

Ecological Consequences of Forest Use: From Genes to Ecosystem— A Case Study in the Biligiri Rangaswamy Temple Wildlife Sanctuary, South India

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Human dependence on forests can have manifold ecological consequences from the level of genes to the entire ecosystem. Despite the extensive use of forest products by communities, especially in tropical countries such as India, there have been hardly any attempts at monitoring these consequences. Understanding the consequences could facilitate the development of management protocols that, while maintaining the livelihoods of the forest-dependent communities, could help minimise the associated ecological cost. In a unique attempt over the last decade, we have examined the ecological consequences of forest use, from genes to ecosystem, in the Biligiri Rangaswamy Temple Wildlife Sanctuary, south India. In this article we review these findings and demonstrate that monitoring of biodiversity elements from genes to ecosystem is important in understanding the underlying process of change and in formulating appropriate strategies for the conservation of biodiversity.

INTRODUCTION

NON-TIMBER FOREST product (NTFP) species constitute an important source of livelihoods for rural people in most human-dominated forest landscapes in tropical countries. However, this human dependence on forests for livelihoods is not always

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without a cost to the ecosystem, be it a reduction of focal species productivity or a decline in ecosystem functioning. Efforts to minimise these ecological costs would greatly help in not only targeting larger conservation goals, but also serve to sustain livelihoods of the people making use of these species over the long term. Recently, Uma Shaanker et al. (2004) conceptualised a model that attempts to address the potential conflicts of forest use from the perspectives of livelihood gains and ecological costs. According to this model, under most current extractive practices, gains in livelihoods attract an ecological cost (win–lose situations; Figure 1). Lose–win situations (with no apparent livelihood gain and thus no ecological cost) are perhaps typical only of nationally protected areas, from where extraction of NTFP is prohibited; on the other hand, lose–lose situations may be typical of degraded wastelands, where due to past exploitative extraction, for example, livelihood gains are absent and the area has already incurred an ecological cost. The most ideal scenario would be the win–win situation, where there is an equilibrium between livelihood gains and ecological costs. Within the available possibilities, it appears that unless efforts are taken to reduce the skew between gains and costs (in the win–lose situation), sooner or later it will transform to a lose–lose situation (because of over-extraction). Reduction of skew between gains and costs could be the first step in redirecting the trajectories of change to a win–win situation.

Figure 1
A 2×2 Matrix of Livelihood Gains and Ecological Costs

		Ecological costs	
		Win	Lose
Livelihood gains	Win	<i>Win–Win</i> (Desired situation) ←	<i>Win–Lose</i> (Existing situation) ↓
	Lose	<i>Lose–Win</i> (Protected areas)	<i>Lose–Lose</i> (Wastelands)

Note: The bold arrow indicates the desired trajectory; the dotted arrow indicates the likely trajectory if disparities between gains and costs widen.

Though conceptually the 2×2 matrix of win–lose (Figure 1) offers a rich canvas to navigate options, in practise success in reaching a win–win situation has been far from desired. In the absence of timber extraction in countries such as India, NTFP have come to stay as the major extractable produce of the forest. Under these conditions, managing NTFP extraction is key to both conserving the forest as well as to ensuring the livelihood needs of the rural poor. While there has been a general realisation that dependence of forest fringe communities on forest resources could entail a certain ecological cost, there have not been many

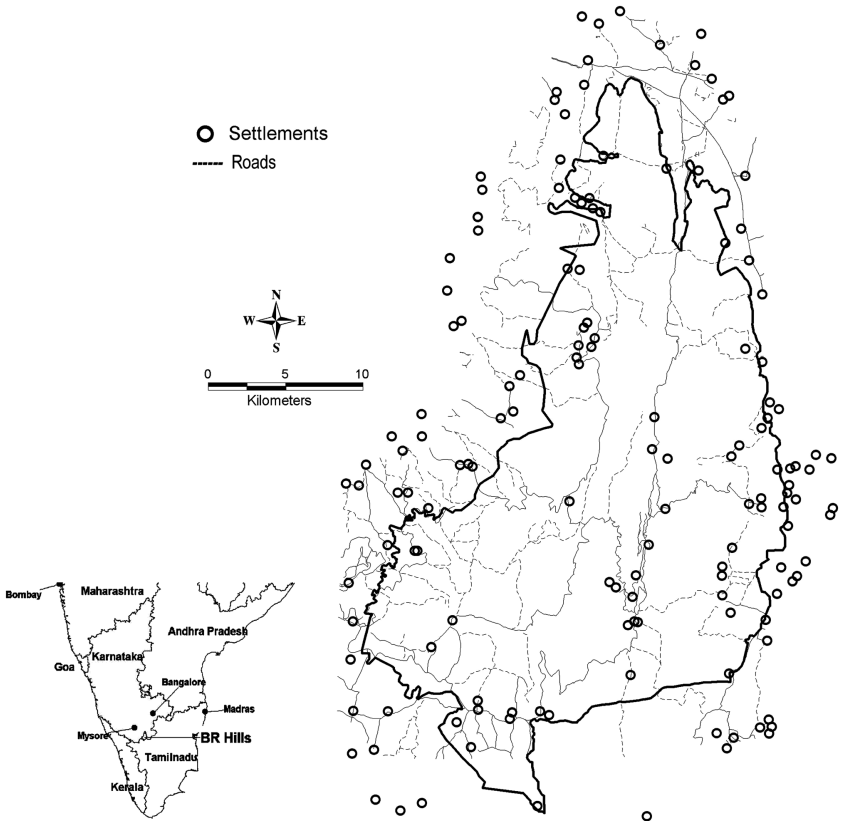
efforts to explicitly address the costs (Ticktin 2004; Uma Shaanker et al. 2004). Understanding the nature of these ecological costs would be illustrative as well as useful in developing strategies to mitigate them while maintaining livelihoods. One of the reasons for the relatively scarce treatment of ecological costs is the inherent difficulty in quantifying them. Costs could be implied at various levels, from individual populations to the entire species, and from tangible to non-tangible. The task is admittedly excruciating, but if addressed, can offer rich insights into not only the nature of ecological consequences but also the nature of possible solutions that could reduce the skew between livelihood gains and ecological costs.

In a unique effort spread over the last decade, we have attempted to comprehensively understand the ecological consequences of human dependence on forests in south India from the level of genes to ecosystem. In this article we briefly review the results of these efforts and argue that monitoring the various consequences is an important first step in understanding the underlying process of change and in formulating appropriate protocols for the conservation of biodiversity in general and NTFP resources in particular. Against the backdrop of the theoretical framework presented above, we believe that if long-term dependence of people on forest resources has to be safeguarded, it is imperative to reconcile livelihood gains with ecological costs. In the absence of such a reconciliation, the long-term dependence of communities on forest resources would be jeopardised, as would the resources themselves.

THE STUDY SYSTEM AND METHODS

Study Site: The Ecological and Human Setting

The ecological consequences reviewed in this article are based on a series of studies carried out in the past decade at the Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary (11.40° to 12.09° N and 77.05° to 77.15° E) located at the easternmost ridge of the Western Ghats, in the state of Karnataka, India (Figure 2). The 540 sq.km sanctuary contains a rich diversity of vegetation types ranging from scrub to montane evergreen forest. The terrain is highly undulating and the altitude ranges from 600 to 1800 m. The sanctuary is inhabited by an indigenous community, the Soligas, who live in small settlements called *podus*. The Soligas harvest a number of NTFP for their food, fibre, shelter and medicine (Hegde et al. 1996; Murali et al. 1996; Uma Shankar et al. 1998). It is estimated that nearly 60 per cent of the cash income of the Soligas is derived from NTFP alone (Hegde et al. 1996; Uma Shaanker et al. 2004). Besides the Soligas, people in the foothills of the sanctuary also depend on a number of forest-based resources. The individual studies reviewed here were designed to address the impacts of anthropogenic pressures on: (a) the genetic structure of populations of a few NTFP species; (b) the population dynamics of NTFP species; (c) forest composition and community structure; and (d) ecosystem-level attributes or processes.

Figure 2*Map Showing Location of Biligiri Rangaswamy Temple Wildlife Sanctuary in South India*

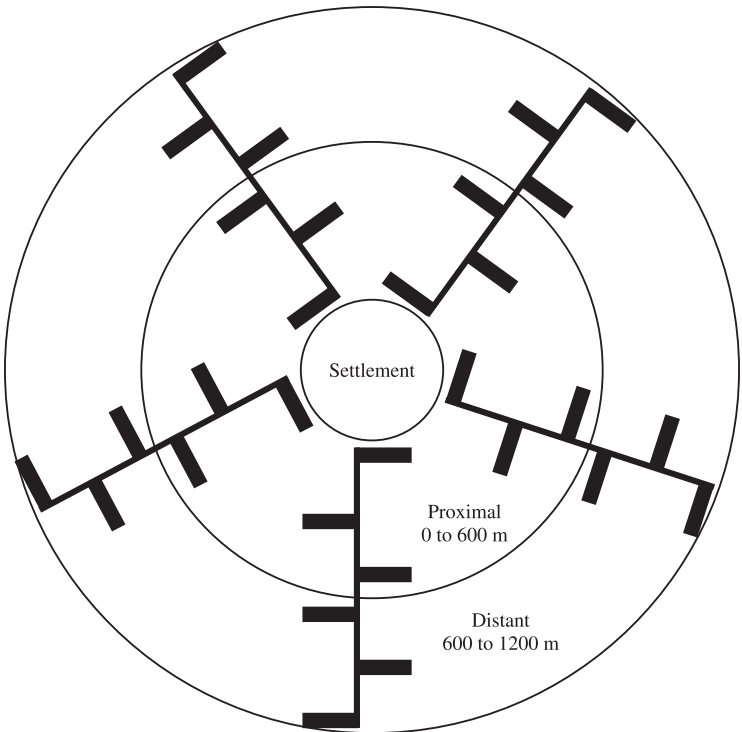
Study Design

One of the major constraints in analysing the ecological consequences of human dependence on forests is the lack of methodology that can best capture the direct and indirect effects of human disturbance. Almost all human use of forests, besides affecting the local species or population of interest, is accompanied by a host of human-induced disturbances such as settlement, grazing, fire, etc. (Murali et al. 1996; Padmini et al. 2001; Uma Shaanker et al. 2001a). Thus, any method that attempts to analyse the impacts of human disturbance needs to capture most, if not all, of the direct and indirect effects.

In the studies conducted at BRT, a novel disturbance-gradient approach was adopted to elucidate the ecological consequences of human dependence on the forest. It was tacitly assumed that forest sites proximal to human settlements are relatively more disturbed than sites distant from settlements. This assumption rests on the fact that the opportunity cost of harvesting forest resources decreases

with distance from the settlement (Ganeshaiyah et al. 1998; Murali et al 1996; Uma Shaanker et al. 2003). Thus, sampling forest sites along a gradient of distance from the settlement will capture different degrees of disturbance. All the studies reviewed here have adopted this basic design though the details vary from one study to the other. Studies were conducted by laying sampling plots (such as quadrats or transects; Figure 3) either along the gradient or at discrete sites proximal and distant to the settlements. Further details of the sampling protocols and other methods are available in the respective studies cited in the text.

Figure 3
Diagrammatic Representation of Sampling Strategy Adopted in the Studies Reported Here



Note: The bars indicate the position of transects of dimension 10×1000 m.

The proportion of cut and broken stem per sampling unit has been used frequently as a quantitative measure of human-induced disturbance (Aravind et al. 2001; Barve et al., forthcoming; Ganeshaiyah et al. 1998). This measure fairly accurately reflects the relative anthropogenic pressure at a site. For example, the distant and proximal sites at BRT were 0.03 and 8.5 respectively, indicating that these sites indeed reflect the different disturbance regimes (Murali et al. 1996; Padmini et al. 2001).

ECOLOGICAL CONSEQUENCES: FROM GENES TO ECOSYSTEMS

Genetic Diversity of NTFP Species as a Function of Forest Use

Of all levels of ecological hierarchy, the impact of anthropogenic pressures at the level of genes has been least realised (Uma Shaanker et al. 2001b; Young et al. 2000). The impact at this level has been particularly hidden from major agendas of conservation despite the fact that this might be the most important lifeline of the species. Surprisingly, except for a few studies investigating the effect of logging on the genetic diversity of trees, hardly any have addressed the impact of other anthropogenic pressures on the genetic diversity of trees (Burchert et al. 1997; Wickneswari and Boyle 2000; Young 2000; Young et al. 2000).

We assessed population-level genetic diversity of a few NTFP species, namely, *Phyllanthus emblica*, *Terminalia bellerica* and *T. chebula*, which are extracted by the Soligas in BRT, was assessed (Nageswara Rao et al. 2000; Padmini et al. 2001; Uma Shaanker et al. 2003). Populations of each of the species were sampled proximal and distant to human settlements and assessed for their genetic diversity using isozyme analysis (Padmini et al. 2001). Several population genetic parameters including per cent heterozygosity of populations and genetic differentiation statistics were computed. While the former (per cent heterozygosity) indicates the relative level of genetic variability of a population, the latter (genetic differentiation statistic) indicates if the populations under study are indeed genetically distinguishable from each other. Besides, Padmini et al. (ibid.) also computed the relative sensitivity of alleles to anthropogenic pressures by analysing the frequencies of specific alleles in populations proximal to settlements compared to those distant from settlements.

Namkoong et al. (1996) considered the possible consequences of different forms of NTFP collection on genetic processes. They concluded that the main effect of harvesting of whole individuals would be via genetic drift and indirect selection, and only harvesting of reproductive structures would be most likely to affect gene flow and the mating system. The response of species to harvesting pressures might be influenced by species-specific features (intrinsic features). Harvesting the entire organism (for example, in the case of lichens), or harvesting parts of the organism that result in killing the entire organism, (for example, de-barking stems of *Kydia calycina* [Uma Shaanker et al. 1997], or harvesting bamboo [Chalavaraju et al. 2001] or heartwood of sandal [Nageswara Rao et al. 2001]) would be catastrophic to the regeneration of the respective species and their genetic resources. On the other hand, harvesting leaves may only marginally affect the genetic diversity. In a study on the impact of disturbance on the genetic diversity of forest species in Thailand, Kowit et al. (1997) showed that the expected heterozygosity increased with disturbance levels for pioneer species, and decreased or remained unchanged for non-pioneer species. A comprehensive study by Wickneswari et al. (1997a, 1997b) in the tropical rainforest of Malaysia reported a reduced percentage of genetic diversity (5 to 23.4 per cent) after early logging for five species with

different life history strategies. Similarly, Burchert et al. (1997) reported appreciable loss in genetic diversity (mean and total number of alleles) of white pine (*Pinus strobus*) in Ontario immediately after harvesting. However, there were no adverse changes in genetic diversity for *Shorea leprosula* and *Dryobalanopus aromatica* in regenerated stands compared to unlogged stands.

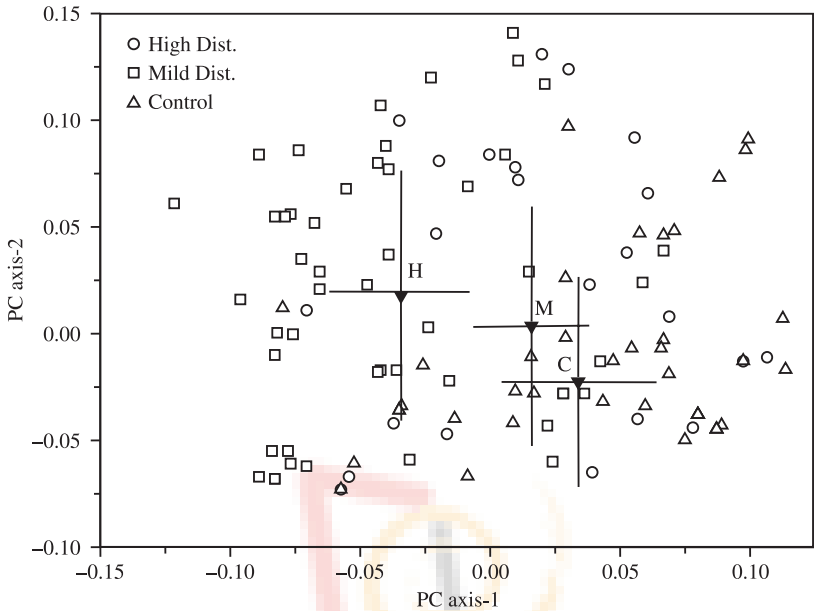
In the study conducted at BR Hills, Padmini et al. (2001) and Uma Shaanker et al. (2001a) examined the impact of harvesting of fruits of *P. emblica*, *T. bellerica* and *T. chebula* at sites proximal and distant to human settlements. In all three species there was no clear pattern of loss of genetic diversity across the various disturbance levels. Compared to *P. emblica*, the levels of genetic variability in the *Terminalia* species were very low. In the latter species, populations at all the three disturbance levels (least disturbed, moderately disturbed and most disturbed) seem to suffer from heterozygote deficiency. Perhaps reflecting the low levels of genetic variability, in both species of *Terminalia* regeneration was very poor in the highly disturbed (proximal to settlements) populations. Uma Shaanker et al. (1997) argued that the poor regeneration in *T. chebula* could also be due to a high level of developmental lethals in the system, a possible consequence of the high levels of inbreeding in the population.

In all the three species there was clear genetic differentiation of the populations along the gradients of disturbance, suggesting that individuals from different disturbance regimes may have assorted themselves with specific allelic configurations. In all the species populations from the least (control) and moderately disturbed sites clustered together, while those from the highly disturbed sites grouped separately. Finally, in all three species there appeared to be a disturbance-driven change in allele frequency at several loci. A few of the alleles tend to be adversely affected by disturbance. These occur with a low frequency in the most disturbed populations compared to the least disturbed one. On the other hand, a few other alleles actually increased in frequency under disturbance (Padmini et al. 2001; Uma Shaanker et al. 2001a).

The genetic differentiation of the populations exposed to the most disturbance from those exposed to the least disturbance could be either due to: (a) directional selection of populations due to harvesting pressures; or (b) a reduced population size (due to harvesting) leading to mating constraints (Figure 4), or a combination of these factors. To what extent is such fine scale genetic structuring of populations as a result of human disturbance important? Could these changes lead to a cascade of events that change the original genetic configuration of populations? And if so are they crucial in maintaining the natural genetic resources of the respective species and their populations? While these are important issues to ponder, it is clear that if such genetic structuring were to go on unabated it could certainly lead to loss of sizeable proportion of the genetic variation in the natural populations.

These studies are some of the very few to have demonstrated quantifiable genetic consequences of harvesting and human disturbances on the genetic structure of NTFP species. While more studies are clearly required, the studies point to the necessity of maintaining harvesting intensities and anthropogenic pressures that

Figure 4
Principal Component Analysis (PCA) of *Phyllanthus emblica* Populations
from the Three Disturbance Regimes at BRT



Source: Padmini et al. (2001).

Note: The standard deviations from the mean for both axes for each of the populations are depicted: C = least disturbed (control), M = moderately disturbed, and H = most disturbed. The PCA is based on the electromorph frequencies obtained from the isozyme analysis (for details see Padmini et al. 2001).

least distort the original (at the least disturbed sites) genetic variability and structure. Ideally, these studies should lead to the identification of acceptable threshold levels of disturbance for different species such that appropriate management protocols can be prescribed.

Impact of Anthropogenic Pressures at the Level of Populations

At each of the sites, the density, regeneration and size class distribution of the focal NTFP species were recorded in transects at both the proximal and distant sites. Regeneration attributes were also recorded for non-NTFP species and compared with those for NTFP species (Murali et al. 1996; Padmini et al. 2001).

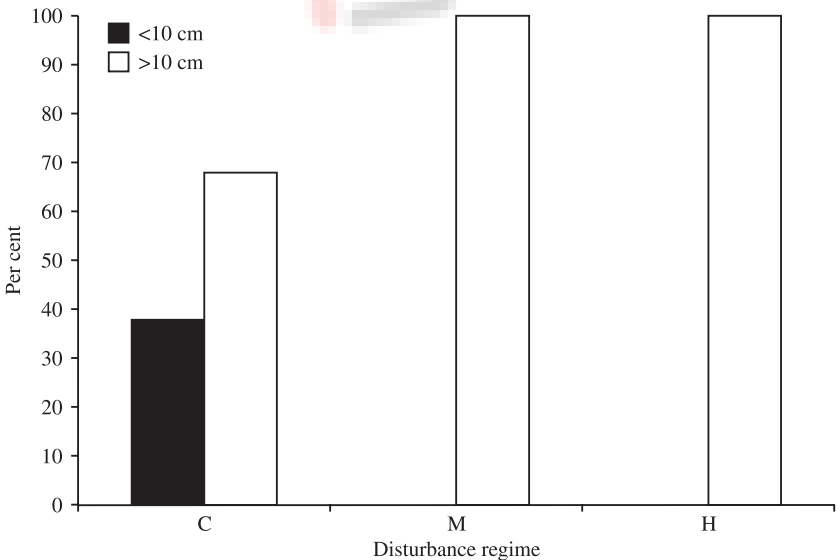
In an excellent and exhaustive review, Ticktin (2004) summarised that most NTFP tend to be overharvested, leading to poor regeneration and finally to unsustainable population sizes. Local populations of NTFP seem to be indiscriminately extracted, often leaving behind almost no growing stock. Several approaches have been proposed to analyse quantitatively the state of health of a harvested population

with reference to the regeneration potential of the species. One of the earliest treatments of this subject was offered by Hall and Bawa (1993), who argued that the departure from an inverse J-curve in the size class of stems could be a good reflection of the stability or otherwise of a population. While this offers a simplistic view of the problem, in most cases it offers a good thumb rule to determine population regeneration. More recent studies have resorted to analysing the regeneration index by generating transition matrices and predicting the future health of the population (Ticktin 2004). The latter models have a more rigorous theoretical basis, and often provide a rational index and approach towards the problem of turnover of populations (Uma Shaanker et al. 2004). Direct effects of harvesting NTFP on populations have been reported by a host of workers (Daniels et al. 1995; Ganeshaiyah and Uma Shaanker 1998; Hegde et al. 1996; Kruckeburg and Rabinowitz, 1985; Murali et al. 1996; Nageswara Rao et al. 2001; Uma Shaanker et al. 1996, 1997; Young et al. 2000).

In the studies conducted at BRT Hills, it was found that populations at the proximal site (most disturbed) were more affected than those at the distant site (least disturbed). There was a relatively smaller proportion of small size class individuals (recruits) in the proximal sites compared to the distant sites (Figure 5). Thus, anthropogenic pressures, especially harvesting of NTFP, may lead to poor regeneration of these species (Nageswara Rao et al. 2000; Uma Shaanker et al. 1996).

Figure 5

The Proportion of Seedlings and Saplings (<10 cm dbh) and Adults (>10 cm dbh) of Terminalia bellirica at the Different Disturbance Levels at BRT



Source: Uma Shaanker et al. (2001a).

Note: C = least disturbed (control), M = moderately disturbed, H = most disturbed

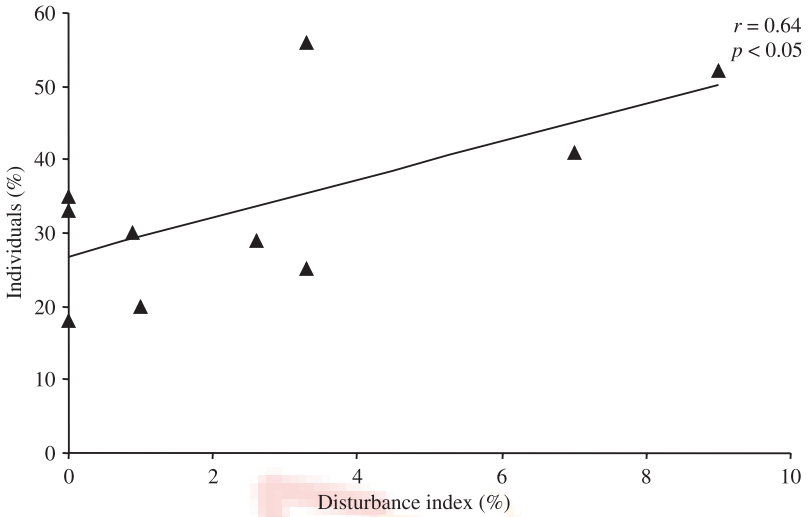
At an individual species level, there was a significant decrease in the small size class (<10 cm dbh) individuals of all the three major NTFP species, namely, *P. emblica*, *T. bellerica* and *T. chebula* at the BRT sanctuary. For instance, in *P. emblica* the proportion of stems in the <10 cm dbh category decreased from 80 per cent in the control or least disturbed sites to 61 per cent in the moderately disturbed sites and 9 per cent in the most disturbed sites (Padmini et al. 2001; Uma Shaanker et al. 1997). Regeneration was nearly uniformly affected across the disturbance regimes in *T. chebula*. In fact, at BRT the regeneration of saplings of NTFP species was uniformly affected across species and compared to non-NTFP (Murali et al. 1996), and even adult trees were not recorded in the most disturbed sites. On the other hand, the regeneration of *Terminalia crenulata*, a dominant timber species, showed little or no effect of anthropogenic disturbance compared to the NTFP species (Murali et al. 1996; Uma Shaanker et al. 1996).

A key issue that will serve the cause of conservation lies in identifying the threshold levels of disturbance that a species will tolerate such that the fallouts of disturbance could be rationally managed. The studies reviewed here show that anthropogenic pressures, including harvesting and other activities such as grazing and fuel wood collection, do affect regeneration of NTFP species, and that there might exist different threshold levels below which different species can tolerate such disturbances. Studies such as these can highlight these thresholds and thus provoke management interventions that can prevent populations from being exploited beyond critical thresholds.

Impact of Anthropogenic Pressures at the Level of Communities: Forest Composition and Community Structure

To assess the impact of human disturbance at a community level, Ganeshaiah et al. (1998) obtained information on the vegetation composition and structure at transects at both the proximal and distant sites, and analysed for associations with species' life history traits. Among the various life history parameters, one that could be obtained with the least amount of ambiguity is the dispersal mode of a species. The dispersal modes of the different species were inferred from secondary sources including flora and other published literature, and personal observations (ibid.). The frequency distribution of the species and individuals into different dispersal mode categories, namely, animal dispersed, passively dispersed, and wind dispersed in the proximal and distant sites was evaluated against a null hypothesis of random distribution of species and individuals in the different categories of disturbance (ibid.).

Ganeshaiah et al. (ibid.) found that though the two sites did not differ with respect to the proportion of the species belonging to the different dispersal modes, they differed with respect to the frequency of the individuals with different dispersal modes. The proximal site had a greater proportion of wind-dispersed stems (Figure 6) than the distant site, while in the latter there was a greater proportion of animal-dispersed stems.

Figure 6**Relation of Per Cent Wind-dispersed Stems with Disturbance Index at BRT**

Note: Disturbance index of transects at the proximal and distant sites were estimated and the per cent stems of wind dispersed species arrived at for each of the transects (adapted from Ganeshiah et al. 1998).

These results confirm the generally held view that disturbance, or opening of the canopy, leads to colonisation by early successional species that are likely to have wind-dispersed propagules. In fact, this study showed that wind-dispersed species are favoured in the disturbed habitats, while animal-dispersed species may perhaps be at a disadvantage because of interference to the animal dispersal vectors or due to loss of safe sites. The number of seedlings and saplings per adult of wind-dispersed species was more than the number per adult of animal-dispersed species in the proximal sites compared to the distant sites. The response of forest vegetation to anthropogenic pressures may depend upon the intrinsic features of its flora (Kruckeberg and Rabinowitz 1985). In particular, the response of species to human-induced pressures would be sensitive to the reproductive features and regeneration potential of the species. In orchids, species with large, brightly coloured flowers suffer a greater risk of becoming vulnerable or extinct following human pressures (Lokesh and Vasudeva 1992). On the other hand, species with good coppicing ability are likely to be less vulnerable to human-induced pressures than non-coppicing species, as inferred from their greater abundance in human-influenced humid forests of the Western Ghats (Daniels et al. 1995). In general, it appears that human disturbance to forest leads to a more open canopy that can then potentially result in change of forest structure and perhaps make the habitats more susceptible to invasion (Cunningham 1993). In fact, Uma Shankar et al.

(1998) hypothesised that anthropogenic pressures may have led to the creation of scrub forest from dry deciduous forests.

The results of these studies show that anthropogenic pressures can significantly alter vegetation composition, resulting in forest mosaics, and leading perhaps to the local extinction of certain vegetation types. Species that are dispersed and pollinated by animals or insects might be more sensitive to disturbance than species that are dispersed and pollinated by wind (Figure 7). In fact, we believe that the mosaics in species occurrence resulting from anthropogenic pressures in otherwise contiguous populations can mimic the effect of landscape fragmentation. Accordingly, it might be worthwhile to lay particular emphasis on animal-dispersed species in conservation efforts in disturbed habitats.

Figure 7
Schematic Illustration of Vulnerability of Species to Human Disturbance

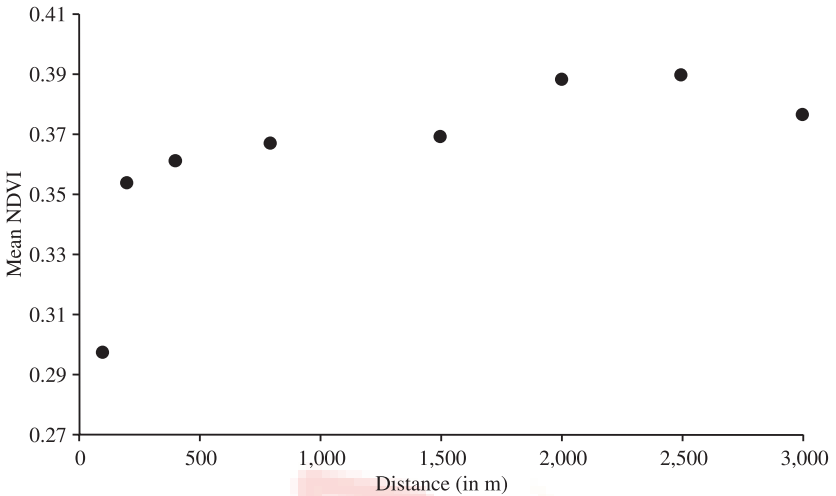
Pollination mode	Dispersal mode		
	Wind	Passive	Animal
Wind	Least		
Small insects			
Animal			Most

Impact of Anthropogenic Pressures at the Level of Ecosystem

Gross effects of human disturbance on forests are best captured at the ecosystem level. Ganeshaiyah and Uma Shaanker (1999) evaluated the impact of human disturbances on land cover changes in BRT by analysing remotely sensed images between 1980 and 1995. To assess the gross impact of human disturbance on the forest at the ecosystem level, Ganeshaiyah and Uma Shaanker (1998) analysed the IRS 1C/D and LISS III satellite imagery for three seasons (summer, monsoon and winter) and calculated the mean normalised difference vegetation index (NDVI), a measure of green biomass (Ganeshaiyah and Uma Shaanker 1999). Superimposing the Soliga settlement map on the NDVI layer, they calculated the mean NDVI within buffers demarcated at different radial distances from settlements to reflect changes in vegetative cover as a function of increasing distance from settlements (ibid.).

A number of sites within the sanctuary show signs of intensive alterations in land cover over the last two decades. The greatest change appears to be concentrated at the periphery of the sanctuary, where human pressure is highest. On an average, the changes in the periphery have led to reduced vegetation cover. This is supported by the generally low values of NDVI at the periphery of the sanctuary compared to the interior (Figure 8). As a measure of the extent of disturbance, the mean NDVI decreased with decreasing distance from settlement. Thus, forest sites proximal to human settlements tend to be more open and less dense than

Figure 8
Mean NDVI as a Function of Distance from Settlements in BRT Wildlife Sanctuary ($R^2 = 0.693$, $p < 0.05$)



Note: Slope of the regression line: $y = -1E-08x^2 + 6E-05x + 0.3218$ (2^0 polynomial fit).

sites distant to human settlements. While these differences with distance from settlements cannot be attributed to extraction pressures alone, they do reflect the sum total of the consequence of human use of forests.

CONCLUSIONS

Forest products form an important source of income for millions of people living in and around forests throughout the world. In India alone, about 50 million people depend on NTFP for their basic livelihood (Hegde et al. 1996; NCHSE 1987; Tewari 1998). Besides meeting the livelihoods of the rural poor, in the recent past large-scale commercial extraction driven by national and global market forces has led to enormous pressure on forest products, especially in tropical countries (Mendelsohn and Balick 1995; Nepstad and Schwartzman 1992; Nepstad et al. 1992; Panayotou and Ashton 1992; Runk 1998). This high dependence is, however, not without an ecological cost and has been shown to affect forest structure and dynamics at various levels (Sinha and Bawa 2001). For example, in India, Chalavaraju et al. (2001) and Nageswara Rao et al. (2001) reported a steady decline in the extraction of bamboo and sandalwood over the last few decades, presumably as a consequence of over-extraction of these resources. In southern India, due to human pressures, as many as 154 species of medicinal plants are reported to have become rare, endangered and threatened (Ved et al. 2001). It has been shown that plant communities in general (Murali et al. 1996) and NTFP species in particular (for example, the Indian gooseberry [ibid.] and the Brazil nut [Boot and Gullison

1995; Peres et al. 2003]) that have been subject to continuous harvest lack juveniles. Besides affecting populations of the specific resource extracted, the consequence of forest use could also extend to other levels in the ecological hierarchy such as species, community and ecosystem. An evaluation of the effects at these scales would not only offer an understanding of the impact of forest dependence, but also facilitate the formulation of strategies that could mitigate the consequences. However, despite the extensive dependence on forest resources, there are surprisingly few studies that have addressed the ecological consequences of forest use at all these scales.

The studies reviewed here offer perhaps the most comprehensive documentation of the impacts of human disturbance at scales from genes to the ecosystem at a given site. Admittedly, the ecological consequences, and hence the cost of human use of forests, transcends the specific NTFP that is harvested. For example, besides direct costs such as decline in resource abundance, and changes in the population dynamics and demography of harvested species, human use of forest might have a number of indirect costs such as reduced ecosystem services, a constrained genetic base or loss of ecological knowledge within the local forest-dependent communities. It is clear that if livelihoods are to be maintained or improved, the existing win-lose situations have to be transformed to win-win situations, where resource extraction is not at the cost of undermining the very livelihoods dependent upon the resource. Besides improving our understanding of the consequences, as these studies have done, it is challenging to explore how such studies can lead to a management prescription for NTFP, which maintains livelihoods and minimises the consequences. Uma Shaanker et al. (unpublished) suggest that any effort that can reconcile the conflicts between livelihood gains and ecological costs should be explored, as this might be the only way to ensure the long-term sustenance of livelihoods of the people that are dependent on forest resources, as indeed of the resources themselves. For example, at BRT the conflicts could be minimised by: (a) exploring alternative sources of income generation for the people; (b) enhancing indigenous ecological knowledge of the extractors or collectors; and (c) improving market structures for forest-based commodities.

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