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Conservation status of the littoral forest of south-eastern Madagascar: a review

An Bollen and Giuseppe Donati

Abstract The littoral forest of the Fort Dauphin region of south-east Madagascar is expected to lose numerous endemic plant and animal species in the near future as a result of deforestation and consequent habitat changes. The disruption of plant-animal interactions is of particular concern. This review describes the conservation status of the littoral forest of Sainte Luce, Fort Dauphin, and examines the role of animal-facilitated seed dispersal in regeneration. The main threats to this habitat are described and possible management implications are discussed in relation to existing initiatives. Protection of the largest remaining forest fragments has been agreed by local communities and a draft plan for forest management is currently under evaluation. Over the next few years plantations will be created to provide local people with wood for fuel and other purposes. An important flying fox *Pteropus rufus* roost site needs to be included in conservation plans because of its importance for long-distance seed dispersal. Despite the presence of natural barriers, the creation of forest corridors will be crucial for connecting isolated fragments and facilitating genetic exchange between subpopulations. Increased attention needs to be given to the need to promote conservation-related income activities.

Keywords Fort Dauphin, fragmentation, littoral forest, Madagascar, *Pteropus rufus*, Sainte Luce, seed dispersal.

Introduction

Madagascar is considered an important global conservation priority because of the high endemicity of its fauna and flora (Mittermeier *et al*., 1998; Dumetz, 1999) and the severe threats to the island's environment. Over 80% of the island has already been stripped of its native vegetation cover (Dupuy & Moat, 1998). At current deforestation rates it is estimated that in 2025 forest will only remain on the steepest slopes and in remote areas and nature reserves (Green & Sussman, 1990).

The littoral forest on sandy soils in the Fort Dauphin region is one of the most threatened Malagasy ecosystems, with <2,835 ha remaining (QMM, 2001). This forest type has been severely degraded and consists of many fragments, ranging in size from 1 to 377 ha. In the Fort Dauphin (Taolagnaro) area the remaining littoral forests on sandy soils form three groups of fragments, Petriky, Mandena and Sainte Luce (Fig. 1). Even though the floristic composition of the forest in Sainte Luce and Mandena is similar, that of Sainte Luce has the highest species diversity and is one of the most intact littoral forests remaining in Madagascar (Rabevohitra *et al*., 1996; Dumetz, 1999). In a 377 ha forest fragment at Sainte Luce 98% of the 189 plant species are endemic to Madagascar (Rabevohitra *et al*., 1996; Razafimizanilala, 1996). At least 40 plant species are endemic to the littoral forest of the Fort Dauphin region (Lowry, 2001).

Here we review the conservation status of the littoral forest of Sainte Luce. The review is based on research carried out from September 1999 to February 2001 (Donati, 2002; Bollen, 2003), published information, personal communications from other field scientists, and our own personal observations. We focus on the causes of habitat loss and forest fragmentation, and highlight the importance of seed dispersal for landscape restoration. We also discuss ongoing conservation efforts in this region.

Major threats

Three villages, Ambandrika, Ampanasatomboky and Manafiafy are close to the largest forest fragments of Sainte Luce; S6 (147 ha), S7 (198 ha), S8 (129 ha), S9 (377 ha) and S17 (237 ha) (Fig. 2). Approximately 700 villagers depend on the forest for crop growing, timber and non-timber forest products for both subsistence and commercial activities. The main cause of forest loss in Sainte Luce, as elsewhere in Madagascar, is the practice

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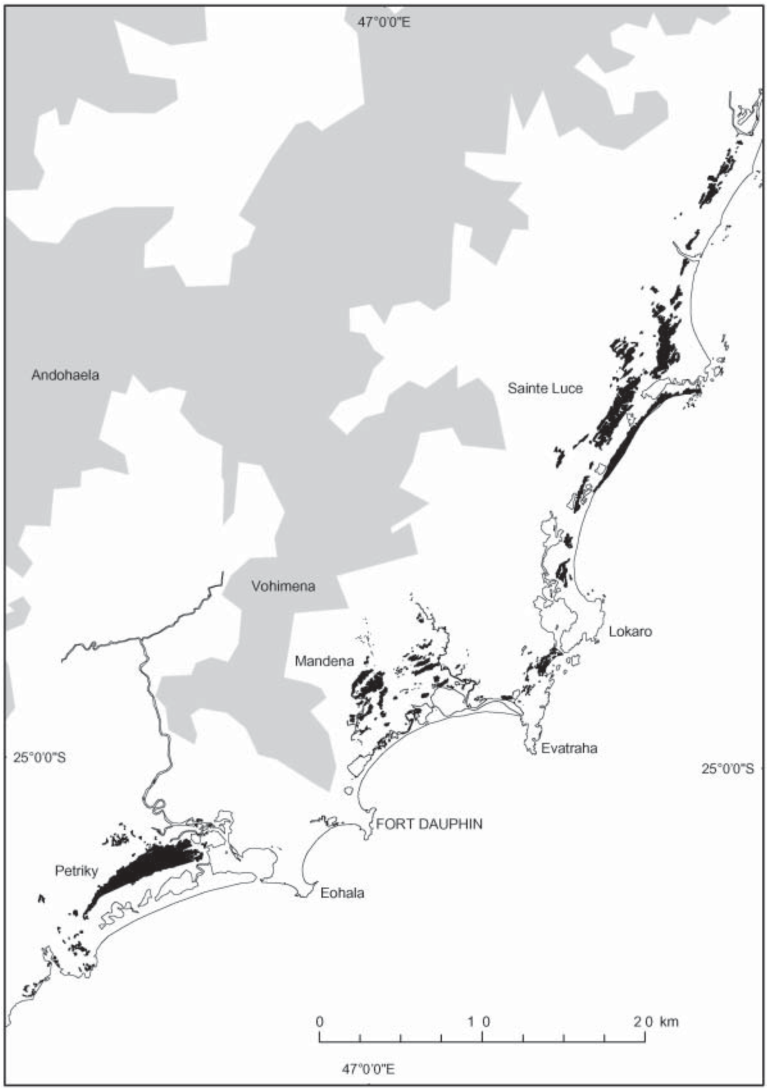

Fig. 1 The Fort Dauphin region of south-east Madagascar. The remaining littoral forests are indicated in black, and the humid montane rainforest in grey.

of *tavy* (shifting slash-and-burn cultivation), which is often accompanied by bushfires. These bushfires are frequently uncontrolled, resulting in further deforestation. *Tavy* contributes directly to habitat loss, edge effects and soil sterilization. After clearance, grasslands develop in early successional stages and are later replaced by fire-resistant shrublands dominated by invasive heath shrubs *Erica* spp. (Lewis Environmental Consultants, 1992).

Logging is another threat. People cut mainly large, mature trees for fuelwood, construction and tools. Because of the limited size of the forest fragments and the characteristic slow growth of most tropical tree species the current level of logging in the area appears to be unsustainable. Moreover, only parts of the felled trees are taken out of the forest, resulting in a wasteful use of resources (A. Bollen & G. Donati, pers. obs.). Selective removal of timber and fuelwood has already changed the distribution pattern of some tree species (G. Donati, unpubl. data). Discussions with local people and observations of many trucks loaded with tree trunks lead us to the conclusion that some tree species, such as *Cinnamosma madagascariensis*, are already rare because of selective logging (G. Donati, pers. obs.). At the beginning of our research period logging only occurred for subsistence and on a local scale, but in December 2000 logging intensified and became more commercialized, apparently related to the growing need for wood in Fort Dauphin and the depletion of the forests closer to the city. The only wood people are legally allowed to take out of the littoral forest and without a permit is dead wood. However, people have been inventive in interpreting this law. They cut several trees in the forest, leave the logs there for a month, and afterwards collect this dead wood (G. Donati & A. Bollen, pers. obs.). The villagers take several other products out of the forest. Large palms (*Dypsis prestoniana* and *Dypsis saintelucei*) are cut at the

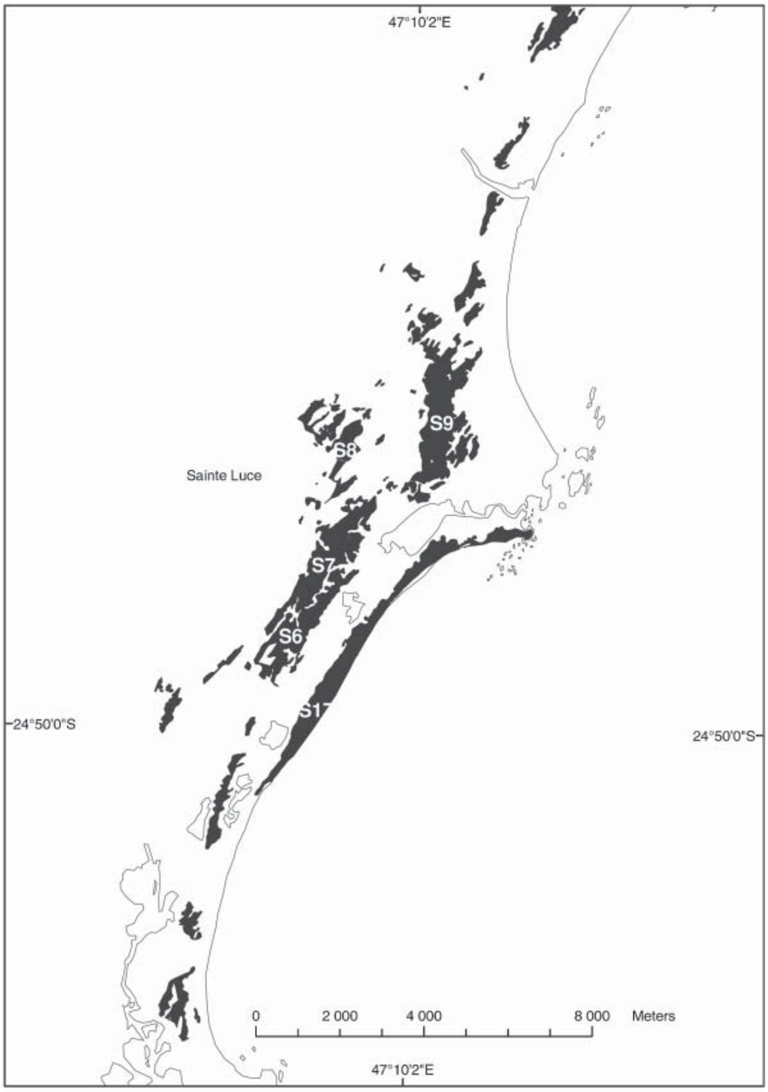

Fig. 2 The largest forest fragments (S6, S7, S8, S9, S17) of the littoral forest of St Luce (see Fig. 1 for location), indicated in black.

base to collect the fibres from their leaves, from which traps for crabs and lobster are made, but the logs are often left behind unused. Canoes are dug out of the largest trees, such as *ramy Canarium boivinii* and *vitano* (*Calophyllum* sp.; Table 1) and various species of vine are used for fishing gear.

Hunting also has its impact on forest dynamics, but in contrast to sites further inland (Andohaela, Vohimena; Randriamanalina *et al.*, 2000) the impact of hunting in Sainte Luce is limited because of the importance of fish and shellfish in the local diet and as a major source of income. Bushmeat is only eaten on rare occasions and during traditional events. Nocturnal lemurs, such as *Cheirogaleus major*, *Cheirogaleus medius* and the tiny *Microcebus rufus*, which hibernate in hollow tree trunks, are easily caught. The endemic *Eulemur fulvus collaris*, which occurs only in south-east Madagascar (Mittermeier *et al.*, 1994) and is categorized as Vulnerable on the IUCN Red List (IUCN, 2004), is hunted by a traditional technique called *tandroho* (Randriamanalina *et al.*, 2000) in which a strip of forest (50 m^2) is cleared so that gaps in the canopy are too large for the lemurs to cross. Long logs are then placed between both ends of the canopy as the only crossover point, and two snares are set in the middle. This hunting technique could be responsible for an unbalanced sex-ratio in favour of males, reported in fragment S9 (G. Donati, unpubl. data), as in this species females often initiate the travelling. *E. f. collaris* is also captured by the use of slings, a practice particularly favoured by young men, and probably responsible for the shyness of these lemurs at this site.

Discussion with several local residents suggested that hunting pressure on *E. f. collaris* declined drastically in S9 because of the presence of researchers (G. Donati, pers. obs.). In the nearby fragment S17 traps were, however, still encountered in September 2000. The endemic

Table 1 Plant species from Sainte Luce (Fig. 2), by family, with their vernacular names, status, any known uses, number of frugivorous species that feed on them, and whether used as food by local people.

Family	Species	Vernacular name	Status[1]	Use[2]	Frugivores[3]	Food[4]
Anacardiaceae	*Poupartia chapelieri*	sisikandrongo	A	C	7	
	Protorhus cf. *lecomtei*	kangy			LS	
Anonaceae	*Monanthotaxus* cf. *malacophylla*	vahimbotany	C			
	Polyalthia madagascariensis	fotsivavo			8	
	Polyalthia capuronii	menapeka			LS	
Apocynaceae	*Cabucala madagascariensis*	tandrokosy				Fruit
Araceae	*Typhonodorum lendleyanum*	via				Root
Araliaceae	*Schefflera rainaliana*	voatsilana sp. 1		F,M		
	Polyscias sp.	voatsilana sp. 2			7	
Arecaceae	*Dypsis fibrosa*	boakandambo	L		LS	
	Dypsis nodifera	raotry	L			
	Dypsis prestoniana	boakabe	L		9,key?	
	Dypsis saintelucei	telopolombilany	L			
	Dypsis scottiana	raosy amboza	L		6	
Bignoniaceae	*Ophiocolea delphinensis*	akondronala	C,E	U		Fruit
	Phyllarthron madagascariense	zahambe	E	C		
	Phyllarthron sp.	zahambe manongaroa	E	C		
Burseraceae	*Canarium boivinii*	ramy		C,M	LS	
Canellaceae	*Cinnamosna madagascariensis*	vahabatra sp. 2			LS	
Capparaceae	*Crataeva obovata*	belataka	C		LS	
Clusiaceae	*Psorospermum revolutum*	harongampanihy		F,M		Fruit
	Calophyllum sp.	vitano		C		
	Garcinia chapelieri	haziny tomate			LS	
	Garcinia cf./aff. *madagascariensis*	disaky kely			LS	
Combretaceae	*Terminalia fatraea*	katrafa		C		
Dichapetalaceae	*Dichapetalum* sp.	vahihazo			LS	
Ebenaceae	*Diospyros gracilipes*	hazomainty blanc		F	LS	
	Diospyros sp.	hazomainy	L	F	LS	
Elaeocarpaceae	*Elaeocarpus alnifolius*	sanga			LS	
Ericaceae	*Vaccinium emirnense*	tsilantria		C,F	9	Fruit
Erythroxylaceae	*Erythroxylum braxifolium*	fangora sp. 1		F		
	Erythroxylum nitidilum	fangora sp. 2		F		
Euphorbiaceae	*Uapaca ferruginea*	voapaky lahy sp. 1		C,F	6	
	Uapaca littoralis	voapaky vavy		C,F	9	
	Uapaca thouarsii	voapaky lahy sp. 2	L	C,F		
Fabaceae	*Cynometra* cf. *cloiselii*	mampay	A	C		
	Phylloxylon xylophylloides	sotro	E	C		
	Intsia bijuga	harandrato		C		
Flacourtiaceae	*Aphloia theiformes*	fandramana	C			
	Bembicia uniflora	bemalemy	A	C,F		
	Homalium louvelianum	ramirisa		C,F		
	Scolopia orientalis	zoramena	C	F	7	
Hypocrataceae	*Salacia madagascariensis*	voatsimatra	C		LS	Fruit
Icacinaceae	*Apodytes dimidiata*	hazomamy marecage	E		9	
	Apodytes sp. nov.	hazomamy an ala	E	U	LS	
Lauraceae	*Cryptocarya* sp.	tavolohazo		U		
	Ravensara acuminata			M		
Liliaceae	*Dracaena reflexa* var. *nervosa*	falinandro	C,L	F,M		
	Dracaena reflexa var. *nervosa*	tavolobotroka	C,L	F,M		
Loganiaceae	*Anthocleista longifolia*	lendemilahy	C	C		
Loranthaceae	*Bakerella* sp.	velomihanto			6	
Melastomataceae	*Tristemma mauritianum*	voatrotoky				Fruit
Meliaceae	*Malleastrum mandenense*	sarigoavy	C,E			
Monimiaceae	*Tambourissa castri-delphinii*	amborabe		C,F,M		
	Tambourissa purpurea	ambora		C,F,M	7	
Moraceae	*Ficus guatteriaefolia*	fihamy		M		
	Ficus pyrifolia	nonoka			7	
Myricaceae	*Myrica spatulata*	tsilaka		M		

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Table 1 (*continued*)

Family	Species	Vernacular name	Status[1]	Use[2]	Frugivores[3]	Food[4]
Myristicaceae	*Brochoneura acumineata*	mafotra sp. 1	C	C,M	LS	
	Brochoneura madagascariensis	mafotra sp. 2	C	C,M	LS	
Myrsinaceae	*Embelia incumbens*	taratasy		M		
Myrtaceae	*Eugenia cloiselii*	ropasy sp. 1	C,E	C,F,M		
	Eugenia sp.	ropasy sp. 2		C,F,M	LS	
	Syzigium sp. 1	rotry ala		C	7	Fruit
	Syzigium sp. 2	rotry mena		C	10,key?	Fruit
Oleaceae	*Jasmimum kitchingii*	vahifotsy kely	C			
	Noronhia cf *lanceolata*	hazondraotry		M		
	Noronhia sp. 1	belavenoka		M		
	Olea sp.	vahabatra sp. 1	A	M	7	
Pandanaceae	*Pandanus dauphinensis*	vakoanala	A	C	LS	
	Pandanus aff. *longistylus*	fandranabo		C	LS	
	Pandanus rollotii	fandranabotonboky		C	LS	
Podocarpaceae	*Podocarpus madagascariensis*	harambilo		C,F,M		
Rhopalocarpaceae	*Rhopalocarpus coriaceus*	tsilavimbinanto			LS	
Rubiaceae	*Canthium* sp.	fantsikaitra sp. 1		C,F,M		
	Canthium variistipule	fantsikaitramainty	C	C,F,M	6	Fruit
	Ixora sp.	unknown	C	U		
	Plectronia densiflora	fantsikaitra sp. 2		M		
	Psychotria sp.	tanatananala		F		
	Hyperacanthus mandenensis	taholagna		U		Fruit
	Tricalysia cf. *cryptocalyx*	hazongalala		F		
Rutaceae	*Vepris eliotii*	lahinampoly	C,E	C,F,M	6	
Sapindaceae	*Macphersonia radlkoferi*	sanirambaza		U		
	Plagioscyphus jumelei	ambirimarika pionair		U		
Sarcolaenaceae	*Leptolaena multiflora*	fotombavy	C	C,F		
	Sarcolaena multiflora	meramaintso	C,L	C,F	9	Fruit
	Schizolaena elongata	fotondahy		C		
Saxifragaceae	*Brexia* sp.	kambatrikambatri	C			
Sphaerosepalaceae	*Rhopalocarpus coriaceus*	tsilavimbinanto	C	U		
Strelitziaceae	*Ravenala madagascariensis*	ravenala		C,M		
Taccaceae	*Tacca leontopetaloides*	tavolo				Root
Theaceae	*Asteropeia multiflora*	fanolafotsy		C,F,M		
Verbenaceae	*Vitex chrysomallium*	nofotrako	L	C		

[1]A, abundant; C, common; E, endemic; L, typical littoral forest species. Data from Koechlin (1974), Lewis Environmental Consultants (1992a), Rabevohitra *et al*.(1996), Razafimizanilala (1996), Dumetz (1999) and QMM (2001)
[2]C, construction wood; F, fuelwood; M, medicinal use; U, unknown use
[3]Number of plant species consumed by frugivores; LS, large-seeded plant species for which *Eulemur fulvus collaris* is the only seed disperser; key?, potential keystone species during periods of fruit scarcity.
[4]Food species for people, with indication of plant part eaten

Malagasy flying fox *Pteropus rufus*, categorized as Vulnerable on the IUCN Red List (IUCN, 2004), is hunted at the colony's roost site (S6; Fig. 2). Slings, long branches and stones were often found under their roost site and as a consequence of this hunting pressure the colony moved their roost site twice in 2000 (Bollen & Van Elsacker, 2002). Terrestrial birds are trapped using snares or other simple systems placed on the ground. Fruit pigeons (*Treron australis* and *Alectroenas madagascariensis*), parrots (*Coracopsis vasa* and *Coracopsis nigra*) and bulbuls *Hypsipetes madagascariensis* are hunted with arrows or slings. Small branches covered with sticky latex, placed in *Ficus* or other fruiting trees by young men, are also used to catch fruit pigeons. Tenrecs (*Setifer setosus* and *Tenrec ecaudatus*) are hunted with the aid of dogs at dusk. Hunting is mainly for food but occasionally animals are traded regionally for pets, in particular *E. f. collaris* and *Coracopsis* spp. (A. Bollen, pers. obs.).

The future extraction of ilmenite by QIT Madagascar Minerals (QMM) is an imminent threat. The littoral forests of Sainte Luce, Mandena and Petriky lie within the QMM concession zone. Mining activities will start in 2009 in Mandena and 20–45 years later in Petriky and Sainte Luce, respectively, lasting up to 60 years (M. Vincelette, pers. comm.). In Mandena, Sainte Luce and Petriky 62.8, 661.8 and 705.8 ha, respectively, of the remaining littoral forest will be lost (QMM, unpubl. data). However this impact is partially mitigated by a

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large investment in environmental impact assessment studies, instalment of tree nurseries and plantations, establishment of seed banks, and extensive research into reforestation. QMM also cooperates with the Department of Water and Forestry, Ministry of Environment and local communities to ensure the establishment of conservation zones in the mining area.

Impacts on the ecosystem and on seed dispersers

Plant-frugivore interactions are important components of complex forest communities, and seed dispersal by vertebrates is a key process in vegetation dynamics and recovery (Wallace & Painter, 2002). Frugivores play a vital role in the maintenance of biodiversity in tropical forests, where they constitute a large proportion of the vertebrate biomass (Fleming *et al.*, 1987), and zoochorous tree species make up the bulk of tropical plant species (Howe & Smallwood, 1982). Loss of fruit-frugivore interactions can thus have profound consequences (Corlett, 1998). Many animal species in Sainte Luce rely on fruit as an essential food resource and also provide valuable dispersal services to many fruit-bearing plants (Bollen *et al.*, 2004a; Table 1). As Malagasy forests become more fragmented the remaining patches become increasingly isolated and inaccessible to arboreal lemur species (Ganzhorn *et al.*, 2001). As a consequence gene flow and seed dispersal between patches may become critical for long-term survival of many plant species.

Large frugivores are often the most vulnerable to habitat fragmentation (Johns & Skorupa, 1987; Kannan & James, 1999) and this is the case for *E. f. collaris* in Sainte Luce, where the species is only present in the largest fragments, S9 (377 ha) and S17 (237 ha). *E. f. collaris* is also particularly important for dispersal of the seeds of numerous plant species (Bollen *et al.*, 2004a). We found this to be the only frugivore in these forests able to swallow and thus disperse large seeds (up to 16.5 mm diameter; Ganzhorn *et al.*, 1999; Bollen *et al.*, 2004a; Table 1). Local extirpation of *E. f. collaris* could lead to the eventual loss of those plant species that are dependent on it for seed dispersal. Other specialist frugivores, such as *P. rufus, T. australis* and *A. madagascariensis* are vulnerable as well, in particular when important food sources are logged (Table 1). Frugivorous birds and flying foxes are the most important mobile seed dispersers at Sainte Luce, transporting seeds of numerous species into grasslands and early successional vegetation. The simple structure of these communities poses less of a barrier to birds and bats than to arboreal lemurs.

Our studies (Bollen 2003; Bollen *et al.*, 2004a, 2004b) found no evidence for coevolution, nor any strong indication of the existence of dispersal syndromes at Sainte Luce. A syndrome (Van der Pijl, 1969) is a set of morphological and nutritional traits that determine bird, bat and mammal dispersed fruits. However, we found that there is substantial dietary overlap among frugivore species (Bollen, 2003). Most frugivores seem to be opportunistic in fruit selection, eating whatever is available given the limitation of fruit and seed size and certain feeding preferences (Bollen *et al.*, 2004a, 2004b).

Protection measures

Forest

Sainte Luce contains some of the most intact littoral forest fragments on sand, which differ in floristic diversity from sublittoral forest fragments on laterite, such as S8 (Fig. 2), and from the inland montane forest of Vohimena (Rabevohitra *et al.*, 1996; Dumetz, 1999). Several studies in Madagascar have demonstrated that protection of a few large fragments as opposed to several small ones will maximize the conservation of reptiles and amphibians (Ramanamanjato, 2000), birds (Raherilalao, 2001) and lemurs (Ganzhorn *et al.*, 2000). The protection of the remaining primary forest is crucial for the maintenance of the present biodiversity. Ganzhorn & Schmid (1998) showed that 40-year old secondary dry forests in western Madagascar are unlikely to provide a suitable habitat even for the smallest, least threatened, lemur species such as *Microcebus murinus*. Although studies still have to confirm this, it is also likely to be the case for the littoral forest.

Conservation priorities for the remaining forest fragments have been categorized based on 10 criteria: size, integrity, biodiversity, representativity, manageability, endemicity (local, regional and national), number of rare, threatened and vulnerable species, protected area, complementarity and natural borders (QMM, 2001). At Sainte Luce the fragments S9 and S17 (Fig. 2) have the highest conservation priority and may act as reservoirs from where indigenous species of flora and fauna can colonize new habitats. These forest fragments are different from each other in appearance and floral composition and harbour a large faunal and floral diversity (Lewis Environmental Consultants, 1992). They are representative of the south-eastern littoral forest ecosystem. Additionally, protection of the flying fox roost site in S6 is important as this species is the only long-distance seed disperser. These three fragments comprise *c.* 1,000 ha of littoral forest, are within close proximity, and include littoral forest, mangroves, dunes and marshes, sandy beaches, a lake and an estuary. The proposed conservation zones (QMM, 2001) involve 190 ha of S9 and all of S17 (237 ha); their main purpose is to protect primary forest, with the banning of all logging, hunting and *tavy* within the fragments. The establishment of S9 and S17 as conservation zones has been agreed by the local communities, the Department of Water and Forestry, QMM and the NGO Azafady, and is based on *dinas*. From 1996 the *Gestion Local Securise* legislation incorporated *dinas*, the primary local rule making, into official management (Journal Officiel de la République de Madagascar, LOI N°2000–027). The Sainte Luce *dina* has been accepted by all local stakeholders and the co-management plan is expected to be signed at the end of 2005. Active protection of the forest fragments S9 and S17 will then be ensured, as these areas will be officially classified as protected areas in the Système des Aires Protégées de Madagascar. Cooperation with local people in decision-making and control systems, as promoted by the Malagasy National Environment Action Plan (1990–2005), will be an essential feature if this conservation plan is to succeed.

Animals

The effects of forest fragmentation on a given species are related to its tolerance to habitat change and its capability to use the grasslands, shrublands and wetlands surrounding forest fragments. *E. f. collaris*, almost exclusively arboreal, is particularly vulnerable as it appears to be reluctant to cross open areas (G. Donati, pers. obs.), thus increasing the problems of inbreeding depression for the remaining populations. Moreover, because of the spatio-temporal patchiness of its food resources (A. Bollen & G. Donati, unpubl. data) *E. f. collaris* needs large home ranges (up to 100 ha) and covers long distances daily (1,500–3,500 m; Donati, 2002). At present, fragments S9 and S17 are important refuges for *E. f. collaris* (Donati, pers. obs.). Several groups (a total of 28 individuals) were translocated in 2000 and 2001 in Mandena (Fig. 1). They were captured from the fragment M3–M4 (100 ha), which was exploited for charcoal, and transferred to the Conservation Zone in Mandena (M15–M16, 230 ha). Despite the initial loss of some individuals the lemurs seem to have adapted to their new habitat and post-monitoring studies indicate that the animals were able to survive and reproduce normally (G. Donati, pers. obs.). In 2003 the total number of *E. f. collaris* in M15–M16 was estimated to be *c*. 34 individuals. Unfortunately, in early 2004 at least seven fossa *Cryptoprocta ferox*, the large endemic viverrid that preys extensively on lemurs, were recorded in the Mandena conservation zone and killed >6 *E. f. collaris* (Donati *et al.*, unpubl. data), thus compromising the success of the translocation. However, translocation and reintroduction of primates, especially in rescue situations such as in Mandena, are becoming increasingly important conservation tools (Soorae & Baker, 2002).

Nocturnal lemur species are still present even in the smaller forest fragments in Sainte Luce (Ganzhorn *et al.*, 2000). However, they are unable to cross deforested areas and are therefore threatened by inbreeding depression and their seed dispersal services are also limited to within single forest fragments. *P. rufus*, however, may cover long distances and rely on resources collected in other forest areas (Bollen & Van Elsacker, 2002). Restriction of access to the roost is required for conservation of *P. rufus*. Frugivorous birds are not restricted to particular fragments and seem to be abundantly present in both small and large fragments as well as intact and degraded ones (Watson *et al.*, 2004).

Tree species

Phenological data show that frugivores in the littoral forest face unpredictable periods of fruit abundance and scarcity (Bollen & Donati, 2005). We were unable to identify the keystone species (*sensu* Terborgh, 1986) for this forest but there are several important food species for frugivores (Table 1), including *Syzigium* sp. 2 (Myrtaceae) and *Dypsis prestoniana* (Arecaceae). Both species fruit when overall fruit availability is low, produce large fruit crops and are eaten by all frugivores present in Sainte Luce (Table 1). For example, 80% of the time *E. f. collaris* spent feeding in June 2000 was on *Syzigium* sp. 2, and 20% of time spent feeding in April was on *Dypsis prestoniana* (Donati, 2002). Because of high intercorrelation of all phenophases (floral reproductive phases), no alternative food sources (such as young leaves or flowers) are available for the animals during these periods, and they therefore rely heavily on only a few fruiting species. Protection measures and possibly *ex situ* conservation may be needed for these plant species that contribute disproportionately to the diets of certain animal species at a time of year when alternative sources are unavailable.

Corridors

Because of high levels of degradation and fragmentation, active protection of the remaining intact forest fragments in south-east Madagascar is insufficient to conserve and restore this ecosystem. Furthermore, natural regeneration via secondary forests is generally too slow to counteract the loss of primary forests (Ganzhorn *et al*., 1999). The creation of corridors (Beier & Noss, 1998) is considered a conservation priority for this area (Ganzhorn *et al.*, 1997; Holloway, 2004). Corridors promote increased plant and animal movement among patches, which enhances population viability and recolonization, and increases pollination and seed dispersal (Beier & Noss, 1998; Tewksbury *et al.*, 2002). However, while some species readily move between fragments using habitat corridors, others do not (Chapman & Peres, 2001). In 1999 a corridor was created between the forest fragments M4 and M5 in the Mandena area by planting a mixture of endemic (20%) and exotic fast-growing species (80%) to accelerate the formation of a bridge for tree-dwelling animals. Unfortunately, the corridor was recently burned down, together with most of the two forest fragments. In Sainte Luce the three largest fragments (S9, S7 & S17) are relatively close to each other, and the establishment of corridors to connect these fragments needs to be considered. However, the establishment of corridors in this area is challenging because of the presence of roads, swamps and rivers between fragments.

Plantations

Unassisted succession restores biomass better than it does biodiversity (Corlett, 2002), and dependence entirely on natural seed dispersal may result in secondary forest dominated by a particular subset of the forest flora. Large-seeded plant species (e.g. *Canarium boivinii, Diospyros* sp., *Apodytes* sp. nov.; Table 1) that have few seed dispersers are less easily dispersed and may require planting for re-establishment (Wunderle, 1997; Kitamura *et al.*, 2002; Ingle, 2003). By planting both native and exotic species regeneration can be promoted and at the same time this can provide alternative wood sources. Experiments in a tree nursery have shown that a variety of non-invasive exotic trees such as *Eucalyptus, Acacia* and *Casuarina* spp. (QMM, 2001) may be suitable for landscape restoration in this area. Planting of these tree species may accelerate natural forest succession by ameliorating impoverished soil and understorey microclimatic conditions, suppressing invasive dominant grasses, improving soil fertility and nutrient availability, and attracting seed dispersers (Corlett, 2002). There are *c.* 30 ha of plantations, on either private or state property, close to Mandena, and QMM have created 300 ha of plantations around Mandena and 2 ha in Sainte Luce and have a commitment to establish 100 ha of plantations each year (M. Vincelette, pers. comm.). Mixed species plantations in Ampijoroa have been shown to provide acceptable habitats for the majority of the lemur species there (Ganzhorn, 1987). In Mandena *C. medius* and *Microcebus murinus* have been observed to feed on the flowers of the exotic *Melaleuca quinquenervia* (Myrtaceae; QMM, 2001). In other eastern sites even the larger *Eulemur* spp. have been seen to rely on *Eucalyptus* flowers (Ganzhorn, 1985; Overdorff, 1988). However, the floristic diversity of plantations is limited and may not provide food year-round for all lemur species (Ganzhorn, 1987; Ganzhorn & Abraham, 1991). Therefore, plantations should ideally border natural forests. Planting important fruiting trees in corridors, plantations or clearings is another way to enhance reforestation by attracting frugivores and stimulating the seed dispersal they provide. Dietary data on frugivores should be taken into account when choosing fruit species to be included in planting projects (Table 1).

Conclusions

The littoral forest of the Fort Dauphin region is being cleared at an alarming rate and is not yet represented in protected areas. The declaration of the Malagasy President Ravolomanana, at the Fifth World Parks Congress in Durban, to triple the protected areas in Madagascar to 6 million ha by 2009 will change this situation (IRG-PAGE, 2001). Understanding forest dynamics and plant-animal interactions in this degraded ecosystem is essential if existing forests are to be conserved and deforestation is to be slowed down or halted. Besides active protection measures, there is also great need for integrated management combining research, conservation and developmental aid. Firstly, there is a need for alternative fuel and wood sources, which could be provided by plantations of fast-growing non-invasive species. Secondly, income generating activities such as small-scale ecotourism, butterfly farming and beekeeping are also required. Finally, environmental education is required in the villages of the region.

Recruitment of local people and environmental education in Mandena, promoted by QMM in the last decade, have resulted in the halting of deforestation in the conservation zone M15-M16. Ecotourism has also been functioning since 2004. In Sainte Luce environmental and social programmes are conducted both by QMM and Azafady. QMM has built a school, recruited local staff and invested in forest-related activities such as beekeeping. There have been recent reductions in hunting and forest clearing in the conservation zones established by the local *dina* (G. Donati, pers. obs.). Nevertheless, substantial effort is needed to provide the local people of Sainte Luce with alternative resources to ensure protection of the remaining biodiversity of the littoral forest.

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