VOCAL REPERTOIRE OF THE TAHITI PETREL *PSEUDOBULWERIA ROSTRATA*: A PRELIMINARY ASSESSMENT

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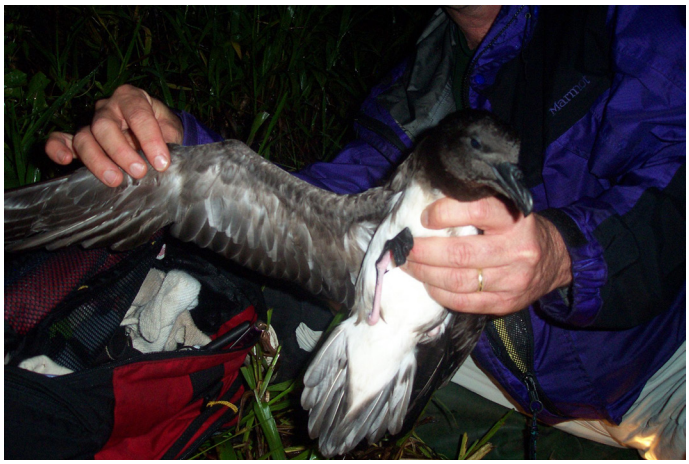

Tahiti Petrel captured on Mt. Lata, December 2002 (Photo: M. Fialua).

SUMMARY

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The Tahiti Petrel *Pseudobulweria rostrata* is a little-known seabird of tropical Pacific islands. Nocturnal at the colony and a burrow nester, the species relies on acoustic signals to communicate. Its vocalizations have not been intensively studied, and our study is the first to analyze the vocalizations made by the Tahiti Petrel in American Samoa. We found two main vocalizations, a ground call and an aerial call. The ground call consists of seven parts that allow variation to occur in duration and frequency in any portion of the call. That would be important to individual and gender variation, which may be critical to finding mates in burrows in the montane rainforest. The aerial call appears to be a condensed version of the ground call, used when approaching the colony in fog and darkness, and may have echolocating qualities. The *Pseudobulweria* genus has uncertain evolutionary relationships among petrels, and vocalization may provide a link to ancestral relationships to help better understand evolution of this group.

Keywords: Tahiti Petrel, *Pseudobulweria*, vocalizations, sonograms, voice, American Samoa, Ta'u, harmonics

INTRODUCTION

The Tahiti Petrel *Pseudobulweria rostrata* belongs to the most endangered seabird genus, with three Critically Endangered species — Fiji Petrel *Pseudobulweria macgillivrayi*, Beck's Petrel *Ps. becki* and Mascarene Petrel *Ps. aterrima.* The Tahiti Petrel itself is Near Threatened, with a tentative population estimate of 10 000 pairs (Villard *et al.* 2006, Gangloff *et al.* 2012, BirdLife International 2013). The Fiji Petrel was rediscovered in 1983 and may number as few as 50 (Watling & Lewanavanua 1985, Shirihai 2009). Beck's Petrel was known from only two specimens until it was rediscovered at sea in 2007, and Mascarene Petrels may number fewer than 100 individuals (Bird 2012). The rarity and difficulty of access characterizing this group limits their study, so very little is known about this tropical genus of petrels. Any additional information, among other things, would help to clarify the phylogeny of this genus and determine proper conservation actions for these extremely rare seabirds.

Pseudobulweria is a monophyletic genus, whose sister taxa include *Bulweria* and the shearwater genera *Calonectris*, *Puffinus* and *Fulmarus* in the maximum-parsimony tree (Gangloff *et al.* 2012). *Pseudobulweria* may be a relic genus that formerly had wider distribution; investigation of its biochemistry, genetics and behavior is badly needed to understand their phylogenetic relationships (Warham 1992). For example, two subspecies of Tahiti Petrel were once considered to exist but are not supported by recent genetic work (Gangloff *et al.* 2011). In regard to their taxonomy, Bretagnolle (1996) suggests that petrels are a good model to study the evolution of vocalizations because there is a causal link between the diversity

of petrel vocal repertoire and parallel diversity of their life histories. The processes that led to the observed variety and distribution of taxa suggest that reproductive isolation between populations, and thus speciation, could occur if immigrant individuals cannot adjust to colony-specific activity patterns, including vocalizations (McKown 2008).

We studied the Tahiti Petrel in American Samoa and identified a variety of vocalizations not previously described. The length and variety of their calls appear to be more complex than the short sharp monosyllabic or disyllabic calls given by the diurnal *Pterodroma* of the tropical Pacific (Thibault & Holyoak 1978). Bretagnolle (1996) described the vocal repertoire of Tahiti Petrels as having more than one minor call and one or two major calls, in comparison with seven *Pterodroma* species having more than four minor and three major calls. We found that Tahiti Petrels have two main calls, a ground call and an aerial call, and present here a series of sonograms showing the distinctiveness of the Tahiti Petrel calls and contrast those to petrels in the genus *Pterodroma*.

METHODS

The Tahiti Petrel ranges at sea across the subtropical Pacific Ocean from Mexico and Peru to Taiwan and Indonesia. They are primarily austral summer breeders with an extended breeding season among the Society, Gambier and Marquesas islands, New Caledonia, Fiji, Samoa, and possibly Vanuatu, Tonga and Cook islands (Pratt *et al.* 1987, Villard *et al.* 2006).

The Samoan population of the Tahiti Petrel is under US management in the National Park of American Samoa (NPSA), which includes three islands: Tutuila, Ofu and Ta'u. We studied the species on Ta'u (14°14′S, 169°26′W), the largest of the Manu'a Islands, located approximately 100 km east of Tutuila, and the largest island in the eastern Samoan Archipelago (Fig. 1). Approximately half of the island of Ta'u was leased to the National Park Service (NPS) when the National Park of American Samoa was established in 1993.

The Ta'u Island unit encompasses 2 160 ha of coastal, upland and montane scrub forests rising from the eastern and southern coastlines to the highest point in the eastern portion of the Samoan Archipelago at the summit of Mt. Lata (966 m) (Craig 2002).

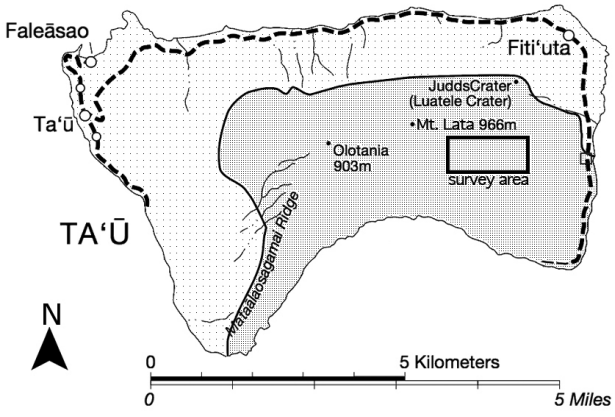

Fig. 1. Ta'u Island in the Manu'a Group with the Ta'u Unit of the National Park of American Samoa shaded. The dashed line represents the island's road (adapted from the National Parks Service map). Details of the survey area are shown in Figure 2.

Rainfall at the summit can exceed 750 cm per year, and misty conditions characterize the daily weather. Typhoons shape the island vegetation. The scrub montane rainforest is an impenetrable tangle of ferns *Cyathea* spp. and *Asplenium multifidum*, dense thickets of vines *Freycinetia storkii* and *F. reinecki*, and small trees and shrubs, such as *Cyrtandra* spp., *Melastoma* spp. and *Psychotria* spp., which are endemic to Samoa and the Manu'a islands in particular. The invasive South American melastome shrub, "Koster's Curse" *Clidemia hirta* and the Norway Rat *Rattus norvegicus* have also been found on the summit tract (Whistler 1992, O'Connor & Rauzon 2004).

We made two expeditions to Mt. Lata on 1–9 December 2001 and 10–18 December 2002. The summit is accessed from the main village of Fiti'uta via a difficult 4–6 h hike up a trail on the north flank of the volcanic island (Figs. 1, 2). The trail follows a stream course to the summit ridge, where an established campsite exists. Because visits to the top are very infrequent, the trail usually has to be cleared using a machete. The summit trail leaves the campsite and follows along the edge of a collapsed caldera with 500 m of near-vertical relief. The 2 km survey trail traverses petrel habitat and, while representative, it is very limited in scope and dangerously close to the cliff edge (Fig. 3).

We walked the summit track after dark, stopping periodically to play a recording of Tahiti Petrel calls made on Moorea (Society Islands) in 1974 by Jean-Claude Thibault. Samoan birds responded to the taped calls with a series of their own vocalizations. We recorded these on Sony Hi-Bias 60-min tapes with a Marantz PMD-222 recorder using a Tesinga microphone with a Stith parabolic dish for amplification. Vocalizations were recorded while we walked along the summit track at night and while focusing the parabolic dish below the cliff edge where petrels were calling. Calls were analyzed using the Kay Elemetrics DSP Sona-Graph (model 5500) and were selected for sonogram portrayal by their aural complexity and variety. The tapes are now archived at the Macaulay Library (formerly the Cornell Library of Natural Sounds). An audio recording of the petrels and auditory environment of Ta'u was published as a compact disc recording (Rauzon 2003).

RESULTS

Approximately 200 birds were heard calling below the summit during the hour-long nocturnal listening periods along the summit trail. Based on the estimated number of calling birds along this length

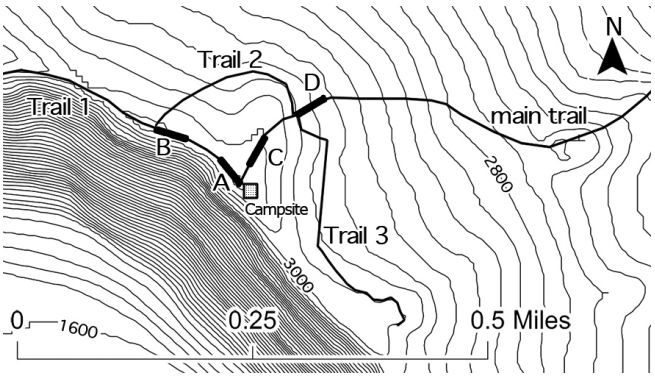

Fig. 2. Survey trails and rat transects (A–D) in the survey area near the summit of Mt. Lata on Ta'u. Elevation is indicated in feet (1 ft = 0.3048 m).

of the 2 km trail and the potential 10 km summit ridge, as many as 2000 pairs may be present at the summit. Previous investigators reported Tahiti Petrel as an uncommon resident of Ta'u, heard from Olotania crater to the summit and beyond (Murphy 1924, Crossin *in* Amerson 1982). "Birds can be heard all along the top from the first lookout [Olotania Crater] to way beyond the top of Saua. They appear to range deep into the forest…the numbers of calling birds indicates that thousands are present" (Crossin *in* Amerson *et al*. 1982). Other researchers also reported that Herald's Petrel *Pterodroma heraldica*, Collared Petrel *P. brevipes* and Polynesian Storm-Petrel *Nesofregetta fuliginosa* were present on Mt. Lata (Amerson 1982, Banks 1984, Pyle *et al.* 1990). During our visit, besides the Tahiti Petrels, we heard only the Tropical Shearwater *Puffinus bailloni* (O'Connor & Rauzon 2004), although in 2013 Herald's Petrels were relocated by Park researchers.

Tahiti Petrels began calling ~30 min after sunset (~18h00) and called actively from the ground until around 22h00, but flight calls could be heard all night. Using a sound-collecting parabola, we filled two 60 min tapes in an attempt to document vocalization types and the densities of petrels along the 2 km trail. We noted two basic vocalization types: a long drawn-out braying call of birds on the ground and an aerial call that appears to be the ground call condensed into an ascending whistle. Approximately 40 calls were graphed: 27 versions of the typical seven-part ground calls including duets, and two single-note ground calls, as well as 11 aerial calls.

The ground call is composed of seven main syllables as illustrated in Figure 4: (1) the initial "hiccup'" followed by (2) a pause, or an inhalation, then (3) a trio of harmonics, merging into (4) the main body of the call, transitioning into (5 & 6) an elongated two-part whistle/shriek, ending with (7) a descending moan. The ground call ranges between 1 and 6 MHz and lasts about 2.5 s.

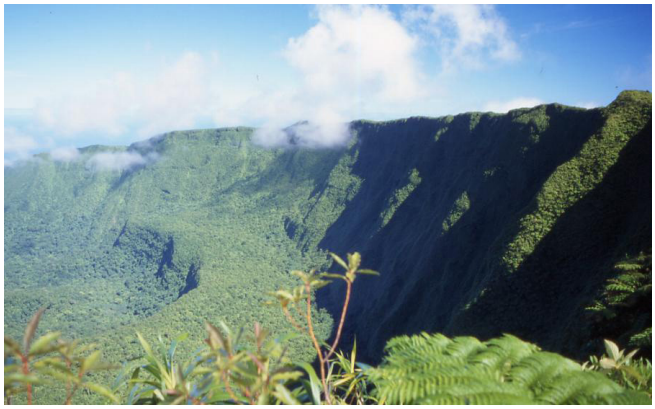

Fig. 3. Photograph of the Ta'u crater and cliff habitat of Tahiti Petrels (Photo: M. Rauzon).

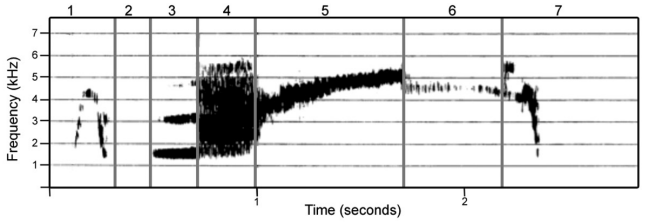

Fig. 4. A typical example of a ground call, apportioned into 7 parts.

Each ground call starts with a "hiccup" note separated by a gap (possibly an inhalation). This is followed by the variable center portion, usually consisting of three harmonics merging into the main body of white noise before focusing on one prolonged principal note. The latter rises to the highest pitch, drawn out for over a second, then drops to the frequency at which the call began. By varying the pitch and harmonics in the body of the call, birds appear to individuate their calls and synchronize them with a mate to create a unique duet. Although we were unable to make a visual confirmation, studies of *Pterodroma* (Bretagnolle 1996) have made similar recordings in which the first bird, nearing the end of its call with a descending whistle-like moan, finishes on the same pitch as the initial "hiccup" portion of its mate's call, as in the recording shown in Figure 5. The bodies of both calls are sexually dimorphic. Presumably, the fuzzy call is a harsh rasp made by a female, which, as with *Pterodroma*, is harsher than the call of males (Bretagnolle 1996).

Several different sonograms demonstrate the variety of the basic ground call, as follows. Figure 6-A shows the initial call truncated by an overlapping, more robust call; Figure 6-B shows the initial "hiccup" flowing into the harmonics without pause, followed by the presumed mate's call after a pause, starting on the same note, on frequencies below 2 kHz. The individual dimorphic characters as well as mate similarities in duration and density of harmonics are demonstrated in Figure 6-C, which shows that one bird's completed call is presumably picked up by its mate in an abbreviated style.

The vocalizations in Figures 7 A-D demonstrate how each one of four vocalizations develop harmonic complexity. The vocalizations show how various call components can be stressed or clipped to create an abbreviated or elongated ground call. Vocalizations by

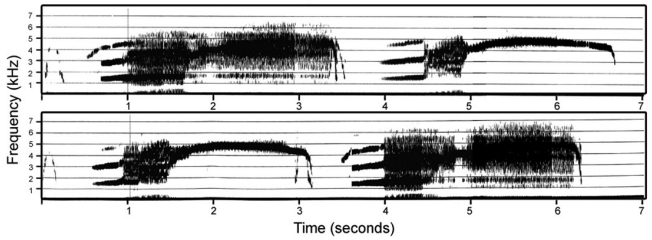

Fig. 5. Two sets of ground calls showing complicated harmonics and response of a dueting pair over a 7 s interval.

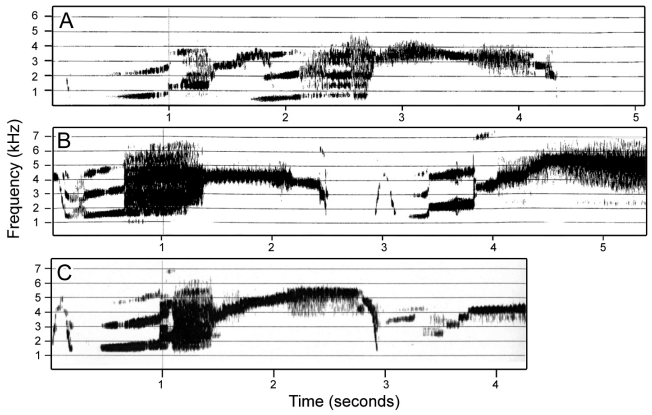

Fig. 6. Three duet sets of calls highlighting individual variation as well as the pattern of call and response.

different birds develop from initial notes that may extend to a full call. Calls 7-A and 7-B portray clear frequencies that are described as "steady screech," and calls 7-C and 7-D show harmonic vibrations between frequencies. Figure 7-D is suspected to be from a male exhibiting defensive behavior as it approached and challenged the recording device while it played a Tahiti Petrel call (Bretagnolle & Lequeete 1990).

The aerial call shown in Figure 8 is a version of the ground call modified for flight. It is an up-slurred and extended whistle, a rising *peurrr* increasing in pitch and intensity (O'Connor & Rauzon 2004). Some whistles are attenuated, while others are short, and some exhibit the Doppler effect as the caller approaches the microphone. Tahiti Petrels can occasionally give a full ground call in flight. The flight calls may be used as birds approach the nesting area, in an acoustically challenging environment of surf, fog, rain, and wind. Their piercing whistles are enhanced or echoed in the amphitheater of the cliffs.

DISCUSSION

Tahiti Petrels use a repertoire of sounds in a flexible way. The short staccato initial "hiccup" note of the ground call introduces a body of harmonics that then focuses down to a single sustained braying sound that ends in a moan at the initial frequency. Tahiti Petrels can vary the length and depth of the "hiccup," the frequencies and harmonics of the braying calls, and the use of the up-slurred whistle as an introductory phrase or as a high-pitched drawn-out vocalization in flight. The flexibility in the structure of this species' call, with a wide repertoire of basic sounds, may display gender and individuality as well as a wide range of emotions conveying many different messages as noted in the Northern Fulmar *Fulmarus glacialis* (Robb & Mullareny 2008).

Pseudobulweria are evolutionarily antecedent to the gadfly petrels, so petrel vocalizations may have been derived from *Pseudobulweria*. Portions of the seven-part ground call may have been "sampled" by later-evolving species as sounds from the base ancestral calls. For example, two *Pterodroma* vocalization types are illustrated in Figure 9. The Kermadec Petrel *P. neglecta* makes the *kuk-u-er* or the *quor-wik* call that is described as "syllables of unstructured white noise spread across a wide band of frequencies" that are low-pitched drawn-out notes followed or preceded by one or more staccato *ti* or *wik* notes (Warham 1992). These sounds are present in the Tahiti Petrel call. The Phoenix Petrel *P. alba* call is composed of short staccato notes repeated in a long sequence, described by Warham (1992) as the typical *ti-ti* call: a series of short staccato notes that produces a continuous chattering chorus. The *ti-ti* call is known from 21 petrel species both large and small (Warham 1992) and is the sound of the introductory note of the Tahiti Petrel call. While *Pterodroma* calls can be acoustically complex with much variation within the repertoire of a single bird, among individuals, between sexes and even between colonies (Warham 1992, McKown 2008), they lack rapid amplitude modulation and rapid frequency modulation. Further, most petrel calls are divided into one to three syllables of stereotyped duration that may vary position in the call (Bretagnolle 1996).

Every Tahiti Petrel sonogram illustrated in Figures 4 to 8 shows recognizably distinct calls, suggesting that this species has one of the more varied sets of vocalizations among the family Procellariidae. Tahiti Petrels vary the frequency, timing and the

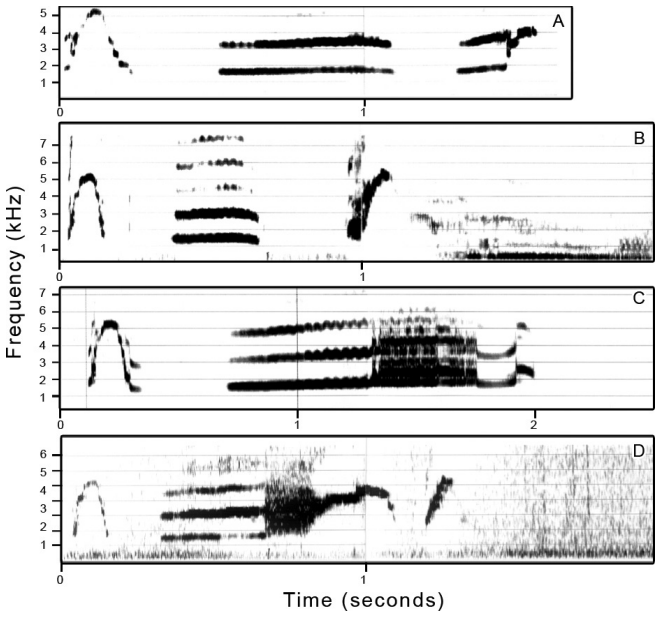

Fig. 7. A series of vocalizations, A and B assumed to be males, and C and D assumed to be females.

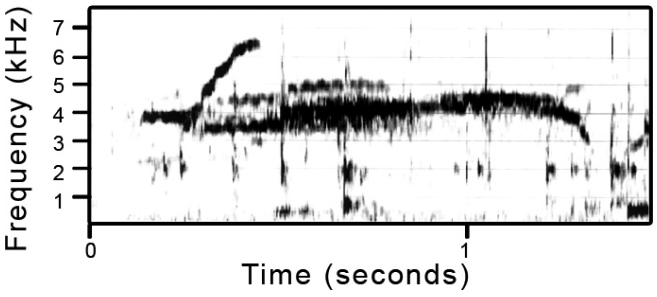

Fig. 8. Aerial call showing truncated main body of call focused into a prolonged whistle that may be shifted downwards by the Doppler effect.

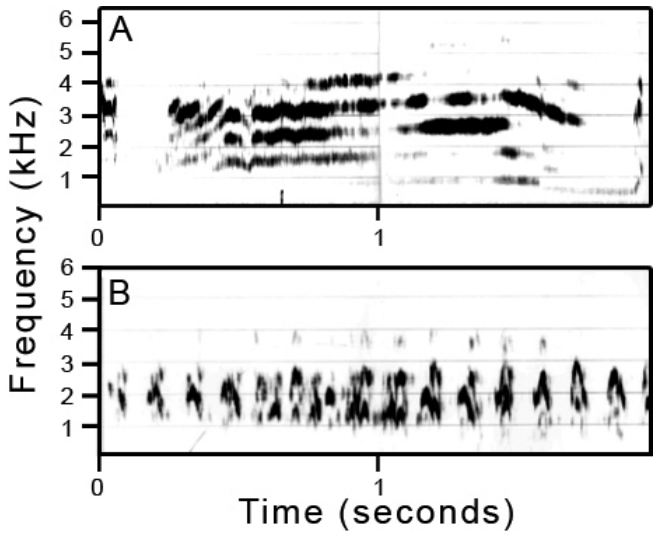

Fig. 9 A) Kermadec Petrel call that shows similar harmonic structure to the Tahiti Petrel call; **B)** the monosyllabic *ti-ti* call of the Phoenix Petrel.

duration of segments to create individual voices that seemingly would allow mate and species recognition in a mixed-species colony. Dobzhansky (1937) posited that isolating mechanisms are the basis for speciation. For nocturnal seabirds, vocalizations vary with individual and sexual dimorphism, and call variety becomes a prime candidate for the isolating mechanism, especially in mixed-species colonies, where communication over the incipient background noise is paramount to finding a mate. Indeed, these seabirds present several characteristics that make their vocalizations particularly important from an evolutionary perspective (see, for instance, Bretagnolle 1996). More research is needed into *Pseudobulweria* vocalizations to determine whether variety extends across the genus. If it does, this work could be a good starting point to explore the extent of sound sequencing by later-evolving petrels.

CONCLUSION

Pseudobulweria is one of the least known and most endangered of all seabird genera, and *Ps. rostrata* is considered Near Threatened (Villard 2006). The remoteness of the breeding grounds makes it incredibly difficult to determine even the magnitude of the population. Reaching the island summit in Samoa where Tahiti Petrels exist is very challenging, requiring trail cutting, extreme physical exertion, communication problems, expensive operations, lack of freshwater, inclement and often severe weather, impenetrable vegetation, and remote and dangerous terrain.

Information about the biology and morphology of *Ps. rostrata* is necessary to understand and conserve these petrels. The vocal nature of the species allows for auditory surveys using remote recording devices to help determine the population size of the Ta'u population (Berrow 2000, Borker 2014). Efforts to use vocalizations to monitor the Ta'u populations are planned for the near future. Learning as much as possible about the vocalizations with this species may be useful in developing efforts for the extremely rare Beck's and Fiji petrels. Conservation is increasingly important in Samoa, since invasive Norway Rats were discovered in the montane forests during our study. These alien mammals pose a threat to the continued survival of the Tahiti Petrel at its main colony in the Samoan archipelago, where rats may have eliminated the other petrels that had once been known to exist there. Any safe and reliable management efforts (i.e. basic research, sound monitoring, predator control) in an extremely remote location will require significant planning and future financial commitments.

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