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The montane grasslands of the Western Ghats, India: Community ecology and conservation

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Abstract: The montane (shola) grasslands of Western Ghats, South India are a component of a landscape mosaic including the better-studied shola forests. The conservation of the grasslands depends upon understanding their ecology. This review compiles available information and aims to evaluate the conservation potential of these grasslands. Most studies on these grasslands are descriptive in nature. There is little information regarding habitat heterogeneity, landscape configuration, natural disturbance, grazing and productivity in maintaining the grasslands. Succession is poorly understood because of the short-term nature of most studies. Human activities have historically influenced these grasslands and will continue to do so in more intensive manner. Threats to these grasslands include habitat loss, fragmentation, fires, and invasive species.

Introduction

The montane grasslands and adjacent evergreen tropical forests (locally called the shola grasslands and shola forests) of the Western Ghats form a distinctive vegetation mosaic. The Western Ghats is a mountain range that runs north-south parallel to the western coastline of the Indian peninsula from 8° N to 22° N. This range is classified (based on species distributions) as a distinct biogeographic zone of India (Rodgers and Panwar 1988) and a biodiversity hot-spot along with Sri Lanka (Myers et al. 2000). The montane grasslands and adjacent forests face several threats largely due to increasing anthropogenic activities (Pramod et al. 1997). Once widespread across the high altitudes of Western Ghats, the grasslands are now highly fragmented and restricted to approximately 400 km^2 (Karunakaran et al. 1998). Unlike the adjacent forests (Gadgil and Vartak 1975, Chandran et al. 1998, Brown et al. 2006), the grasslands have not received much attention from biologists and conservationists. However, the presence of an endemic and endangered wild goat, the Nilgiri tahr (*Hemitragus hylocrius* Ogilby), implies the grasslands are in need of study and conservation (Mishra and Johnsingh 1998).

Setting up preserves is an important step towards conservation, which needs to be backed up by research at various levels: the population, the community, and the ecosystem (Soulé and Kohm 1989, Soulé 1991). In this respect, *ad-hoc* preserves and sanctuaries have been established to save the tahr and its habitat. However, research on these grasslands is scanty and highly dispersed. The objective of the present article is to describe the existing literature on the montane grasslands of the Western Ghats, and to evaluate this literature with respect to conservation.

Geography, physical environment and paleohistory

The montane grasslands are located on the high plateau (1500 m) of the Nilgiri, Palni and Anamalai Hills, covering the tops of hills. The valleys of hills contain forests with stunted evergreen trees (Ranganathan 1938, Meher-Homji 1965, Karunakaran et al. 1998). The coexistence of two contrasting vegetation types creates a landscape of interest to ecologists (Ranganathan 1938, Bor 1938, Meher-Homji 1968, Nagendra and Utkarsh 2003).

The climate is often referred to as 'temperate' because of the low mean annual temperatures compared to the surrounding plains. The region is characterized by greater diurnal variation of temperature than seasonal variation

(Ranganathan 1938, Meher-Homji 1965, 1967). The higher precipitation and low average elevation of Western Ghats causes climate to differ from other tropical montane regions. Most of the precipitation is received from the seasonal monsoon winds; particularly, the southwest monsoon between April and September. The precipitation is highly variable across the mountain range, decreasing from west to east, and locally as high as 7000mm. The orographic effect of the mountains causes most of the monsoon rains to fall along the western slopes of the Western Ghats, while the eastern slopes depend on cyclonic storms from the northeast monsoon (Ranganathan 1938). The soil of the grasslands is calcium deficient (Ranganathan 1938) and is derived from parent rocks which are gneiss, charnockites and schists (Meher-Homji 1967, Sukumar et al. 1993).

Paleohistorical accounts of the montane grasslands are few, and scientific generalizations are difficult. In a pollen analysis of a bog in the Nilgiris, the dominant community throughout the quaternary period was grassland with occasional declines and concomitant increase in pteridophytes, the latter indicating moist conditions (Menon 1967). Radiocarbon studies reveal a fluctuating climatic history of the Nilgiris; with arid conditions dominated by C_4 plants around 16000 years ago, an interim wet period dominated by woody C_3 plants at 12kyrBP and the present return of dry conditions (Sukumar et al. 1993). The association between mean annual temperatures and monsoon may have serious implications for the grasslands in the face of global warming (Sukumar et al. 1993). Overall, paleohistorical studies suggest that both grasslands and forests were present prior to human habitation and the vegetation types were largely determined by monsoonal fluctuations. However, human activities since the Paleolithic also influenced the current montane vegetation (Chandran 1997).

Biodiversity and community composition

Early works describe vegetation of these grasslands by the most ubiquitous plant species (Ranganathan 1938, Gupta 1960, Meher-Homji 1965). Botanists have classified the shola grasslands into communities based on dominance of certain grasses (Gupta et al. 1967, Blasco 1970). A study on the ecology of Nilgiri tahr describes the tahr habitat as grassland dominated by *Eulalia phaeothrix* (Hack.) Kuntze and *Dicanthium polyptychum* (Steud.) A. Camus (Rice 1988). More recently, grassland community composition was found to be strongly related to environmental and soil factors, like depth of soil, presence or absence of rocks and boulders, grazed and / or burnt conditions, forest-grassland edges and rocky or non-rocky slopes (Karunakaran et al. 1998, Rawat et al. 2000). Soil type, altitude and precipitation also determined the vegetation composition of montane grasslands in Sri Lanka (Pemadasa and Mueller-Dombois 1979, Pemadasa 1990).

There has not yet been an exhaustive inventory of the plant species of the montane grasslands, although surveys from selected preserves (e.g. Shetty and Vivekanadan 1971) reveal a number of endemic species. However, with high endemism rates associated with the island-like conditions of mountaintops (Karunakaran et al. 1998) the grasslands are undoubtedly a conservation priority.

Dynamics of the shola grasslands and the climax concept

Much of the research on the shola grasslands, and their relation to the forests, has been heavily influenced by Clementsian ideas of mono-climactic succession (Clements 1936). For example, the grassland has been considered a frost-related climactic climax (Meher-Homji 1965, 1967), or as a sub-climax maintained by disturbance (Bor 1938, Noble 1967), or as a dual climax (Ranganathan 1938). Some considered the grasslands and forests to be edaphic climaxes caused by differences in soil moisture (Ranganathan 1938, Gupta 1960), and there are distinct edaphic microclimatic differences between the forests and grasslands (Jose et al. 1994). The debate becomes obscured by a flurry of terms like climatic climax, dual climax, biotic climax, pre-climax and so on.

The cause of the landscape mosaic

There are two completing explanations for the co-occurrence of the two distinctly different physiognomies of the shola grasslands and shola forests, for which there is no clear resolution (Karunakaran et al. 1998): the frost hypothesis (Ranganathan 1938, Meher-Homji 1965, 1967), and fire (Bor 1938, Gupta 1960, Chandrasekharan 1962, Noble 1967). The frost hypothesis is largely supported on biogeographic grounds (see next section): the grassland species are of temperate or subtropical origin while the forest species are of tropical origin. According to the fire hypothesis, the grasslands are the consequence of frequent burnings from pastoral and agricultural activities by the early human settlers (Bor 1938). With no conclusive evidence for the frost hypothesis, the fire hypothesis has gained favor among ecologists and managers (Jose et al. 1996) with annual summer burning being the current management practice. In the only known experimental study investigating the effects of fire (Karunakaran et al. 1998), winter burning was found to check the spread of woody species and also minimize damage to endemics like *Strobilanthus kunthiana* (Nees) T. And. This suggests that fire has been important in maintaining the grasslands.

The existence of a landscape mosaic, whether stable or not, is of general interest to ecologists. Other landscapes, such as the crosstimbers of Oklahoma (Shirakura et al. 2006), Rocky Mountain parklands (Lynch 1998), and some Mediterranean systems (Díaz-Villa et al. 2003), consist of mosaics of forests and grasslands. The vegetation switch concept (Agnew 1997, Walker et al. 2003) predicts that a combination of negative and positive feedback loops can result in abrupt boundaries in vegetation. Thus, grassland-forest mosaics may be ideal test systems for ecological theory.

Biogeography of the shola grasslands and forests

In a phytogeographical study of the forest-grassland biome, Meher-Homji (1965, 1967) found that the shola species show two principal floristic elements: tropical and extra-tropical (or temperate). The species of the shola interiors are mostly from tropical regions like the Western Ghats, Sri Lanka, or Indo-Malayan region, while the woody species along the fringes of the shola and in the adjacent open grasslands have subtropical to temperate origins (Meher-Homji 1967). Frost-induced stress is evoked to explain this distributional pattern. Ground frosts on the open grasslands prevent tropical species from establishing while the few that succeed in establishing are the temperate frost-adapted species (Meher-Homji 1967).

Biogeographic comparisons show that montane grasslands of Western Ghats are more similar to the Western Himalayan region than to the tropical montane grasslands of Sri Lanka (Karunakaran et al. 1998). These results parallel a recent study on the molecular phylogeny of herpetofauna of Western Ghats and Sri Lanka (Bossuyt et al. 2004). All suggest minimal exchange of organisms between the two land masses and imply that they should not be considered a single biogeographic unit (Bossuyt et al. 2004).

Human history and impacts

The first human occupation of the Western Ghats region occurred around 12 000 years ago during the late Paleolithic, and the first signs of agri-pastoralism occurred around 3000 – 5000 years ago (Chandran 1997). The earliest settlers and their origins remain unknown; speculations point towards southward migration of the Harappan people (Chandran 1997). Early works have addressed the ethnobiology of the people of Nilgris and vicinity (Ranganathan 1938, Bor 1938, Noble 1967) with detailed additions by Rajan et al. (2002) and a comprehensive account by Hockings (1989). These studies revealed as many as seven different ethnic groups belonging to the hills of Western Ghats. While almost nothing is known about their origins and early history, each ethnic group is identifiable as an occupational guild with a distinct culture (Hockings 1989, Rajan et al. 2002). Together they make a socio-economic system, like the caste system of the plains, in which groups exchanged goods and services (Hockings 1989).

Some people like the Badagas practiced slash and burn agriculture, while the pastoralist Todas tended buffaloes (*Bubalus bubalis* L.) which grazed these grasslands. Thus, anthropogenic modification has long been important (Bor 1938, Noble 1967, Karanth et al. 2006). Cultural practices and traditions often highlight human-nature interactions, but such information is sparse concerning the grasslands of Western Ghats. Among the few such traditions that ethno-biographical studies document include worship of buffaloes (Hockings 1989, Rajan et al. 2002) and the pastures by the pastoral Todas and the Badaga funeral practice of seeking absolution from a list of sins which are mostly crimes against nature (Hockings 1989).

The British rule abolished slash and burn cultivation and began large scale commercial plantations of cash crops like *Eucalyptus globulus* Labill., *Acacia mearnsii* De Wild and *Camellia sinensis* (L.) Kuntze (Chandran 1997). The towns of Ooty and Kodaikanal were established as a result of the trade and commerce initiated by the British. Thus, the British era saw the human impacts on the mountain system turn more exploitative and environmentally damaging. The monoculture plantations are now owned by Indian business houses and continue to have detrimental effects on the ecosystem (Gadgil and Guha 1995, Pramod et al. 1997). Overall, the human history on the Western Ghats is long, with a trend of increasing human activity and consequent environmental harm.

Karunakaran et al. (1998) studied the effects of black wattle (*Acacia mearnsii*) plantations on the montane grasslands and found that older plantations within the grasslands contained fewer endemic species and more weedy species compared to more recent plantations. Studies on *Eucalyptus globulus* have shown that they lower water table in the vicinity by absorbing large quantities of subsoil moisture (Samra et al. 2001, Dharmalingam 2004). Besides these, there are not many studies that specifically address the effects of plantations on the montane grasslands of Western Ghats.

Present status and conservation

The increase in the intensity of land use, as described above, has resulted in several threats to the biodiversity of Western Ghats (Pramod et al. 1997). For example, Ooty and Kodaikanal have been transformed into summer holiday resorts with an unconstrained and booming tourism industry (Dharmalingam 2004), and the frequency of economically damaging forest fires has increased threefold (Karunakaran et al.1998, Rawat et al. 2000, Kodandapani et al. 2004). Further, in post-globalization times there appears to be a strong influence of global market dynamics on local resource consumption patterns. The impact on local resource utilization like pastoral dung manure production is heavily influenced by adjacent coffee plantations and fluctuations in global coffee prices (Madhusudhan 2005).

Invasive species

Invasive alien species are also recognized as a serious threat to this high altitude ecosystem. Some, like *Acacia mearnsii* and *Eucalyptus globulus* are the consequence of commercial plantation and afforestation drives (Dharmalingam 2004). Other invasives include *Lantana camara* L. and *Ageratina adenophora* (Spreng.) King & H. E. Robins; the reasons for their introduction are not known (Munniappan and Viraktamath 1993)) although *Lantana* is commonly planted as an ornamental.. It needs to be stressed that most information on invasive species pertains to the mountain system as a whole and there is hardly any published information this topic related to the montane grasslands.

Threatened species

As many as 30 grassland species have been categorized as endangered in the Eravikulam National Park (Karunakaran et al. 1998). Another study on the hills of Palani found 70 rare or threatened species (Mathew 1999). However, autecological studies of any of these species are not known. Among the 30 species identified at Eravikulam National Park, Poaceae and Orchidaceae together comprise the majority; primary reasons for their endangered status are habitat loss and overexploitation by orchid collectors (Karunakaran et al. 1998).

Climate change

Another area of concern is the potential impact of global warming. Sukumar et al. (1995) predict that increase in mean annual temperatures would favor C_3 plants because increased CO_2 levels enhance the photosynthetic rates in C_3 plants and higher temperatures reduce ground frost enabling the C_3 forest plants to colonize grasslands. Given that the role of frosts in maintaining the forest-grassland mosaic is in dispute, this prediction is speculative.

Conservation of the Nilgiri tahr

The Nilgiri tahr demands special mention because the shola grasslands are both known through them and have gained conservation priority because of them. The Nilgiri tahr is one of the most well studied species of the grasslands (Schaller 1970, Rice 1988, Mishra and Johnsingh 1998) and was once widespread through most of shola-grasslands of the Nilgiri plateau. However, today they are reduced to few scattered populations through most of its former range (Mishra and Johnsingh 1998, Madhusudhan and Johnsingh 1998). Tahr populations severely declined in unprotected areas from 450 to 175 between 1978 and 1988 (Mishra and Johnsingh 1998). However, in protected areas like Eravikulam National Park, the tahr populations showed the opposite trend with an increase in numbers from approximately 500 to almost 800 in the same period (Mishra and Johnsingh 1998). Habitat loss, increase in poaching and other anthropogenic disturbances resulting from spread of human settlements are the main factors behind their dwindling numbers outside of protected areas (Rice 1988, Mishra and Johnsingh 1998). While the role played by Nilgiri tahr as a flagship species has benefited the conservation efforts, their ecological role within the grassland community is unstudied. Research needs to address the effects of grazing by Nilgiri tahr on the grassland community composition and structure.

Conclusions

Most research on the montane grasslands of the Western Ghats has been static in time and descriptive in nature. Even so, there is recognition that more rigorous surveys are needed (Urfi et al. 2005). Inventories are important for informed decision making, but more research is needed on function and dynamics. From the perspective of a multi-species community, they allow better understanding of species interactions and coexistence, and ultimately, conservation. The static description of plant communities based on dominant species has prevailed in India; this needs to be replaced by a more dynamic and quantitative approach, which views communities as mutable through space and time (Palmer and White 1994a).

Even improved static data can help us understand important processes. For example, investigating species-area relationship could reveal the role of habitat diversity or the island like conditions of mountain tops in maintaining species diversity (Kohn and Walsh 1994). Also, species-area relationships can be useful in determining reserve area and design (Gitay et al. 1991) and in estimating extinctions following habitat loss (Pimm et al. 1995). Future descriptive studies also need to integrate the role of scale, as most patterns are strongly scale-dependent (Levin 1992, Palmer and White 1994b). For example, the relative species richness of Rocky Mountain grasslands in grazed vs. ungrazed conditions depends on the scale of observation (Stohlgren et al. 1999).

Long-term studies are necessary to understand succession, and in their absence much of the current knowledge concerning succession of the Western Ghats remains speculative. Although disturbances like frost, cattle grazing and fire are prevalent in the montane grasslands, there are few studies that examine their impact. The dynamic view of grasslands adopted by ecologists (White 1979, Niering 1987, Collins 2000, Ghermandi et al. 2004) is lacking in studies of shola grasslands. However, there is research on the successional dynamics of grasslands in lower elevations of the Western Ghats (Puyravaud et al. 2003).

Worldwide, much is known about the dynamics of grassland in relation to disturbance. Grasslands are often dependent on disturbances for preventing invasion by shrubby species (Pickett et al. 1987, Collins 2000). Disturbances are an important source of spatial variability, which may be essential for coexistence among species in a community (Pickett 1980, Sousa 1984). Not surprisingly, knowledge of local disturbance regimes is a constant subject of research and application in grassland conservation, e.g., fire in tallgrass prairie (Collins 2000), gophers in serpentine grasslands (Hobbs and Mooney 1995) and grazing in prairie and Serengeti grasslands (McNaughton 1985, Knapp et al. 1999). Herbivores often play keystone roles in grassland dynamics (Hobbs and Mooney 1985, Olff and Ritchie 1998, Knapp et al. 1999). We suspect that the Nilgiri tahr and fire play critical 'keystone' roles in the shola grasslands, and comparisons with other grassland systems will lead to a better understanding of their dynamics. While deep comparisons will be valuable, they must be honed by local natural history expertise and a sense of realism.

Despite a long history of human presence, studies evaluating the effects of changes in anthropogenic influence mediated through changing socio-economic conditions and cultural values are almost absent except for Madhusudhan (2005). As previously discussed, a wide variety of potential conservation threats have been identified: invasive species, forest fires, fragmentation, habitat loss and climate change. A thorough understanding of the root causes of these threats, and their ecological effects, would greatly aid conservation efforts.

Conservation should be based on scientific principles (Soulé and Kohm 1989), and knowledge gaps about the ecology of Western Ghats need to be filled. An important part of conservation is preservation: identifying endangered species, communities or ecosystems followed by the creation of a preserve or sanctuary summarizes the conservation approach in India. This has led to the creation of as many as 578 protected areas (national parks and sanctuaries) accounting for 4.7% of total land area and plans are drawn to increase the reserve numbers to 870 with an eventual cover of 5.74% (Rodgers et al. 2002). It is implicit from these numbers that an increasing number of preserves will be small and discontinuous fragments of much larger landscape. Therefore, the creation of preserves is necessary but insufficient for conservation in India (Saberwal 1996, Mishra and Rawat 1998) and scientific principles need to guide conservation (Soulé and Kohm 1989). This strengthens the need for goal-oriented management of these small pockets of wilderness and such management depends heavily on the ecological knowledge of the species, communities or ecosystems they contain. While generalizations based on grasslands elsewhere will be useful in guiding conservation efforts, this must be coupled with more intensive, local research efforts, to ascertain the validity of the generalizations.

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