Oryx Vol 35 No 4 October 2001

Short Communication

The biodiversity of Madagascar: one of the world's hottest hotspots on its way out

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Abstract Madagascar is renowned not only for its high biodiversity and high degree of endemism, but also for ongoing loss of the original primary vegetation. Here we draw attention to the critical degree of vulnerability of Madagascar's littoral forest, western dry deciduous forest, and evergreen forests of the high plateau. Conservation efforts in these forest formations have been low compared to those in the evergreen rainforest of eastern Madagascar. Due to their fragmented nature these ecosystems urgently require reinforced conservation programmes.

Keywords Conservation, dry deciduous forest, littoral forest, Madagascar.

Biodiversity hotspots are defined as areas with exceptional species richness and concentrations of endemic species, and the loss of >70 per cent of the original primary vegetation (Myers *et al.*, 2000). Madagascar is one of eight 'hottest' biodiversity hotspots based on richness and endemism of plants (*c.* 12,000 spp. of vascular plants, >90 per cent endemic, Schatz, 2000) and vertebrates (>700 spp. with *c.* 50 per cent endemism in birds and >98 per cent in amphibians, reptiles and mammals, Langrand & Wilmé, 1997), and on habitat loss (estimated at >90 per cent, although no reliable up-to-date map is available, Lowry *et al.*, 1997). Madagascar also stands out because of its endemism at higher taxonomic levels (genera and families) among plants and vertebrates (Myers *et al.*, 2000).

The recognition of Madagascar's conservation importance coupled with the recent discovery of many new taxa has renewed interest in this island (Lourenço & Goodman, 2000). Despite major conservation efforts, at least three unique ecosystems are now so fragmented and degraded that many native large animal species have been lost, and the remainder are unlikely to maintain viable populations beyond 2020–2040. These ecosystems are eastern littoral forest on sand, western dry deciduous forest, and woody formations that once covered much of the centre of the island. The first two were classified as top priorities for conservation at a 1995 workshop defining national research and biodiversity conservation needs (Ganzhorn *et al.*, 1997). Subsequently, several sites of dry deciduous forest were declared or upgraded to national parks but the other two ecosystems remain neglected (Ramarokoto *et al.*, 1999), and awareness of the need for protection remains poor. A possible explanation could be that public opinion has largely focused on 'tropical rainforest' – i.e. evergreen humid forests – whilst ignoring other forest types (Janzen, 1988; Lerdau *et al.*, 1991).

Deforestation in eastern Madagascar has been most rapid in areas with low topographic relief (Green & Sussman, 1990). The eastern littoral forests (at sites near sea level on sand within Madagascar's humid bioclimatic region) are among the country's most highly threatened and impacted formations, and are condemned to extinction unless immediate steps are taken (Schatz, 2000; Schatz *et al.*, 2000). Very little undisturbed eastern littoral forest remains. Du Puy & Moat's (1996) map of remaining primary vegetation shows only 11 patches, with a total area not exceeding *c.* 450 sq km. If one assumes conservatively that littoral forest once occupied a coastal strip averaging 3 km wide along the 1500 km from Vohemar to Fort Dauphin (i.e. 4500 sq km, or 0.77 per cent of the total land area), then at most 10 per cent of the original forest remains. However, this is almost certainly an overestimate: littoral forest often extended over 5 km inland, and the remaining cover mapped by Du Puy & Moat (1996) was based on data from the 1970s. Recent information indicates that an additional 35 variously degraded littoral forest stands exist, or at least existed in the recent past (Ratsirarson & Goodman, 1998; Missouri Botanical Garden, unpublished data). This might bring the number of patches to 46, of which only three are

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Revised manuscript accepted for publication 19 June 2001

situated within protected areas and about 20 occur as small, more or less degraded, classified forests with little protection (cf. MIR Télédétection, 1998; Rabevohitra *et al.*, 1998; Dumetz, 1999), a problem acknowledged by the Malagasy government (COEFOR, 1993).

Dry deciduous forests are among the most threatened biomes of the world (Janzen, 1988; Lerdau *et al.*, 1991). Within Madagascar they once covered a much larger area than eastern littoral forests, but have suffered from clear-cutting at a faster rate (Whitmore, 2000). A recent estimate indicates that by 1990 deciduous forest cover had been reduced to approximately 3 per cent of its original extent, with few fragments larger than 800 ha (Smith, 1997). Two of the largest blocks (Ankarafantsika and the forests of the Menabe) were recently reduced substantially by fires, illegal logging and deforestation for agriculture (S. Sommer, A. Toto Volahy, U.S. Seal, unpublished data).

Woody formations on Madagascar's high plateau have almost completely disappeared (Gade, 1996; Rakotondravony & Goodman, 1998; Ratsirarson & Goodman, 2000). With the exception of a few areas, only tiny remnants (rarely exceeding a few sq km) have escaped destruction.

It is unlikely that any of these ecosystems will maintain their present levels of biodiversity over time. It is already too late for the formations that once covered much of central Madagascar, and the remaining littoral forest patches face a similar fate in the next decade. The situation in deciduous forests is not as critical, but the recent high rate of deforestation and fragmentation is a matter of serious concern. Empirical data on lemurs from forests that were fragmented 20–40 years ago indicate that populations of fewer than 40 adults were unable to survive (Ganzhorn *et al.*, 2000). None of the remaining patches of littoral forest are large enough to maintain viable populations of the larger lemurs (approximately 800–1000 ha would be required for *Propithecus* or *Indri*) and only a few deciduous forests will be able to sustain populations of all the lemurs characteristic of this vegetation type. Few if any of the remaining forest areas in central Madagascar are sufficient to support the larger extant lemurs, as illustrated by the demise of *Propithecus verreauxi coronatus* from the largest fragment of Ambohitantely Reserve between 1960 and 1985 (Petter & Andriatsarafara, 1987). When *P. vereauxi coronatus* was still present in the 1960s the fragment measured about 2000 ha, but was reduced to approximately 1250 ha by 1991 (Ratsirarson & Goodman, 2000).

Even in the larger forest stands (>10,000 ha), where fragmentation and edge effects are not yet obvious, many species can no longer tolerate increasing human impacts. One flagship species is the Malagasy giant jumping rat *Hypogeomys antimena*, an endemic rodent restricted to less than 800 sq km of primary deciduous forest. Within a 100-ha study area at Kirindy (44°49'E, 20°27'S), which is part of a forest block of 10,000 ha, the population of this species collapsed during the last decade from about 58 adults in 1995 to 33 individuals in 1997 and 22 in 2000. The same phenomenon has occurred throughout its remaining range (Goodman & Rakotondravony, 1996). This decline is probably a result of the indirect effects of logging and hunting of other species, and the presence of dogs that hunt the jumping rats (Rakotombololona, 1999; Sommer & Hommen, 2000).

Many of Madagascar's ecosystems have been reduced in size and degraded beyond the point of recovery and will suffer further losses of biodiversity, but there may still be time to slow the trend. Success will depend on whether conservation and development agencies, the research community, and Madagascar's political and administrative establishment will look beyond the study and conservation of isolated 'pristine' areas, and focus instead on truly effective protection of remaining natural habitats embedded in a cultural landscape (Kremen *et al.*, 1999).

Acknowledgements

Our studies have been conducted with the support of the 'Commission Tripartite' of the Malagasy Government, the Département de Biologie Animale and the Département de Paléontologie et Biologie Evolutive de l'Université d'Antananarivo, the Ministère des Eaux et Forêts, the Centre de Formation Professionnelle Forestière de Morondava, the Parc Botanique et Zoologique de Tsimbazaza, the Association Nationale pour le Gestion des Aires Protégées, Conservation International, WWF International, WWF Madagascar, QIT Madagascar Minerals, and the German Research Foundation. We are grateful to O. Langrand and an anonymous reviewer for thoughtful comments on the manuscript.

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https://doi.org/10.1046/j.1365-3008.2001.00201.x Published online by Cambridge University Press