Deforestation and apparent extinctions of endemic forest beetles in Madagascar

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Knowledge of tropical insects is particularly limited. One exception is the fauna of Singapore, which has been studied since 1819 (Brook et al. 2003). The historically documented extinction rate is 34% for birds, 43% for mammals, 26% for vascular plants and 38% for butterflies (Brook et al. 2003). Again, there is no difference between vertebrates, plants and butterflies.

Here, we examine apparent extinctions in a well-studied group of ca 60 endemic forest-inhabiting dung beetles in Madagascar. Our extensive sampling across Madagascar during 2002–2006 yielded 54% of the described species, as well as four new ones. We analyse the factors that explain whether a previously known species was included in our samples or not. We refer to the latter species as ‘apparently extinct’ for short. We are particularly interested in examining whether regional forest loss may explain apparent extinctions. The annual rate of deforestation has been 1.4% between 1953 and 1993 and 2.0% between 1993 and 1999 (Dufils 2003), and hence roughly half of the forest cover has been lost in the past 50 years. The endemic forest dung beetles have small ranges (Viljanen et al. in preparation), as have many other taxa in Madagascar (Wilné et al. 2006), and hence it is possible that many species have become (effectively) extinct due to a regionally high rate of forest loss.

2. MATERIAL AND METHODS

The taxonomy of the endemic tribe Helictopleurini (Cuprinae, Scarabaeidae) is well known (Lebis 1960; Paulian 1986 and other papers; Montreuil 2005, in press and other papers). We recorded the sampling information for all specimens in the main collections of the Paris National Museum of Natural History. The collections include 51 species for which locality information is available, sampled from 126 distinct localities (figure 1a) during 1875–1990 (3541 specimens). Half of the specimens have been collected prior to 1926 but almost none since the mid-1970s. The remaining nine species either lack sampling information (three species) or there are no specimens in Paris. We suspect that several of these latter species should be synonymized with the better known species.

During the years 2002–2006, we sampled Helictopleurini using dung and carrion-baited traps. Our sample of 4880 specimens was collected from 61 localities (figure 1b), including larger samples from Ranomafana National Park (NP), Masoala NP, Makira Reserve, Andasibe NP, Ambila-Lemaitso, Manombo reserve, Isalo NP, Zombitse-Vohibasia NP and Andaholo NP. Smaller samples were collected by the personnel of forest reserves in 52 localities across Madagascar using trapping kits provided by us. Our samples include four new species (Montreuil 2005, in press).

A single map of forest cover change between the years 1970, 1990 and 2000 was provided by Conservation International (CI) at approximately 30 m resolution (Harper et al. 2005, unpublished data). This map was reclassified to single out forest cover for the year 2000. The main sources of data were the Inventaire Écologique et Forestaire National (IEFN) classification of Landsat Thematic Mapper 5 data for the year 1993 and estimates of forest cover for the year 1999 carried out by the Joint Research Centre (JRC)–Space Application Institute, Ispra, Italy, using SPOT-4 data. Where possible, CI used additional SPOT images to add detail in the regions covered by dense cloud in the original IEFN and JRC images. CI also provided a digitized version of the 1953 forest cover map produced by Humbert et al. (1965), rasterized at the same resolution as the 2000 map. The original map was produced using aerial photographs and ground truthing. The 1953 study seems to have focused on mapping major forest blocks, as the map does not contain small fragments in remote areas that were present in the satellite images. We assume that the additional small fragments present in 1970 had not grown in the intervening years, and hence any forest cover present in 1970 but absent in the 1993 map was added to the latter.

The maps for 1953 and 2000 were summarized as percentage of forest cover in grid cells of 0.1° resolution (11.2 km at the equator). Using these maps, we calculated the extent of forest cover within...
3. RESULTS

Out of the 51 species sampled prior to our work and for which locality information is available, we have sampled 29 species but failed to collect 22 other species. We ran stepwise logistic models with the explanatory variables described in §2 to explain apparent extinctions. Relative forest loss ($F_{r,2000}/F_{r,1953}$) entered the model first (table 1). The other two variables that were selected were distance to our sampling localities ($D_x$) and PC1. An equally good model was obtained if PC1 was dropped from the candidate variables, in which case the last year when the species had been sampled was selected at 5% level.

Since the uncollected species cannot be included in our molecular phylogeny (Koivulehto et al. in preparation), we cannot critically assess possible phylogenetic bias in apparent extinctions. However, we may use the eight taxonomic species groups of Lebis (1960) as a proxy, as these groups match the clades in the molecular phylogeny reasonably well. There is no difference in the fraction of apparently extinct species among the morphological groups ($p = 0.46$).

Most of the 22 species that we have not collected have been previously collected from only one ($n = 9$) or two ($n = 6$) localities, widely scattered across Madagascar (figure 1c). The most striking exception is *Helictopleurus undatus*, which has been collected from 27 localities across much of Madagascar. A closer examination shows that since 1950 this species has been restricted to a small region in the northeast (figure 1d), giving the impression that it gradually disappeared from its former range during the twentieth century.

4. DISCUSSION

*Helictopleurini* are mostly relatively large, many species have colour-patterned elytra and are diurnal and easy to sample with dung and carrion-baited traps. For these reasons, *Helictopleurini* have been relatively well collected in the past. In our specialized sampling, only four new species were discovered, all of which appear to be very localized and rare. Four species compose only 7% of the described species, which is a small percentage for tropical insects in as large and diverse an area as Madagascar. We conclude that *Helictopleurini* have been sufficiently well collected in the past to warrant this analysis.

The best predictor of whether a species was collected by us or not was relative forest loss within its past range. The estimated remaining forest cover from 1953 to 2000 ranges from 10 to 60% for different species (figure 2). Species for which less than one-third of the 1953 forest cover remains tended to be apparently extinct. The other factors that had a significant effect on species’ occurrence...
tracking forest loss and fragmentation with a time lag to deforestation, and the occurrence of species may have been on decline already in 1953 due to the environment may better reflect species' responses. Furthermore, in many regions forest loss from 1953 to 2000 was a continuation of a longer process. Some species may have been on decline already in 1953 due to deforestation, and the occurrence of species is tracking forest loss and fragmentation with a time lag (Hanski & Ovaskainen 2002).

Forest loss and fragmentation is associated with an increasing pressure on lemurs, the most important dung producers in Madagascar. According to the fossil record, 16 large-bodied lemur species have gone extinct since 2004. The long-term decline of H. undatus (figure 1d) may be due to high degree of resource specialization. Unfortunately, nothing is known of its biology and by now this once exceptionally widespread species may already be extinct.

Madagascar has large numbers of species with narrow geographical ranges (Wilmé et al. 2006). In this situation, and taking into account that Madagascar has already lost most of its forests, very large numbers of insects and other poorly known taxa may already be extinct, effectively extinct or rapidly heading towards extinction due to past and current deforestation. The current plans to expand the protected area network to six million hectares will amount to ca 10% of the original forest cover. Species–area considerations suggest that this will protect roughly half of the species (MacArthur & Wilson 1967). Our results are consistent with this prediction.

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Figure 2. Plots showing whether a species has been collected by us (open symbols) or not (closed symbols, ‘apparently extinct’ species), depending on relative forest loss within the range of the species plotted (a) against the last year when the species was collected prior to our sampling and (b) against the past commonness of the species (PC1).


Humbert, H., Cours Darne, G., Besaire, H., Blasco, F., Legris, P. & Riquier, J. 1965 Carte International du Tapis Vegetal et conditions ecologies a 1/1.000.000. Extrait des Traveux de la Section Scientifique et Technique de L’Institute Français de Pondichéry, France. Digitized by the Center for Applied Biodiversity Science, Washington, DC.


