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ENDANGERED SPECIES IN LOW ELEVATION CLOUD FOREST ON GAU ISLAND, FIJI

DICK WATLING AND A. N. GILLISON

Gau (pronounced "ngau" with a soft "ng") is Fiji's fifth largest island, with an area of 140 km^2. Its rugged inland topography comprises the northern upland, which is dominated by the twin summits of Delaco (715 m) and Delacoboni (705 m) and the main ridge running southward. Fifty-five percent of the island supports dense rain forest, while the rolling country of the eastern coast and the island's extremities are covered with grass or reed, with some recently established plantations of Caribbean pine.

In view of Gau's location (Figure 1) less than 80 km from Suva, Fiji's capital on the island of Viti Levu, it is surprising that Gau's flora has been the subject of only superficial collection and no research. No publications exist on the flora of Gau. Although the botanist A. C. Smith visited Gau island in 1953, it was clearly a very brief visit, for certain interesting species, notably *Physokentia rosea* which is locally abundant on the island, are recorded in his *Flora Vitiensis Nova* as endemic to Viti Levu (Smith 1979). No records seem to exist of other botanists visiting Gau, although some plant specimens were collected during the visit of HMS *Herald*, a British Royal Navy survey ship, in 1854 and 1855.

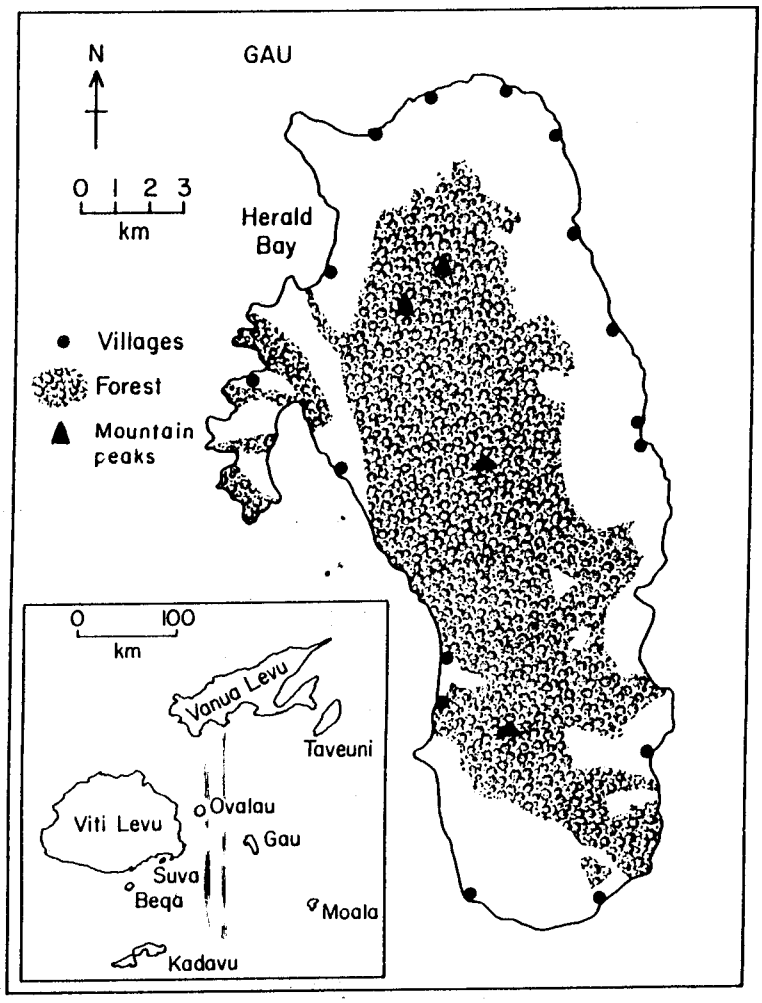

FIGURE 1. *Gau and its location within the Fiji Islands.*

Until the senior author initiated a search on Gau in 1983 for the enigmatic Fiji petrel (*Pseudobulweria macgillivrayi*), the vertebrate fauna was only marginally better known, following the two visits of HMS *Herald*, and the visit of the Whitney South Sea Expedition in February 1925, which made a small collection of birds. Watling's works (1985a, b; 1986a, b) provide records and observations of the terrestrial fauna of Gau.

Although broad regional climate patterns can be interpolated for Gau, there are no actual meteorological data (i.e., rainfall) available from the island.

CLOUD FOREST IN FIJI

With the exception of Ash (1987) and Gillison (1992 and in press), there has been no specific research on tropical montane cloud forest (TMCF) in Fiji. Ash (1987) studied the vegetation and microclimate of a stunted ridge-top cloud forest on the island of Taveuni. In a general comment he stated: "The extent of cloud-forest in Fiji is very limited, occupying only the ridges on the highest peaks. In Taveuni TMCF occurs along about 10 km of the main range and in the other islands it is restricted to 1–2 km of ridges around isolated peaks which are separated by 30–100 km."

Berry and Howard (1973) undertook Fiji's first national forest inventory and described 41 forest types based on interpretation of aerial photographs, structure, and floristic composition. Their study distinguished "ridge thicket" as a distinct forest type "along the top of every major ridge." The trees of the ridge thicket form a dense canopy of about 7 m; the thicket is difficult to penetrate and the diameters of trees at breast height average 20 cm (Berry and Howard 1973). An examination of the series of 36 forest maps (scale 1:50,000) produced by the inventory indicates that ridge thicket is widespread and in some areas extensive on the islands of Viti Levu and Vanua Levu. Berry and Howard (1973) enumerated just under half of Fiji's estimated total forest area of 838,750 ha (Viti Levu, Vanua Levu, and Kadavu only), and of this 2,523 ha was identified as ridge thicket but with the important rider "the type is widespread but difficult to map because it occurs in long thin strips at the crest of every ridge." Although conjectural at this stage of analysis, there is, in all probability, well over 5,000 ha, perhaps 10,000 ha, of ridge thicket in Fiji's forests.

It is certain that not all ridge thicket as described by Berry and Howard (1973) is cloud forest; it may occur for other reasons, such as inadequate soil nutrients. However, it is within this forest classification that Fiji's true cloud forest will be found. Thus potential cloud forest researchers should initiate their studies with this source of information.

Kirkpatrick and Hassal (1985) and Hassal and Kirkpatrick (1985) investigated the vegetation and flora along an altitudinal transect through tropical forest on the southeast coast of Viti Levu. The transect passed over the summit of Mount Korobaba (422 m), a prominent and isolated breccia cone with stunted vegetation. Kirkpatrick and Hassal (1985) discussed the environmental relationships of the six forest types distinguished along the transect. They noted a strong development of the Massenerhebung effect (Grubb 1971) in eastern Viti Levu. At Mount Tomaniivi in the interior of the island, three of their forest types are to be found only on steep, exposed ridges above 1,000 m, whereas these types occurred below 400 m at Mount Korobaba.

Recent work by Gillison (1992 and in press) describes Fijian cloud forest according to plant functional attributes within the context of a broad range of Fijian vegetation and includes detailed descriptions of cloud forest sites in Viti Levu, Vanua Levu, and Taveuni.

Although Fijian TMCF falls more or less within a predictable biogeographic continuum, it has unique plant ecological features represented by the predominance of ferns, especially large ferns *Cyathea* spp., *Leptopteris*, and climbing Pandanaceae (*Freycinetia* spp.). In this respect it has features in common with some TMCF of Papua New Guinea and New Zealand, but the superabundance of these groups is what provides an ecological signature for Fijian cloud forest. There is no immediate explanation of this phenomenon other than perhaps that of an "ecological release" of such groups within a relatively impoverished flora (about 2,900 vascular plant species for the Fiji group).

Although data are insufficient to determine the climatic limits for Fijian cloud forest, these, in general, fall within the upper limits of megatherm to mesotherm/microtherm (Gillison, in press). The environmental envelope can be approximated within a range of 10°–20° C mean annual air temperature, where annual rainfall exceeds 3,500 mm and where the distribution of annual rainfall is not strongly

seasonal (Figure 2). No data are available for mist interception, which may be a critical component for the establishment and survival of bryophyte and pteridophyte assemblages. Total precipitation (mist + rainfall) data are urgently needed to better define the physical environmental boundaries for cloud forest in Fiji.

CLOUD FOREST ON GAU ISLAND

Gau island may prove an ideal location to investigate the relationship between Fiji's "stunted ridge thicket" and true TMCF as alluded to earlier, because of the short distances and low altitudes involved. Spur ridges on Gau's eastern and southern (windward) coasts start developing a stunted ridge thicket on any exposed ridge close to the shoreline. The stunted vegetation can form a continuum along ridges up to the central ridge and summit.

The uplands of Gau are renowned for their shroud of clouds. Although the summit is only 715 m, the ridges over 200 m intercept the southeast trade winds which blow persistently for up to 8 months of the year. The buffered coastal maritime climate, together with the frequent cloud interception, appears to be responsible for producing the cloud forest at a very low altitude on Gau (Figure 3).

The stilt-rooted palm (*Physokentia rosea*), previously regarded as endemic to "dense forest and ridge forest on Viti Levu at altitudes of 750–1,120 m" (Smith 1979), was found to be locally abundant on Gau at elevations as low as 250 m, with some individuals at even lower elevations. A similar altitudinal shift was observed for the attractive orchid *Dendrobium mohlianum*.

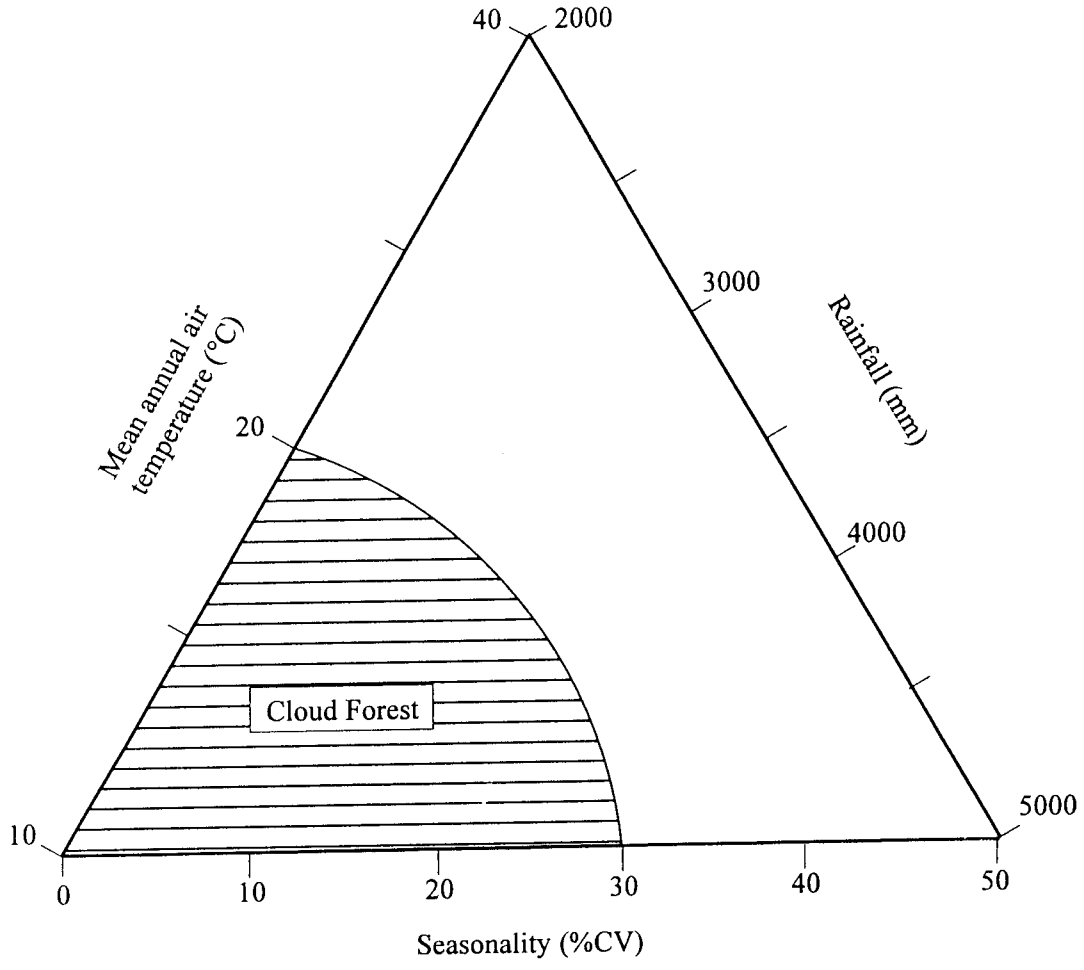

FIGURE 2. *Approximate climate envelope for cloud forest in Fiji.*

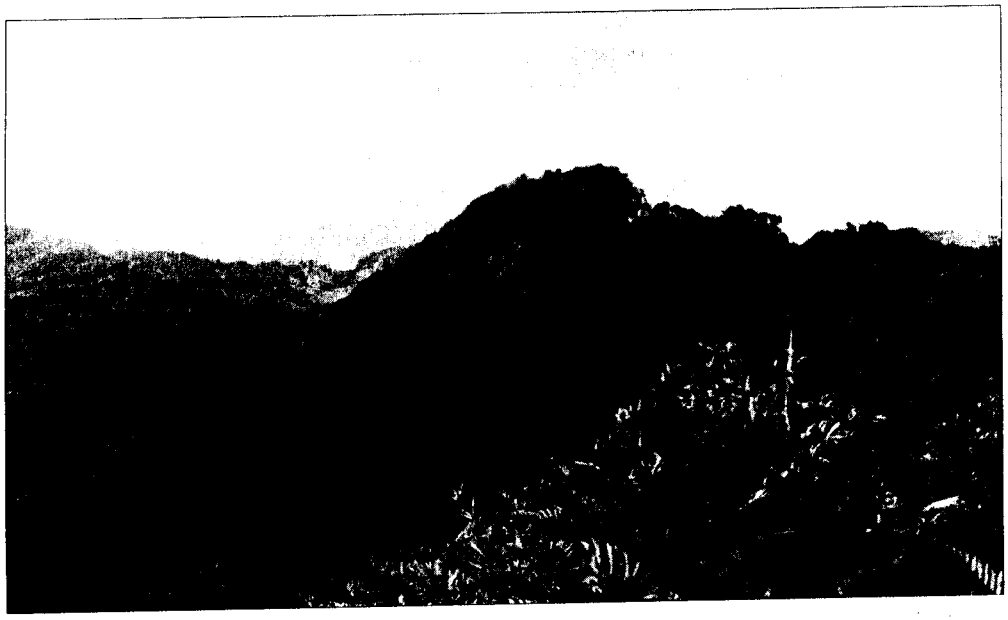

FIGURE 3. *Cloud forest near the summit of Gau at 600 m.* Photo by Dick Watling.

CLOUD FOREST ORIGINS

It is generally accepted that cloud forest flora show taxonomic affinities with continental taxa at mid-to-high latitudes that are adapted to long-distance dispersal, mainly by wind (cf. Smith and Cleef 1988). Despite this likely source there are other factors which may play a significant role in the origins and maintenance of cloud forest flora in islands. These include previous evolutionary contact with shoreline or littoral flora and the relatively well-buffered humid environments that are common to both.

As with montane plants, many pantropical littoral flora (including saline and freshwater swamps) are adapted to rapid dispersal; many plants in both environments specialize in vegetative mobility. This is advantageous under conditions of episodic "edge" effects brought about by changing environments (e.g., mobile shorelines or fire or strong wind or both; cf. Gillison 1970a, b). One can speculate that rapidly emerging islands will carry with them a suite of littoral taxa which, under the right conditions, could speciate and adapt to upland environments. In Fiji *Casuarina* and *Scaevola* are cases in point.

Littoral taxa from previously cool, postglacial climates would also likely migrate inland and upland with subsequent climatic warming, taking with them remnants of primitive as well as derived taxa (*Casuarina, Agathis, Dacrydium, Podocarpus*). In some island interiors, certain rock substrates, such as raised limestone reefs, continue to support taxa with strong affinities to present-day coral strand flora. In Fiji, an example of this can be found in the Naqalimare limestone massif of Viti Levu.

Despite the potential for spatial change (retreating or advancing forest fronts due to fire or changes in shoreline position), both littoral and cloud forest climates tend to be well-buffered (humid maritime vs. an upland saturated atmosphere). But whereas growth under warm, coastal conditions is likely to be rapid, it is relatively slow in cloud forest. Taken as a whole, cool, humid conditions are more likely to favor refugic sinks where rates of extinction and speciation are such that endemism and alpha diversity exceed those in intermediate lowland zones with more variable habitats.

Implications for Associated Fauna

From the foregoing it can be argued that, as with plant taxa, cloud forest will be among those animal habitats least subject to change over evolutionary time. It is this aspect that is of specific relevance to the Fiji petrel (*Pseudobulweria macgillivrayi*), a seabird known only from the cloud forest of Gau.

THE FIJI PETREL

MacGillivray's or the Fiji petrel was known only from a single specimen collected in 1855 on Gau island during the visit of the survey ship HMS *Herald*. The petrel was not seen again either on Gau or at sea and was reported as either "lost" or extinct.

A search commenced for this "missing" petrel in May 1983. The initial phase spanned 16 months to August 1984 with visits of 1–3 weeks every 2 months. During the first two visits extensive discussions were held with Gau villagers to obtain local information and gauge traditional knowledge. The local name *Kacau* is clearly a petrel in Fijian, but the islanders appeared to have no reliable contemporary knowledge of petrels. Potential nesting habitat was assessed and trails cut across the northern ridge. The presence of petrels on the island was soon confirmed by the discovery of nesting burrows well below the cloud forest, which were subsequently identified as belonging to collared petrels (*Pterodroma brevipes*).

On subsequent visits spotlighting from prominent locations was initiated and then augmented by the use of amplified petrel calls. On 30 April 1984, a single Fiji petrel flew into the light. It was examined, measured, and weighed. The next day the petrel was photographed before being shown to villagers and then released (Figure 4).

Despite seven more spotlighting visits to Gau in the intervening years, no more Fiji petrels have been captured. However, in 1987, a second species of *Pseudobulweria*, the Tahiti petrel (*P. rostrata*), was recorded nesting on Gau (Plant et al. 1989). Because of the increased awareness among the villagers of Gau and visiting ornithologists, the number of observations of the Fiji petrel has risen to eight. The majority of these are juveniles which presumably have just left the nest and are attracted to village lights at night.

Origin of the *Pseudobulweria* Petrels

The Fiji petrel and its five relatives were for many years regarded as a distinct group of Gadfly petrels. However, Imber (1985) argued that they represent a much more ancient lineage, a lineage that diverged from the ancestors of the *Procellaria* (the central lineage of the Gadfly and related petrels) a very long time ago, perhaps during the Oligocene or Miocene epoch (Imber 1985). The *Pseudobulweria* petrels are morphologically heavier and sturdier than the

FIGURE 4. *The Fiji petrel* Pseudobulweria macgillivrayi.
Photo by Dick Watling.

Gadfly petrels, and in this manner resemble the modern *Procellaria* petrels. Unlike the Gadfly petrels, which are agile tree climbers and so can nest at any altitude, *Procellaria* petrels are relatively cumbersome and are solely ridge-top nesters with prominent take-off and landing sites. It is believed by the authors that the Fiji petrel is similar and is nesting somewhere in the cloud forest ridges of Gau. Many hundreds of hours of searching by several researchers and assistants have failed to find any nesting burrows.

With the exception of the Tahiti petrel, which is quite widespread in the Pacific, the three other extant *Pseudobulweria* petrels are very rare and one, *P. rupinarum* from St. Helena, is extinct. In addition to the Fiji petrel, which is quite obviously critically endangered, Beck's petrel (*P. becki*) is known from only two specimens taken more than 60 years ago from the waters off the northern Solomon Islands. The Reunion petrel (*P. atterima*) was "rediscovered" in the early 1970s on Reunion Island and is now known from only three specimens.

The four extant members of the group are tropical species. We speculate that, as with other petrels of procellarian ancestry, they originated in cool southern latitudes. During a glacial maximum they expanded their range into all three tropical oceans, but with the onset of warmer times survive today only in suitable refugia. It is believed that the cloud forest of Gau has provided a stable refuge for the Fiji petrel as well as for the more adventurous Tahiti petrel.

The intriguing question is: Why is the Fiji petrel apparently restricted to Gau? Two possibilities are (1) the low altitude of the cloud forest (perhaps the petrel is averse to flying far over land); and (2) the absence of feral pigs. Feral pigs are a major predator of nesting petrels and can wipe out colonies with ease. Gau is the largest and by far the most diverse island in Fiji without feral pigs. If this has always been the case then this circumstance has profound implications for the flora as well, something well worth investigating.

CONSERVATION OF CLOUD FOREST

Gau

Following the rediscovery of the Fiji petrel on Gau, considerable effort was diverted into conservation measures. These focused more on community awareness and education rather than on attempts to set up a protected area, because:

1. the location of the nesting site or colony is unknown;
2. the uplands are very little used by the Gau villagers (no pig hunting, just some gathering of wild yams), and all intervillage communication is by sea or the coastal road;
3. establishment of "protected areas," a new concept in Fiji, is difficult because of the communal tenure of landholding and the lack of a dedicated government agency to undertake it; and
4. increasing the number of people and paths on the high ridges, in the absence of management, is likely to attract feral cats, a known predator of petrels on Gau, and cause damage to the cloud forest.

Community awareness has been used to engender pride in the *Kacau ni Gau* (Gau petrel) as it is referred to, and this has been very successful. Initially, discussions were held in each village; these were followed with slide presentations and lectures by the National Trust for Fiji and the distribution of a poster and pamphlet. Fiji's domestic airline, Fiji Air, which flies to Gau, has adopted a stylized *Kacau* as the company emblem. The school magazine of the Gau Secondary School is called *Kacau*.

This awareness needs to be continually reinforced, however. Researchers working on Gau are a positive way of doing this, and cloud forest research is greatly encouraged. The research on the Fiji petrel is now intermittent; as much as is considered possible has been done in the opportunistic manner to date. Funds and personnel for the concerted effort which is required are not available, either within government or elsewhere.

Other Fijian Islands

The only protected area in Fiji that is known to have cloud forest is the 1,322 ha Mount Tomaniivi Nature Reserve around the nation's highest peak on Viti Levu. However, it is limited to a ridge of less than a kilometer in length at an altitude of more than 1,200 m. The ridge thicket forest described by Berry and Howard (1973) is classified as a Protection Forest for Department of Forestry management purposes and as such cannot be logged. Enforcement of this policy is currently very poor, nonetheless

there should be little reason for logging this forest type. More damage is likely to occur from forestry roads whose normal location is along ridges.

Protection of representative areas of forest types is poorly developed in Fiji, although it is now receiving attention through recent policy shifts within the Department of Forestry and the creation of a Department of Environment. Cloud forest, however, is receiving no specific attention.

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