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# DISTRIBUTION, ECOLOGY, AND THREAT TO SELECTED MADAGASCAN ORCHIDS

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ABSTRACT. Madagascar has a rich orchid flora, approaching 1000 species, of which almost 90% are considered to be endemic. Published information on the orchids includes only generalized information on distribution and ecology and nothing on their conservation status in the wild or threat of extinction. Nevertheless, it is widely considered that many Madagascan orchids are threatened, particularly by habitat destruction that has been widely reported. Little factual data, however, has been published on these aspects of Madagascan orchids. Using herbarium data, we have entered the known historical distribution of species from different habitats in Madagascar onto base maps that include details of geology, elevation, aspect, and vegetation type. These maps can be used to indicate where species occurred historically and whether the vegetation they once occupied still persists. They also can be used to indicate where a species might be found in surviving stands of natural vegetation. Herbarium records based on algorithms developed to predict possible extinction events can be used to prioritize the rare taxa most under threat. These predictive algorithms have been applied to a selection of Madagascan species that are considered to be threatened by extinction.

*Key words:* Orchidaceae, extinction, algorithm, distribution, herbaria

## INTRODUCTION

Madagascar has a rich orchid flora, approaching 1000 species in 59 genera. Of these more than 88% of the species and 17.6% of the genera are considered to be endemic (TABLE 1). The last floristic account appeared some 62 years ago (Perrier de la Bâthie 1939–1941), and an updated checklist was published recently (Du Puy et al. 1999). These treatments included only generalized information on distribution and ecology, and nothing on the conservation status of plant species in the wild or the threat of extinction facing them. It is widely considered, nevertheless, that many Madagascan orchids are threatened, particularly by habitat destruction that has been widely reported.

Little factual data, however, has been published on these aspects of Madagascan orchids. Using herbarium-based data, we have entered past and present distributions onto base maps that show remaining vegetation classified as to type and extinction modelling. These base maps indicate that some species indeed are endangered and that many survive in healthy numbers in remaining habitats. Currently team members of a collaborative project sponsored by Kew, Parc Tsimbazaza, and the University of Antananarivo are undertaking studies of the ecology, population size and structure, and pollination success of a number of threatened orchids from the eastern rain forests and from both granite inselberg and sandstone massifs of the central plateau region.

Ex-situ propagation of selected species also is being undertaken as part of the program for exhibition at Parc Tsimbazaza and to provide the horticultural trade with healthy seedlings and take the pressure off the remaining populations.

Madagascar is a large island, about two and a half times the size of Great Britain and with a population of about 16 million people. Estimates of vegetation cover provided by Dufils (2003) suggest that about 5.5 million ha of evergreen forest survive, mainly in the mountains on the eastern side of the island along with some in the north. Dry forest is the second largest area of natural habitat with 4.1 million ha surviving (FIGURE 1). Secondary vegetation covers 7.1 million ha and mangrove forest, 435,000 ha. Orchids occur in all these habitats. Another significant orchid habitat is provided by the granite sandstone on the central plateau region and the limestone outcrops in the north and west of the island.

Du Puy and Moat (1996) provided a base map of existing natural vegetation type using satellite imagery and geological and edaphic data. Some distinct vegetation types, often greatly reduced from their former extents, are not included in any of the current national parks.

## ORCHID HABITATS AND TAXONOMIC TREATMENTS

Some of the major orchid habitats in Madagascar (eastern rain forests, inselbergs and sand-

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TABLE 1. Endemism in Madagascan orchids.

| Genus | Species No. | Endemic species No. | Endemism % |
|---|---|---|---|
| *Acampe* | 1 | 0 | 0 |
| *Aerangis* | 20 | 15 | 75 |
| *Aeranthes* | 41 | 39 | 95 |
| *Agrostophyllum* | 1 | 0 | 0 |
| *Ambrella** | 1 | 1 | 100 |
| *Angraecopsis* | 1 | 0 | 0 |
| *Angraecum* | 143 | 131 | 92 |
| *Auxopus* | 1 | 1 | 100 |
| *Bathieorchis** | 1 | 1 | 100 |
| *Beclardia* | 2 | 1 | 50 |
| *Benthamia* | 28 | 26 | 93 |
| *Brachycorythis* | 2 | 1 | 50 |
| *Brownleea* | 2 | 0 | 0 |
| *Bulbophyllum* | 197 | 187 | 93 |
| *Calanthe* | 5 | 4 | 80 |
| *Cheirostylis* | 1 | 0 | 0 |
| *Corymborkis* | 1 | 0 | 0 |
| *Cryptopus* | 3 | 2 | 67 |
| *Cymbidiella** | 3 | 3 | 100 |
| *Cynorkis* | 162 | 153 | 94 |
| *Didymoplexis* | 1 | 1 | 100 |
| *Disa* | 4 | 3 | 75 |
| *Disperis* | 21 | 15 | 71 |
| *Eulophia* | 25 | 18 | 72 |
| *Eulophiella** | 4 | 4 | 100 |
| *Galeola* | 1 | 1 | 100 |
| *Gastrorchis** | 9 | 9 | 100 |
| *Goodyera* | 4 | 4 | 100 |
| *Grammangis** | 2 | 2 | 100 |
| *Graphorkis* | 3 | 2 | 67 |
| *Gymnochilus* | 2 | 2 | 100 |
| *Habenaria* | 27 | 20 | 74 |
| *Hetaeria* | 1 | 1 | 100 |
| *Imerinaea** | 1 | 1 | 100 |
| *Jumellea* | 48 | 47 | 98 |
| *Lemurella* | 4 | 3 | 75 |
| *Lemurorchis** | 1 | 1 | 100 |
| *Liparis* | 38 | 35 | 92 |
| *Malaxis* | 4 | 4 | 100 |
| *Megalorchis** | 1 | 1 | 100 |
| *Microcoelia* | 10 | 8 | 80 |
| *Microterangis* | 4 | 3 | 75 |
| *Neobathiea* | 6 | 5 | 83 |
| *Nervilia* | 8 | 2 | 25 |
| *Oberonia* | 1 | 0 | 0 |
| *Oeceoclades* | 24 | 19 | 79 |
| *Oeonia* | 4 | 2 | 50 |
| *Oeoniella* | 1 | 0 | 0 |
| *Phaius* | 1 | 0 | 0 |
| *Physoceras** | 9 | 9 | 100 |
| *Platycoryne* | 1 | 0 | 0 |
| *Platylepis* | 4 | 2 | 50 |
| *Polystachya* | 22 | 18 | 82 |
| *Satyrium* | 5 | 3 | 60 |
| *Sobennikoffia** | 4 | 4 | 100 |
| *Solenangis* | 2 | 0 | 0 |
| *Tylostigma** | 7 | 7 | 100 |
| *Vanilla* | 5 | 5 | 100 |
| *Zeuxine* | 3 | 3 | 100 |
| 59 | 936 | 829 | 88 |

* Endemic. Of the 59 genera, 12 are endemic.

Source: Du Puy et al. (1999), La Croix et al. (2002), Bosser and Cribb (2003).

stone outcrops on the plateau, dry forests, secondary grasslands, marshes and rice paddy) are described below, along with a selection of characteristic orchid species.

### Eastern Rain Forests

This is the most extensive of all the remaining vegetation zones and extends across the north and down the east of the island inland from the coast to the crests of the mountains that parallel the coast. The rain forest is in better condition in the north and northeast than further south, where extensive clearance has left, at best, a mosaic of forest patches and often no forest cover at all. The most extensive area of forests survives in the Masoala Peninsula in the northeast. Botanical exploration of this region remains limited because of its relative inaccessibility.

**Eulophiella roempleriana** (Rchb.f.) Schltr. belongs to an endemic genus of three species (FIGURE 2A). A showy orchid, it is confined to the eastern rain forests of the island from Ranomafana in the south to Ile Ste Marie in the north. This epiphyte apparently is confined to the crowns of *Pandanus.* Its host tree is usually *P. utilis,* up to 25 m or so tall, that grows in forest swamps. Unfortunately, the orchid is collected from accessible sites for the horticultural trade, resulting in some colonies having very few (3–10) adult plants or no longer having any at all. A more severe problem is that the host is harvested for its leaves, which are used for weaving baskets. On Ile aux Nattes at the south end of Ile Ste Marie, the orchid is protected, but its unprotected host tree is regularly harvested. No adult orchids survive in the wild there, but seedlings were found in one swamp. Other showy orchids, such as *Cymbidiella falcigera* that grows on raffia palms, were common in the swamps nearby, suggesting that the harvesting of the host had a greater effect than collecting the orchid. Fortunately, in December 2003, fieldwork at Ranomafana, Mantadia, and Ambovatikely located several healthy populations of *E. roempleriana* in remote places with up to 50 mature plants. Observations of pollinating bees attracted to the flowers suggest that the orchid flowers might mimic those of tree Melastomataceae that have similar rose-purple flowers with bright yellow anthers.

**Eulophiella elisabethae** Rolfe is closely allied to *E. roempleriana* but has smaller white and pink flowers in shorter denser inflorescences (FIGURE 2B). Like the latter it also

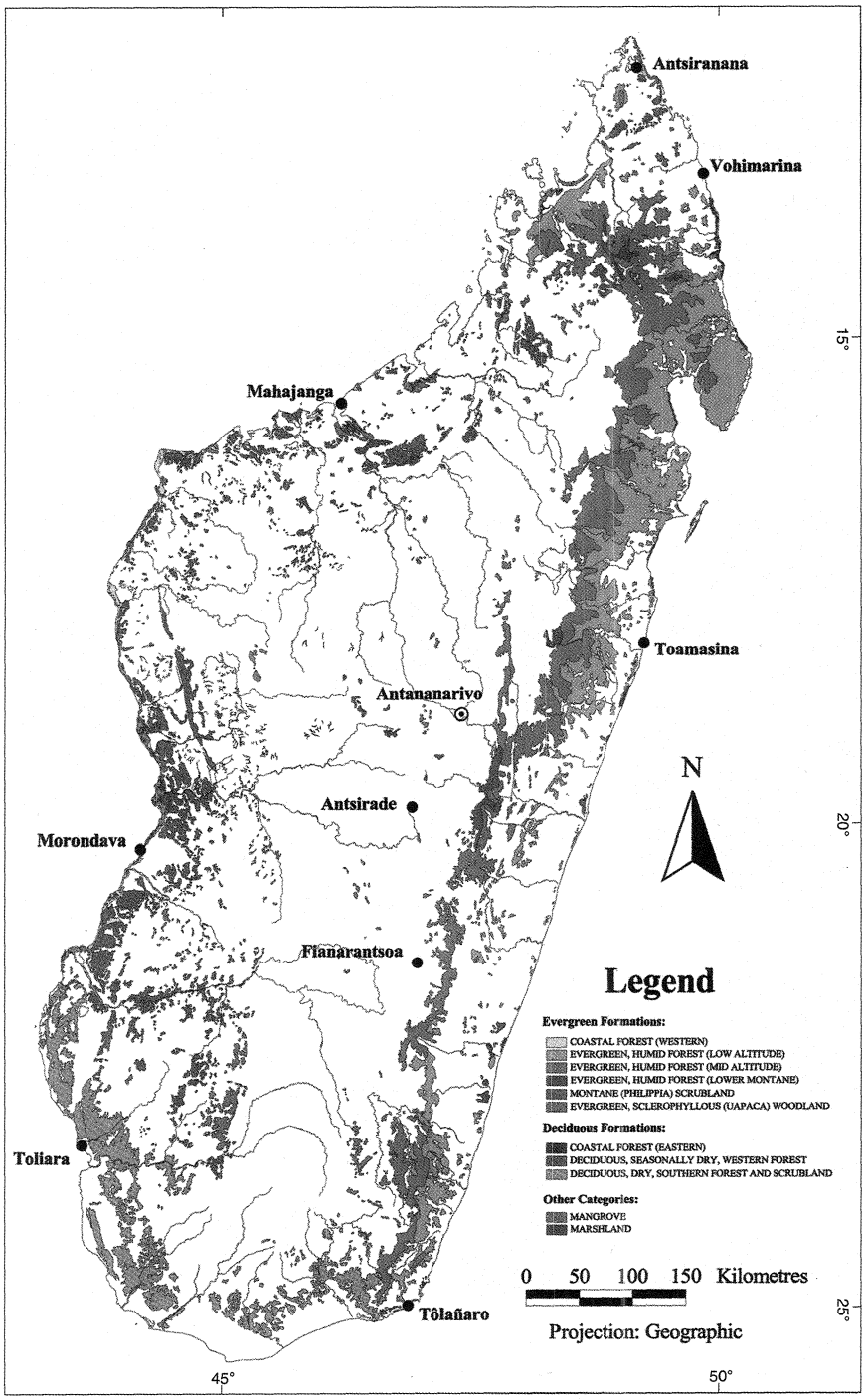


FIGURE 1. Remaining primary vegetation in Madagascar (Du Puy & Moat 1996).

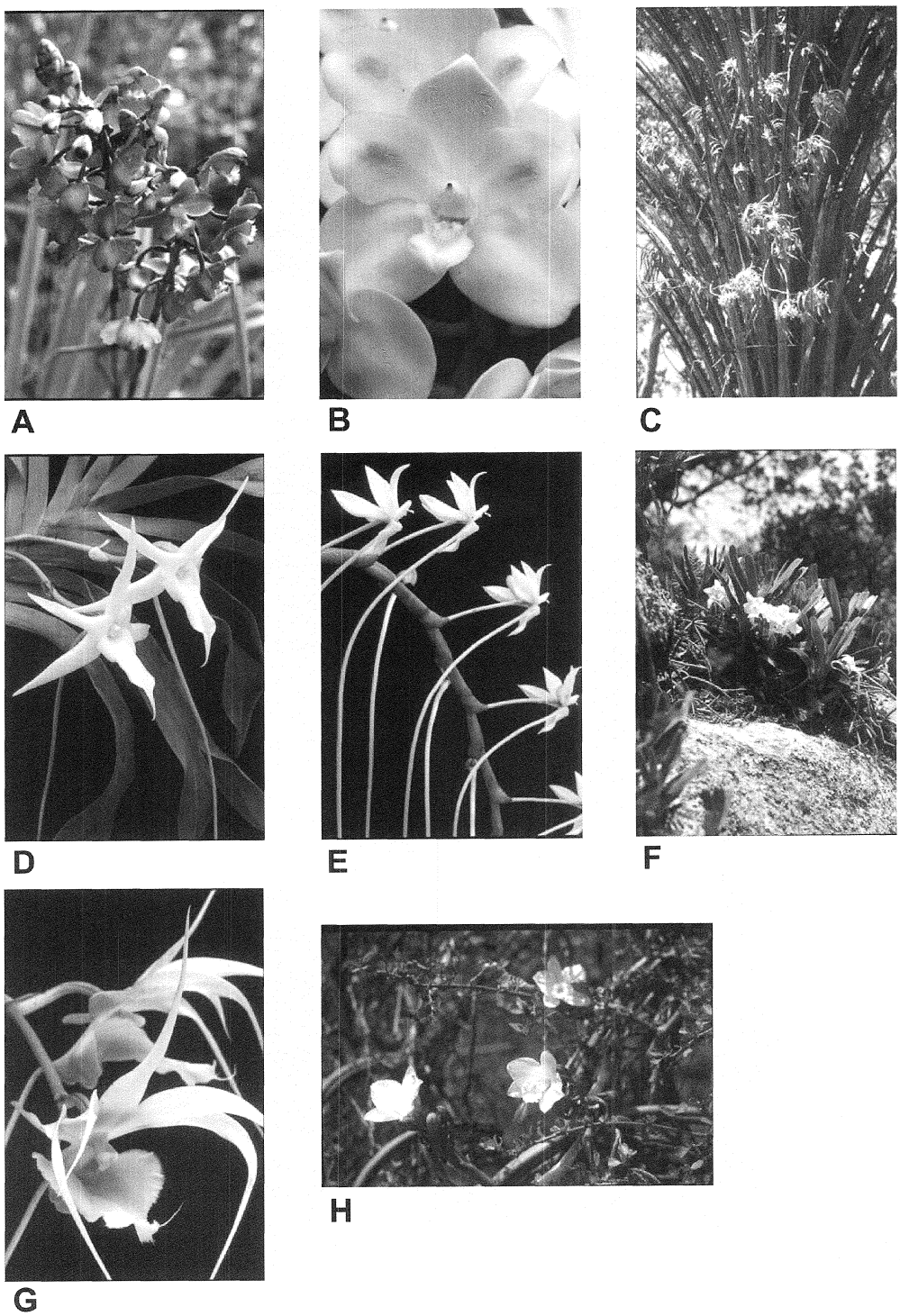


FIGURE 2. Madagascan orchids. **A.** *Eulophiella roempleriana.* **B.** *Eulophiella elisabethae.* **C.** *Eulophia epiphytica.* **D.** *Angraecum sesquipedale.* **E.** *Aerangis ellisii.* **F.** *Angraecum magdalenae.* **G.** *Aeranthes henrici.* **H.** *Vanilla madagascariensis.*

favors a specific host, namely a palm, *Dypsis fibrosa* (C.H. Wright) Beentje & Dransf. With a distribution far more restricted than that of *E. roempleriana,* it has been found only on the southern and northern margins of the Masoala Peninsula (Dransfield & Beentje 1995). Somewhat surprisingly, the distribution of the host palm is extensive, being found in northwest Madagascar and from Masoala to Toliagnaro in the east. Detailed ecological studies of this orchid urgently are needed to see what effects deforestation and orchid collecting have had on its survival.

**Eulophia epiphytica** P.J.Cribb, Du Puy & Bosser (FIGURE 2C) was described recently from southeast Madagascar, where almost its entire population inhabits a raffia swamp close to the main road north out of Tolagnaro (Cribb et al. 2002). Most of the raffia palms recently were felled to make way for construction. This strange orchid survives but only by the skin of its teeth. Recent molecular studies suggest that it should be transferred to a new genus, a fact supported by its unusual monopodial habit. Fortunately, it has proved easy to grow from seed at Kew.

**Angraecum sesquipedale** Thouars, the comet orchid, is perhaps the best-known and most widely cultivated Madagascan orchid (FIGURE 2D). Widely distributed throughout eastern Madagascar, although most common near the coast, it is still found in locations, such as Ile Ste Marie, where it survives in small remnant patches of forest in the middle of the island. The comet orchid can be found growing on trees near habitation, where people have transplanted it to decorate their gardens. In some locations, it is under threat, particularly in the south, where it grows in forests on white sand that is being mined for the titanium dioxide deposits that the sand covers.

### Inselbergs and Sandstone Outcrops on the Plateau

The vegetation changes dramatically on the eastern side of the high mountains that parallel the east coast. Extensive areas have been cleared for rice cultivation and cattle rearing. The importance of cattle as an indicator of wealth has led to large herds that eke out an existence in the secondary grasslands of the plateau. The tough grass tussocks that develop by the end of each dry season traditionally are burnt so that the cattle can graze on the tender new shoots produced when the rains start. Vegetation suitable for orchids is very limited nowadays in this region. In contrast, the rocky outcrops of granite and sandstone have their own distinct flora, including orchids. Some *Angraecum* and *Jumellea* species grow on the bare rocks or on grassy tussocks on the rocks. Some terrestrials, especially *Cynorkis* and *Habenaria* species, survive in the humus-filled cracks and ledges. The valleys and gulleys also harbor remnants of the forests and savannah woods that once inhabited the region. Again some orchids survive in these pockets, providing an orchid refuge. A few orchids grow in the tussocky grasslands, notably some *Cynorkis* and *Eulophia* species.

**Aerangis ellisii** (Rchb.f.) Schltr. is the only Madagascan orchid on Appendix I of CITES (FIGURE 2E). *Aerangis ellisii* and two names known to be synonyms of it were uplisted last year despite detailed arguments contrary to the action, as FIGURE 1 shows. A widespread orchid, *A. ellisii* grows both epiphytically in the eastern forests and as a lithophyte on granite inselbergs on the plateau. It is also common in cultivation outside Madagascar and readily available in flask. Apparently, its elevation to Appendix I status was motivated by politics, not science.

**Angraecum longicalcar** (Bosser) Senghas is a spectacular species, being both a large plant and having large white flowers with a long spur. Considered by some to be a subspecies or variety of the ubiquitous *A. eburneum,* it sufficiently differs ecologically and morphologically to be considered distinct at specific rank. *Angraecum longicalcar* grows on granite inselbergs in the central plateau. Over-collection has made it a very rare species, apparently now confined to several locations near Ambositra. Recent fieldwork located about ten flowering plants in one locality and about the same in a second nearby one.

**Angraecum magdalenae** Schltr. & H.Perrier (FIGURE 2F) likewise has a very restricted distribution on rocky outcrops in *Uapaca* woodland on the plateau. Plants are still collected from its best-known locality, where flowering plants now number ca. 100.

**Aeranthes henrici** Schltr. has the most spectacular flowers in the genus (FIGURE 2G). It occurs as two widely separated varieties, the typical one in the northeastern rain forests, and *A. henrici* var. *isaloensis* in the gorges of the sandstone Isalo massif in the southwest, near Toliara. Two populations of

*A. henrici* var. *isaloensis* were located last autumn in the Isalo National Park, growing low down on tree trunks and low branches just above streams in deep gorges. The habit and roots of this species are quite unlike those of other *Aeranthes* species, suggesting that its generic affinities would be worthwhile investigating.

### Dry Forests

Dry forests and woods survive in the west and south of the island and have their own very distinctive flora. Several orchids are found in these areas. The genus *Oeceoclades* and some *Eulophia* species have an almost *Sanseveria*-like growth. *Bulbophyllum* species in these areas also have very reduced and tough pseudobulbs and leaves. The pseudobulbs are fleshy and tough, and the leaves, reduced in number, are leathery. These features are adaptations to a harsh environment. Other orchids survive by reducing their water loss by having scale-like leaves, for example, the leafless *Vanilla* species, such as *V. madagascariensis,* and leafless epiphytes in the genera *Microcoelia* and *Solenanagis.*

The dry forests on limestone have an orchid flora that is akin to that of the spiny forests in the south. The limestone massifs, known as "tsingy" (an onomatopoeic name from the sound the limestone makes when it is struck), are rich in orchids and form a safe refuge because of the nature of the site, which is particularly inhospitable to humans.

**Vanilla madagascariensis** Rolfe is found in the spiny forests of the south of the island (FIGURE 2H). It is a scrambling leafless vine that climbs by hooked roots up shrubs and trees. West of Tolagnaro, the spiny forests are being depleted rapidly for sisal plantations funded by the European Union. In addition, the vines are gathered by local people and sold as one ingredient of a potion that is said to be an effective aphrodisiac.

**Oeceoclades decaryana** (H.Perrier) Garay & P.Taylor is confined to the dry and spiny forests in the south of Madagascar (FIGURE 3A). Its succulent leaves and pseudobulbs are adapted ideally to its arid environment. Many of its former localities are now outside the present-day limits of the dry forest.

### Secondary Grasslands

Most orchids cannot survive the fire regimes imposed by humans on the grasslands of the plateau. A few species can tolerate and thrive in these places, such as terrestrial species of *Cynorkis* and *Eulophia,* which are best adapted to the conditions. Overall, however, the grassland areas are species-poor.

**Cynorkis flexuosa** Lindl. is common and widespread in the plateau grasslands. Its underground tubers survive the fires (FIGURE 3B).

**Eulophia rutenbergiana** Kraenzl. has pseudobulbs that can resist fire to some extent (FIGURE 3C).

### Marshes and Rice Paddy

Flat marshy areas on the plateau and coastal plains are valuable areas for rice paddy. Marshes do persist in limited areas, for instance, below dams, but most have been converted to arable land or fish farms. *Cynorkis* and *Habenaria* species thrive in marshes.

**Cymbidiella flabellata** (Thouars) Lindl. is surely the most spectacular orchid of boggy areas (FIGURE 3D). It grows in *Sphagnum*-sedge communities, sometimes in abundance. Its existing habitat, however, is much depleted nowadays by drainage and arable farming. The historical distribution of *C. flabellata* was extensive, along the eastern side of the island and from sea level to 1500 m elevation. The few remaining populations on the plateau east of Antananarivo are now greatly threatened as water tables are manipulated by humans to increase the area under cultivation.

**Eulophia plantaginea** (Thouars) Rolfe ex Hochr. was one of the earliest orchid discoveries in Madagascar by du Petit Thouars, who described it in 1822 (FIGURE 3E). Widespread throughout the island, it favors the banks of drainage ditches in rice paddy areas.

### Threats to Habitats and Orchids

The major threats to the flora of Madagascar have been well documented. Loss of habitat through forest destruction continues to inflict substantial losses on the remaining forests, both wet and dry. Wetlands are turned into rice paddy and fishponds. The main agent of forest destruction is shifting agriculture, but fires running out of control from adjacent grasslands, themselves the result of the long-standing tradition of burning unpalatable tussocks and stimulating grass-growth for cattle feed, also destroy significant amounts of forest (Krull 2003). Timber extraction for lumber and firewood is a cause of forest loss. Durbin et al. (2003) suggest that firewood extraction by the residents of Toliara alone ac-

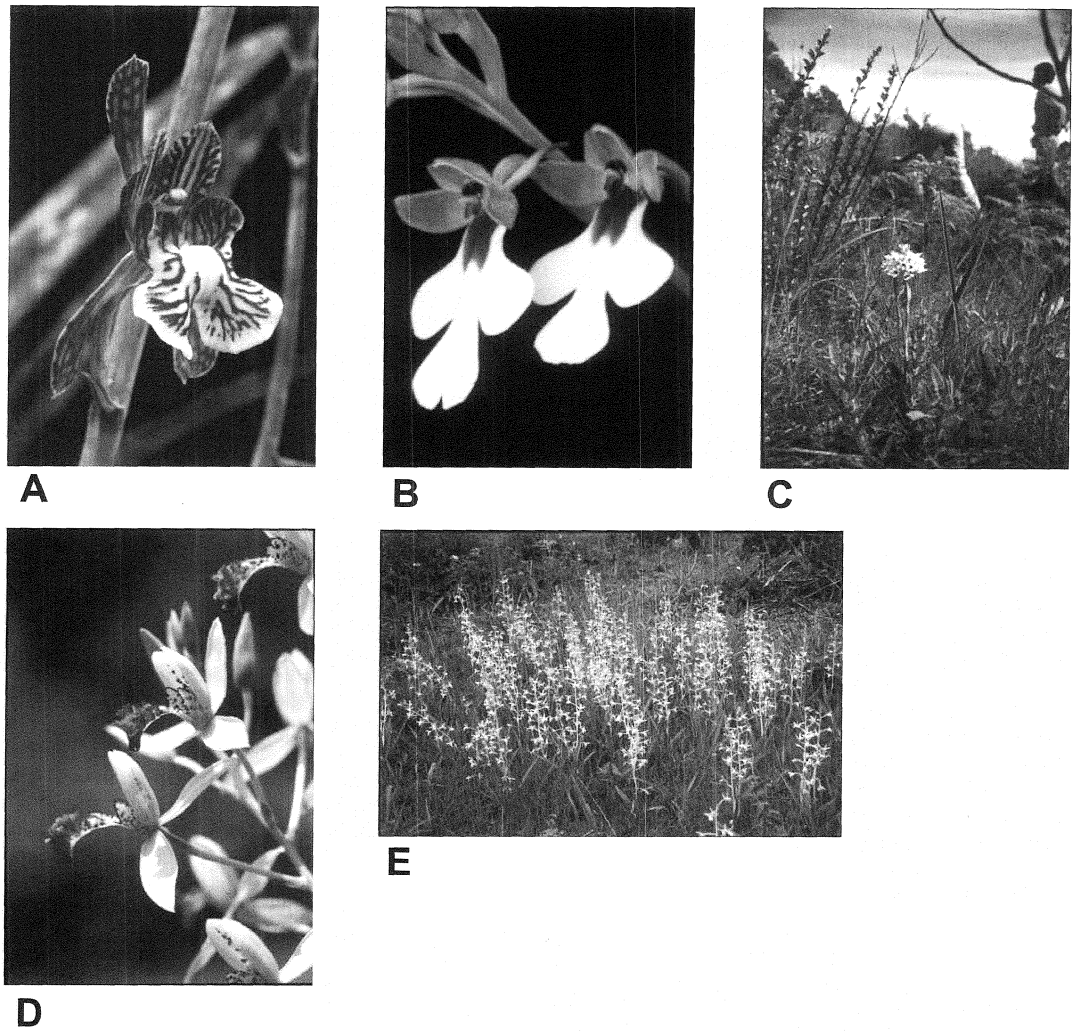


FIGURE 3. Madagascan orchids. **A.** *Oeceoclades decaryana.* **B.** *Cynorkis flexuosa.* **C.** *Eulophia rutenbergiana.* **D.** *Cymbidiella flabellata.* **E.** *Eulophia plantaginea.*

counts for 8000 ha of lost forest per annum. Overall destruction accounted for 110,000 ha of forest destroyed per annum 1950–1985 (Harcourt & Thornback 1990). The rate probably has increased during the past two decades, as human populations have grown rapidly (Durbin et al. 2003). Quarrying affects some lithophytic species, especially around the larger population centres on the plateau.

Some of the leafless native vanilla species used medicinally are collected in some quantity in the south. Collection of orchids for horticulture certainly affects populations of some of the showier species. Orchid nurseries in Antananarivo traditionally have accepted wild-sourced plants from collectors; but recently several laboratories have raised some of the more spectacular orchids from seed (see the Ranarivelo et al. poster on the Madagascar Threatened Plants Project in this issue, which covers this aspect).

## MATERIALS AND METHODS

Herbarium data from the Natural History Museum, London (BM), Geneva (G), Kew (K), Paris (P), Parc Tsimbazaza (TAN), and Vienna (W) have been used to enter the known historical distribution of species from different habitats in Madagascar onto base maps that distinguish the remaining vegetation in Madagascar based upon details of aerial mapping, geology, and elevation (Du Puy & Moat 1996). These maps can be used

TABLE 2. Levels of decline in selected orchid species from Madagascar based on the analysis of herbarium collections, where No. is the number of sightings.

| Species | No. | Solow | Solow & Roberts | McInerny et al. |
|---|---|---|---|---|
| *Aeranthes henrici* var. *henrici* | 4 | 0.772 | 0.800 | 0.760 |
| *Aeranthes henrici* var. *isaloensis* | 3 | 0.342 | 0.543 | 0.233 |
| *Aeranthes henrici* | 7 | 0.597 | 0.750 | 0.572 |
| *Angraecum longicalcar* | 2 | 0.725 | 0.725 | 0.680 |
| *Angraecum magdalenae* var. *magdalenae* | 6 | 0.595 | 0.273 | 0.567 |
| *Angraecum magadalenae* var. *latilabellum* | 1 | — | — | — |
| *Angraecum magdalenae* | 7 | 0.536 | 0.273 | 0.504 |
| *Bulbophyllum hamelinii* | 6 | 0.171 | 0.625 | 0.112 |
| *Cymbidiella falcigera* | 18 | 0.276 | 0.091 | 0.238 |
| *Cymbidiella flabellata* | 18 | 0.570 | 0.0636 | 0.540 |
| *Eulophia epiphytica* | 1 | — | — | — |
| *Eulophiella elisabethae* | 13 | 0.022 | 0.132 | 0.007 |
| *Eulophiella roempleriana* | 14 | 0.247 | 0.083 | 0.205 |

Source: Solow (1993), Solow and Roberts (2003), G. McInerny, D. Roberts, A. Davy, and P. Cribb (unpubl. data).

to indicate where species occurred historically, whether the vegetation they once occupied still persists, and whether this data can be used to indicate where a species might be found in surviving stands of natural vegetation.

Based on algorithms developed by Solow (1993), Solow and Roberts (2003), and G. McInerny, D. Roberts, A. Davy, and P. Cribb (unpubl. data), herbarium records can be used to predict potential probabilities of extinction of rare taxa. These algorithms have been applied to a selection of Madagascan species that are considered to be threatened by extinction.

## RESULTS

Both the Solow (1993) and the Sighting Rate (G. McInerny, D. Roberts, A. Davy, and P. Cribb unpubl. data) equations show a similar pattern of ranked probabilities. The Solow and Roberts (2003) equation differs slightly since it was designed for limited data; however, the overall trend is similar. Species with low probability ($p$) values include *Eulophiella elisabethae* and *E. roempleriana.* Both species are frequently collected and have limited ranges in the eastern rain forests. For instance, *E. elisabethae* is found only on the Masoala Peninsula, whereas *E. roempleriana* is restricted to a narrow ecological range, only being found on *Pandanus.* In contrast, *Angraecum longicalcar, A. magdalenae,* and *Aeranthes henricii* are more restricted in their distributions, being found on the central plateau in very restricted habitats. They also have been collected frequently. The results, therefore, suggest that the species from the eastern rain forest are currently in decline, whereas those of the central plateau probably declined many years ago when the central plateau was cleared. Their present populations represent remnants, lingering at the end of a long period of decline (TABLE 2).

## CONCLUSIONS

Information on the distribution, ecology, and threat to Madagascan orchids is largely confined to data gleaned from herbarium collections. Nevertheless, analysis of the existing data can reveal trends in orchid distribution and abundance that enable sensible conservation measures to be proposed for threatened species. Team members of a collaborative project sponsored by Kew, Parc Tsimbazaza, and the University of Antananarivo currently are undertaking studies of threatened populations of a number of orchids from the eastern rain forests and from both granite inselbergs and sandstone massifs of the plateau. They also are undertaking ex-situ propagation of selected species to provide the horticultural trade with healthy seedlings and to take the pressure off the remaining populations. A long-term aim is to reintroduce selected species to areas from which they have been exterminated by over-collection.

## ACKNOWLEDGMENTS

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