

Short note

## Breeding habitat and conservation priorities in *Pterodroma barau*, an endangered gadfly petrel of the Mascarene archipelago

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Received 17 December 1998; received in revised form 23 June 1999; accepted 25 June 1999

### Abstract

The endemic Barau's petrel (*Pterodroma barau*) is restricted to the island of La Réunion in the Mascarene archipelago where it breeds on the upper slopes of the highest mountains in areas that are virtually inaccessible to humans. Although the species is considered to be critically endangered, little is known about its biology and the actual threats for Barau's petrel on its breeding grounds have never been investigated. In this paper we report data that were collected during the first ever visit of a Barau's petrel colony. The species breeds underground in upland elfin forests between 2400 and 2700 m above sea level. A thick, undisturbed, humus layer appears to be a prerequisite to burrow establishment, which implies that the species may be especially susceptible to trampling by humans or other large vertebrates. We found evidence of past exploitation of Barau's petrel by humans. In addition, the colony is inhabited by three, possibly four, species of introduced commensals, including *Rattus* sp., which imposes predation on eggs and chicks and may affect the breeding success. We stress the need to establish control campaigns to eradicate potential predators from the nesting colonies and long-term monitoring projects for the Barau's petrel before it undergoes irreversible population decline. © 2000 Elsevier Science Ltd. All rights reserved.

**Keywords:** Gadfly petrel; *Pterodroma barau*; Conservation; Island; La Réunion; Mascarene archipelago; Predation; Introduced animals

### 1. Introduction

Tropical gadfly petrels *Pterodroma* spp. have recently attracted considerable attention from conservation biologists. Most species are endemic to oceanic archipelagoes (Warham, 1990), where they might be vulnerable to human-caused alterations (e.g. habitat destruction, predation by introduced vertebrates) that characterize most, if not all, island ecosystems (Vitousek, 1988). Tropical gadfly petrels are active at night on their breeding-grounds and some species nest in remote mountain locations at high elevation. As a consequence, information on their breeding ecology and possible problems encountered at nesting sites is often lacking. Assessing extinction risk and determining appropriate conservation plans thus remain a challenge in many species.

The Mascarene archipelago, in the southwestern Indian Ocean, is unique among the oceanic archipelagoes that are inhabited by gadfly petrels in that its two endemic species (Mascarene petrel [*Pseudobulweria aterrima*] and Barau's petrel [*Pterodroma barau*]) are restricted to the island of La Réunion (Jouanin, 1987). Both petrel species are considered to be "critically endangered" based on their restricted range and low abundance, with the elusive Mascarene petrel being one of the most endangered seabirds in the world (Collar et al., 1994). By contrast, the Barau's petrel is still commonly observed around La Réunion from September to April (Jouanin and Gill, 1967; Barré and Barau, 1982). However, recent studies suggested that the total breeding population size is small, not exceeding 3800 pairs and being possibly as low as 2200 pairs (Bretagnolle and Attié, 1991; Stahl and Bartle, 1991). There has been some growing concern about a possible population decline over the last few years, although insufficient data are currently available to determine the factors that might account for changes in population size. In particular, virtually nothing is known about the breeding of

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Barau's petrel. This is mostly because this petrel breeds on the upper slopes of the highest mountains of La Réunion in remote areas that are difficult to access (Jouanin and Gill, 1967; Brooke, 1978).

It is recognized that introduced animals may have major impacts on reproductive success in populations of gadfly petrels living on oceanic islands, mostly through habitat destruction or direct predation on adults and chicks (Cruz and Cruz, 1987). Since the island of La Réunion has been colonised by a suite of mammals, including rats, goats, cats, and dogs (Probst, 1997), the possibility that introduced animals may have harmful effects on breeding Barau's petrels clearly needs to be evaluated.

In 1995, one of us (JMP) found a new colony of Barau's petrel in areas previously never visited by researchers (Probst et al., 1995). We report here the new data available on the breeding habitat and investigate the actual and potential threats for the Barau's petrel on its breeding grounds with regards to direct and indirect impact of humans. This information should aid in determining conservation priorities that might help protecting this rare seabird before it undergoes irreversible population decline. It also particularly illustrates how species that breed in apparently remote and safe breeding areas can in fact be at risk. This exemplifies the problems that are involved in assessing extinction risks in long-lived species when major threats can be hard to detect without knowledge of habitat requirements and monitoring of habitat quality.

## 2. Study area and methods

La Réunion, located 800 km east of Madagascar, is the largest island (2512 km<sup>2</sup>) of the Mascarene archipelago, which also comprises Mauritius and Rodrigue. The island consists of two coalescing shield volcanoes, extinct Piton des Neiges (the highest point in the whole Indian Ocean, 3069 m above sea level) and still active Piton de La Fournaise (2560 m a.s.l.) (Gillot et al., 1994). Two petrel colonies are known to occur in very steep cliffs of the Piton des Neiges, between 2400 and 2700 m a.s.l. (Brooke, 1978; Bretagnolle and Attié, 1991). However, none of these colonies has ever been visited by researchers since they are located in inaccessible mountain areas. In January 1995, we collected data from a newly discovered colony in Grand Bénare, a mountain peak located 10 km west of Piton des Neiges summit, though part of the same massif. The study colony was found along the ridge joining Grand Bénare to Piton des Neiges at ca. 2400 m elevation, immediately above an area called Col du Taibit. The entire area has a very rough topography and is characterized by series of vertical cliffs, sloping plateaus and very narrow ridges. To assess nest density, we counted all burrows in a

100 m<sup>2</sup> quadrat that was laid out in the only area where the ground was relatively flat. Additionally, we made visual estimates of burrow density in relatively inaccessible places for a total area surveyed of ca. 9000 m<sup>2</sup>. This included a plateau (2000 m<sup>2</sup>), a ridge (3400 m<sup>2</sup>), and a pass (3600 m<sup>2</sup>). Great caution was taken to disturb the colony area as little as possible as burrowing petrels are known to be susceptible to trampling. To determine characteristics of Barau's petrel burrows, the length, width and height of the entrance of 100 burrows were measured using a tape. We searched the vicinity of nests for signs of predation by introduced mammals (droppings, bones, predated eggs or chicks). Finally we collected osteological materials that were found in what appeared to be a former human settlement to confirm past exploitation of the colony by humans. This material has been examined and identified by Cécile Mourer-Chauviré from the Centre des Sciences de la Terre, Université Claude Bernard, Lyon, France.

## 3. Results and discussion

### 3.1. Breeding habitat and potential threats

The colony was associated with upland elfin forest (Fig. 1) in which endemic shrubs such as *Philippia montana* (Ericaceae), *Hypericum lanceolatum* (Guttiferae), *Phyllica nitida* (Rhamnaceae), and *Sophora denudata* (Fabaceae), and *Erigeron karwinskianus* (Asteraceae) an introduced herbaceous species, were the dominant plants. On the plateaus, where humus can accumulate >0.5 m depth (Cadet, 1977), the vegetation was very dense and reached 4–5 m high. By contrast, ridges had a sparser and lower vegetation on a thin (<0.2 m) and discontinuous soil layer. Mean burrow density was 0.11 burrow/m<sup>2</sup> ( $n = 1000$  burrows). There was considerable



Fig. 1. Photograph of an adult Barau's petrel at a nest entrance. Note the endemic shrub *Sophora denudata* (Fabaceae) in the foreground.

variation among the three habitats encountered across the breeding grounds ( $\chi^2 = 10.54$ ,  $df = 2$ ,  $p < 0.01$ ), with estimated densities of 0.35 burrows per  $m^2$  in the plateau and 0.05 and 0.03 burrows per  $m^2$  in the pass and the ridge, respectively. Burrow density was at its highest in our 100  $m^2$  quadrat in which 62 burrows were found. Petrels dug burrows in the thick humus layer ( $> 0.5$  m) that accumulated on the plateau and directly in loose soil in the other habitats. Two nests (out of a total of 1000) were located in crevices under rocks. Burrow characteristics varied little among the plateau, the pass and the ridge (one-way ANOVAs, length:  $F_{2, 99} = 1.15$ , *NS*, width:  $F_{2, 99} = 0.21$ , *NS*, height:  $F_{2, 99} = 0.05$ , *NS*), being on average 98 cm long, 19 cm wide, and 11 cm high. These results suggest that a thick humus layer may be a prerequisite to burrow establishment in Barau's petrel. This implies that any disruption of the forest canopy on the breeding grounds is likely to reduce habitat availability through rapid erosion of soil surface in mountains with heavy rainfall ( $> 3$  m/year; Cadet, 1977). Underground nesting in loose soils also suggests that the species, like other gadfly petrels (see e.g. Cruz and Cruz, 1987), may be especially susceptible to trampling by humans or other large vertebrates. For example, feral goats were observed at close proximity to the study colony (ca. 1 km; J.M. Probst, personal observation) and it is well known that goats can have devastating effects on vegetation and soils, in particular on oceanic islands (Hobbs, 1996). No evidence of browsing by goats was found in the colony and its vicinity at the time of the study. However, feral goats may still threaten the long-term viability of this population since they are currently increasing in number (J.M. Probst, personal observation). Upland elfin forests are among the least altered ecosystems of the Mascarene archipelago (Thébaud and Strasberg, 1997). Unfortunately, they have recently undergone major transformations in relation to the rapid development of a nature-related tourism (Thébaud, 1993). Tourist paths, access to viewpoints, and mountaineering activities have flourished in the most remote areas of La Réunion, including the upper slopes of Piton des Neiges. They contribute to the opening-up of many areas that are not yet easily accessible, and are thus likely to affect directly (e.g. visits) or indirectly (e.g. path-associated landslides, erosion) the Barau's petrel in the long-term. Additionally, they may act as invasion corridors, facilitating the access of otherwise undisturbed forest tracts by introduced animals.

### 3.2. Evidence for past exploitation of Barau's petrel by humans

An abandoned camp site was discovered in the breeding site. This settlement consisted of two 0.5 m. high stone walls entirely covered with humus and well-developed

vegetation. Around these walls, several human artefacts were found. These includes remains of a hearth, a metallic knife, pieces of a whetstone. Furthermore, goat bones were found together with bones of rats *Rattus* sp., Barau's petrels and Audubon's shearwaters (*Puffinus lherminieri*). Although we are unable to date with precision the presence of humans in the nesting colony, the importance of the vegetation covering the walls suggests that the camp has been abandoned for at least a century. In the only reference to Barau's petrel before the mid-20th century, Bory de Saint Vincent (1804) reported that local people used to eat chicks of "Taille vent" (creole name for Barau's petrel) and other procellariids at the turn of the 19th century. Our findings are consistent with these observations. Evidence indicates that our study colony was formerly exploited by local hunters for food resources. This may explain why, despite its current inaccessibility to humans, the colony is inhabited by at least three species of introduced human commensals (the mouse [*Mus musculus*], a shrew [*Suncus murinus*] and one, possibly two, species of rat). However, it is possible that the colony was invaded well before human occupation. Rats were presumably introduced to the island during the early colonial period (1650–1750) and they now occur in all habitats including the most pristine areas which they colonised without human assistance (Moutou, 1980). At the time of our visit, four eggs and two downy chicks had been recently predated. Although no predation event had been seen, there can be little doubt that rats are responsible for the observed losses of eggs and young nestlings. It is, therefore, reasonable to assume that Barau's petrel suffer reduced recruitment as a consequence of predation on breeding grounds by introduced mammals, as it has been observed in other gadfly petrel colonies where rats have been introduced (Imber, 1984; Simons, 1985).

## 4. Conclusions and recommendations

Factors other than the impacts of tourism and introduced mammals are likely to affect the population dynamics of the petrel. For example, in the last 40 years, urban development has led to a dramatic increase in the number and intensity of streetlights and other bright lights which confuse large numbers of fledging Barau's petrels on their way to the sea at night. Grounded birds are usually killed by vehicles or predated by dogs and cats (C. Thébaud and M. Le Corre, personal observations). Although this may represent an important source of mortality, a recent public awareness campaign has been successfully implemented on La Réunion and 3–400 birds have been rescued and released at sea every year since 1997 (M. Le Corre, unpublished data).

Our data provide circumstantial, but in our view compelling evidence, that Barau's petrel is at risk owing

to direct and indirect effects of human activities. Although we are currently unable to provide scientific evidence that the population is declining, we follow Cree et al. (1995) when they recommend that potentially damaging environmental activities should be avoided when there is reason to assume harmful effects. Currently, the pressure for tourism to remote areas of La Réunion is increasing (Thébaud, 1993). This suggests that conservation efforts should include strict regulation of human activities in the vicinity of the colonies, particularly hiking and mountaineering activities. Control campaigns should also be undertaken to eradicate potential predators from the nesting colonies; methods that have already been implemented in other islands are likely to be effective in the case of the Barau's petrel (Cruz and Cruz, 1987; Taylor and Thomas, 1993).

Risk assessment of threatened species is often fraught with "assumptions of ignorance" owing to the lack of appropriate data (Mace and Lande, 1991). For most species, changes in population size cannot be accurately estimated and assessment of extinction risks usually relies upon identifying geographic range contractions or obvious declines in habitat quality throughout a species range. In long-lived and elusive species such as gadfly petrels, such changes in range or habitat quality can be especially hard to detect. Thus, it is vital to incorporate prior information as well as uncertainty caused by lack of information into risk assessments of such species. Declines in habitat quality due to interactions with introduced organisms have clearly translated into long-term changes in population size, structure or distribution of many island organisms (Vitousek, 1988). Therefore, if we wish to preserve threatened species in general, and Barau's petrel in particular, it is important to distinguish such interactions and to delineate the ways that could reduce their impact before it is too late.

### Acknowledgements

We thank Direction Régionale de l'Environnement de La Réunion (DIREN, Ministère de l'Environnement) and Société Réunionnaise des Amis du Muséum for permission to study Barau's petrels and financial support. Fieldwork was made possible by the efforts of Pascal Colas from the Maison de La Montagne. We also thank Dominique Strasberg, Roger Safford, Christian Jouanin and two anonymous referees for constructive comments on the manuscript.

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