots varies according to the size and shape of the forests. The circular plot with radius of 3.99 m was designed with slope correction in the mountainous area. Circular plot was preferred over rectangular one, for it is convenient to construct. The spacing between the plots in a given forest patch was about 200 m. In each plot, we measured floristic composition (total number of woody species), stand structure (species type and density), and dbh at 1.3 m height for trees with diameter greater than 5 cm. The measurements were conducted in Nov–Dec 2002 and Mar–Apr 2003.

We calculated relative values of density, frequency, and dominance in order to find the importance value index (IVI) and the important percentage (IMP) for each species according to Mueller-Dombois and Ellenberg (1974). We broke down dbh into ten classes of diameter size (in centimeters): 5–10, 10–15, 15–20, 20–25, 25–30, 30–35, 35–40, 40–45, 45–50, and ≥50; then we determined the stocking density of each size class. We calculated expected values for each diameter class using a negative exponential model following de Liocourt (1898) (Eq 1), in order to determine the impact of human disturbance on each diameter class of trees. We analyzed distribution of species using variance to mean ratio (Ludwig and Reynolds 1988) at the forest level.

$$aq^{n-1}\ \ aq^{n-2}\ \ aq^{n-3}\ aq^{n-4}\ldots\ldots aq^{3}\ \ aq^{2}\ \ aq^{1}\ \ a \qquad \text{.....(Eq 1)}$$

where,

a, number of trees in the largest size class of interest
q, ratio between diameter class
n, number of classes (de Liocourt 1898)

We calculated species richness or number of species per unit area (Shannon and Weiner 1949, Margalef 1958); species diversity index (Simpson 1949); and evenness, or distribution of abundances among the species (Shannon and Weiner 1949) following Eq 2, Eq 3, Eq 4, and Eq 5.

Species richness

a. Margalef index

$$SR = \frac{S-1}{\ln(n)} \qquad \text{....... (Eq 2)}$$

b. Shannon-Weiner index

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad \text{......(Eq 3)}$$

Simpson's diversity

$$D = 1-\lambda \quad (\lambda = \sum_{i=1}^{s} p_i^2) \qquad \text{......(Eq 4)}$$

Evenness

$$E = \frac{H'}{\ln(S)} \qquad \text{....... (Eq 5)}$$

where,

S, number of species
ln, natural logarithm
n, total number of individual trees in the area
λ, Simpson's concentration of dominance
p_i, the proportion of individuals found in the i_{th} species

Results

Forests of the Bharse area are considered indigenously managed forests except for some privately owned patches, even though in the legal sense they are all under the national forest owned by the government. The forest management system in the Bharse area was formally initiated in 1952 by communities within the VDC in order to protect forest resources and reduce the risk of landslide, drought and scarcity of water (Budhathoki, 1955). At first there were six *banpales* (forest guards) under the forest management committee, including eleven members of the Village Panchayat. Since 1995 there have been only two *banpales* to manage the entire forested area of Bharse. Every household contributes to the protection of forest resources by respecting the regulations they themselves drew up. As a result, the forest area has increased (Gautam and Watanabe 2004a).

A total of 652 trees representing 32 species were identified within the sampled areas in three forest stands: 198 trees (15 species) in RK, 304 trees (22 species) in RB, and 150 trees (11 species) in TL. The largest number of trees, 2640 ha^{-1}, was found in forest RK (**Table 2**) whereas the greatest basal area, 105.19 $m^2 \cdot ha^{-1}$, was found in RB (**Table 3**). Both the number of trees (1875 ha^{-1}) and the basal area (58.35 $m^2 \cdot ha^{-1}$) were smallest in TL (**Table 4**).

Species-area curve

A species-area curve for natural forest indicates the quick addition of newer species in consecutive plots at first, followed by stabilization (Shankar et al. 1998). In our study, the rate of species addition increased gradually up to the 4th plot and was constant from the 4th to 6th plot in all forests (**Figure 1**). In RB

TABLE 1. General characteristics of the studied forests

	RK	RB	TL
Area (km^2)	1.12	2.04	0.83
Sample plots	15	24	16
Slope aspect	S, SE	S, SW, SE	S, SW
Altitude (m)	1480–2100	1620–2390	1850–2570
Slope gradient*		>30°	
Distance by foot from settlement in minutes	10–60	5–55	70–120
Soil type/texture*		Lithic subgroups of ustorthents /loamy skeletal	
Management status**	Controlled-cutting only for timber paying a fee to management committee	Managed, but open for unrestricted grazing	Open: no restriction on either cattle grazing or collection of forest products

RK: Raiker; RB: Raniban; TL: Thaple; *LRMP (1986); **Field survey in 2002

TABLE 2. Statistical summary of tree species of the forest in Raiker (RK)

Species	Code	D (ha^{-1})	F (ha^{-1})	BA ($m^2 \cdot ha^{-1}$)	RD	RF	RDM	IVI	IMP
Schima wallichii (D.C.) Korth.	S32	627	187	20.23	23.74	16.67	28.06	68.46	22.82
Quercus lanata Roxb.	S28	387	147	19.25	14.65	13.10	26.69	54.43	18.14
Rhododendron arboreum Smith	S31	440	160	9.37	16.67	14.29	13.00	43.95	14.65
Quercus semecarpifolia Sm.	S29	227	80	9.98	8.59	7.14	13.85	29.57	9.86
Castanopsis indica (Roxb.) A.DC.	S02	213	93	5.44	8.08	8.33	7.55	23.96	7.99
Luculia gratissima (Wall.) Sweet.	S16	227	93	1.72	8.59	8.33	2.38	19.30	6.43
Myrica esculenta Buch-Hom. ex D. Don	S20	93	80	1.67	3.54	7.14	2.32	13.00	4.33
Lauri layanch*	S12	93	80	0.51	3.54	7.14	0.71	11.39	3.80
Pinus roxburghii Sargent	S24	107	53	0.84	4.04	4.76	1.17	9.97	3.32
Myrsine semiserrata Wall.	S21	67	27	1.65	2.53	2.38	2.28	7.19	2.40
Osmanthus fragrans (DC.) H.Hara.	S22	53	40	0.55	2.02	3.57	0.77	6.36	2.12
Fraxinus floribunda Wall.	S07	53	40	0.30	2.02	3.57	0.42	6.01	2.00
Machilus odoratissima Nees	S18	27	13	0.16	1.01	1.19	0.23	2.43	0.81
Castanopsis tribuloides (Smith) A. DC.	S03	13	13	0.38	0.51	1.19	0.53	2.23	0.74
Eriobotrya dubiya (Lindl.) Dence.	S04	13	13	0.04	0.51	1.19	0.06	1.75	0.58
Total (n=15)		2640	1120	72.12	100.00	100.00	100.00	300.00	100.00

D: density; F: frequency; BA: basal area; RD: relative density; RF: relative frequency; RDM: relative dominance; IVI: importance value index; IMP: important percentage; *: local name

TABLE 3. Statistical summary of tree species of the forest in Raniban (RB)

Species	Code	D (ha^{-1})	F (ha^{-1})	BA ($m^2 \cdot ha^{-1}$)	RD	RF	RDM	IVI	IMP
Quercus semecarpifolia Sm.	S29	800	133	29.68	31.58	15.38	28.21	75.18	25.06
Quercus lanata Roxb.	S28	175	83	28.19	6.91	9.62	26.80	43.32	14.44
Lyonia ovalifolia (Wall.) Drude	S17	358	100	9.52	14.14	11.54	9.05	34.73	11.58
Schima wallichii (D.C.) Korth.	S32	250	67	16.03	9.87	7.69	15.24	32.80	10.93
Rhododendron arboreum Smith	S31	158	58	3.97	6.25	6.73	3.77	16.75	5.58
Castanopsis tribuloides (Smith) A. DC.	S03	125	58	3.60	4.93	6.73	3.43	15.09	5.03
Eurya cerasifolia (D. Don.) Kobuski	S05	125	67	1.70	4.93	7.69	1.61	14.24	4.75
Castanopsis indica (Roxb.) A. DC.	S02	125	58	1.98	4.93	6.73	1.88	13.55	4.52
Prunus cerasoides D. Don	S26	58	33	1.82	2.30	3.85	1.73	7.88	2.63
Machilus odoratissima Nees	S18	67	25	0.85	2.63	2.88	0.80	6.32	2.11
Myrica esculenta Buch.-Ham. ex D. Don	S20	42	25	1.84	1.64	2.88	1.75	6.28	2.09
Alnus nepalensis D. Don	S01	67	17	1.31	2.63	1.92	1.25	5.80	1.93
Ficus nemorelis Wall	S06	33	25	0.63	1.32	2.88	0.60	4.80	1.60
Grewia species	S09	33	25	0.40	1.32	2.88	0.38	4.58	1.53
Eriobotrya dubiya (Lindl.) Dence.	S04	25	25	0.59	0.99	2.88	0.56	4.43	1.48
Quercus spicata Smith	S30	25	17	0.41	0.99	1.92	0.39	3.30	1.10
Litsea doshina Buch.- Ham.ex D.Don	S15	17	8	1.14	0.66	0.96	1.08	2.70	0.90
Garuga pinnata Roxb.	S08	17	8	0.29	0.66	0.96	0.28	1.90	0.63
Michelia champaca L.	S19	8	8	0.64	0.33	0.96	0.61	1.90	0.63
Myrsine semiserrata Wall.	S21	8	8	0.25	0.33	0.96	0.24	1.53	0.51
Pyrus pashia Buch.-Ham. ex D. Don	S27	8	8	0.19	0.33	0.96	0.18	1.47	0.49
Ghan Ghane*	S10	8	8	0.17	0.33	0.96	0.16	1.45	0.48
Total (n=22)		2533	867	105.19	100.00	100.00	100.00	300.00	100.00

D: density; F: frequency; BA: basal area; RD: relative density; RF: relative frequency; RDM: relative dominance; IVI: importance value index; IMP: important percentage; *: local name

TABLE 4. Statistical summary of tree species of the forest in Thaple (TL)

Species	Code	D (ha^{-1})	F (ha^{-1})	BA ($m^2 \cdot ha^{-1}$)	RD	RF	RDM	IVI	IMP
Quercus semecarpifolia Sm.	S29	675	150	12.45	36.00	23.53	21.34	80.87	26.96
Rhododendron arboreum Smith	S31	213	100	9.68	11.33	15.69	16.59	43.61	14.54
Eurya cerasifolia (D. Don.) Kobuski	S05	200	75	8.62	10.67	11.76	14.78	37.21	12.40
Lindera species (Shere*)	S14	200	63	6.69	10.67	9.80	11.47	31.94	10.65
Garuga pinnata Roxb.	S08	200	75	2.79	10.67	11.76	4.78	27.21	9.07
Lyonia ovalifolia (Wall.) Drude	S17	200	50	2.65	10.67	7.84	4.54	23.05	7.68
Patale*	S23	75	38	6.04	4.00	5.88	10.35	20.23	6.74
Myrsine species (Bajra Danthhi*)	S25	25	25	6.44	1.33	3.92	11.05	16.30	5.43
Ilex insignis Hook. F.	S11	63	38	2.82	3.33	5.88	4.84	14.05	4.68
Ghan Ghane*	S10	13	13	0.13	0.67	1.96	0.22	2.85	0.95
Lindera species (Goal Saple*)	S13	13	13	0.03	0.67	1.96	0.04	2.67	0.89
Total (n=11)		1875	638	58.35	100.00	100.00	100.00	300.00	100.00

D: density; F: frequency; BA: basal area; RD: relative density; RF: relative frequency; RDM: relative dominance; IVI: importance value index; IMP: important percentage; *: local name

TABLE 5. Distribution pattern of dominant and co-dominant species

Species	Distribution pattern in		
	Raiker (RK)	Raniban (RB)	Thaple (TL)
Castanopsis tribuloides	R	C	-
Castanopsis indica	C	C	-
Eurya cerasifolia	-	C	C
Garuga pinnata	-	C	C
Lindera species (Shere*)	-	-	C
Luculia gratissima	C	-	-
Lyonia ovalifolia	-	C	C
Patale*	-	-	C
Myrsine species	-	-	R
Quercus semecarpifolia	C	C	C
Quercus lanata	R	C	-
Rhododendron arboreum	C	C	C
Schima wallichii	R	C	-

*: local name; R: regular; C: clumped; -: absence

TABLE 6. Density-diameter distribution

Diameter	Raikar (RK)		Raniban (RB)		Thaple (TL)	
	OD	ED	OD	ED	OD	ED
5-10	1013.3	1255.9	425.0	1198.6	512.5	883.3
10-15	426.7	775.9	591.7	842.1	450.0	594.4
15-20	480.0	479.4	591.7	591.7	400.0	400.0
20-25	186.7	296.2	316.7	415.7	212.5	269.2
25-30	240.0	183.0	275.0	292.1	112.5	181.1
30-35	160.0	113.1	141.7	205.2	25.0	121.9
35-40	93.3	69.9	108.3	144.2	75.0	82.0
40-45	13.3	43.2	33.3	101.3	62.5	55.2
45-50	26.7	26.7	33.3	71.2	0.0	37.1
> 50	-	-	50.0	50.0	25.0	25.0
Ratio (q)	1.62		1.42		1.49	

OD: observed density; ED: expected density; -: absence

Ratio (q) was calculated using negative exponential model (de Liocourt 1898) (Eq 1)

the curve leveled off between the 7th and the 19th plot and then increased slightly up to the 21st plot. The curve leveled off completely after the 21st plot. In RK, the curve leveled off after the 10th plot, whereas in TL it leveled off after the 11th plot. The curve of all forests shows that the sample plots are sufficient for these specific forests. The species-area curve for TL shows that the number of species is small compared to other forests (**Figure 1**). Grazing and cutting led to the poor number of species.

TABLE 7. Diversity indices of the studied forests

Diversity indices		RK	RB	TL
Species richness	Margalef	2.64	3.67	1.99
	Shannon-Wiener's index	2.26	2.36	1.93
Simpson's index		0.87	0.85	0.81
Evenness (Shannon-Weiner)		0.83	0.76	0.81

Species composition

The importance percentage (IMP) shows that *Schima wallichii* is a dominant species of forest RK (**Table 2**). The co-dominant species of RK are *Quercus lanata* and *Rhododendron arboreum*. *Quercus semecarpifolia* is the dominant species of RB and TL (**Tables 3 and 4**). The co-dominant species of these forests

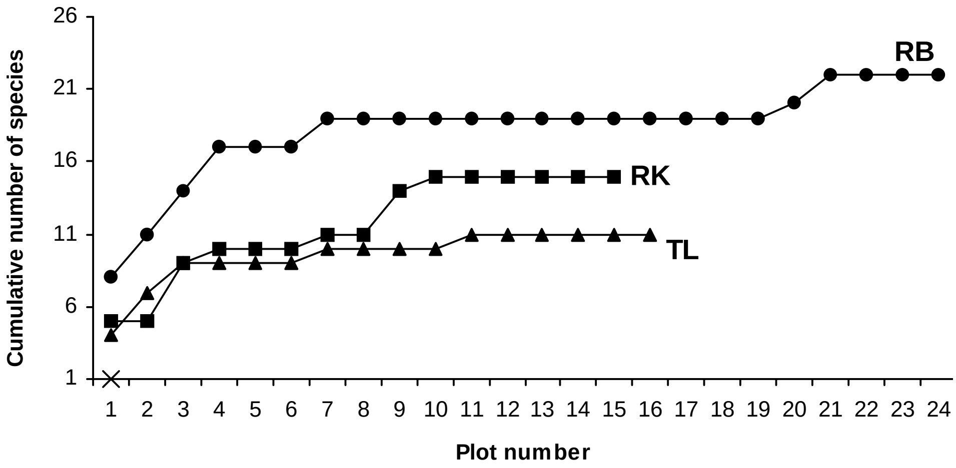

FIGURE 1. Species-area curves for forests RK, RB and TL

are quite different: *Rhododendron arboreum*, *Eurya ceracifolia* and *Lindera* species (Shere in local name) in TL, *Quercus lanata*, *Lyonia ovalifolia* and *Schima wallichii* in RB.

The tree species composition of all surveyed forests is given in **Figure 2**. Some species were found only in one particular forest (**Figure 2**). However, two species (S29 and S31) were found to be common in all three forests. Eight species (S02, S03, S04, S18, S20, S21, S28 and S32) were found to be common to RK and RB, whereas four species (S05, S08, S10 and S17) were common to RB and TL. Forests RK and TL do not have species in common except the two most prevalent species, S29 and S31. In summary, RK and TL have different characteristics in their species composition, whereas RB has many species in common with both RK and TL (**Figure 2**).

Species distribution

Two species, *Quercus semecarpifolia* and *Rhododendron arboreum*, were consistently found to be in clumped distribution among all forests (**Table 5**). In forests open to cattle grazing (RB) and cattle grazing plus cutting (TL), all species showed a clumped distribution, with the exception of *Myrsine* species in forest TL. *Castanopsis tribuloides*, *Quercus lanata,* and *Schima wallichii* were found to have regular distribution in forest managed for cutting (RK); but a clumped distribution in RB. No uniform distribution occurred among the forests studied.

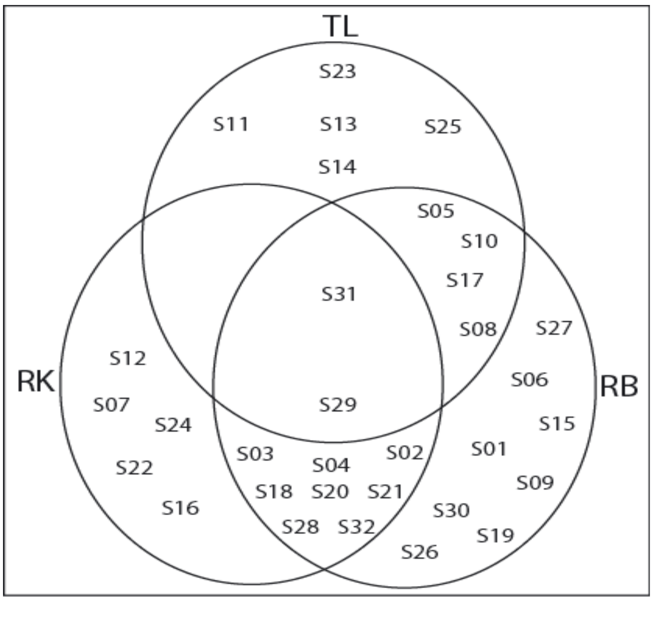

FIGURE 2. Species composition in the studied forests. S01...S32 are species symbols (see Tables 2–4)

Density-diameter distribution

There were large differences among forests in the densities of each dbh size class (**Table 6**). The theoretical distribution of density-diameter in an uneven-aged forest should roughly approximate a reverse J (Kairo et al. 2002). But in the studied forests the density-diameter curve showed a multimodel distribution quite different from the typical reverse J (**Figure 3**). In each of our stands, the density of the 15–20 cm diameter class was higher than those of the preceding and successive size classes. We surmised, therefore, that 15–20 cm was the undisturbed class for all forests. We then calculated the ratio between the actual densities of diameter classes and the expected values, using de Liocourt's negative exponential model.

For the 10–15, 20–25 and 40–45 cm dbh classes, the tree density is low in RK compared to the density of preceding and successive dbh classes (**Figure 3a**). No trees were found with diameter size greater than 45 cm in RK. However, the observed density of the 25–30 and 30–35 cm dbh classes was slightly higher than the expected density.

In contrast, the density of 5–10 cm dbh trees was very low in RB compared to the 10–15 cm dbh class (**Figure 3b**). Small differences were found between observed and expected tree densities in the 10–15, 20–25 and 40–45 cm dbh classes. The density of smaller size trees was low in RB due to grazing.

The total number of trees was quite low in TL, and, due to grazing and cutting, there were quite few of small trees (**Figure 3c**). The observed density of the 30–35 and 45–50 cm dbh classes was smaller than their preceding and successive dbh size classes.

Diversity indices

Species richness of Margalef ranged from 1.99 to 3.67, with RB having the highest value and TL the lowest (**Table 7**). Similar pattern was observed by Shannon-Weiner index. However, RK had the highest values for Simpson's index (0.87) and evenness (0.83).

Discussion

TL, distant from the settlements of Dabhung and Bharse, showed signs of more intense disturbance than RK and RB, which are located near the above settlements. Our research shows that this difference is due to the fact that a wide variety of resources are legally harvested from TL (**Table 1**). This finding contradicts the general consensus that forests close to settlements are invariably more intensively exploited than more remote forests (e.g., Acharya 1999, Sagar et al. 2003).

Analysis of tree species composition in the three forests showed different assemblages with different dominants and co-dominants. However, there were some similarities (**Figure 2**). The two major species in the study area, *Quercus semecarpifolia* and *Rhododendron arboreum*, were found in all three sites. The main differences in the species composition may be due to altitudinal gradient (**Table 1**), a feature not addressed in this study.

Clumped distribution is common in undisturbed forests, while regular distribution is generally found only in very uniform environments (Odum 1971). Species distribution in our study sites tended to be clumped, except for *Myrsine* species, in those forests subject to grazing and/or uncontrolled cutting whereas more species were found to have regular distribution in those forests with controlled-cutting and no grazing (**Table 4**). Two species, *Quercus semecarpifolia* and *Rhododendron arboreum*, showed no effect of such disturbances on dispersal behavior and were characterized by clumped distribution. The various patterns of distribution of a species in each forest might have been caused by various factors such as mode of seed dispersal (Richards 1996), gap on growth of numerous saplings (Newbery et al. 1986) as well as peculiarities of topography, slope, and soil.

Assuming that the undisturbed tree size is15–20 cm dbh for all forests, the observed values should be similar to the values (**Figure 3**) predicted by de Liocourt's negative exponential model. According to this model, the ratio between the numbers of trees in neighboring diameter classes should be roughly constant for a particular forest, but actually varies from one forest to another. This prediction has been confirmed in a number of uneven-aged forests throughout the world (Clutter et al. 1983) and applies particularly well to mixed forests with continuous natural regeneration.

If we compare the observed values for the 5–10 cm dbh class in each forest with the expected values, we find that regeneration of trees has been more effective in the controlled-cutting forest (RK) than in either the forest opened for grazing (RB) or the forest used for both grazing and cutting (TL). The density of the 5–10 cm dbh class in forests RB and TL (**Figure 3b** and **3c**) indicates that a cattle grazing has had a direct and substantial effect on the regeneration of tree species due to trampling and over-browsing. Forest TL showed the significant differences between the expected and observed values, except for the 35–40 cm and 40–45 cm dbh classes. However, the density in each dbh is smaller than that in the other studied forests. RK showed more complex results, although only two dbh classes have notable differences between observed and expected values (**Figure 3a**).

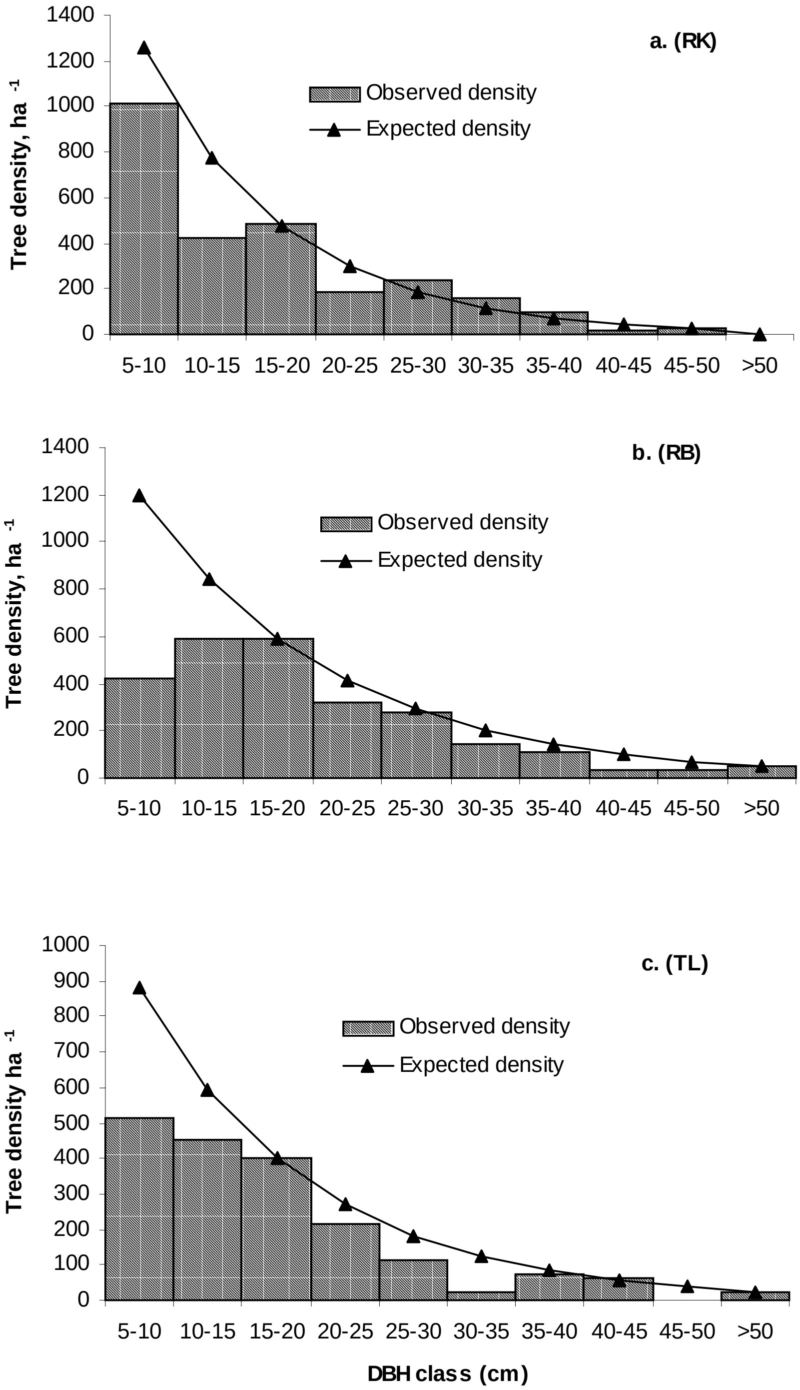

FIGURE 3. Density-diameter distribution of the studied forests

The different shapes of density-diameter distribution (**Figure 3**) show the extent of effect of disturbances on the density of dbh classes. In a montane rain forest in Mexico, Ramirez-Marcial et al. (2001) found that stem density decreases with disturbance intensity. Our study also found that the stem density declined with increasing disturbance. Grazing damages saplings through trampling and browsing (Glatzel 1999, Roder et al. 2002); therefore, the density of small diameter classes is low in the forests opened to grazing (Gautam and Watanabe, 2004a).

Both indices of species richness (Margalef and Shannon Weiner) showed higher values in forest RB than RK and TL. However, species richness value alone, though interesting, is not informative enough (Onaindia et al. 2004). Simpson's diversity index and evenness (Shannon-Weiner) showed a high value in RK (**Table 7**), which means that the controlled-cutting forest is in a more advanced state of regeneration compared to those forests open to grazing and/or cutting.

Species richness was highest in RB; however, RB also had the lowest value for evenness (**Table 7**), showing that the species are not equally abundant. This may be due to the presence of fugitive species. Only competitive species can survive in area with little or no disturbance, while fugitive species can survive in areas with high level of disturbance. Therefore, species richness is maximal at an intermediate level of disturbance (Abugov 1982). TL, a highly disturbed forest, has a medium level of evenness, which is an indication that high disturbance might have an adverse impact on evenness. However, both species richness and diversity are lowest among the studied forests because of the direct influence of disturbance. The comparison of species richness, distribution pattern, and diversity of tree species suggests that controlled-cutting is more conducive to higher diversity than either open grazing or completely open management.

The studied forests are under the national forests, controlled and managed by local people through coherent rules and regulations. Such forests are distributed throughout the entire country, and are known as an "indigenous managed forests." Generally, in Nepal, there is no consistency in defining the forest cover at the national level (HMGN 1988, HMGN 1993, DFRS 1999). It is therefore difficult to generalize how much area of forest cover is under each form of management. This study suggests that the indigenous knowledge of local people is quite sound for protecting the forest resources using various methods of management over a period of many decades. Nevertheless, studies found that many species adapted to open grazed forests can disappear (Bengtsson et al. 2002, Onaindia et al. 2004). It is likely that, in the present study, grazing resulted in a forest with more openings and gaps, leading to a higher abundance of large trees and fewer saplings. However, controlled cutting conserves the cover of those tree species typical of natural forests. Therefore, a high value of diversity can be found in those forests that have been managed for controlled-cutting. The observed value of 0.87 for Simpson's diversity in a controlled-cutting forest is higher than the average value of 0.85 reported from 104 patches of managed forests in the entire Middle Hills of Nepal (Tachibana and Adhikari 2004). It is also higher than the range of 0.70–0.82 observed in two community forests in the mid-west Nepal (Kunwar and Sharma 2004). These observations suggest that controlled cutting is the best type of management for the study area as far as the diversity of tree species is concerned.

Conclusions

An analysis of the composition, distribution (stand structure), and diversity of tree species in studied forests shows that controlled-cutting is more effective than some other management systems in conserving the diversity of tree species. However, there is no clear visible trend in the distribution of density-diameter classes. The density-diameter distribution indicates poor regeneration in forests used heavily for cattle grazing. The density was extremely low in the forest open to both cutting and grazing. However, the largest basal area was found in the grazing forest. Our data shows that the forests with grazing (RB and TL) were characterized by clumped distribution of species, whereas the forest with controlled-cutting (RK) was mixed (clumped and regular). The moderately disturbed forest, Raniban (RB), showed the highest species richness of the three forests. The differences are probably due to effective forest management practices by the local inhabitants. ■

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Fuelwood harvest, management and regeneration of two community forests in Central Nepal

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From July to December 2003 we studied the impact of forest resource use and management practices on community structure and regeneration of locally managed *Shorea robusta* (sal) forest in the mid-hills of central Nepal. We carried out a household survey in two villages (Namjung village of Gorkha and Khari village of Dhading district), and studied the community structure and regeneration of important multipurpose tree species (*Shorea robusta* Gaertn. and *Schima wallichii* (DC.) Korth.) in community forests. Dependency on forests has been decreasing due to limited access to resources, decrease in cattle number and the cultivation of more fuelwood and fodder trees in non-forested land. Nonetheless, forests remain the major source of fuelwood, supplying 63% of the total. Alternative energy sources (biogas and solar cell) were not significant at the time of our study. *S. robusta* was the dominant tree in both forests, with high relative density (74%) in Namjung forest (NF) and 50% in Khari forest (KF); its importance value index (IVI) was 171 in NF and 152 in KF. Tree density of sal in NF was the highest (909 tree ha^{-1}) among the reported values in references for the same species. Both forests had comparatively low species diversity (1.09 in NF and 1.30 in KF); local management appears to contribute to reduced diversity. Regeneration of sal was sustainable and fairly high, with a typical reverse-J-shaped size class diagram (in NF), a good predictor of mono-dominant sal forest. Regeneration of *S. wallichii* was unsustainable in both forests.

Key words: *Schima wallichii*, *Shorea robusta*, size class diagram, species diversity

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Rural people depend on forest resources for their energy needs, fodder, timber and employment. Fuelwood is one of the most important forest resources, accounting for an estimated 7% of the world's total energy supply (FAO 1999). It plays a major role (80%) in the energy supply of Nepal, and its consumption is increasing by 2.0% per annum (Shrestha 2000). Fuelwood has the potential to be an attractive renewable source of energy because it is CO_2-neutral and economically affordable for rural people. Fuelwood consumption is not and will not be the main cause of deforestation; non-forest land is and will continue to be the main source of fuelwood (RWEDP 1997). However, some people believe that the demand for fuelwood in developing countries can only be met by over-exploitation of forests, which is the major cause of deforestation (Schulte-Bisping et al. 1999). To resolve these conflicting views, we need adequate reliable data, which, in the case of Nepal, is lacking (Shrestha 2002).

Forested areas, a major source of fuelwood, are decreasing at the rate of 1.8% per annum in Nepal (FAO 2001) and all five Development Regions suffer fuelwood deficits (RWEDP 1997). The impact of fuelwood collection on forests has been controversial and its role in rural livelihoods and deforestation the subject of considerable debate. The practice of using a few selected species for fuelwood and absolute conservation of dominant species in community-managed forests may affect the regeneration process and community structure of forests. The impact of fuelwood collection on forests is largely determined by the extent of peoples' relative dependency on forested and non-forested lands for fuelwood. To elucidate the relationship between fuelwood consumption and forest structure, the use patterns of fuelwood in two villages of central Nepal and their forests were studied with the following specific objectives: 1) to quantify the use of forest resources (fuelwood and fodder) by local people; 2) to identify the relative importance of forest and non-forest sources of fuelwood and fodder; and 3) to assess the impact of local management on forest structure and regeneration.

Materials and methods

Study site

We surveyed fuelwood consumption in two mid-hill villages of central Nepal: Majhitar of Namjung Village Development Committee (VDC), Gorkha district, and Kumaltari of Khari VDC, Dhading district; we refer to these as NV and KV, respectivly. There were 78 households in NV and 116 in KV; about 90% households were engaged in subsistence agriculture. They obtained timber from the forest, but fuelwood and fodder were obtained from both farmland and forest.

We studied vegetation structure and regeneration in *Jhakreko Pakha*, or "Namjung forest"(NF) near NV and Devisthan Community Forest, or "Khari forest" (KF) near KV. NF lies on the south-east face of a hill with slope 60º at 27º 56' N, 84º 43' E, alt. 500–800m; KF lies on the north-west face of a hill with slope 70º at 27º 56' N, 84º 44' E, alt. 450–1000m. NF has been protected for the past 15 years, and the use of *Shorea robusta* (sal) in any form has been prohibited. Limited timber harvesting for non-commercial purpose was permissible, provided royalties were paid. KF has been protected for the last four years, and the use of sal and *Terminalia alata* in any form were completely prohibited. The harvest of *Schima wallichii* and *Castanopsis indica* for non-commercial purposes were allowed in KF. Sal is the dominant tree species in both forests; major associated species are *S. wallichii* and *Terminalia alata* in NF and *S. wallichii, C. indica* and *Engelhardia spicata* in KF. Grazing was common in both forests. Forest fires were less common in recent years but were more frequent until 4–5 years back. Fallen branches, dead trees and live individuals of shrub species were collected for fuelwood. In KF the practice of thinning has been implemented at limited areas.

Sampling and data analysis

Household survey

We collected field data during October 2003. Using structured questionnaires, we surveyed 12 households (representing >10% of total) in each village. All ethnic groups and economic classes were proportionately represented in the samples. The survey focused particularly on the supply of fuelwood and fodder from farmland and forestland. The woody part of fodder left over by animals is also used as fuelwood; thus it was included in our survey. We determined the number of domestic animals per capita, per capita fuelwood consumption (kg/person/year), and proportion of total supply of tree (woody) fodder and fuelwood derived from forest and farmland.

Forest sampling

In view of the heterogeneous landscape, we chose to use relatively small quadrats of 10m x 10m. Each forest was divided vertically into halves and in each a single quadrat was laid out at altitude increments of 50m. We studied twelve quadrats in NF from 500 to 750 masl and 17 quadrats in KF from 500 to 950 masl. In KF a single quadrat was studied at each of 500, 550 and 950 masl due to the physical inaccessibility of potential sampling sites. We measured diameter at breast height (dbh, at 137 cm height), of all trees (dbh ≥10 cm), and we counted the number of saplings (≥20 cm height and <10 cm dbh) and individuals of shrub species. We did not record seedlings or herbs. We identified plants with the help of standard references (Stainton 1997, Polunin and Stainton 2000). The nomenclature follows DPR (2001). We calculated density (ha^{-1}), frequency (%), and basal area (m^2·ha^{-1}) of trees, as well as their relative values. Importance Value Index (IVI) was calculated as the sum of relative values of density, frequency and dominance (Zobel et al. 1987). Tree density and dbh classes (10–15 cm, 15–20 cm, 20–25 cm, etc.) of sal and *S. wallichii* were used to develop a size-class distribution diagram. Simpson's index of dominance (C) and the Shannon-Wiener index of species diversity (H') were calculated following Barbour et al. (1999). We compared the species diversity of the two forests (tree layer) using the Student t-test following Jayaraman (2000).

Results

Household survey

The average family size was six persons and the average number of domestic animals 12 per family in NF, and seven and 10.5 respectively in KF. Forest resources were being used for non-commercial and domestic purpose. The dependency of local people on forests for fuelwood and fodder had decreased in 50% of households, remained the same in 33% and increased in 17% as compared to 10 years prior to our study. The decrease in dependency, where it occurred, was due to reduced supply, restriction in use, reduced numbers of cattle, and installment of biogas and solar power facilities. Increased use of forest resources was related to increase in family size, increase in number of cattle, and decreased supply of fuelwood and fodder from farm land. The four preferred species for fuelwood were *Schima wallichii*, *Lagerstroemia parviflora*, *Adina cordifolia* and sal. People depended more on forest (63% of total supply) than farmland (37%) for fuelwood (**Table 1**). Per capita fuelwood consumption was 541/kg/person/year in NV and 388 kg/person/year in KV. Fuelwood was used for cooking (both for humans and animals) and for space heating. Generally, fuelwood was cut during February-March, sun-dried for a few weeks and stored in a dry place for use throughout the year. 95% of households used fuelwood for cooking and space heating, and 92% used kerosene

TABLE 1. Comparison of per capita domestic animals, and supply and types of fodder and fuel wood in two villages

Village	Per capita domestic animals	Fodder type (%)		Supply of tree fodder (%)		Per capita fuelwood consumption (kg/person/yr)	Supply of fuelwood (%)	
		Grass	Tree	Forest	Agri. land		Forest	Farm land
Namjung	2.15	50	50	39	61	541	58	42
Khari	1.63	48	52	29	71	388	68	32
Average	1.89	49	51	34	66	464.5	63	37

TABLE 2. Density (D, ha^{-1}), Basal Area (BA, m^2·ha^{-1}) and Importance Value Index (IVI) of tree species at Namjung Forest (NF) and Khari Forest (KF)

Name	Namjung Forest (NF)			Khari Forest (KF)		
	D	BA	IVI	D	BA	IVI
Shorea robusta Gaertn.	909	30.97	171.23	125	10.88	151.61
Schima wallichii (DC.) Korth.	108	8.27	45.63	84	3.5	92.21
Semecarpus anacardium L.f.	67	1.86	26.01	6	0.078	7.51
Terminalia alata Herne ex Roth	25	0.48	10.36	-	-	-
Syzygium cumini (L.) Skeels	17	0.49	7.31	6	0.078	7.51
Lagerstroemia parviflora Roxb.	17	0.22	6.69	-	-	-
Engelhardia spicata Leschen. ex Blume	17	0.48	4.69	12	0.127	14.85
Cleistocalyx operculatus (Roxb.) Merr. & Perry	17	0.25	6.78	6	0.047	7.31
Mangifera indica Linn.	17	2.07	10.65	6	0.73	11.72
Wendlandia sp.	17	0.19	4.08	6	0.047	7.31
Adina cordifolia (Wild. ex Roxb.) Benth. & Hook. f. ex Brandis	8	0.15	3.26	-	-	-
Castanopsis indica (Roxb.) Miq.	8	0.13	3.21	-	-	-
Total	1227	45.56	299.9	251	15.48	300

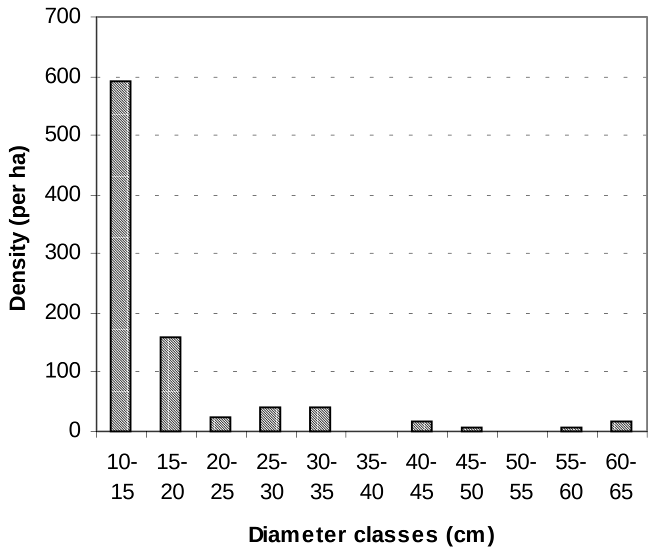

FIGURE 1. Density of different diameter classes of trees of *S. robusta* in Namjung forest

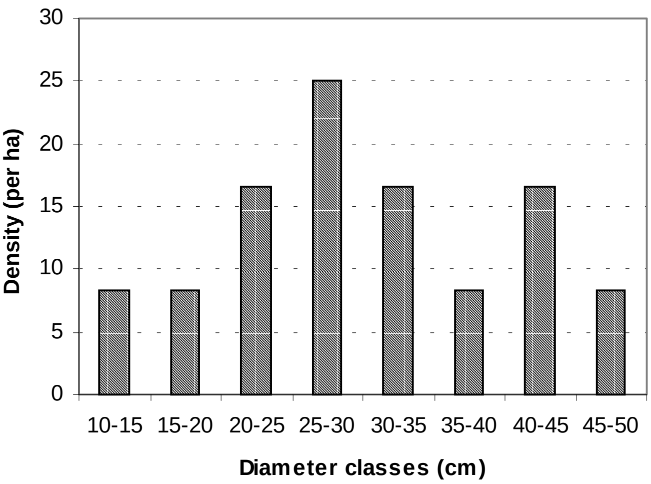

FIGURE 2 Density of different diameter classes of trees of *S. wallichii* in Namjung forest

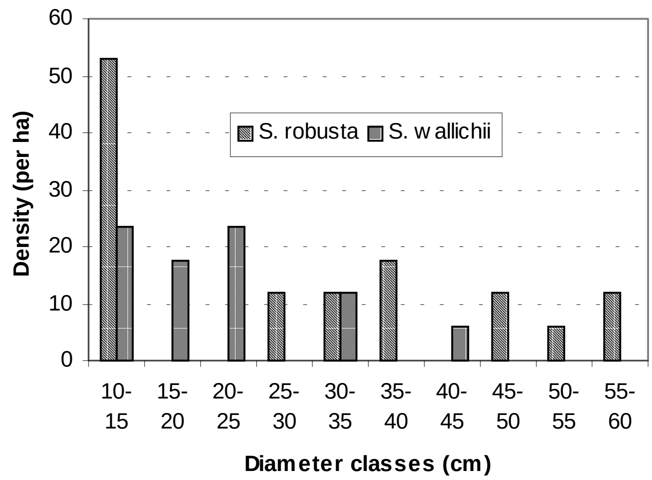

FIGURE 3 Density of different diameter classes of trees of *S. robusta* and *S. wallichii* in Khari forest

for lighting. Most of the households used the "improved stove," which significantly reduced fuelwood consumption. Alternative energy sources such as biogas and solar panels were not widespread: only 5% of the households used biogas and 8% solar power. Many households were facing problems in collecting fuelwood, but they had not installed biogas due to economic constraints and lack of technical know-how. Most, however, believed that the used of biogas was a good idea.

Every household kept domestic animals such as cow, buffalo, and goat. Per capita ownership of domestic animals (0.78) was higher than the national rate (CBS 2002). Due to the highly accidented landscape, buffaloes were kept at home on a permanent basis, while cows and goats were brought to nearby forest and grassland for grazing. As fodder, villagers used grasses (non-woody herbaceous fodder plants) and tree fodder in nearly equal amounts (**Table 1**). Farmland was the major source of tree fodder (66% of total supply). In the past, a greater proportion of fodder had been derived from the forest. Sal was the preferred tree for fodder, but use of this species as fodder was restricted after the inception of community management. People could harvest sal only by thinning in specified months.

Besides timber, fuelwood and fodder, people also used the leafy branches of *Castanopsis indica* for roofing, small trees of *Schima wallichii*, *Holoptelea integrifolia* and *Adina cordifoli*a as support (locally called *thakra*) in growing vegetables, medium sized trees of *S. wallichii* and sal for making plows, and leafy branches of *Engelhardia spicata* and *S. wallichii* as green manure and mulch. Black dye extracted from the bark of mature sal was used for painting doors, windows and verandas. Most of villagers were in favor of the current conservation practices, but some wanted more access to fodder plants such as sal.

Forests

Both forests were dominated by sal, with *S. wallichii* as co-dominant. In NF 12 species were recorded at tree stage (**Table 2**). Density ranged from 8 to 909 ha^{-1}, and basal area ranged from 0.13 to 30.97 $m^2 \cdot ha^{-1}$. The total basal area of all tree species was 45.56 $m^2 \cdot ha^{-1}$. Sal had the highest IVI (171), which was nearly four times higher than the IVI of the co-dominant species, *S wallichii* (46). Sal was fairly regenerating with a typical reverse-J-shaped size-class distribution (**Figure 1**). The sapling-to-tree ratio was 14:1, with sapling density at 12,642 ha^{-1}. The regeneration of *S. wallichii* was poor, as was reflected in the bell-shaped size-class distribution curve (**Figure 2**). The sapling-to-tree ratio was 1.23:1, and the sapling density was 133 ha^{-1}. In Khari Forest (KF), eight species were recorded in tree stage (dbh >10 cm, **Table 2**). The total basal area of all trees was 15.48 $m^2 \cdot ha^{-1}$. KF trees are larger than NF, with average dbh of 30 cm (N = 19) and open canopy. The relative density of sal was 50% whereas that of *S. wallichii*, an important associate species, was 33.46%. Sal regeneration was discontinuous, with individuals not represented in dbh classes of 15–20 cm, 20–25 cm and 40–45 cm (**Figure 3**). Sapling density was 6383 ha^{-1} (**Table 3**), and sapling-to-tree ratio was 51:1. *S. wallichii* appeared to be regenerating, but its density was very low (**Table 2**). Two dbh classes were absent from the population of *S. walichii* (**Figure 3**). Sapling density was 505 ha^{-1} and sapling-to-tree ratio was 6:1. Seven tree species in NF and eleven in KF were represented only at the sapling stage (**Table 3**). There were six shrub species in NF and nine in KF (**Table 4**).

Forest fire, grazing and lopping were important pressures on both forests. Fire damage was followed by termite ➡

infestation. We observed saplings that had fallen due to fire damage and subsequent termite infestation. In KF tree felling was very frequent before the beginning of community management. Stumps were present in 65% of quadrats, up to five stumps in a single sample (10 m x 10 m). A total of 31 stumps were recorded (sal 21, *Schima wallichii* 7, *Castanopsis indica* 1, *Wendlandia* 1 and *Lyonia ovalifolia* 1). The total density of stumps was 182 ha^{-1}, which was more than the density of dominant tree (sal, 125 ha^{-1}).

Tree species richness was higher in NF than in KF (**Table 5**). The contribution of a single dominant species (sal) was much greater than other associated species (**Table 2**). Therefore, NF had a higher Simpson's index (C) but a lower Shannon-Wiener index (H') than KF. Despite the small number of tree species, KF had a significantly higher species diversity ($t = 2.788$, $df = 470$, $p < 0.01$) due to high species evenness. KF also had high species diversity for shrubs.

Discussion

Use of forest resources

People in the study area depended on forest resources for their subsistence livelihood, primarily as a source of fuelwood and fodder. The contribution of these two forest resources (fuelwood and fodder) to Nepal's national income is significant (Katila 1995). A community forest, if managed on an equitable and sustainable basis, can satisfy these basic needs and improve the livelihood of rural people in Nepal (Maharjan 2003).

There was a wide difference between in two villages studied in per capita fuelwood consumption (**Table 1**). The higher rate in NV was due to the greater number of domestic animals per capita. A significant amount of fuelwood was consumed in cooking animal feed. People used to fell trees for fuel wood but in recent times this practice has been prohibited in the community forest. Woody parts of fodder not consumed by animals were an important source of fuelwood from the agricultural sector. Old and dying fodder trees on agricultural land were harvested for fuelwood. The amount of fuelwood derived from the forest had been decreasing, and people had been spending more time collecting fuelwood. People had been learning to use agricultural residues as fuel, and improved stoves had significantly reduced fuel wood consumption, but the forest was still the major source, supplying 63% of the total fuelwood (**Table 1**).

In comparison to the situation ten years ago, dependency on the forest for fodder and fuelwood has decreased in 50% of households. Extraction of these resources from the forest has decreased and the use of several preferred species has been restricted. This has forced people to grow more fodder trees on their private land, and to make better use of agricultural residues (e.g., the woody parts of fodder), which had not used until few decades back. Most of the villagers were aware that growing trees on agricultural land was useful for soil conservation and as a convenient source of fodder and fuelwood; nevertheless, due to the shortage of crop land, the practice is not common. Concerted efforts by government agencies and non-government organizations to provide support services integrating indigenous knowledge may motivate people to grow more trees on agricultural land (Paudel 2003), thereby reducing pressure on the forest.

S. wallichii was the preferred tree for fuelwood. Regeneration of this species was very poor and discontinuous in both forests (**Figure 2** and **3, Table 3**); this may be directly attributed to fuelwood extraction Unfortunately, use of fossil

TABLE 3. Sapling density (ha^{-1}) of trees in Namjung forest (NF) and Khari forest (KF)

Name	Density	
	NF	KF
Adina cordifolia (Wild. ex Roxb.) Benth. & Hook. f. ex Brandis	16	-
Antidesma acidum Retz.*	-	12
Bridelia retusa (L.) Spreng. *	-	6
Callicarpa vestita Wall. ex C.B. Clarke*	8	6
Castanopsis indica (Roxb.) Miq.	16	206
Cleistocalyx operculatus (Roxb.) Merr. & Perry	142	325
Engelhardia spicata Leschen. ex Blume	42	82
Holoptelea integrifolia (Roxb.) Planch.*	142	200
Kummo*#	24	71
Lagerstroemia parviflora Roxb.	92	59*
Lyonia ovalifolia (Wall.) Drude*	8	224
Mangifera indica Linn.	92	35
Phyllanthus emblica Linn.*	242	29
Schima wallichii (DC.) Korth.	133	505
Semecarpus anacardium L.f.	183	347
Shorea robusta Gaertn.	12642	6383
Syzygium cumini (L.) Skeels	84	12
Terminalia alata Herne ex Roth	160	71*
Terminalia belerica (Gaertn.) Roxb.*	16	-
Terminalia chebula Retz.*	8	6
Wendlandia sp.	317	706
Total	14367	9285

* Tree species represented only by saplings; # Local name

TABLE 4. Density (ha^{-1}) of Shrubs in Namjung forest (NF) and Khari forest (KF)

Name	Density	
	NF	KF
Ardisia solanacea Roxb.	-	247
Eurya acuminata DC.	-	35
Holarrhena pubescens (Buch.-Ham.) Wall. ex D.Don	36	-
Inula cappa Wall. ex DC.	-	212
Maesa macrophylla (Wall.) A. DC	-	53
Melastoma normale D.Don	9	167
Rhus javanica Linn.	318	188
Swida oblonga (Wall.) Sojak	191	935
Woodfordia fruticosa (L.) Kurz.	291	576
Zizyphus sp.	9	47
Total	854	2458

TABLE 5. Simpson's index (C) of dominance and Shannon-Wiener index (H') of species diversity for Namjung forest (NF) and Khari forests (KF)

Plant habit	C		H'	
	NF	KF	NF	KF
Tree	0.55	0.36	1.09	1.30
Shrub	0.30	0.22	1.28	1.98

fuels by rural people is neither economically feasible nor environmentally friendly. Efficient use of available agricultural residues through technical innovations may be a better solution to the problem of diminishing fuelwood supply. An improved wood energy system might help to mitigate climate change by reducing reliance on fossil fuels and sequestering CO_2 (the most important greenhouse gas) in growing trees (Heruela 2003). It would also result in significant foreign exchange saving for countries like Nepal. Alternatively, popularization of biogas and solar cells may reduce dependency on fuelwood.

Forest structure

The community structures of NF and KF were quite distinct in term of the contribution of dominant species and basal area cover. These two forests had an equal number (19) of tree species but seven species in NF and 11 in KF were found only in sapling stage (**Table 3**). Most of the species represented only in sapling stage do not yield high quality timber when they mature to tree, nor are they preferred for fodder or fuelwood. Since the initiation of community management, however, pressure on these species as a source of fodder and fuel wood has increased due to restrictions on the use of the preferred tree species.

The number of species forming tree canopy was high in NF but single dominant species (sal) had very high density and relative density (**Table 2**); therefore NF is developing into mono-dominant sal forest. Density of sal was higher than values reported for sal anywhere else in Nepal (Giri et al. 1999) or India (Negi et al. 2002). Basal area of sal (30.97 $m^2 \times ha^{-1}$) and total basal area (45.56 $m^2 \times ha^{-1}$) of all trees were also higher than in a Terai sal forest (Giri et al. 1999). However, individual sal trees were small, with average dbh of 18 cm (N = 113). A mono-dominant sal forest (relative density >70%) is particularly susceptible to the sal borer (*Hoplocerambyx spinicornis*) due to lack of ecological balance (Negi et al. 2002). We would recommend that the management of this forest be modified: thinning of sal and restraint in exploitation of other species such as *S. wallichii* can prevent the forest from progressing toward monodominant type.

Although sal was the dominant tree species in KF, its density (125 ha^{-1}) was very low in comparison to Giri et al. (1999) and Negi et al. (2002) and distribution was not uniform (frequency 41%). However, sapling density (**Table 3**) and sapling-to-tree ratio (51:1) for sal was high as compared to NF (14:1), indicating high regeneration potential. This forest may also develop into mono-dominant sal forest if the management practice is not changed.

Density and species richness of the shrub layer was higher in KF than in NF (**Table 4**), which appears to be due to the open canopy condition in former. Intense disturbance and excessive felling of trees in the past resulted in open canopy in KF, allowing the growth of large number of shrub species. Similarly, recent conservation efforts have resulted in a rapid increase in sapling density (**Table 3**) of tree species.

Despite the higher tree species richness in NF (**Table 2**), it has a lower species diversity (**Table 5**). The contribution to forest community of a single dominant species (sal) was very high while other species became rare. It appears that associated species have been over-exploited for sal conservation. Fifteen years of local management have preserved a forest but disturbed the natural ecosystem. KF, which has been conserved for four years, had a significantly higher species diversity ($p<0.01$) due to higher species evenness (i.e. more uniform distribution of relative density among the species). The decrease in species diversity due to local extinction of less common species makes the ecosystem less stable. Ecosystem stability cannot be ensured merely by high species diversity, but diversity is certainly a prerequisite for ecosystem stability (Naeem and Li 1997, McCann 2000). Both of these forests had a lower species diversity than natural sal forests studied in India (e.g., Pandey and Shukla 1999, Shankar 2001). Therefore, conservation of species diversity should also be a priority of community forest management.

Regeneration

The reverse-J-shaped size-class distribution (**Figure 1**) of sal in the studied forests indicates sustainable regeneration (Vetaas 2000). The absence of certain larger dbh classes from the population was due to severe disturbance in the past before conservation. Forest conservation greatly increased the sapling density (**Table 3**) and sapling-to-tree ratio. Thus sal will continue to be the dominant species of these forests in future if the same management practice prevail. However, *S. wallichii*, the most important associate of sal in this forest, had a bell-shaped size-class distribution (**Figure 2**), which indicates the lack of sustainable regeneration (Vetaas 2000). Sapling density (**Table 4**), and sapling-to-tree ratios were very low. *S. wallichii* was the most preferred species for fuelwood; with the use of sal restricted, *S. wallichii* was also being harvested to meet timber needs. Finally, regeneration by coppice is weaker in *S. wallichii* than in sal. The combined effect of all these anthropogenic disturbances and inherent behavior has hampered the regeneration *S. wallichii* in NF.

The size-class distribution curve of sal in KF resembled neither a reversed J nor a bell shape (**Figure 3**). Since the lowest diameter class had the highest density, the regeneration potential was high, but regeneration had not been continuous in the past. The poor representation of two successive small-dbh classes might have been due to intense forest fires in successive years, which prevented seedling establishment and sapling recruitment and resulted in the discontinuous population structure of sal in KF. Recent management practice has rapidly increased the sapling density (**Table 3**). Within a few decades this forest may change into a dense forest with closed canopy. The canopy closure occurs at an exponential rate and the time required for full canopy closure depends on the type and magnitude of disturbance and on the species involved in regeneration (Valverde and Silvertown 1997); it may range from 8 to 40 years for tropical and temperate forest. The status of *S. wallichii* in KF was better than that in NF, with high sampling density (**Table 3**) and sapling-to-tree ratio, and good representation of small trees in the population (**Figure 3**). The forest had several moist sites, which are suitable for growth of *S. wallichii*. The open canopy also promoted sapling recruitment and tree growth at early stage.

The regeneration potential of sal was fairly high in both these forests, and regeneration was continuous in NF. The density of sapling and small trees has increased rapidly in recent years as the effect of community management. In Nepal, sustainable regeneration of sal has been reported from both Terai (Rautiainen 1996 and Giri et al. 1999) and the hills (Rai et al. 1999). However, regeneration was not sustainable in natural dense forest with a high density of larger trees (Rai et al. 1999). Sal has been facing a serious threat to its existence in the tropical and subtropical belts of India due to infestation by the sal borer (*Hoplocerambyx spinicornis*) and also to moisture stress caused by the combined effects of intensive grazing, repeated fire, lopping and indiscriminate harvesting (Negi et al. 2002). Mortality rates of seedling and smaller trees are high under these situations. The problems of stem borer and heart and root rot diseases have also been reported from a leasehold forest in Rupandehi of Nepal (Hartz 1999). Although the extent of damage was not serious, damage frequency and distribution have been increasing and that trend is likely to deteriorate in the future. The problem will be more serious if it spreads into community forests, which are evolving toward mono-dominance due to excessive removal of the unprotected plant species. As noted before, mono-dominant sal forest is more susceptible to sal borer attack (Negi et al. 2002) probably due to local extinction of borer's natural predators. Similarly, large-scale defoliation (>90%) of young sal leaves by red ants has been observed in a few community managed sal forests in Gorkha (Nepal) (personal observation, June 2005). This, obviously, has a negative impact on the growth and survival of individual trees and on the sustainability of the forest. However the community structure and insect-plant interactions in these forests have not been studied.

Conclusions

In comparison to the situation ten years ago, dependency on forests for fodder and fuelwood has decreased in 50% of households due to increased supply from non-forest lands, decrease in cattle number, and limited access to forest. Although fuelwood has been extracted from both forest and non-forest lands, forests were the major source (63%). Limited access to forest has encouraged people to use fuelwood from non-forest sources more efficiently. The trend showed that with technological innovations in fuelwood use, alternative energy (biogas and solar cell), and growth of more trees in non-forest lands, dependency on forests for fuelwood will decrease in the future. The regeneration potential of sal (*Shorea robusta* Gaertn.) was fairly high in both community forests, but community management in the NF and KF appears to be non-sustainable, as the species diversity has been decreasing. The present management practices may lead to the development of mono-dominant sal forests with insignificant contributions from other associated species. *Schima wallichii,* a multiple use plant, has become the most preferred tree species for fuelwood. Regeneration of this species was not sustainable and it has been overexploited for the sake of sal conservation. ■

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Health costs of pesticide use in a vegetable growing area, central mid-hills, Nepal

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This pilot study estimated the health costs resulting from pesticide-related acute health symptoms in a mid-hill vegetable growing area of Nepal. Farmers reported up to 13 acute symptoms due to the use of pesticides. Using the averting cost approach, on average a farmer spent NR 119 (US$ 1.58) annually for safety gear (at the time of study, NR 75 equaled US$ 1). Using the cost-of-illness approach, the total annual household expenditures due to the use of pesticides ranged from NR zero to NR 4451, with an average of NR 1261. Similarly, household willingness to pay (WTP) for safer pesticides ranged from as low as NR 1500 per year to as high as NR 50,000.

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Household is the primary supplier of labor inputs required to operate subsistence farms, hence the health of household members is critical to productivity, and it is no secret that the use of pesticides in farms has a significant impact on farmers' health (Rola and Pingali 1993, Antle and Pingali 1995, Antle et al. 1998, Ajayi 2000). There are also correlations among higher productivity, high chemical input use, environmental degradation and adverse effects on human health wherever commercial agriculture is widespread (Wilson 2000). In Sri Lanka, studies using the cost-of-illness approach (Wilson 2000, Wilson and Tisdell 2001, Wilson 2002a and b, Wilson 2003) have estimated that a farmer on average incurs a cost of around US $ 97.58 annually in handling and spraying of pesticides. Using the defensive behavior approach, the cost was estimated to be around US $ 7.23 a year. Additionally, WTP came up with a higher value, US $ 204.83, because it considers all costs, including the tangible costs of ill health (both direct and indirect), and averting/defensive behavior costs as well as intangible costs. Dung and Dung (1999) estimated the health cost at over US $ 6.92 per rice season. Ajayi (2000) estimated US $3.92 per household per season in the case of cotton-rice systems in Cote d'Ivoire, West Africa. Yanggen et al. (2003) found that the immediate costs equaled the value of 11 days of lost wages per year in the Carchi, Ecuador. Clearly, the environmental and social costs of pesticide use are enormous. **Table 1** summarizes findings from assessments in a number of countries, revealing costs totaling millions of dollars.

Farmers, especially in developing countries like Nepal, do not take account of the expenditure incurred in the treatment of illness arising from direct exposure to pesticides, and they dismiss intangible costs such as discomfort, pain and suffering as a normal part of their work. Because of the lack of appropriate methodologies and reliable data, the health impacts of pesticide use have traditionally been omitted from the analysis of returns on agricultural research and from the evaluation of specific agricultural policies. Therefore, this study focuses on estimating the averting behavior costs, costs-of-illness, and WTP – i.e., the economic value of costs incurred by subsistence farmers due to direct exposure to pesticides during handling and spraying.

In the study area, farmers spray insecticides such as parathion-methyl (classified as extremely hazardous 'Ia' by WHO, see IPCS 2002); dichlorvos (highly hazardous 'Ib'); cypermethrin, deltamethrin, and fenvelerate (moderately hazardous 'II'), and fungicides such as mancozeb, and carbendazim (non-hazardous under normal use 'U') on crops such as potato (*Solanum tuberosum*), tomato (*Lycopersicon esculentum*), bitter gourd (*Momordica charantia*), cucumber (*Cucumis sativa*), chili (*Capsicum* spp.), cabbage (*Brassica oleracea* var. *capitata*) and cauliflower (*Brassica oleracea* var. *botrytis*). On average farmers were spraying pesticides on crops like potato for 12.3 years, tomato for 9.8 years, and other crops such as bitter gourd and cucumber for 2.7 years. Introducing new crops meant dealing with more toxic pesticides. Surprisingly, only one-fifth of the respondents had taken integrated pest management (IPM) training. Thus, there is an urgency to raise awareness on pesticides, their alternatives and IPM. Many respondents reported eye irritation, headache and skin irritation or burns (**Table 2**). Similarly, one-third had experienced weakness, respiratory depression, sweating, muscle twitching and chapped hands. As many as 13 symptoms were identified as immediate effects of pesticide exposure, averaging six acute symptoms per person per year.

Many farmers believed that safety measures only hinder their work. For example, they thought that wearing a mask makes breathing difficult. They preferred to wear a long-sleeved shirt or long pants (75% of the respondent) or a handkerchief (37.5%). However, 12.5% of the respondents were not using any protective measures – not even a long-sleeved shirt or long pants. One of the main reasons for not using any safety measure is the lack of awareness of the acute and chronic effects that pesticides are known to have on human health.

On average, averting costs for each farmer was a meager NR 119.2 annually on safety gear (**Table 3**). Farmers also treat acute symptoms with local cures such as salt-water gargle, oil massage, turmeric (*Curcuma longa*) water, papaya (*Carica*

thirst, etc. 7 (29.2%)

TABLE 1. Environmental and social cost of pesticide use in different countries

Country	External cost estimated per year	Source
Sri Lanka	Ill health cost to farmers from pesticide exposure = 10 weeks' income	Wilson and Tisdell (2001)
Philippines	61% higher health costs for farmers exposed to pesticides than those not exposed	Pingali et al. (1995)
Vietnam	Health cost of over US $ 6.92 each per rice crop	Dung and Dung (1999)
Mali	Annual indirect and external cost of pesticide use = US$10 million	Ajayi et al. (2002)
West Africa	The economic value of the pesticide-related health costs equals to US$ 3.92 per household per season in the case of cotton-rice systems	Ajayi (2000)
Ecuador	The immediate costs of a typical intoxication (medical attention, medicines, days of recuperation, etc.) equaled the value of 11 days of lost wages	Yanggen et al. (2003)
Zimbabwe	Cotton growers incur a mean of US $ 4.73 in Sanyati and $ 8.31 in Chipinge on pesticide related direct and indirect acute health effects	Maumbe and Swinton (2003)

TABLE 2. Incidence of acute health symptoms. Number of respondents, N = 24

Acute symptoms	Suffered respondents
Eye irritation	23 (95.8%)
Headache	20 (83.3%)
Skin irritation/burn	20 (83.3%)
Weakness	11 (45.8%)
Respiratory depression	9 (37.5%)
Excessive sweating	8 (33.3%)
Muscle twitching/pain	8 (33.3%)
Chapped hands	8 (33.3%)
Throat discomfort	7 (29.2%)
Pain in chest	6 (25%)
Nausea	5 (20.8%)
Blurred vision	5 (20.8%)
Lacrimation	4 (16.7%)
Vomiting	1 (4.2%)
Diarrhea	1 (4.2%)
Other symptoms like dizziness, nose irritation, thirst, etc.	7 (29.2%)

papaya) and tomato, eating mint (*Mentha* spp.) and basil (*Ocimum sanctum*) plant; they seek medical attention only when suddenly exposed to pesticides**.** On average, farmers spent only NR 97.5 as medication costs each year to treat acute illness because most of these symptoms last only for a single day in general (**Table 3**).

On an average, households' productivity loss was found 6.54 days (equals NR 981.7) a year due to pesticide-related health problems (**Table 3**). One respondent mentioned that, due to illness, she could not sprayed pesticides on her bitter gourd when necessary, resulting in a loss of NR 1500 that season. On average, other costs associated with pesticide exposure come to NR 181.2 per year per household. Loss of productivity due to pesticide exposure was found to be greater than the total cost of averting behavior, medication and other costs. This indicates that pesticide use associated health problems increased the indirect costs rather than the direct costs. It is therefore important that cost-benefit analyses of pesticide use should take such costs into account, along with the cost of environmental degradation.

Finally, an open-ended WTP bid for safer pesticides was administered, keeping crop area and productivity constant (same as the previous year), with expenditure on pesticides during the previous year being used as a reference point and taking into account the full range of consequences of illness including productivity loss, effects on other family members, and possible long term health impacts as well as immediate discomfort, pain and stress. The possible effects of pesticides on environment: soil, water, air, animals and birds were not explained to participants at the time of the exercise. Considering the aforementioned effects of pesticides, farmers were asked, "How much would you be willing to pay per year (please state the highest value) for the use of a safer pesticide?" This study found a wide range of WTP bids, ranging from NR 1500 to NR 50, 000 per year per household (**Table 3**). The WTP bids exceeded the sum of cost of illness and averting cost because the WTP bids take into account pain, suffering, discomfort and other intangible costs in addition to the aforementioned costs. Farmers in the study area were willing to increase their pesticide expenditure by 94.2% if provided with safer pesticides or other sound alternatives.

In conclusion, while commercialization of agriculture has resulted in the introduction of new crops such as bitter gourd and cucumber, it has also resulted in increased exposure to hazardous pesticides due to which farmers are experiencing acute health symptoms. The medication and averting expenditures are inadequate. The productivity loss was found to be significant. It is strongly recommended that a nationwide survey be conducted to determine the overall costs of pesticide use in Nepal. Such costs should be taken into account when programs and policies relevant to pesticide use are formulated.

Methods

Only acute symptoms that appeared within 48 hours of pesticide sprays were considered. Long-term and chronic health impairments were not considered due to methodological difficulties. This study applied three morbidity valuation methods: cost-of-illness (COI), which measures the cost incurred as a result of illness; contingent valuation (the most commonly used stated preference method), which measures respondents' WTP for hypothetical health improvements and the averting behavior (a revealed preference method) that estimates WTP from observed behavioral responses to real situations. See **Table 4** for a summary of the three most common morbidity valuation methods for this study. COI includes medication costs (present market value of the materials used and time taken to prepare local treatments, consultation fee, hospitalization cost, laboratory cost, medication cost, travel cost to and from, time spent in traveling, and dietary expenses resulting from illness), productivity loss (work efficiency loss in farm, loss of work days in farm, number of family members involved and time spent by them in assisting or seeking treatment for the victim), and other costs (crop losses/damage due to inability to tend them, costs associated with hiring replacement labor, and any income foregone due to illness). Averting costs includes precautions taken to reduce direct

TABLE 3. Statistical measures for the selected variables (N = 24)

Symptoms	Unit	Min	Max	Mean	SE of Mean
Sex	Female = 0, Male = 1	0	1	0.7	0.09
Age	Years	17	53	35	1.90
Education	Years of schooling	0	12	5.9	0.89
IPM Training	No = 0, Yes = 1	0	1	0.21	0.08
Pesticide use in potato	Year	2	25	12.3	1.31
Pesticide use in tomato	Year	2	20	9.8	1.10
Pesticide use in other crops	Year	0	10	2.7	2.85
Symptoms experienced	No/person/year	0	13	5.9	3.50
Averting Costs	NRS/year/person	0	373.3	119.2	18.34
Medication Costs	NRS/year/household	0	536	97.5	37.25
Productivity loss	NRS/year/household	0	4443.7	981.7	232.91
Other Costs	NRS/year/household	0	2550	181.2	120.79
Total cost-of-illness (sum of medication, productivity and other costs)	NRS/year/household	0	4451.3	1261	296.62
WTP for safer pesticides	NRS/year/household	1500	50000	9962.5	2062.60
Expenditure on unsafe pesticides	NRS/year/household	1300	16000	4800	705.95

TABLE 4. Evaluations of three most common methods for morbidity valuation

Method	Approach	Advantages	Disadvantages
Cost-of-illness	Measures direct costs such as medical expenses and indirect costs such as foregone earnings.	Relative ease of application and explanation. Does not require household surveys.	Does not measure WTP. Ignores important components of WTP such as pain and suffering.
Contingent Valuation	Surveys elicit WTP for hypothetical changes in health effects.	Flexibility allows application to variety of health effects. If designed properly, allows measurement of complete WTP, including altruism.	Hypothetical nature introduces many sources of potential inaccuracy and imprecision. Method is controversial and often expensive.
Averting Behavior	Infers WTP from costs and effectiveness of actions taken to defend against illness.	WTP estimates based on actual behavior.	Difficult to isolate value of health from other benefits of averting action. Difficult to measure individual perceptions of cost and effectiveness of averting action.

Source: EPA (2000)

exposure to pesticide such as mask, handkerchief, and so on.

The study was carried out during 2004 in Srirampati of Hokse Village Development Committee in Jhikhu Khola Watershed of Central Nepal, which is about 40 km northeast of the capital. Twenty-five farmers spraying pesticides in his/her farm were randomly selected and interviewed with a carefully designed questionnaire that was also translated into Nepali language. For this study, due to the small sample, minimum, maximum, mean and standard deviation of mean for the selected variables are provided. One questionnaire was excluded due to duplication: both father and son were inadvertently interviewed. ■

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Biology of mistletoes and their status in Nepal Himalaya

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The mistletoes constitute a polyphyletic group of flowering parasitic plants and are commonly known as "*Ainjeru*" or "*Lisso*" in Nepali. Of the over 1300 mistletoe species occurring worldwide, Nepal is home to 19. Mistletoes are entirely dependent on their hosts for water and nutrients and affect their hosts mainly by competing for limited resources. Mistletoes play a vital role in natural plant communities by interacting with hosts, herbivores and dispersers. A large number of invertebrates and vertebrates use mistletoes as a shelter, as nesting and roosting place and as an important source of food. Oddly, botanists have accorded little attention to Nepal's mistletoes, and our knowledge of this remarkable group of plants is quite deficient.

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Mistletoe (order: Santalales) refers to a group of perennial flowering plants attached to branches of other trees and shrubs as aerial parasites (Barlow 1987, Kuijt 1990). The name 'mistletoe' derives from the Anglo-Saxon misteltan (or mistiltan); 'mistel' meaning dung, and 'tan' meaning twig. Thus it literally means 'dung-on-a-twig' (Calder 1983). Taxonomically, the mistletoes constitute a highly specialized and diverse group of angiosperms. They are obligate stem parasites whose dependency ranges from holoparasitic to hemiparasitic, and they are characterized by the development of a haustorium, an absorptive organ that serves as a sort of root, attaching to the host and penetrating its conductive tissues in order to pass nutrients to the parasite.

Diversity

Despite a large number of botanical explorations in Nepal, biologists have made scanty collection of mistletoe specimens. The heterogeneous geomorphology of the Himalayas and the rich floral diversity offers a good habitat for a variety of mistletoe species. In their comprehensive catalogue of Nepalese flowering plants, Hara et al. (1982) mentioned 12 mistletoe species belonging to six genera of Loranthaceae and three species belonging to two genera of Viscaceae. While this number has been confirmed by recent publications (Press et al. 2000 and HMGN 2001). Devkota and Glatzel (2005) and Devkota and Koirala (2005) have reported four species new to Nepal: *Viscum multinerve* Hayata, *V. loranthi* Elmer and *V. moniocum* Roxb ex DC (family Viscaceae), and *Scurrula gracilifolia* (Schult.) Danser (family Loranthaceae), extending the list of mistletoe species to 19.

Grierson and Long (1983) have reported 15 mistletoe species belonging to Loranthaceae and six species of Viscaceae in Bhutan. Apart from some scattered data (e.g., Zakaullah 1977, Zakaullah and Khan 1982), no information on mistletoe diversity is available from Western Himalayas. However, over 1300 species have been reported from the world (**Table 1**).

Biogeography

Mistletoe families Loranthaceae and Viscaceae have separate geographic origins and different cytological history (Barlow 1983). Loranthaceae are older than the Viscaceae; they originated in the mesic, warm to mild, closed forest of Cretaceous Gondwana, dispersing subsequently to Africa, Europe, and North America (Barlow 1983). The parasitic habit did not arise as a response to water stress but rather due to competition for nutrients in complex ecosystems (Barlow 1983). The younger Viscaceae, previously considered to have a Laurasian origin in the Tertiary period (Barlow 1983), are now believed also to have originated in Gondwana (Barlow 1987). Nearly all mistletoe genera are exclusively tropical or subtropical and only a handful of species are found elsewhere (Kuijt 1969). The Loranthaceae and Viscaceae are presently distributed widely throughout Europe, the Americas, Africa, Asia, and Australia, ranging from boreal climate to temperate, tropical, and arid zones, and absent only from extremely cold regions (Barlow 1983, Kuijt 1969). The Loranthaceae is distributed primarily in tropical and south temperate habitats; Africa, Indomalaya-Australia, and South America are the major centers of diversity. The Viscaceae are also widespread in the tropics but extend further towards the northern temperate zone (Barlow 1987).

Host range

Mistletoes are found on a wide range of woody plants, from forest trees, avenue trees, fruit trees and ornamental trees to shrubs, thorny scrubs, euphorbs and cacti. Mistletoes preferentially parasitize trees and shrubs, and their greatest diversity is found in forests and woodlands (Kuijt 1969, Calder 1983, Hawksworth 1983). They prefer disparate hosts in diverse biomes: conifers in boreal forests (Hawksworth 1983, Hawksworth and Wiens 1996), succulent euphorbs and cacti in the African and South American deserts (Martinez del Rio et al. 1996, Polhill and Wiens 1998), monocots and bracken ferns (Fineran and Hocking 1983) and orchids (Kuijt and Mulder

1985) in tropics. Many individual mistletoe species are capable of parasitizing a large number of host species (**Table 2**).

Distribution pattern

The distribution of mistletoes in natural plant communities is not uniform, being affected by many local environmental factors. Mistletoes spread mainly along roadsides, riverbanks, in the vicinity of fields and villages, in orchards, on warm slopes and in forests (Zakaullah and Khan 1982, Xiao and Pu 1988, Lopez et al. 2002, Devkota 2003). Hawksworth (1959), Ganguly and Kumar (1976) and Zakaullah (1977) reported the highest frequency of mistletoes on ridges; fewer were found on slopes and fewest on the plains. The high density of mistletoe on ridges is due to the presence of ample light intensity (Ganguly and Kumar 1976, Lopez et al. 2002). Distribution of mistletoes in the Annapurna Conservation Area, is impacted by three major factors: forest structure, site mesoclimate and zoocore dispersal (Devkota 2003). The distribution of host trees and the behavior of avian visitors seem to be primary factors determining the distribution of mistletoes in Kathmandu Valley (Devkota and Acharya 1996). Kuijt (1969) concludes that mistletoe distribution depends entirely upon the habits of the birds that disseminate the seeds.

Mistletoe-host interaction

Mistletoes affect host viability by withdrawing essential resources. The parasite competes with its host for water, inorganic nutrients and organic compounds. The extent to which the host is affected depends not only on how much of the resource is diverted by the parasite, but also on the overall supply available to the host (Graves 1995). Some leafy mistletoe may live for decades in association with their host trees and result in little apparent damage (Schulze and Ehleringer 1984), while others inflict severe damage.

Mistletoes affect hosts in many ways, including reduced growth, diminished vigor, premature mortality, impaired quality and quantity of wood, reduced fruit set, and heightened susceptibility to attack by other agents such as insects or fungi. When one part of the host is intensively attacked by mistletoe, the reproductive and photosynthetic potential of the part distal to the infestation declines leading to death of the part (Kuijt 1969). But the extent of damage caused to the host depends on size of the parasite, the growth rate and metabolic activity of the parasite, the degree of dependency on the host for resources, and the stage of development of the host (Hawksworth 1983). In Australia, however, Race and Stelling (1997) did not find a significant correlation between the health of individual host plants and the number of mistletoe plants afflicting them; they concluded that mistletoe may not necessarily be harmful to its host.

Mineral nutrition

While mistletoes are entirely dependent on their hosts for water and nutrients (Glatzel 1983, Popp and Richter 1998), they differ greatly in the extent to which they rely on the supply of photosynthetic products from their hosts. The extent to which mistletoes depend on heterotrophic carbon input from the host is one of the most important aspects in the mistletoe nutrition.

Xylem tapping mistletoes are capable of fixing atmospheric carbon dioxide and are therefore partially heterotrophic; others also parasitize phloem of their hosts and are regarded as holoparasites. The latter group lacks chlorophyll or has reduced photosynthetic organs, whereas the xylem parasites are regarded as 'obligate hemiparasitic' as they rely only partially on host-derived carbon (Tsivion 1978). The xylem tapping mistletoes have a higher transpiration rate than their host, as a mechanism to draw sufficient nutrients from the host xylem sap. Since there is no phloem connection between host and such mistletoes, retranslocation of excess nutrients back to the host cannot occur. As a result, mistletoe tissues accumulate higher concentrations of nutrient elements than those of their hosts (Glatzel 1983, Devkota 2003).

Mutualism involving mistletoes and birds

Many bird species are intricately involved in the life cycle of mistletoes especially in pollination and seed dispersal (Kuijt 1969, Barlow 1983, Reid 1991, Ladley and Kelly 1995a). The establishment of the host-mistletoe association cannot be examined without understanding the role of seed-dispersing birds, especially the frugivores. The feeding habits of the birds and the duration of seed retention within their body determine the successful dispersal of the mistletoes.

Old world sunbirds (*Nectariniini*), Oriental flowerpeckers (*Dicaeini*) and white-eyes (*Zosterops*), Australian honeyeaters (*Meliphagidae*), and neotropical humming birds (*Trochilidae*) are the most common avian pollinators (Docters van Leeuwen 1954, Gill and Wolf 1975, Reid 1986). Studies by Ali (1931) and Davidar (1978, 1983, 1985 and 1987) in the Oriental region have shown that the sunbirds and the flowerpeckers, when foraging for nectar, probe mistletoe flowers in distinct ways, thus effecting pollination.

Most Loranthacean species have fleshy, animal-dispersed single-seeded fruits (Kuijt 1969, Johri and Bhatnagar 1972), which are an important source of food for many bird species worldwide (Docters van Leeuwen 1954, Kuijt 1969, Reid 1986, Watson 2001). Small frugivorous birds that feed largely on the fruits of mistletoes have evolved independently several times in different parts of the world and are the major fruit consumers and most effective dispersers of their fruit (Ali 1931, Dowsett-lemaire 1982, Davidar 1983, Liddy 1983, Godschalk 1985). For the mistletoes, where germination is entirely dependent on bird dispersal to remove the exocarp, Ladley and Kelly (1996) conclude that while the current population of sunbirds and flowerpeckers does not appear to threaten mistletoes survival, the role of the dispersers needs to be considered when pursuing mistletoes conservation assessment.

Reproduction

Sexual reproduction in a large number of mistletoe species is influenced by birds, which play a significant role in their pollination and dispersal. Most Loranthaceous mistletoes have large, brightly colored, hermaphroditic flowers, which produce abundant nectar and are bird-pollinated (Kuijt 1969). Ali (1931) concludes that the propagation strategy of mistletoe is so inextricably linked to the behavior of sunbirds and flowerpeckers that they would soon die out altogether in the absence of the birds. Viscaceous mistletoes are pollinated by insects (hymenopterans) or wind (Kuijt 1969), but birds are also important in seed dispersal. In a large number of Loranthaceae and Viscaceae species the succulent fruit pulp (mesocarp) contains nutrients to attract avian dispersers, and endocarp is viscous in order to cement the seed on host branch. Some Viscaceous genera (*Arceuthobium* and *Korhalsella*) are dispersed locally by fruits with explosive mechanisms; however, they may also be dispersed over long distances when the seeds stick to the plumage or pelage of birds and mammals (Barlow 1983).

TABLE 1. Number of genera and species of Mistletoe in the world and in Nepal

Family	World*		Nepal**	
	Genera	Species	Genera	Species
Loranthaceae	74	910	6	13
Misodendraceae	1	8		
Santalaceae	7	51		
Viscaceae	7	ca 350	2	6
Total	**89**	**ca. 1319**	**8**	**19**

Source: *Nickrent 2002; **Hara et al. 1982, Devkota and Glatzel 2005a, Devkota and Koirala 2005b

TABLE 2. Number of host species for some important mistletoe species

Mistletoe species	Number of host species	References
Dendrophthoe falcata	401 (227 genera and 77 families)	Hawksworth et al. (1993)
Macrosolen cochinchinensis	27 (23 genera)	Ganguly and Pal (1975)
Scurrula elata	48 (40 genera and 26 families)	Devkota (2003)
Scurrula parasitica	38 (30 genera and 22 families)	Devkota (2005)
Scurrula pulverulenta	81 (58 genera and 34 families)	Pundir (1995)
Viscum album	452 (96 genera and 44 families)	Barney et al. (1998)

Seed dispersal depends primarily on animals, which are attracted by the colorful fruits or fleshy appendages. Insects are the main pollinators of the Santalaceae, but humming birds also are pollinating agents for two South African genera (Kuijt 1969). Among the Santalaceae, bird dispersal predominates (Kuijt 1969), but ants are also important dispersal agents. The pollination biology of the Misodendraceae is less well understood. Single-seeded fruit (achene), with three barbed awn and a sticky disc at the radical end of Misodendraceous mistletoes plants are dispersed by wind.

The misunderstood mistletoes

Several studies in the past have concluded that mistletoes are an important structural and functional component of forests and woodland communities. The common opinion that mistletoes are destructive weeds should be challenged. Due to their parasitic nature, mistletoes have been considered invasive pests, and as a detriment to forest health by policy makers, foresters, forest owners, lay people and even biologists. Mistletoes need to be promoted as indicators of habitat health, rather than agents of destruction; as Ladley and Kelly (1996) and Watson (2001) suggested, they should be "considered a keystone resource in woodlands and forests, having a disproportionate influence on the distribution patterns of animals." Besides having profound consequences for those species associated with their hosts, mistletoe infection can also have a strong impact on the larger communities in which it occurs by (for instance) altering forest structure and composition (Geils and Hawksworth 2002).

Compared to those of the New World, Old World mistletoes are under-represented in the mistletoe literature despite their dominating presence in highly diverse ecosystems from tropics to temperate. The role of mistletoes in the biodiversity of the Himalayas is unexplored, and it is unknown how mistletoes affect biodiversity. There is very little information available on the mistletoes of the Nepal Himalaya; most reports come from the Western Himalayas of India and Pakistan, and a few from the Southern parts of India (Ali 1936, Davidar 1978).

Potential threats to mistletoes of Nepal Himalayas

The broad-leaved forests of the temperate region (2000–3000 masl) constitute the most suitable habitat for mistletoes in Nepal (Devkota 2003). Nepal's forests, unfortunately, are facing severe stress due to increasing demand for agricultural land, timber, fuelwood and fodder, and to encroachment of settlements on forest areas. The most critical threat to biodiversity is habitat destruction (HMGN/MFSC 2002). Deforestation and land degradation are serious problems in Nepal and major threats to the natural populations of mistletoes. Other threats include depredation by insects and fungal disease; vegetation succession; pressure on bird species that serve as mistletoe pollinators and disseminators; collection of mistletoe for fodder during the flowering and fruiting seasons; and, in general, human negligence of a group of plants incorrectly identified as pests.

Management requirements

Despite their parasitic nature, the mistletoes play important roles in natural ecosystems. Regardless of the National Biodiversity Strategy (HMGN/MFSC 2002), policy makers of Nepal have failed to recognize the importance of mistletoes in biodiversity conservation. As an initial step, we need a nationwide study of the current status of mistletoe, including identification of the host range of individual mistletoe species. The government of Nepal should take the initiative in designing and implementing an action plan to protect mistletoes; Tribhuvan University, IUCN, ICIMOD, and WWF Nepal, should be involved as well. Mistletoe conservation can be initiated by adopting the following measures:

Immediate protection measures

- Conduct mistletoe inventories throughout the country, especially in all protected areas, with a view to conservation management and identify the potential mistletoe habitats,
- Restore and reforest potential habitats especially in broadleaf forests at middle elevation,
- Impose strict rules against fodder collection and tree felling in potential habitats,
- Stop agricultural expansion and grazing in and around potential habitats.

Long term conservation action plan

- Develop a long-term mistletoe conservation plan for Nepal,
- Continue to monitor mistletoe population in their potential habitats; establish and maintain a mistletoe database of Nepal,
- Control human induced disturbance, set the forest resources for natural regeneration and discourage the use and introduction of alien species,
- Control pests affecting mistletoes.

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