Chapter 6.8
Biology, Ecology, Risk of Extinction, and Conservation Strategy for *Eligmocarpus cynometroides* (Fabaceae): A Priority Species at Petriky

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Abstract

Eligmocarpus cynometroides is a tree species restricted to southeastern Madagascar where it grows in the narrow, transitional area between the humid and sub-arid bioclimatic zones. It is classified as critically endangered because it has a predicted decline of 100% due to habitat loss and selective cutting. It occurs within an area of only 77 km^2 and it is known from just two sub-populations. Neither of them is within a protected area, and one is within QMM's proposed mine site at Petriky where this sub-population has a low abundance and small area of occupancy (27 individuals in 0.01 km^2). We propose a strategy for the conservation of this species that includes *ex-situ* propagation, and the reinforcement of the Petriky sub-population and its inclusion in a conservation zone.

Résumé

Biologie, écologie, risque d'extinction et stratégie de conservation pour *Eligmocarpus cynometroides* (Fabaceae), une espèce prioritaire de Petriky. *Eligmocarpus cynometroides* est une espèce d'arbre localisée au sud-est de Madagascar, où elle occupe une étroite zone de transition entre les régions bioclimatiques humide et sub-aride. Elle est classée "en danger critique" car on prévoit un déclin de sa population de 100% par la perte de l'habitat et son exploitation sélective pour le bois. Elle n'est connue que de deux sous-populations (aucune n'est distribuée dans une aire protégée et une est située dans le site minier de Petriky, proposé par QMM). Elle n'est rencontrée que sur une superficie de 77 km^2 et montre une faible abondance ainsi qu'une petite aire d'occupation dans la sous-population de Petriky (seulement 27 individus sur 0,01 km^2). Nous proposons une stratégie pour la conservation de cette espèce dont une propagation *ex situ* et le renforcement de la sous-population de Petriky associé à son inclusion dans une zone de conservation.

Introduction

Faced with the continuing and largely irreversible degradation of natural ecosystems, biodiversity conservation must become a common preoccupation for humanity. Madagascar, classified as a mega-diversity country (Mittermeier 1988), contains an extraordinarily rich endemic flora and fauna. It is currently estimated that the country contains at least 12,000 species of vascular plants in 1600 genera and 210 families (Schatz 2000). Among these families, the Fabaceae, or Leguminosae, with 667 species (including 94 that are introduced or naturalized), is one of the most species-rich on the island (Du Puy *et al.* 2002). *Eligmocarpus* is one of the 22 genera of Fabaceae endemic to Madagascar. It contains just one species, *E. cynometroides*, which is found only in the southeastern part of the island. The region of Madagascar where it is found includes the Petriky Forest, which is a proposed mine site of the QIT Madagascar Minerals' (QMM) ilmenite project. The object of this study was to provide biological and ecological information concerning this species, to uncover successful methods of germinating its seeds, and to present a strategy for its conservation.

Historical background

The origin of the generic name *Eligmocarpus* is the Greek *heligmos*, meaning to spiral or coil, and *carpus* meaning fruit. The specific epithet *cynometroides* refers to the similarity of the leaves of

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this species to those of another genus of Fabaceae, *Cynometra*. The type specimen of *E. cynometroides* was collected by Capuron in 1961 (SF Capuron 20501) from the eastern slopes of Mahatsinjo to the north of the road linking Ranopiso and Bevilany. The first collection from Petriky was made in 1989 by Dumetz (Dumetz 652). In the same year, the Missouri Botanical Garden (MBG), as part of their assessment of conservation priorities among the flora of QMM's mine sites, classified this species as being of the highest priority (Lowry and Faber-Langendoen 1991). Starting in 1996, further exploration of Petriky revealed just 10 individuals of *E. cynometroides*, which led to a revised assessment of this species' conservation priority (Lowry 2001). Additional surveys led to the discovery of 27 living individuals of this taxon. In 1999, the first germination seed trials of *E. cynometroides* commenced in the QMM tree nursery. These were unsuccessful because, although after 3 weeks some seeds began to germinate, all the seedlings subsequently died. Propagation experiments by means of cuttings used various types of substrates, and also failed at both the QMM tree nursery and at the Projet d'Appui pour l'Exportation Agricole in Antananarivo. Likewise, an attempt to propagate the species *in vitro* at the Laboratoire des Symbioses Tropicales et Méditerranéennes in Montpellier failed. Finally, in 2002 after numerous experiments, good seed germination and seedling survival was achieved.

Methods

Distribution and habitat description

The distribution of *E. cynometroides* was examined by plotting the geographic localities of herbarium specimens (TROPICOS, http://mobot.mobot.org/W3T/Search/vast.html), and analyzing their distribution using Arcview 3.2. The general habitat parameters of this plant were described in terms of geology and vegetation (Du Puy and Moat 1996, 1998), and bioclimate (Cornet 1972, 1974). In addition, the habitat occupied by the Petriky sub-population was depicted in terms of vegetation type and associated species.

Pollination and seed dispersal

The possibility that *E. cynometroides* is self-fertilized or apomictic was investigated by observing fruit development on an isolated individual at Petriky that was 5 km away from any other known individual of the species.

The possible importance of pollination by animals was investigated by direct observations of flowers during October 2001. Animals visiting the flowers were identified and aspects of their behavior were noted, such as whether they made contact with the ripe stamens and receptive stigma, and whether they damaged the reproductive apparatus. Detailed measurements were taken of seed size and of the growth of fruits from fertilization to maturity.

To investigate whether *E. cynometroides* was dispersed by animals, a tree with ripe fruits was observed continuously from 14 to 28 October 1999. Animals feeding on fruits or seeds were identified and their treatment of the diaspore was noted.

Germination

Information on germination was collected by field observations and germination tests of seeds were subject to various treatments in the nursery. Seeds from two parent trees were subjected to different treatments. These included direct sowing versus soaking the seeds in cold water for 48 hours, and the use of various types of soil.

Risk of extinction

Rate of population decline

The rate of decline of a species can be predicted based on habitat loss, exploitation, or poor regeneration. The former was thought to be the response of the species to habitat degradation within its extent of occurrence. The latter parameter is difficult to quantify, but includes factors such as selective exploitation and the possibility of poor regeneration resulting, for example, from the rarity of conspecifics, pollinators, or seed dispersers. This information was compiled by observations in the field and interviews of people living close to the Petriky Forest.

Population attributes

Following the IUCN (UICN 2001) classification, the risk of extinction of *E. cynometroides* was estimated from its extent of occurrence, area of occupancy, and the number of its sub-populations. These attributes were calculated by plotting the geographic localities of herbarium specimens and interpreting the result-

ant distribution map using Arcview 3.2. The occurrence of a species is defined as the estimated area contained within the shortest continuous imaginary boundary drawn to encompass all the collection locations. The area of occupancy of a species is defined as the area of suitable habitat for the organism within its occurrence. In this study, we considered individuals to belong to different sub-populations if separated by more than 5 km.

Results

Botanical description
Classification
Subclass: Rosidae
Order: Fabales
Family: Fabaceae
Subfamily: Caesapinoidae
Genus: *Eligmocarpus*
Species*: cynometroides*
Author*:* Capuron
Vernacular name: *lambina, hazomainty*

Trees of this species are 6 to 12 m high with red resin that blackens upon contact with the air. Their wood is very hard. Leaves are alternate and imparipinnately compound with 5-9 opposite penninerved leaflets and an emarginated apex. Stipules are small, lateral, and quickly falling. Inflorescence is an axillary, few-flowered cyme. The flower has five, free yellow petals and 10 stamens (five with short filaments and glabrous anthers, and five with longer filaments and hairy anthers). The fruit is a woody indehiscent pod that is folded like an accordion and scented like vanilla. Further information can be found in Capuron (1968, 1975), Du Puy *et al.* (2002), and Schatz (2001).

Distribution

The distribution of *E. cynometroides* is shown in Figure 1. This is based on the geographic locations of the herbarium specimens listed in Table 1.

Table 1. Herbarium specimens of *Eligmocarpus cynometroides* used to create the distribution map (Fig. 1).

Specimen	Province: site	Latitude (S)	Longitude (E)	Altitude	Date collected
N. Dumetz 652	Toliara: Petriky	25.0667	46.8500	0-10 m	11 April 1989
SF (Lamarque) 8213	Toliara: Mahatsinjo	25.0333	46.6500	-	November 1953
SF (Balthazar) 3498	Toliara: Ranopiso	25.0500	46.6917	0-100 m	07 June 1951
S (Capuron) 20501	Toliara: Ranopiso	25.0333	46.6500	-	11 December 1961
F. Ratovoson *et al.* 102	Toliara: near Andohahela	25.0044	46.6206	180 m	07-11 June 1999
SF (Capuron) 8496	Toliara: Mahatsinjo	25.0333	46.6500	-	23 September 1953
SF 9918	Toliara: Mahatsinjo	25.0333	46.6500	-	10 May 1952
SF (Capuron) 28325	Toliara: Mahatsinjo	25.0333	46.6500	-	10 September 1968
Rabenantoandro *et al.* 1610	Toliara: Ambovo	25.0508	46.8956	6 m	24 June 2004
N. Dumetz & G. McPherson 1102	Toliara: Petriky	25.05	46.52	0-10 m	4 December 1989

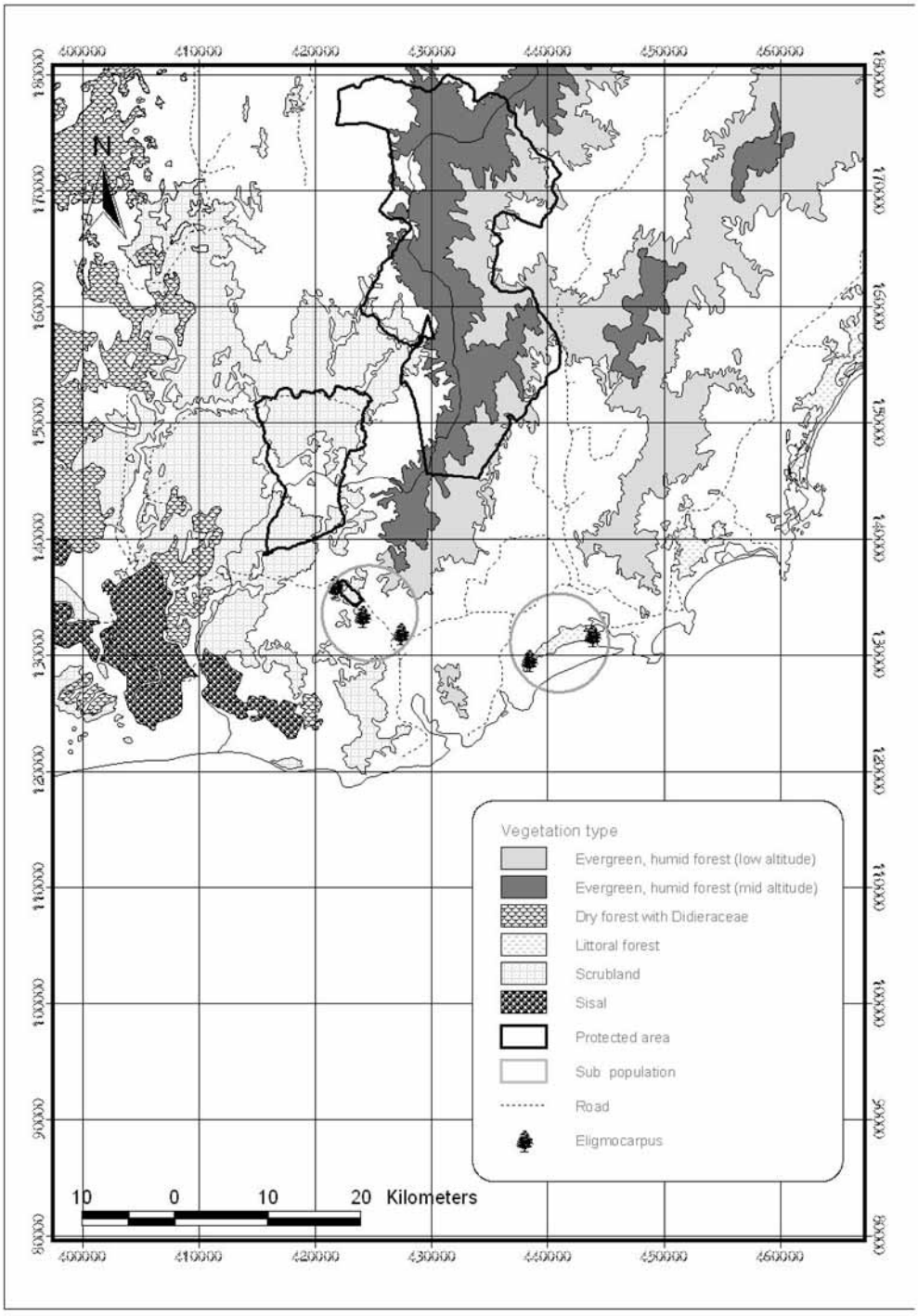

Figure 1. Distribution of *Eligmocarpus cynometroides*.

Table 2. Habitat of *Eligmocarpus cynometroides*.

Sub- population	No. dry months per year	Bioclimate	Geology	Vegetation
South of Andohahela	9	Transition humid to sub-arid	Basement rock	Transition between low elevation humid forest and spiny bush
Petriky	7	Transition humid to sub-arid	Alluvial and lake deposits	Transition between littoral forest and spiny bush

Table 3. Size and location of *Eligmocarpus cynometroides* individuals at Petriky. The number refers to individual trees marked with aluminum tags.

N°	Latitude (S)	Longitude (E)	Altitude (m)	DBH (cm)	Height (m)	Habitat (vegetation - topography)
EL 02	25°04'42.96"	046°49'33.18"	12	16.8	6	Field -slope
EL 03	25°03'14.49"	046°53'41.73"	16	92.5	5	Forest - flat area
EL 04	25°03'11.94"	046°53'39.48"	19	21.5	2,4	Degraded forest- dune
EL 05	25°03'09.00"	046°53'45.96"	16	62.4	5	Degraded forest- dune
EL 06	25°03'14.08"	046°53'41.04"	16	4.1	2	Forest- flat area
EL 07	25°03'15.62"	046°53'42.27"	15	88.3	5	Forest- flat area
EL 08	25°03'09.72"	046°53'48.30"	29	56.1	6.5	Degraded forest- dune
EL 09	25°03'09.52"	046°53'46.13"	16	2	1.5	Degraded forest- dune
EL 10	25°03'08.16"	046°53'43.23"	13	17	5	Degraded forest- inter dune
EL 11	25°03'07.50"	046°53'43.80"	12	22.5	5	Degraded forest - inter dune
EL 12	25°03'09.96"	046°53'38.58"	12	21.7	8	Degraded forest - inter dune
EL 13	25°03'10.07"	046°53'38.82"	12	22	7	Degraded forest - inter dune
EL 14	25°03'07.90"	046°53'39.67"	19	7.5	3	Degraded forest - inter dune
EL 15	25°03'08.40"	046°53'43.06"	14	4.7	3	Degraded forest - inter dune
EL 16	25°03'14.27"	046°53'40.80"	16	2	2	Forest - flat area
EL 17	25°03'06.84"	046°53'44.22"	12	37.7	5	Degraded forest - inter dune
EL 18	25°03'09.62"	046°53'44.42"	21	4.2	3	Forest - flat area
EL 19	25°03'10.76"	046°53'45.14"	20	62.5	10	Forest - flat area
EL 20	25°03'15.80"	046°53'30.40"	26	4.3	5	Forest - flat area
EL 21	25°03'15.90"	046°53'30.48"	12	15.5	7	Forest - flat area
EL 22	25°03'14.58"	046°53'31.20"	12	3.4	3	Degraded forest - dune
EL 23	25°03'14.70"	046°53'31.18"	31	4.6	3	Degraded forest - dune
EL 24	25°03'14.70"	046°53'31.18"	31	7	4	Degraded forest - dune
EL 25	25°03'14.70"	046°53'31.18"	31	3.2	3	Degraded forest - dune
EL 26	25°03'12.52"	046°53'47.26"	11	28	10	Degraded forest - dune
EL 27	25°03'12.51"	046°53'47.06"	16	10	3	Degraded forest - dune
EL 28	25°03'13.11"	046°53'47.14"	14	10.5	5	Degraded forest - dune

Habitat

Table 2 lists the locations of the two sub-populations of *E. cynometroides*, which are near Parcel 3 of the Parc National (PN) d'Andohahela and at Petriky. Both are found in the narrow transitional zone between the humid and sub-arid bioclimatic zones, and with a mixture of humid forest and spiny bush vegetation. The somewhat longer dry season of the Andohahela (Parcel 3) sub-population is perhaps compensated for by its soil type, which retains more water as compared to the sandy soils at Petriky.

At Petriky, *E. cynometroides* grows in a range of habitats including fields, forests, forest clearings, and in the thicket vegetation growing on sand dunes. The dune vegetation is dominated by species that favor arid conditions, including: *Euphorbia intsy* (Euphorbiaceae), *Strychnos spinosa* (Strychnaceae), and *Aloe divaricata* (Asphodeliaceae). In forest settings, *E. cynometroides* is associated with littoral forest species *Gaertnera arenaria* and *Coffea commersoniana* (Rubiaceae), *Eugenia scottii* (Myrtaceae), *Phylloxylon xylophylloides* and *Calliandra scottiana* (Fabaceae), and *Astrotrichilia elliottii* (Sapindaceae).

The location, size, and habitat of each individual *E. cynometroides* at Petriky are presented in Figure 2 and Table 3. All but one of the individuals grows in a small area in the northeast of the forest, and the outlier is located to the southeast of the site.

Pollination and seed dispersal

The flower characteristics of *E. cynometroides* (size, irregular shape, presence of nectar, and yellow petals) indicate that this plant is pollinated by insects. We observed large bees, *Xylocopa calens* (Anthophoridae), gathering flower nectar, and thus, distributing pollen and presumably fertilizing flowers.

During the 2000 to 2002 observations, only one of the trees at Petriky was recorded to flower (No. 02). This was the isolated individual in the southern portion of the site. This tree produced seemingly viable seeds, suggesting that self-fertilization is possible. The small number of flowering individuals (one out of 27 mature individuals) suggests that they may not flower annually.

Once pollinated, the fruits develop rapidly reaching their mature size in just 5 weeks (Fig. 3), although ripening takes longer (2 months). The average length of seeds is 8.6 ± 0.4 mm (n=30). Table 4 lists the number of seeds contained within a sample of 500 pods collected from six trees. Seed production is low, and there was no relationship between seed production and DBH or seed production and tree height.

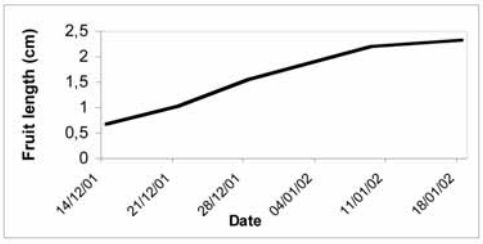

Figure 3. Growth rate of fruits of *Eligmocarpus cynometroides* (n= 48).

Table 4. Number of seeds per individual tree for a sample of 500 fruits.

Tree number	Number of seeds in 500 fruits
n°2	29
n°4	10
n°5	105
n°7	17
n°8	35
n°10	19

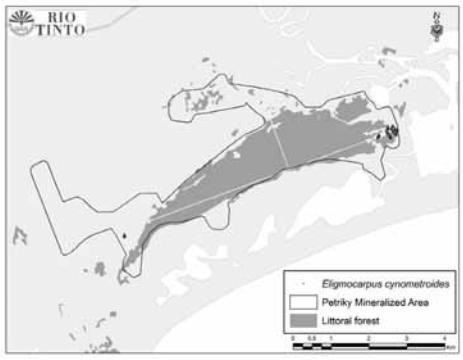

Figure 2. Distribution of *Eligmocarpus cynometroides* at Petriky.

The method of seed dispersal of *E. cynometroides* is unknown. The characteristics of the fruit (dry and fibrous) suggest that it is not dispersed by animals, and its size suggests that it is also not wind dispersed. Based on our observations at Petriky, the ripe fruits seem to simply fall to the ground. During the two weeks of observation at this site, no potential seed dispersers were recorded with the exception of the mouse-lemur *Microcebus murinus*, which was observed eating the upper side of the fruit close to the peduncle, and occassionally other parts (J.-B. Ramanamanjato, pers. comm.). Of 918 fruits examined, 707 had been predated by *Microcebus* (Fig. 4).

Germination and regeneration

In the field, germination of *E. cynometroides* is rarely observed. Among 27 trees examined at Petriky in 2001, seedlings were noted near only three trees (no. 10, 13, 17). Moreover, no more than 10 of these seedlings were alive one year later.

To investigate the best conditions for germination *ex-situ*, we sowed 100 seeds from two different sources (tree no. 2 and tree no. 10) under a range of conditions. Planting seeds of various trees in topsoil from Petriky, Mandena, or from the littoral forest which is mixed with laterite resulted in very low germination rates of less than 5%. However, soaking the seeds for 48 hours in cold water increased germination rates to 43%.

The demography of this tree species, for which DBH is taken as an indicator of age, is shown in Figure 5. It indicates that individuals occur in a variety of size classes. It would seem that *E.*

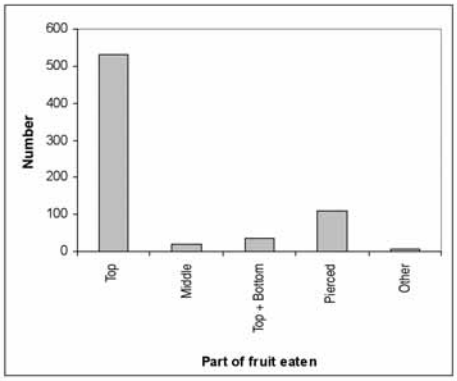

Figure 4. Classification of the fruit parts of *Eligmocarpus cynometroides* eaten by Microcebus (n = 707).

cynometroides grows very slowly. When tree No. 5 (DBH = 62.4 cm) was illegally felled, 600 growth rings could be counted.

Risk of extinction

Although mature plants of *E. cynometroides* can survive in highly degraded habitats, it is a forest species. Given that the species is not included within any protected area, and that the rate of loss of primary vegetation outside protected areas is high in southeastern Madagascar due to charcoal production, shifting cultivation, and uncontrolled fires, we estimate that the population loss of this species will approach 100% within the next 100 years if no preventive measures are taken. The Petriky sub-population has a small area of occupancy (Fig. 2) and could easily be eliminated by current anthropogenic pressures. Moreover, this sub-population occurs within the proposed QMM mining pathway. This tree is also threatened by selective timber exploitation, as its wood resembles that of rosewood (*Dalbergia* sp.). Since 2003, four of the 27 individuals at Petriky (numbers 5, 11, 12, and 17) were felled for timber.

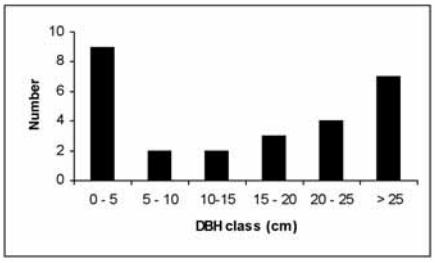

Figure 5. Distribution of size classes of *Eligmocarpus cynometroides* at Petriky, based on DBH classes.

Population attributes

The distribution of *E. cynometroides* is mapped in Figure 1. The population consists of two sub-populations: one near parcel 3 of the PN d'Andohahela, and the other at Petriky. The occurrence of the entire population is 77 km^2. The sub-population at Petriky has been studied in detail, and as of November 2004, contains 23 individuals that occupy an area of only 0.01 km^2.

Based on the information presented above, we classify *E. cynometroides* as Critically Endangered (CR) because of its high predicted rate of decline due to a number of significant threats, its small number of sub-populations, its small area of distribution, its low abundance, and its small area of occupancy.

A Conservation Strategy for *Eligmocarpus cynometroides*

Eligmocarpus cynometroides is likely to become extinct in the near future without the intervention of immediate conservation action. Table 5 presents the actions and associated targets we recommend for the conservation of this species, and the progress that has been made to date towards its effective conservation.

Conclusion

Eligmocarpus cynometroides is a critically endangered tree species with a very restricted distribution that occurs within the narrow band of transition between humid and sub-arid zones in southeastern Madagascar. Better knowledge of the biology and ecology of this species are needed to implement a conservation and priority strategy. Not only is the Petriky Forest important to the future survival of *E. cynometroides*, but it is one of the few remaining natural vegetation fragments within this climatic transition zone, and it is therefore home to several other locally endemic species of plants and animals. This site is of considerable importance for ecological research.

Table 5. Conservation Action Plan for *Eligmocarpus cynometroides*.

Conservation actions			Target	Progress to date
1. Reduction of threats to existing populations	1.1. Promoting public awareness	1.1.1. General public	Increase the awareness among the people at Petriky concerning the importance of *E. cynometroides*.	Since 2003, several awareness-raising workshops have been conducted at Petriky concerning both the importance of *E. cynometroides* and the threats to its habitat.
		1.1.2. Business	Higher management of QMM convinced of the conservation importance of *E. cynometroides*.	Increasing awareness of QMM's management during their visits to the tree nursery at Mandena and also in reports.
	1.2. Direct control of threats	1.2.1. Fire control	No fires within the habitat of *E. cynometroides* at Petriky.	Worked with local people to develop and implement local rules (called *dina*) to control the use to fire.
		1.2.2. Control of timber exploitation	No more trees of *E. cynometroides* cut at Petriky.	Worked with local people to develop and implement dina to control selective exploitation forest trees. Program in place to provide alternative sources of timber and firewood at Petriky.
		1.2.3. Establishment of new conservation areas	The part of Petriky occupied by *E. cynometroides* is set-aside as a conservation area.	Lobbied to ensure that the QMM exploitation of Petriky excludes the block of forest containing *E. cynometroides*.
2. Reinforcement of existing population			Reinforce the population at Petriky to attain 500 individuals.	40 saplings have been planted at Petriky with a survival rate after 17 months of 80%.
3. Location of new populations			Locate at least three new populations by searching potential habitat within known area of occupancy.	In 2007, proposition to search remaining areas of suitable habitat between 24° 59' and 25° 05' S.
4. Creation of new populations (translocation)			Create new sub-population of *E. cynometroides* close to Petriky if a suitable and secure site can be found.	In 2007, proposition to translocate saplings to the conservation zone at Ambatotsirongorongo.
5. *Ex situ* conservation	5.1. Growing plants	5.1.1. Scientific collections	50 plants growing in scientific collections.	Three saplings planted in the Parc Botanique et Zoologique de Tsimbazaza in 2005.
		5.1.2. School and other community gardens	25 plants planted in schoolyards around Petriky.	In 2006, three saplings have been planted in the schoolyard at Loharano.
	5.2. Seed bank		A minimum 1000 seeds preserved in the Millennium Seed Bank at KEW and the SNGF Seed Bank in Antananarivo.	In 2006, 100 seeds were deposited each in the seed banks at KEW and SNGF.

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