# Pacific Sheath-tailed Bat
# American Samoa

*Emballonura semicaudata semicaudata*

Species Report

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# Executive Summary

This Species Report uses the best available scientific and commercial information to assess the status of the *semicaudata* subspecies of the Pacific sheath-tailed bat, *Emballonura semicaudata semicaudata*. This subspecies is found in southern Polynesia, eastern Melanesia, and Micronesia. Three additional subspecies of *E. semicaudata* (*E.s. rotensis*, *E.s. palauensis*, and *E.s. sulcata*) are not discussed here unless they are used to support assumptions about *E.s. semicaudata*, or to fill in data gaps in this analysis.

The Pacific sheath-tailed bat is an Old-World bat in the family Emballonuridae, and is found in parts of Polynesia, eastern Melanesia, and Micronesia. It is the only insectivorous bat recorded from much of this area. These brown bats are small (weight approximately 0.2 ounces (oz); 5.7 grams (g)), communally roost in caves, overhangs, lava tubes or crevasses, and forage in forests on small insects (0.08–0.2 inches (in); 2–5 millimeters (mm)).

The viability of the Pacific sheath-tailed bat was defined as the likelihood of persistence over time. Viability was assessed using three conservation biology principles: resiliency, representation, and redundancy. Specifically, survival and reproduction at the individual, population, and subspecies levels were described along with beneficial and detrimental factors that result in changes in resiliency, representation, and redundancy from historic time to the present.

The best current information shows that the Pacific sheath-tailed bat persists as small and isolated populations on smaller islands in Fiji, and has been extirpated from historically occupied areas in Samoa, American Samoa, Rotuma, Vanuatu, and Tonga. The most significant threats to the continued existence of the subspecies include predation by nonnative mammals, human disturbance of roost caves, habitat loss due to deforestation and overgrazing by ungulates, and stochastic events such as tropical cyclones.

The Pacific sheath-tailed bat is highly susceptible to extinction due to low redundancy (few remaining populations), low representation (due to highly reduced range), and low resilience (due to low fecundity - one pup per year; and high aggregation in single roosts). The bat is also vulnerable to sea level rise, extreme rain events, and increased storm severity due to its geographic location within Western Pacific tropical cyclone storm tracks, and a tendency to roost in caves adjacent to the sea. Under current conditions, losses of individuals and populations are expected to continue.

In summary, predation, habitat modification, disturbance of roost caves, and the risk from extreme storms threaten the viability of the Pacific sheath-tailed bat in Fiji, Samoa, American Samoa, Rotuma, Vanuatu, and Tonga. Low numbers of individuals and populations in a contracted range, along with a low reproductive rate magnify the threats to viability. Existing regulatory mechanisms and conservation efforts do not adequately address these threats, which are likely to continue into the future.

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# Introduction

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## Regulatory History

The Pacific sheath-tailed bat *semicaudata* subspecies was listed by the United States Fish and Wildlife Service as Endangered in 2016 (USFWS 2016a). All subspecies were listed as Endangered (*i.e.*, a very high risk of extinction in the wild) by the IUCN (International Union for Conservation of Nature) Red List (Bonaccorso and Allison 2008). The IUCN rating data include the rate of decline, population size, area of geographic distribution, and degree of fragmentation. The IUCN rankings do not confer any protection or management. The IUCN assessment is currently being updated. The current revision of the IUCN ranking recommends listing *E.s. semicaudata* as Critically Endangered (Waldien and Scanlon *in prep*, p. 2).

### *American Samoa*

Critical habitat has not been designated for the Pacific sheath-tailed bat. Nonetheless, the laws and regulations in the American Samoa Code Annotated (ASAC § 26.0202 et seq.) are designed to ensure that ‘‘environmental concerns are given appropriate consideration,’’ and include provisions and requirements that could address, to some degree, threats to native forests and other habitats important to the Pacific sheath-tailed bat, even though individual species are not named (ASAC § 26.0202 et seq.). Implementation of these regulations has been minimal, and does not reliably include wildlife and natural resources managers (ASAC § 26.026.C). Thus, habitat protection necessary for the conservation of the species has been lacking. Native habitat important to the Pacific sheath-tailed bat continues to be lost to land clearing for agriculture and development (DMWR 2006, p. 71).

### *Fiji*

In Fiji, the Endangered and Protected Species Act (EPSA, 2002) regulates the international trade, domestic trade, possession, and transportation of species protected under CITES and other species identified as threatened or endangered under this act. Under the law, the Pacific sheath-tailed bat is recognized as an ‘‘indigenous species not listed under CITES.’’ Its recognition under the EPSA might help gain public recognition of the importance of conserving the bat and its habitat (Tuiwawa 2015, in litt.). Because the focus of the legislation is the regulation of foreign and domestic trade, and the bat is not a species in trade, this law is not intended to provide protection for the bat or its habitat within Fiji. In addition, there is the Museum Act, which protects indigenous sites. If caves are near historic villages, the Museum Act provides roosts regulatory protection (Fiji Museum Act, 1929). There also is an Environmental Impact Assessment Process in Fiji, which provides protection if environmental resources are identified as at risk from development.

*Tonga*

In Tonga, the Birds and Fish Preservation (Amendment) Act 1989 is a law to ‘‘make provision for the preservation of wild birds and fish.’’ The law protects birds and fish, and provides for the establishment of protected areas, but it does not specifically protect the Pacific sheath-tailed bat or its habitat (Kingdom of Tonga 1988, 1989). Laws and regulations governing management of wildlife and native forest in Tonga do not provide specific protections for the bat or its habitat, or have not resulted in conservation of habitat sufficient to preclude the likely recent loss of this species from the islands of the Kingdom of Tonga.

*Vanuatu*

In Vanuatu, the Environment Management and Conservation Act (2002) provides for conservation, sustainable development, and management of the environment of Vanuatu. Areas of the law that may apply to species protection are the Environmental Impact Assessment process, which includes an assessment of protected, rare, threatened, or endangered species or their habitats in project areas, laws on bioprospecting, and the creation of Community Conservation Areas for the management of unique genetic, cultural, geological, or biological resources (Environmental Management and Conservation Act, Part 3, Environmental Impact Assessment). Although the EMCA contains the regulatory provisions mentioned above, they do not sufficiently address the ongoing threats of deforestation, predation, and small population size for the Pacific sheath-tailed bat in Vanuatu. The Wild Bird Protection law (Republic of Vanuatu 2006) is limited to birds and does not offer protection to the Pacific sheath-tailed bat or its habitat.

## Methodology

This Species Report provides an assessment of the current viability of the of the Pacific sheath-tailed bat’s *semicaudata* subspecies. This assessment is based on the best information available at this time, including peer-reviewed literature, gray literature (government, academic, business, and industry reports), and expert elicitation. Viability is the ability or likelihood of the species to maintain populations over time, *i.e.*, likelihood of avoiding extinction. The viability of federally listed species is currently being assessed using the three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs” (Figure 1; USFWS 2016b, p 12-16). The viability of *Emballoneura semicaudata ssp. semicaudata* was evaluated by describing what the bat needs to be resilient, redundant, and represented, followed by comparing this assessment of what is needed for viability to the status of the bat in its current condition or its condition based on the most recent information.

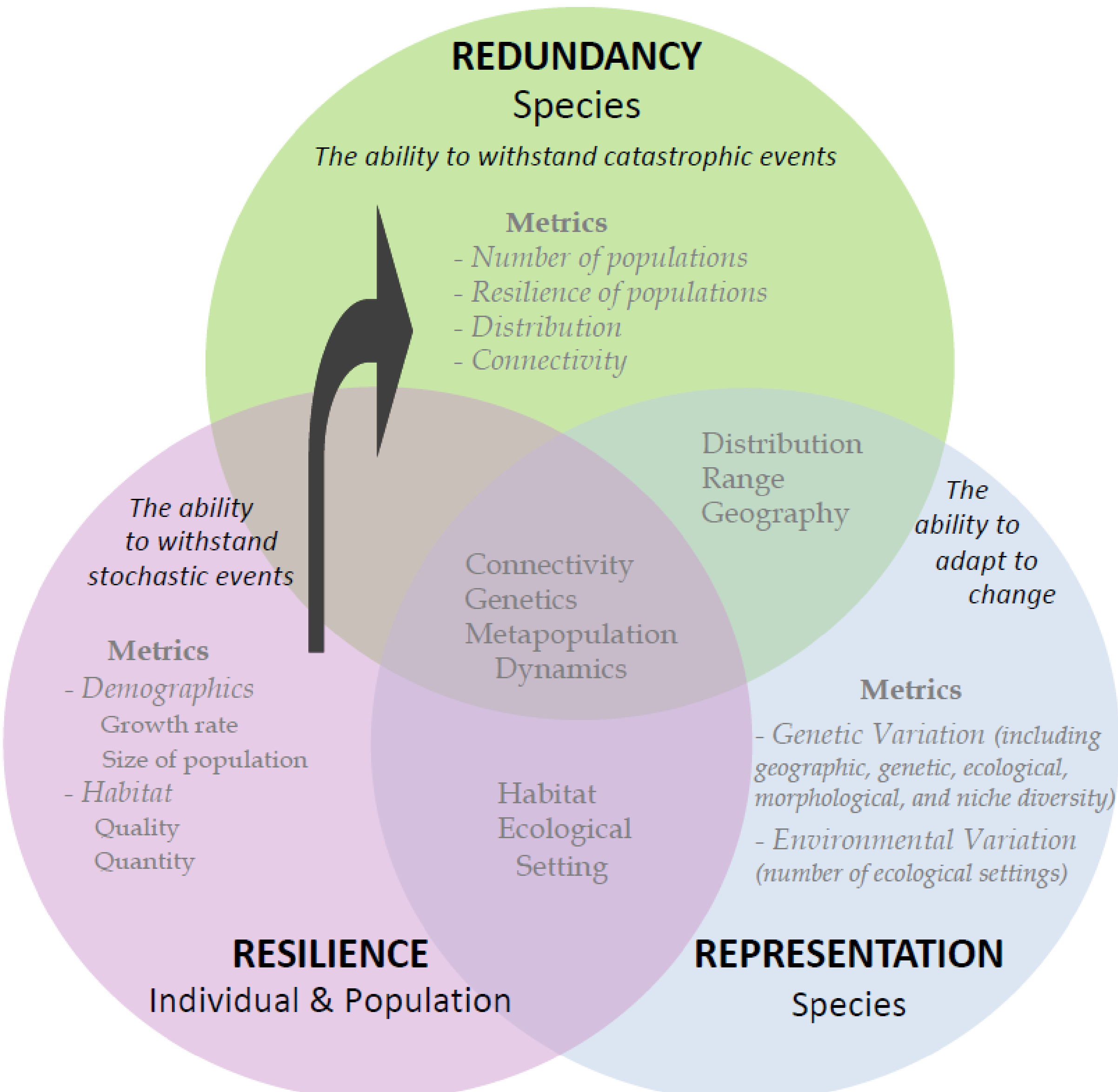



Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs."

The definitions of the "3Rs" are defined below, and are used to infer the status of the species.

- **Resiliency** is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (*i.e.,* environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (*e.g.*, seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may also influence the connectivity among populations.
- **Redundancy** is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (*i.e.,* environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.
- **Representation** is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species.

The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Emballoneura semicaudata ssp. semicaudata*.

# Part 1. Life History and Historical Status

## Species Description and Taxonomy

*Names*

The Pacific sheath-tailed bat (South Pacific subspecies), *Emballonura semicaudata ssp. semicaudata*, is also called Peapea vai in American Samoa, Tagiti in Samoa, and Beka beka in Fiji. The Pacific sheath-tailed bat is a member of the *Emballonuridae*, an Old World bat family that has an extensive distribution in the tropics (Nowak 1994, pp. 90–91). The Pacific sheath-tailed bat was once common and widespread in Polynesia, eastern Melanesia, and Micronesia and is the only insectivorous bat recorded from a large part of this area (Hutson et al. 2001, p. 138).

*Description*

Sheath-tailed bats are rich brown to dark brown above and paler below (Walker and Paradiso 1983, p. 211). This species is a small bat. Males have a forearm length of about 1.8 in (45 millimeters (mm)), and weigh approximately 0.2 ounces (oz) (5.7 grams (g)), and females are slightly larger in size and weight (Lemke 1986, p. 744; Nowak 1994, p. 91; Flannery 1995, p. 326; Uyehara and Wiles 2009, p. 5). The common name ‘‘sheath-tailed bat’’ refers to the nature of the tail attachment: the tail pierces the tail membrane, and its tip appears completely free on the upper surface of the membrane (Walker and Paradiso 1983, p. 209).

Taxonomy

A Samoan specimen was first described by Peale in 1848 as *Vespertilio semicaudatus* (Lyon and Osgood 1909, p. 259). The species was later included in the genus *Emballonura* (Temminck 1838; cited in the Integrated Taxonomic Information System (ITIS) 2014) and is now known as *Emballonura semicaudata* (Smithsonian Institution 1909; Tate and Archbold 1939, p. 8). Four subspecies of Pacific sheath-tailed bats are currently recognized:

- *E.s. rotensis*, endemic to the Mariana Islands (Guam and the Commonwealth of the Northern Mariana Islands (CNMI); listed as endangered in 2014 (80 FR 59497, October 1, 2015), and referred to here as the Mariana subspecies);
- *E.s. sulcata* in Chuuk and Pohnpei;
- *E.s. palauensis* in Palau; and
- *E.s. semicaudata* in American Samoa, Samoa, Tonga, Fiji, and Vanuatu (Helgen and Flannery 2002, pp. 4–5, Koopman 1997, pp. 358–360; Oyler-McCance et al. 2013, pp. 1,030–1,036), referred to here as the South Pacific subspecies.

Recent analysis found greater genetic differences between *E.s. rotensis, E.s. palauensis,* and *E.s. semicaudata* than typically reported between mammalian subspecies (Oyler-McCance et al. 2013, p. 1,030), and species experts suggest that they would likely be classified as individual species if the genetics work was more complete (Wiles 2019, in litt). Hereafter, ‘‘bat’’ or ‘‘Pacific sheath-tailed bat’’ refers to the South Pacific subspecies, *semicaudata*, unless otherwise noted.

## Life History

Little is known about the life history of the *semicaudata* subspecies of *E. semicaudata*. The bat’s generation length (the average age of parents of the current cohort, reflecting the turnover rate of breeding individuals in a population) is believed to be 2.5 years (Pacifici et al. 2013). A field investigation of the Aguiguan population of *E.s. rotensis* used several lines of evidence to infer an annual litter size of one pup per female in late summer (Wiles et al. 2011, p. 303). Bats in this same study were observed to roost “singly (or as lone adults next to lone young), spaced about 5–30 cm apart on the ceiling and upper walls of the [cave] dome, ventral surfaces appressed to the rock surface with heads facing downwards, with spacing intermediate between regular and random patterns” (Wiles et al. 2011, p. 303). Other reports confirm a highly aggregated roosting pattern for individuals of this species in Fiji and American Samoa (Scanlon et al. 2014, p. 456; Palmeirim et al. 2005, pp. 55– 62), with large aggregations (100s to 1000s) in a single “main” cave and a few individuals (1s to 10s) often scattered in several caves close to this location. Other subspecies of Pacific sheath-tailed bats (*E.s. palauensis*) routinely travel distances exceeding 5 km to reach foraging sites in Palau (Wiles et al., 1997).

## Historic Range, Distribution, and Population Status

*E. s. semicaudata* was historically found in Samoa, American Samoa, Fiji, Vanuatu, and Tonga (Figure 2). In Samoa, it was found on Savai'i and Upolu, where it was common; in American Samoa, it was found on Manu'a (Ofu, Olosega, and Ta'u) and Tutuila. This subspecies has now disappeared from Samoa (Lovegrove et al. 1992, p. 30; Park et al. 1992, p. 47; Tarburton 2002, pp. 105–108) and American Samoa (Grant et al. 1994, p. 134; Koopman and Steadman 1995, pp. 9–10; Helgen and Flannery 2002, pp. 4–5, Hutson et al. 2001, p. 138).

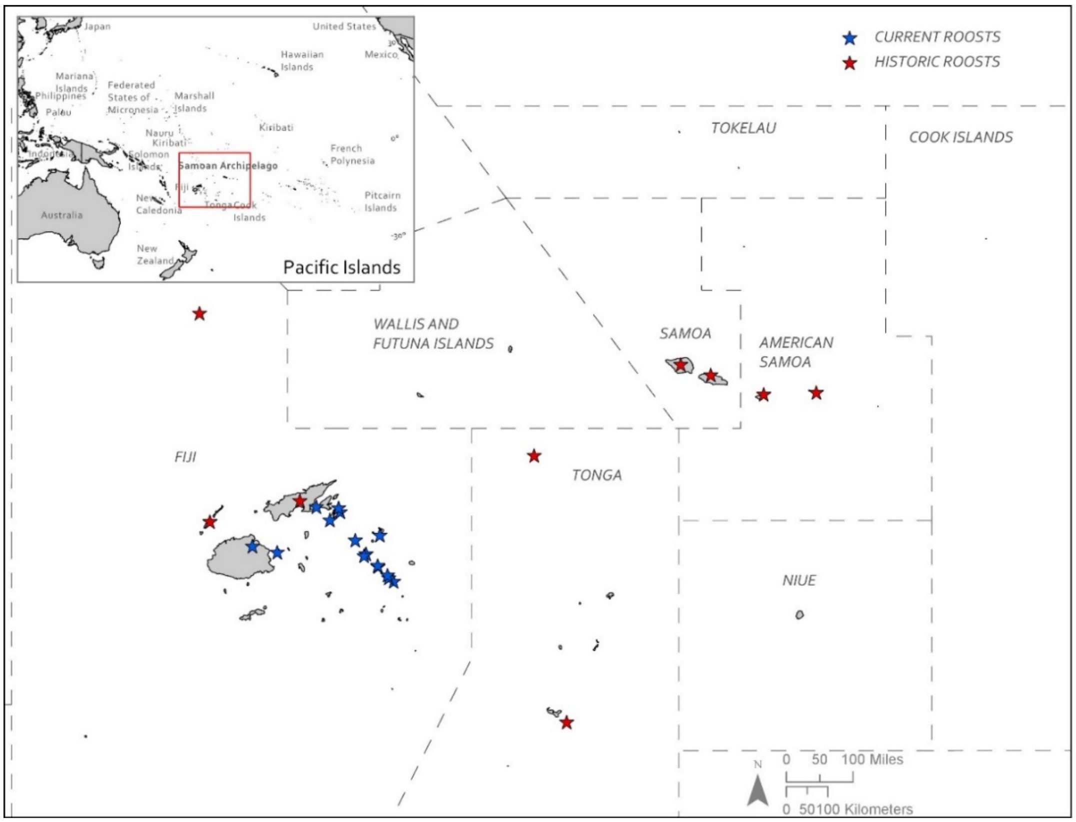


Figure 2. Historic and current roost locations of the Pacific sheath-tailed bat.

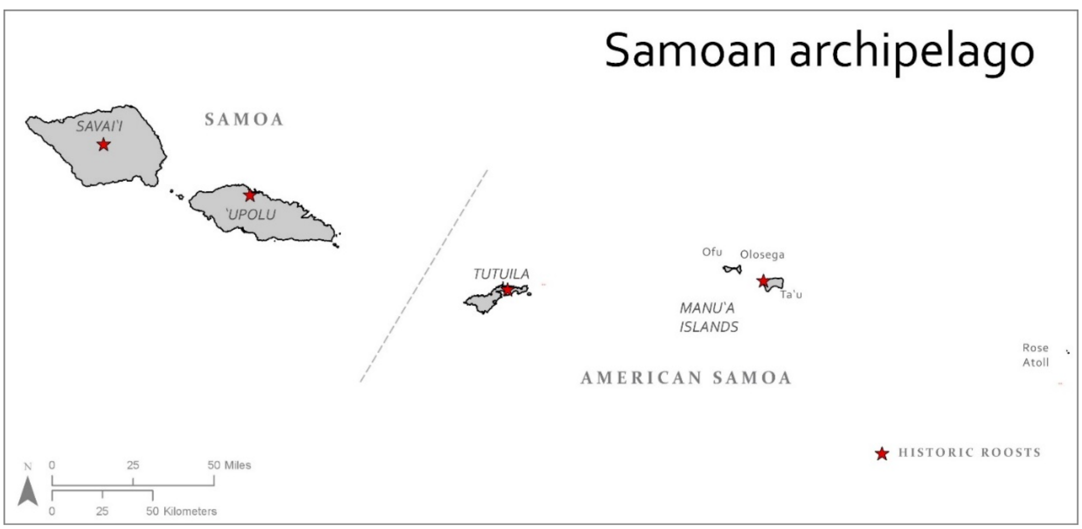
In Tonga, it was found on 'Eua and Niuafo'ou, was last collected in 1989. It is currently considered exceedingly rare or more likely extirpated (Rinke 1991, p. 134; Koopman and Steadman 1995, p. 7, M. Pennay pers. comm. in Scanlon et al. 2014, p. 456).

In Fiji, it was found on Taveuni, Ovalau, the large island Viti Levu, Levu Lakiba (or Lakemba), the Yasawa Group (approximately 30 miles (mi) (48 kilometers (km)) to the northwest of Viti Levu), and Rotuma (approximately 300 mi (482 km) to the northwest of Vanua Levu) (Palmeirim et al. 2005, pp. 31–32, Clunie 1985, pp. 154– 155). It has been lost from the Yasawa Group, and it is likely gone from Rotuma fairly recently (Scanlon et al. 2014, p. 453., Cibois et al. *in press*, p. 1).

In Vanuatu, the subspecies is known historically from the southern end of the 540-mile long archipelago located 600 miles to the west of Fiji. The current status of the bat in Vanuatu is unknown, but it is likely extirpated (Koopman 1997, Helgen and Flannery 2002, pp. 4–5,). Summaries of population status and trends by specific areas follow.

*American Samoa*

In American Samoa (Figure 3), Amerson et al. (1982a, p. 74) estimated a total population of approximately 11,000 Pacific sheath-tailed bats in 1975 and 1976. A precipitous decline of the bat on the island of Tutuila had occurred by 1990 (Grant et al. 1994, p. 134; Koopman and Steadman 1995, pp. 9–10; Helgen and Flannery 2002, pp. 4–5). Knowles (1988, p. 65) recorded about 200 in 1988, and in 1993, observers caught one bat and saw only three more (Grant et al. 1994, p. 134). A single bat was also observed on two occasions in a small cave north of Alao (Grant et al. 1994, pp. 134–135). Additional small caves and lava tubes have been checked more recently for bats however, Tutuila is entirely volcanic and does not have the extensive limestone cave systems that provide bat roosting habitat in the Mariana Islands and other Pacific island groups (Grant et al. 1994, p. 135). Two individuals were last observed in the cave at Anapeapea Cove on the north shore of Tutuila in 1998 (Hutson et al. 2001, p. 138). Surveys conducted by the Department of Marine and Wildlife Resources (DMWR) in 2006 failed to detect the presence of this species (DMWR 2006, p. 53). In an attempt to ascertain whether the species is still extant, DMWR conducted surveys consisting of acoustic sweeps and cave checks on all main islands in 2008 and 2012, and no bats were detected (Fraser et al. 2009, p. 9; U.R. Tulafono 2011, in litt.; DMWR 2013, in litt.). Based on its decline and the lack of detections since it was last seen in 1998, this species is thought to be extirpated in American Samoa (DMWR 2006, p. 54; Uyehara




and Wiles 2009, p. 5). DMWR continues to conduct acoustic surveys in search of the Pacific sheath-tailed bat in American Samoa (Miles 2015a, in litt.).

Figure 3. Historic bat roost locations in Samoa and American Samoa.

*Samoa*

In Samoa, the Pacific sheath-tailed bat is known from the two main islands of Upolu and Savai'i (Figure 3), but the species has experienced a severe decline over the last several decades, and has been observed only rarely since Cyclones Ofa (1990) and Val (1991) (Lovegrove et al. 1992, p. 30; Park et al. 1992, p. 47; Tarburton 2002, pp. 105–108). This species was previously abundant on Upolu with an individual cave estimated to support several thousand individuals (Ollier et al. 1979, pp. 22, 39). A survey of 41 lava tube caves and other locations on Upolu and Savai'i conducted from 1994 to 1997 detected a total of 5 individuals at two sites, which had declined to 2 individuals total by the end of the survey (Hutson 2001, p. 139; Tarburton 2002, pp. 105–108, Tarburton 2011, p. 38). In Samoa, the Pacific sheath-tailed bat was known to occupy sea caves and lava tubes from the coast up to elevations of 2,500 feet (ft) (762 meters (m)). These roost locations ranged from 49 feet (ft) (15 meters (m)) to more than 2,130 feet (ft) (650 meters (m)) in length; varied in height and width, number of openings, and degree of branching; and are likely subject to rockfalls and flooding during high rain events (Tarburton 2011, pp. 40–49). The species is now thought to be extirpated from Samoa (Tarburton 2002, pp. 105–108, Tarburton 2011, p. 38).

*Fiji*

In Fiji, the Pacific sheath-tailed bat is distributed throughout the archipelago (Figure 4). Historically it occupied large islands such as Vanua Levu and Taveuni, medium-sized islands in the Lau group (Lakeba (or Lakemba), Nayau, Cicia, Vanua Balavu), and small islets such as Yaqeta (or Yanggeta) in the Yasawa Group and Vatu Vara and Aiwa in the Lau Group (Palmeirim et al. 2005, pp. 31–32). The largest historic sites were in the Sigatoka Valley on Viti Levu. There were several, and bats have been extirpated from all locations (D. Waldien, 2019a in litt). Bats have also recently been extirpated from Yaqeta (or Yanggeta) and the large island of Vanua Levu (Scanlon et al. 2014, p. 453). Pacific sheath-tailed bats in Fiji roost in lava tubes and limestone caves of varying length and width, beneath rock outcrops, and in cave-like areas formed by irregularly shaped boulders and in sea caves along the coast and up to 6.2 mi (10 km) inland (Palmeirim et al. 2007, pp. 1–13). Running water or pools of water are a common occurrence in inland caves with streams running through or coastal caves that are tidally influenced (Palmeirim et al. 2007, pp. 1–13). Habitat surrounding roost sites includes undisturbed forest, secondary forest, cultivated areas, and forested cliffs (Palmeirim et al. 2007, pp. 1–13). The species was reported as common some decades ago on the small, volcanic island of Rotuma, a Fijian dependency, approximately 372 mi (600 km) from the Fiji archipelago (Clunie 1985, pp. 154–155), however recent surveys there failed to detect any bats (Cibois et al. in press, p. 1). Limited survey effort in Rotuma, Fiji, is ongoing (D. Waldien, 2019b, in litt.). Although once widely distributed, the species has suffered a serious decline since the 1950s as evidenced by a contraction of its range and a decline in density and abundance on the islands where it still occurs (Flannery 1995, p. 327; Palmeirim et al. 2005, p. 31, Scanlon et al. 2014, p. 453). In 2000 to 2001, bats were absent or diminished in numbers in many of the caves known previously to be occupied on 30 Fijian islands, and villagers reported that small bats, presumably Pacific sheath-tailed bats, were no longer commonly seen (Palmeirim et al. 2005, p. 31). The species is predicted to be extirpated or nearly so on Kadavu, and Fiji's two largest islands, Vanua Levu and Viti Levu (Figure 4), where it was known to be widespread until the 1970s (Palmeirim et al. 2005, p. 31; Scanlon et al. 2014, p. 453). Field observations during the 2000 to 2001 surveys documented a single large colony of several hundred individuals on Yaqeta Island in the Yasawa Group and a large colony on Vatu Vara Island in the Lau Group, but otherwise only a few to dozens of individuals scattered among caves on small and remote islands in the Lau Group (Palmeirim et al. 2005, pp. 55– 62). Scanlon et al. 2014 (p. 453) revisited the large cave colony on Yaqeta between 2007 and 2011 and described it as without any evidence of recent use by bats (e.g., odor, fresh guano) and probably abandoned. The forest around the cave entrance had been cleared for agriculture, and it was uncertain from monitoring methods used—visual counts—whether the animals observed previously had moved to a different part of the cave with an entrance about 250m away or had disappeared. The loss of the Yaqeta colony and the species' overall declining trend across the archipelago led Scanlon and others (2014, p. 456) to infer a reduction in population size of greater than 80 percent over the last 10 years. The most important remaining sites for the protection of this species are likely those on small and mid-sized islands in the Lau Group where bats still occur (Palmeirim et al. 2007, p. 512).

Figure 4. Current and historic roost locations of the Pacific sheath-tailed bat in Fiji.

*Tonga*

In Tonga, the distribution of the Pacific sheath-tailed bat is not well known (Figure 5). It has been recorded on the islands of 'Eua and Niaufo'ou (Rinke 1991, p. 134; Koopman and Steadman 1995, p. 7), and is probably absent from Ata and Late (Rinke 1991, pp. 132–133). In 2007, ten nights of acoustic surveys on Tongatapu and 'Eua failed to record any detections of this species (M. Pennay pers. comm. in Scanlon et al. 2014, p. 456). Pennay describes 'Eua as the place most likely to support the Pacific sheath-tailed bat because of the island's large tracts of primary forest and many rocky outcrops and caves, but he considers the bat to be extremely rare or extirpated from both islands (M. Pennay pers. comm. in Scanlon et al. 2014, p. 456).

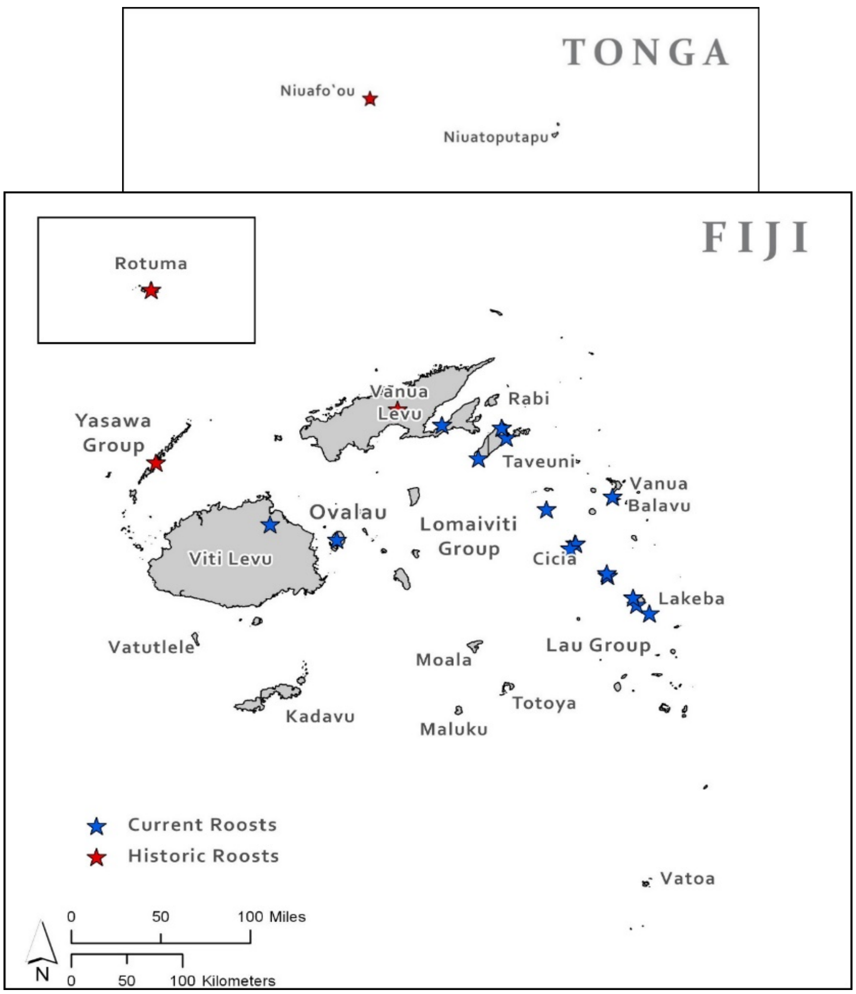



Figure 5. Historic roost locations in Tonga.

*Vanuatu*

In Vanuatu, the Pacific sheath-tailed bat was known from two museum specimens, one collected in 1929 and one collected before 1878, both on the main island of Espiritu Santo (Helgen and Flannery 2002, pp. 210–211). No subsequent expeditions have recorded sheath-tailed bats, suggesting that this species has been extirpated (Medway and Marshall 1975, pp. 32–33; Hill 1983, pp. 140–142; Flannery 1995, p. 326; Helgen and Flannery 2002, pp. 210–211; Palmeirim et al. 2007, p. 517). For example, Medway and Marshall (1975, p. 453) detected seven other small, insectivorous bats (family *Microchiroptera*) in Vanuatu, but failed to observe the Pacific sheath-tailed bat, possibly a result of survey sites and methods. The Vanuatu provenance of the two specimens is not in question (Helgen and Flannery 2002, p. 211). The current disjunct distribution of the Pacific sheath-tailed bat (all subspecies) is suggestive of extirpations from previously occupied islands (Flannery 1995, p. 45). The extirpation of the South Pacific subspecies from Vanuatu could be an example of this (Helgen and Flannery 2002, p. 211). Currently the bat is most likely extirpated in Vanuatu (Helgen and Flannery 2002, p. 211, D. Waldien, pers. comm., June 2019).

# Part 2. Current Conditions and Species Status

## Individual and Population Needs and Stressors

### Caves and roosts

All subspecies of the Pacific sheath-tailed bat appear to be cave-dependent, roosting during the day in a wide range of cave types, including overhanging cliffs, crevices, lava tubes, and limestone caves (Grant 1993, p. 51; Grant et al. 1994, pp. 134–135; Hutson et al. 2001, p. 139; Palmeirim et al. 2005, p. 28). Pacific sheath-tailed bats are commonly found sharing caves with swiftlets (*Aerodramus spp.*) (Lemke 1986, p. 744; Hutson et al. 2001, p. 139; Tarburton 2002, p. 106; Wiles and Worthington 2002, p. 7, Palmeirim et al. 2005, p. 28). Large roosting colonies appear common in the Palau subspecies, but smaller aggregations may be more typical of at least the Mariana subspecies and perhaps other species of *Emballonura* (Wiles et al. 1997, pp. 221–222; Wiles and Worthington 2002, pp. 15, 17). The Mariana subspecies, which persists only on the island of Aguiguan (CNMI), appears to prefer relatively large caves (Wiles et al. 2009, p. 15 in O'Shea and Valdez 2009). The limestone cave ecosystem of the Mariana subspecies on Aguiguan is characterized by constant temperature, high relative humidity, and no major air movement (O'Shea and Valdez 2009, pp. 77–78). With such small populations, it is unclear whether these microclimate parameters are preferences or requirements for the species, or just the habitats the few remaining animals still occupy. Such basic habitat data are lacking for the South Pacific subspecies of Pacific sheath-tailed bat, but may be important because the alteration of climate conditions has been implicated in the abandonment of roost caves by other bat species (Hutson et al. 2001, p. 101).

Roost disturbance, land clearing around cave entrances, mining and quarrying, tourism, and predation by non-native predators are key factors negatively affecting the current condition of sheath-tailed bat's roosting habitats. These are likely having large impacts on reproductive fitness, and thus negatively affecting species resilience in this setting. Both the stressors and current conservation actions working to ameliorate these stressors are described below.

Disturbance of roosting caves has contributed to the decline of the Pacific sheath-tailed bat throughout its range. Disturbance of roost caves by humans is likely a result of recreation, harvesting of co-occurring bat species, and guano mining (Grant et al. 1994, p. 135; Tarburton 2002, p. 106; Wiles and Worthington 2002, p. 17; Palmeirim et al. 2005, pp. 63, 66; Malotaux 2012a *in litt*.; Malotaux 2012b in litt.). Roost disturbance is a well-known problem for many cave-dwelling species (Palmeirim et al. 2005, p. 3). Roosts are important sites for bats for mating, rearing young, and hibernating (in mid- and high-latitude species). Roosts often facilitate complex social interactions, offer protection from inclement weather, help bats conserve energy, and minimize predation risk (Kunz and Lumsden 2003, p. 3); therefore, disturbance at caves and flushing from roosts may cause bats to incur elevated energetic costs, other physiological stress, and potentially increased risk of predation while in flight. Roost disturbance thus likely negatively affects the survival and reproduction of the Pacific sheath-tailed bat. There is evidence the Pacific sheath-tailed bat may be sensitive to roost disturbance. Researchers on Aguiguan noted that the Mariana subspecies was easily disturbed by humans: “Bats always seemed wary, readily flew within the roost if we approached, did not cluster, and did not enter torpor when resting in cloth bags.” (Wiles et al. 2011, p. 303).

In Fiji, caves used as a roosting habitat for the Pacific sheath-tailed bat are under threat from tourism and other more routine visits by people (Malotaux 2012a, p. 3, Dave Waldien, in litt.). On Upolu, Samoa, caves previously known to support bats are well-known locations for visits by tourists, one within O le Pupu Pue National Park and others on village land (Tarburton 2011, pp. 40, 44). Swiftlets (*Aerodramus spp*.) are still observed in significant numbers in these caves (Tarburton 2011, p. 40), but these birds may be more tolerant than bats of human disturbance. We do not have information on human disturbance of roosts in Tonga or Vanuatu.

In American Samoa, human disturbance at the two caves known to be historical roost sites for the bat is likely minimal at present. Although guano mining occurred in the Anape'ape'a caves in the 1960s (Amerson et al. 1982a, p. 74), it has ceased due to the high salt content of the guano as a result of flooding with seawater during the cyclones that likely extirpated the bats from these islands (Grant et al. 1994, p. 135). The Hawaiian names 'ōpe'ape'a and 'āpe'ape'a are for the Hawaiian hoary bat, *Lasiurus cinereus semotus*. The Samoan name, anape'ape'a, may indicate that this area has long been recognized for the occurrence of the Pacific sheath-tailed bat.

Feral goats enter caves for shelter from the sun and consequently can disturb roosting bats, although the extent of this disturbance is unknown (Scanlon 2015b, in litt.). Feral goats have been observed entering caves on Aguiguan Island and disturbing colonies of the endangered Mariana swiftlet (*Aerodramus vanikorensis bartschi*). They likely would disturb the Mariana subspecies of the Pacific sheath-tailed bat as well (Wiles and Worthington 2002, p. 17; Cruz et al. 2008, p. 243; Scanlon 2015b, in litt.). Caves suitable for bats but occupied by goats had no bats present (Guam Division of Aquatic and Wildlife Resources 1995, p. 95). On Yaqeta (also Yanggeta) Island, Fiji, a cave that once supported several hundred Pacific sheath-tailed bats and was located within a small forest fragment frequented by goats and visited by tourists was abandoned by the bats (Scanlon et al. 2014, p. 453).

Populations of the Pacific sheath-tailed bat are concentrated in the caves where they roost, and chronic disturbance of these sites can result in the loss of populations. Because so few populations of this bat remain, loss of additional populations to roost disturbance further erodes its diminished abundance and distribution. Based on the above information, roost disturbance at caves accessible to humans and animals such as feral goats is a current threat and will likely continue to be a threat into the future.

Foraging habitat and deforestation

All Pacific sheath-tailed bat subspecies are nocturnal, and typically emerge around dusk to forage on flying insects (Hutson et al. 2001, p. 138; Craig et al. 1993, p. 51). The Mariana Islands subspecies forages almost entirely in native and nonnative forests near their roosting caves (Esselstyn et al. 2004, p. 307). Other subspecies in Micronesia have been observed foraging beneath the canopy of dense native forest (on Pohnpei) and over town streets (Palau and Chuuk) (Bruner and Pratt 1979, p. 3). The bat's preferred foraging habitat is mature well-structured forest with a high, dense canopy (Kalko 1995, pp. 262–265; Esselstyn et al. 2004, p. 307; Palmeirim et al. 2005, p. 29; Gorreson et al. 2009, p. 336; Valdez et al. 2011, pp. 306–307; Marques et al. 2015, pp. 6–EV–9–EV).

Logging, agriculture, development, and tropical cyclones are the main causes of deforestation in the habitat of the Pacific sheath-tailed bat (Government of Samoa 2001, p. 59; Wiles and Worthington 2002, p. 18) Agriculture and development have caused the destruction and modification of foraging habitat of the Pacific sheath-tailed bat, and resulted in a loss of native vegetation cover and reduction of insect prey. The loss of native plant diversity associated with the conversion of native forests to agriculture and other uses usually results in a corresponding reduction in the diversity and number of flying insects (Hespenheide 1975, pp. 84, 96; Waugh and Hails 1983, p. 212; Tarburton 2002, p. 107). The threat from deforestation is concentrated in Fiji and Samoa, which comprise roughly 62 percent of the land area and occupy the center of the bat's range.

*Mariana Islands*

Based on the preference of the Mariana subspecies for foraging in forested habitats near their roost caves, Wiles et al. (2011, p. 307) predict that past deforestation in the Mariana archipelago may be a principal factor in limiting their current population to the island of Aguiguan, which has relatively healthy native forest.

*Fiji*

Similarly, in Fiji, most sheath-tailed bat colonies are found roosting in caves in or near closed canopy, native forest (Palmeirim et al. 2005, pp. 36, 44); however, much native forest has been lost on the large Fijian islands (Palmeirim et al. 2007, p. 515; Hansen et al. 2013). Data on forest cover in Fiji were obtained from the global forest assessment (Hansen et al. 2013, Figure 6). Not all Fijian islands were mapped for this assessment, which occurred at the 30m pixel scale. This is a coarse scale for mapping these relatively small islands, and this can reduce accuracy in land area calculations relative to data sets mapped at higher resolution. This assessment showed forest covered nearly 1.45M hectares (ha) in mapped areas; 78 percent of the land was covered by forest (Table 1, Figure 6). On specific islands with known bat roost locations forest cover ranged from a low of 44 percent of the mapped land area in the Yasawa Group to 96 percent of the land area of Taveuni. Rates of forest cover change summarized by Global Forest Watch (globalforestwatch.org) report that "from 2001 to 2018, Fiji lost 40.5K ha of tree cover, equivalent to a 2.6 percent decrease since 2000."

Table 1. Forest cover in Fiji (data from Hansen et al. 2013). Only islands with known bat roosts are specifically summarized.

| | **Island** | **Land Area Mapped (Ha)** | **Forest Cover (Ha)** | **% Island Forested** |
|---|---|---|---|---|
| **Islands with Forest Cover Assessment** | Other Islands | 731,119 | 602,322 | 82% |
| | Yasawa Group | 15,491 | 6,749 | 44% |
| | Ovalu | 10,724 | 9,923 | 93% |
| | Taveuni | 44,183 | 42,578 | 96% |
| | Viti Levu | 1,068,777 | 792,704 | 74% |
| | **Total** | **1,870,294** | **1,454,276** | **78%** |
| **Islands without Forest Cover Assessment** | Lakeba | 6,236 | NA | NA |
| | Yasawa Group | 44 | NA | NA |
| | Other Islands | 19,882 | NA | NA |
| | **Total** | **26,162** | | |

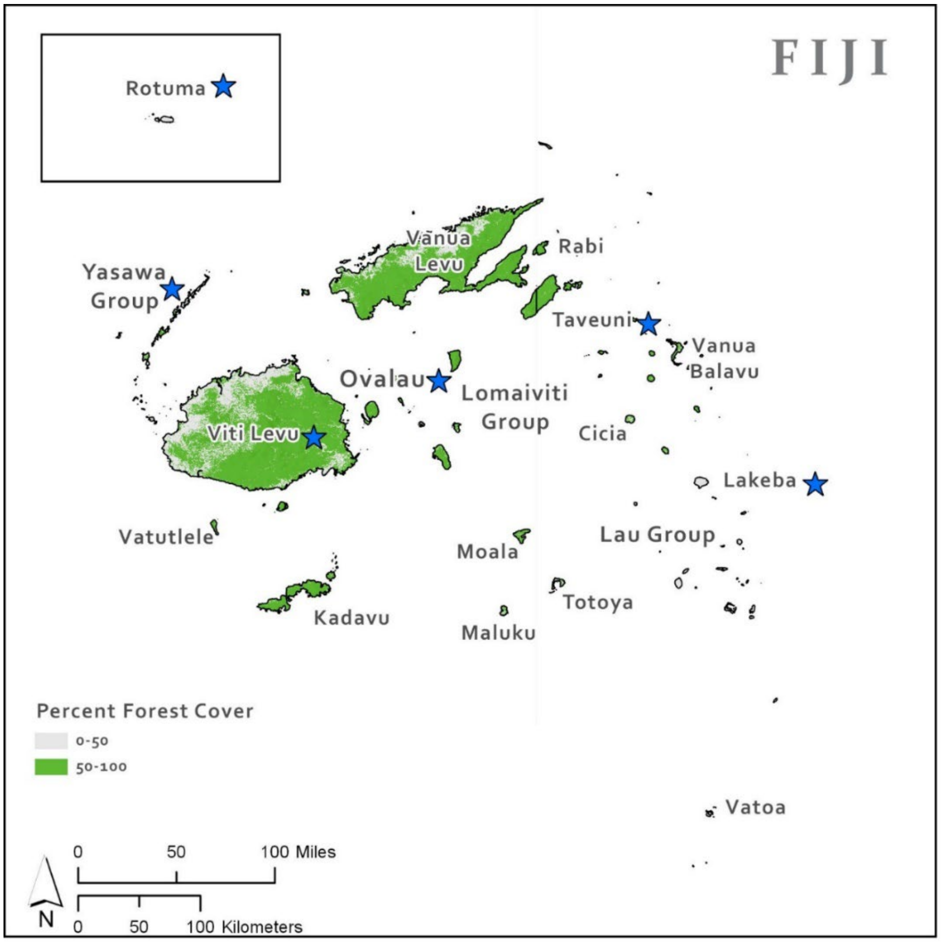


Figure 6. Forest cover in Fiji (data from Hansen et al. 2013).

*Samoa and American Samoa*

Forest cover in the Samoan Archipelago was mapped more recently and at a finer spatial scale than the Fiji Forest Cover. (American Samoa Department of Marine and Wildlife Resources and the Land Institute of New Zealand; Meyer et al. 2017, LINZ 2015, Figure 7). These data show 59 percent of the land mass of the Samoan Archipelago is covered in forest (178,671of 302,797 ha, Figure 7), despite heavy losses to commercial logging in the last several decades (Government of Samoa 2001, p. 59). Forest cover on individual islands ranges from none on the smaller islands of Apolima and Nuusafee to 89 percent on the islands of Ofu and Olosega (Figure 7), which are partly protected within the National Park of American Samoa. Rates of forest cover change for Samoa and American Samoa are not summarized by Global Forest Watch (globalforestwatch.org).

Under a 50-year lease agreement between local villages, the American Samoa Government, and the Federal Government, approximately 8,000 acres (ac) (3,240 ha) of forested habitat on the islands of Tutuila, Tau, and Ofu are protected and managed in the National Park of American Samoa (NPSA Lease Agreement 1993). There is the potential for development surrounding park inholdings, but such forest clearing would be isolated and small in scale compared to the large tracts of forested areas protected. Although the lease agreement results in overall protection of the lands in the national park from development, this protection does not reduce or eliminate the range-wide threats to the Pacific sheath-tailed bat.

Deforestation has been extensive and is ongoing across the range of the Pacific sheath-tailed bat. On the island of Tutuila, American Samoa, agriculture and development cover approximately 24 percent of the island and are concentrated in the coastal plain and low-elevation areas where loss of forest is likely to have modified foraging habitat for sheath-tailed bats (Meyer et al. 2017). Although the large Fijian islands still have some areas of native forest, much of it has been lost (e.g., 17 percent between 1990 and 2000; FAO 2005 in litt., and an additional 2.6 percent since 2000, globalforestwatch.org).

In Samoa (Figure 8), the amount of forested area declined from 74 to 46 percent of total land area between 1954 and 1990 (Food and Agricultural Organization (FAO) 2005 in litt.). Between 1978 and 1990, 20 percent of all forest losses in Samoa were attributable to logging, with 97 percent of the logging having occurred on Savaiʻi (Government of Samoa 1998 in Whistler 2002, p. 132). Forested land area in Samoa continued to decline at a rate of roughly 2.1 percent or 7,400 ac (3,000 ha) annually from 1990 to 2000 (FAO 2005 in litt.). As a result, there is very little undisturbed, mature forest left in Samoa (Watling 2001, p. 175; FAO 2005 in litt.; LINZ 2015, Figure 8). Today, only 360 ac (146 ha) of native lowland rainforests (below 2,000 ft or 600 m) remain on Savaiʻi and Upolu as a result of logging, agricultural clearing, residential clearing (including relocation due to tsunamis), and natural causes such as rising sea level and tropical cyclones (Ministry of Natural Resources and Environment (MNRE) 2013, p. 47). On Upolu, direct or indirect human influence has caused extensive damage to native forest habitat (above 2,000 ft or 600 m) (MNRE 2013, p. 13). Although forested, almost all upland forests on Upolu are largely dominated by introduced species today. Savaiʻi still has extensive upland forests, which are for the most part undisturbed and composed of native species (MNRE 2013, p. 40).

Table 2. Forest Cover Summary for the Samoan Archipelago (data from LINZ 2015 and Meyer et al. 2017).

| Island | Land Area Mapped (Ha) | Forest (Ha) | Island Forested (%) |
|---|---|---|---|
| **Savai'i** | 170,200 | 113,957 | 67% |
| **Aleipata Islands** | 149 | 118 | 79% |
| **Upolu** | 112,428 | 50,517 | 45% |
| **Apolima** | 100 | 0 | 0% |
| **Aunu'u** | 153 | 68 | 44% |
| **Manono** | 291 | 106 | 36% |
| **Nuusafee** | 2 | 0 | 0% |
| **Tutuila** | 13,660 | 9,414 | 69% |
| **Ofu/Olosega** | 1,266 | 1,132 | 89% |
| **Ta'u** | 4,548 | 3,359 | 74% |
| **Total Hectares Land Western Samoa** | 283,323 | 164,766 | |
| **Total Hectares Land American Samoa** | 19,474 | 13,905 | |
| **Western Samoa Forested Area (%)** | | 58% | |
| **American Samoa Forested Area (%)** | | 71% | |
| **Total Hectares Samoan Archipelago** | 302,797 | 178,671 | 59% |

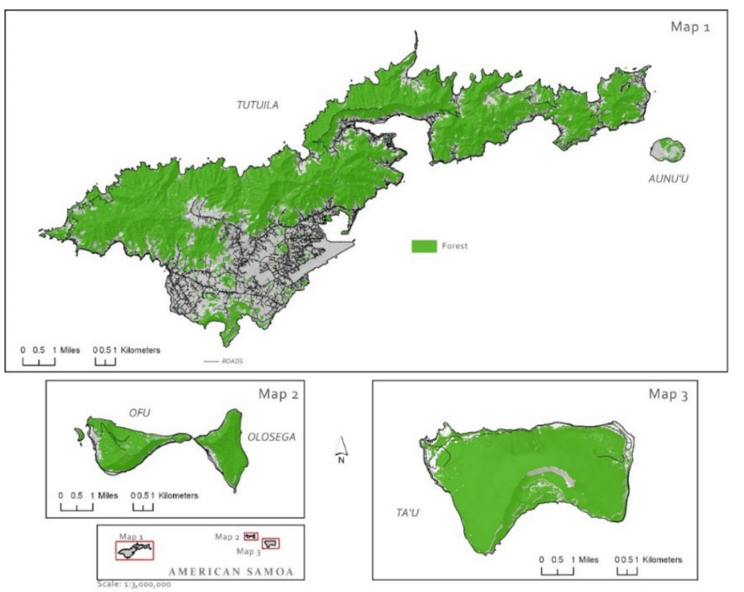



Figure 7. Forest cover in American Samoa (data from: Meyer et al. 2017).

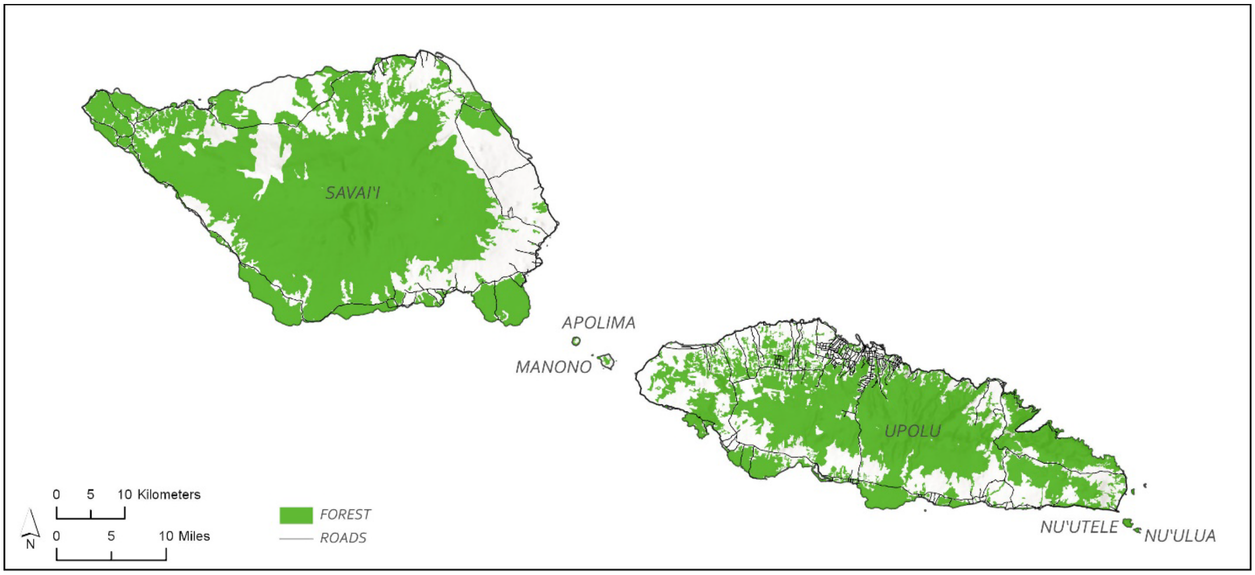



Figure 8. Forest cover in Western Samoa (data from Meyer et al. 2017).

*Tonga*

An island-specific summary of geospatial data for forest cover in Tonga show that the areas historically occupied by bats have more forest cover (43-50 percent forested) than the average, compared to the overall cover (28 percent) for all other islands combined (LINZ 2015;

Table 3). Forest cover on islands with historic bat roost locations in Tonga are shown in Figure 9. Rates of forest cover change for Tonga were not summarized by Global Forest Watch (globalforestwatch.org).

The best available information does not provide the rates of forest loss in Tonga, but the Land Institute of New Zealand provides forest cover enabling GIS analysis (LINZ 2015, Figure 9). In Vanuatu, data layers are not available, but Global Forest Watch Reports a loss of 1.03K ha of tree cover between 2010 and 2018 with deforestation from commercial logging as a primary driver globalforestwatch.org).

Table 3. Summary of Forest Cover on Islands with Historic Bat Roosts in Tonga (data from LINZ 2015).

| Island | Island Area (Ha) | Forest Area (Ha) | Island Forested (%) |
|---|---|---|---|
| **`Eua Island** | 8,808 | 3,748 | 43% |
| **Niuafo`ou** | 5,113 | 2,554 | 50% |
| **Other Islands** | 58,353 | 16,193 | 28% |
| **Tonga Total** | 72,274 | 22,495 | 31% |

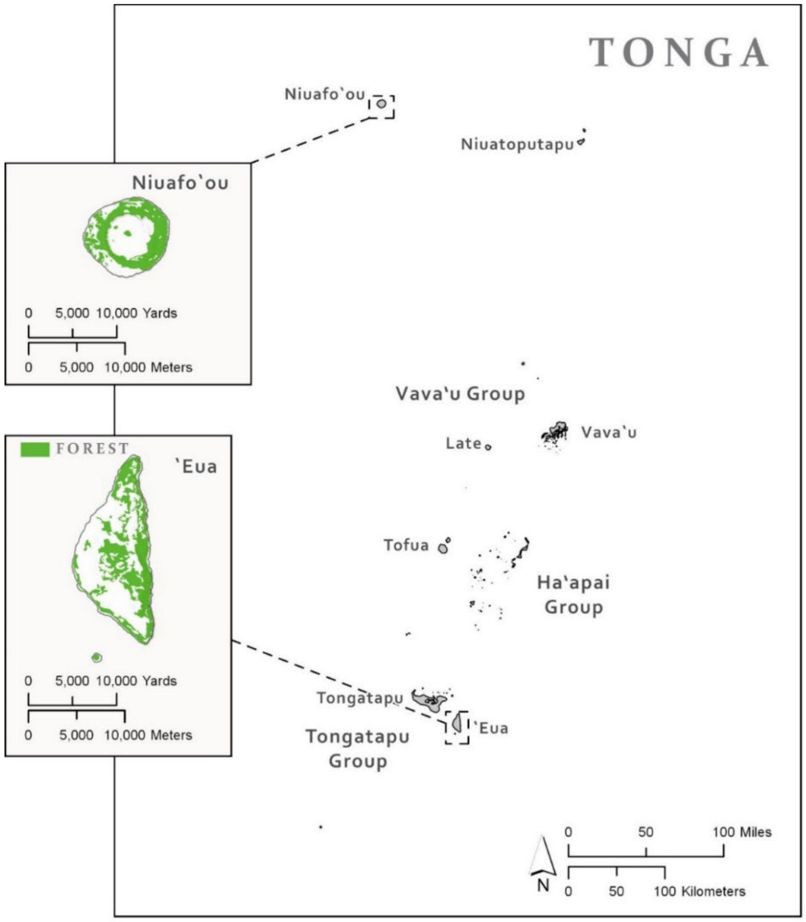



Figure 9. Forest cover in Tonga (data from LINZ 2015).

*Vanuatu*

Geospatial data on forest cover in Vanuatu are not available. Rates of forest cover change were summarized by Global Forest Watch (globalforestwatch.org) report: "In 2010, Vanuatu had 1.15M ha of tree cover, extending over 93 percent of its land area. Global Forest Watch Reports a loss of 1.03K ha of tree cover between 2010 and 2018 with deforestation from commercial logging as a primary driver (https://www.globalforestwatch.org). From 2001 to 2018, Vanuatu lost 12.2K ha of tree cover, equivalent to a 1.0 percent decrease since 2000."

Overgrazing by feral ungulates

Overgrazing by nonnative ungulates (goats and pigs) has resulted in the destruction and degradation of forests on island ecosystems (Esselsytn et al. 2004, p. 307; Palmeirim et al. 2005, p. 46; Berger et al. 2005, pp. 36, 38, 40, 42–47; CNMI– SWARS 2010, p. 15; Kessler 2011, pp. 320–323; Pratt 2011, pp. 2, 36; Welch et al. 2016). In areas of known populations of the Pacific sheath-tailed bat in Fiji and the Mariana Islands, overgrazing of the forest understory by goats resulted in little or no recruitment of canopy tree species (Palmeirim et al. 2005, p. 46). A similar situation has occurred on Aguiguan in the Northern Mariana Islands, where the endangered Mariana subspecies (*E. semicaudata rotensis*) occurs (Gorreson et al. 2009, p. 339). Palmeirim et al. (2005, p. 46) predicted that continued overgrazing would result in the demise of the forests that are so important for the Pacific sheath-tailed bat. Despite the negative impacts of goat browsing on tree recruitment, the current amount of well-developed forest canopy habitat and availability of food resources suggest that the bat is currently able to persist on islands where feral goat browsing is occurring (Esselstyn et al. 2004, p. 307; Palmeirim et al. 2005, pp. 28–29). However, because the direct and indirect impacts of goat browsing on the preferred foraging habitat of the bat are currently occurring and expected to continue into the future in Fiji, we conclude that habitat destruction and degradation by goat browsing is a threat to the continued existence of the bat.

Pesticides

Pesticides may negatively affect the Pacific sheath-tailed bat due to direct toxicity and a reduction in the availability of insect prey. Pesticides are known to adversely affect bat populations by secondary poisoning when bats consume contaminated insects or by reducing the availability of insect prey (Hutson et al. 2001, p. 138; Mickleburgh et al. 2002, p. 19). Pesticides may have contributed to declines and loss of the Mariana subspecies of Pacific sheath-tailed bat on islands where pesticides were once applied in great quantities (Guam, Saipan, and Tinian) and concurrent with the bat's decline (Wiles and Worthington 2002, p. 17). In American Samoa and Samoa, current levels of pesticide use are likely lower than several decades ago when, particularly during the years in which taro was grown on large scales for export (1975–1985), use coincided with the decline of bats in both places and has been implicated as the cause (Tarburton 2002, p. 107). However, Grant et al. (1994, pp. 135–136) dismissed the role of insecticides in the decline of the bat in American Samoa based on the absence of a similar population crash in the insectivorous white-rumped swiftlet (*Aerodramus spodiopygius*) and the limited use of agricultural and mosquito-control pesticides. On the island of Taveuni in Fiji, where bat populations have persisted at low levels over the last 10 years (Palmeirim et al. 2005, p. 62, Malotaux 2012, in litt., Waldien 2019b, in litt.), several locals reported that pesticide use was quite widespread, and their use may be similar on other Fijian islands (Malotaux 2012, in litt.). We do not have information about pesticide use in Tonga or Vanuatu.

Tropical cyclones

The Pacific sheath-tailed bat has coexisted with severe tropical storms and cyclones for millennia. However, these storms exacerbate other threats to the species by adversely affecting habitat and food resources and pose a particular threat to its small and isolated remaining populations.

American Samoa, Samoa, Fiji, Tonga, and Vanuatu are irregularly affected by tropical cyclones (Australian BOM and CSIRO 2011 Vol. 1, p. 41; Figure 10). Located in the Southern Hemisphere, these countries experience most tropical cyclones during the November to April wet season, with the maximum occurrence between January and March (Australian BOM and

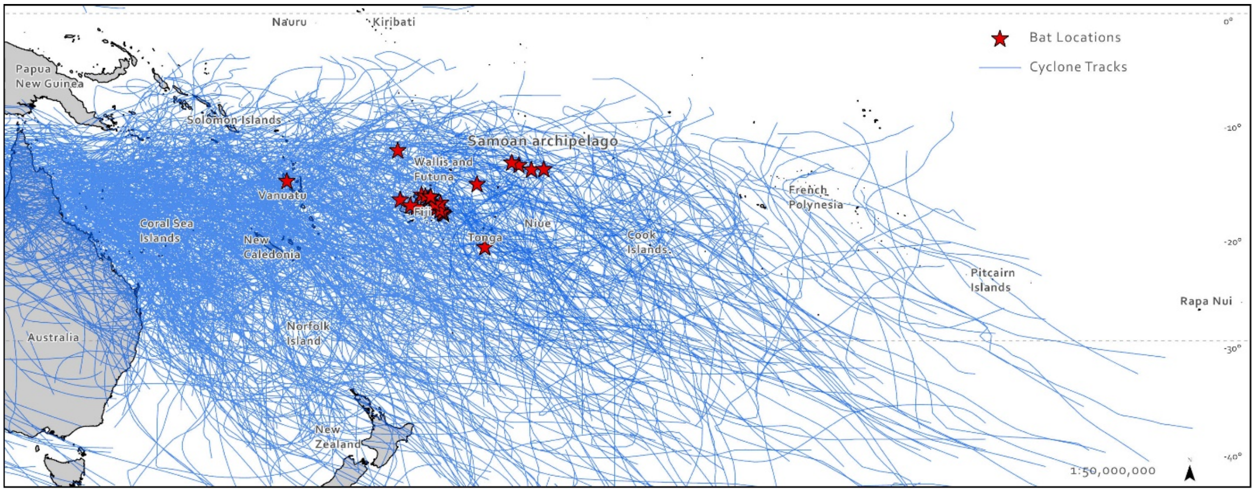


Figure 10. Cyclone tracks for the central South Pacific from 1898 to 2019. All data from Knapp *et al*. (2010) and NOAA IBTrACS (2019).

CSIRO 2011 Vol. 1, p. 47). In the 41-year period ending in 2010, more than 280 tropical cyclones passed within 250 mi (400 km) of Samoa (52 storms), Tonga (71), Fiji (70), and Vanuatu (94) ( Figure **8**, Australian BOM and CSIRO 2011, pp. 76, 186, 216, 244). In recent decades, several major (named) storms have hit American Samoa and Samoa (Tusi in 1987, Ofa in 1990, Val in 1991, Heta in 2004, and Olaf in 2005 (MNRE 2013, pp. 31–32; Federal Emergency Management Agency 2015, in litt.)); Tonga (Waka in 2001 and Ian in 2014 (Tonga Meteorological Service 2006, in litt.; World Bank 2014, in litt.)); Fiji (Tomas in 2010, Winston in 2016 (Digital Journal 2010, in litt.)); and Vanuatu (Pam in 2015 (BBC 2015, in litt.)).

The high winds, waves, strong storm surges, high rainfall, and flooding associated with tropical storms, particularly severe tropical cyclones (with sustained winds of at least 150 mi per hour or 65 m per second) cause direct mortality of the Pacific sheath-tailed bat. Cyclones Ofa (1990) and Val (1991) removed the dense vegetation that had obscured the entrance to the larger cave at Anapeapea Cove, American Samoa, inundated the cave with water, filled it with coral and fallen trees, and washed the cave walls clean (Craig et al. 1993, p. 52; Grant et al. 1994, p. 135). If they did not leave the roost, the sheath-tailed bats in the cave were likely killed when the hurricane hit (Grant et al. 1994, p. 135).

Tropical cyclones may also cause indirect mortality of the Pacific sheath-tailed bat due to the cessation of foraging and starvation during extended periods of high wind or rain. Cyclone Val (December 1991) remained stationary over the Samoan archipelago for 4 days, and Pacific sheath-tailed bats likely were unable to feed during this time (Grant et al. 1994, p. 135). Despite the ability of Pacific sheath-tailed bats to enter torpor to survive episodes of inclement weather, the high ambient temperatures in Samoa may preclude the energy savings necessary to sustain a small (4–7g) torpid bat for an extended period (Grant et al. 1994, p. 135).

Tropical cyclones may also cause modification of the roosting habitat of the Pacific sheath-tailed bat by modifying vegetation in and around cave entrances, causing landslides that block entrances, or altering conditions within roosting caves. Microchiropterans, such as the Pacific sheath-tailed bat, can spend over half their lives in their roosts; consequently, the microclimate of these habitats can exert a strong influence over their heat-energy balance (Campbell 2011, p. 174). The presence of nearby forest cover and a well-developed tree canopy at cave entrances is likely to be important in maintaining temperature and humidity, and minimizing air movement in bat roosts, while allowing for passage. O'Shea and Valdez (2009, pp. 77–78) characterized the limestone cave ecosystem of the Mariana subspecies on Aguiguan as having constant temperature, high relative humidity, and no major air movement. Although such data are lacking for other populations of the Pacific sheath-tailed bat, alteration of microclimate conditions has been implicated in the abandonment of roost caves by other bat species (Hutson *et al*. 2001, p. 101).

Loss of forest cover from tropical cyclones can reduce foraging opportunities for bats. Following Cyclones Ofa (1990) and Val (1991), about 90 percent of the forests on Upolu and Savaii were blown over or defoliated (Park et al. 1992, p. 4; Elmqvist et al. 2002, pp. 385, 388). Recent Super Typhoon Yutu, which hit the Marianas Islands in 2018 showed similarly high levels of defoliation and loss of forest cover, based on an analysis of satellite imagery (Amidon et al. 2019. in prep.). Tarburton (2002, p. 107) noted that the abundance of flying insects remained low for weeks after cyclones had defoliated trees. Although the Pacific sheath-tailed bat has the capacity to forage in a variety of habitats, a study of habitat use by the Mariana subspecies showed a clear preference for forested habitats (Esselstyn et al. 2004, p. 307). The Pacific sheath-tailed bat's severely diminished abundance and distribution increase the likelihood that mortality events from typhoons, either through direct mortality or through habitat and food resource disruption, will cause population level impacts and increase the vulnerability of the few remaining populations of the species to environmental catastrophes.

Disease-free populations

Disease may contribute to the decline of the Pacific sheath-tailed bat, especially because of the bat's communal roosting behavior (Wiles and Worthington 2002, p. 13). Microchiropterans have been severely affected by diseases such as white nose syndrome in North America. While disease has not been observed either in the Mariana or South Pacific subspecies of Pacific sheath-tailed bat (Palmeirim et al. 2007, p. 517; Wiles et al. 2011, p. 306), the possibility exists that an undetected disease has led or contributed to the extirpation of this species on several islands (Malotaux 2012a in litt.). Available information does not indicate that disease is a threat to this species.

Human overutilization

Hunting or other forms of utilization are not considered a threat to the Pacific sheath-tailed bat. We found no information indicating that the Pacific sheath-tailed bat is collected for commercial, recreational, scientific, or educational purposes. Historically, the people of Fiji ate the bat, but this practice is likely much reduced based on the bats current abundance and increased bat conservation outreach to local communities. Research and collection of this species is regulated through permits issued under section 10(a)(1)(A) of the Act.

Predation

Predation by nonnative mammals is a factor in the decline of the Pacific sheath-tailed bat throughout its range. Terrestrial predators such as cats and rats may be able to take the bat directly from its roosts, which are often in exposed sites such as shallow caves, rock overhangs, or cave entrances. Rats and feral cats are present throughout the range of the Pacific sheath-tailed bat. Predation of related subspecies and other cave roosting bats by rats and feral cats strongly suggests a high probability of predation of the Pacific sheath-tailed bat.

*Cats*

Domestic and feral cats (*Felis catus*) can capture low-flying bats and cats have been documented to wait for bats as they emerge from caves and capture them in flight (Tuttle 1977 in Palmeirim et al. 2005, p. 33; Ransome 1990 in Palmeirim et al. 2005, p. 33; Woods et al. 2003, pp. 178, 188). Consequently, even a few cats can have a major impact on a population of cave-dwelling bats (Palmeirim et al. 2005, p. 34). Of the predators introduced to Fiji, cats are the most likely to prey on bats (Palmeirim et al. 2005, pp. 33–34). On Cicia Island in the Lau group in Fiji, Palmeirim et al. (2005, p. 34) observed a cat next to the entrance of a cave where Pacific sheath-tailed bats roosted, far from any human settlement. On Lakeba (Lau), a cave that once harbored a large colony of Pacific sheath-tailed bats is now empty and called Qara ni Pusi (cave of the cat; (Palmeirim et al. 2005, p. 34)). Feral cats are also present on Tutuila and on the Manu'a Islands in American Samoa, (Freifeld 2007, in litt.; Arcilla 2015, in litt.). Feral cats have also been documented in Samoa, Tonga, and are likely present in Vanuatu (Atkinson and Atkinson 2000, p. 32; Freifeld 2007, in litt.; Arcilla 2015, in litt.).

*Rats*

Rats (*Rattus spp*.) may also prey on the Pacific sheath-tailed bat. Rats are omnivores and opportunistic feeders and have a widely varied diet consisting of nuts, seeds, grains, vegetables, fruits, insects, worms, snails, eggs, frogs, fish, reptiles, birds, and mammals (Fellers 2000, p. 525; Global Invasive Species Database 2011). Rats are known to prey on young bats that have not developed the ability to fly (non-volant). Predation occurs at roosting sites and can be a major threat to bat colonies (Wiles et al. 2011, p. 306). Of several nonnative rats found on islands in the Pacific, black rats (*R. rattus*) likely pose the greatest threat to Pacific sheath-tailed bats because of their excellent climbing abilities (Palmeirim 2015, in litt.). Although we lack direct evidence of black rats preying on Pacific sheath-tailed bats, this rat species has had documented, adverse impacts to other colonial species of small bats, such as Townsend's big-eared bat (*Corynorhinus townsendii*) in California (Fellers 2000, pp. 524–525), and several species in New Zealand (Daniel and Williams 1984, p. 20). Based on observations of swiftlets, cave nesting birds often share bats' roosting caves, where smooth rock overhangs in tall caverns provide nesting surfaces safe from rats, cats, and other predators (Tarburton 2011, p. 38). Bats that roost in caves with low ledges or filled with debris from rockfalls or severe weather events are likely to either abandon such caves or become more accessible to predators such as rats. Rats have been postulated as a problem for the Mariana subspecies of the Pacific sheath-tailed bat (Wiles et al. 2011, p. 306); their remaining roost sites on Aguiguan appear to be those that are inaccessible to rodents (Wiles and Worthington 2002, p. 18; Berger et al. 2005, p. 144). Rats are present throughout the range of Pacific sheath-tailed bats (Atkinson and Atkinson 2000, p. 32), and are considered to be a threat to the bats.

## Range-wide Species Needs and Stressors

*Metapopulation Equilibrium*

The Pacific sheath-tailed bat is thought to have a metapopulation structure (Palmeirim et al. 2005, p. 29) that will only persist in an archipelago if the island colonization rate is sufficiently high to compensate for the rate of extirpation caused by stochastic factors on individual islands (Palmeirim et al. 2005, p. 36). The colonization rate is proportional to the availability of source populations; immigration of bats to recolonize sites or islands where the species was extirpated is dependent on sufficient numbers of animals existing in multiple other sites or islands within a feasible dispersal distance (Hanski and Gilpin 1991, pp. 4–14). Consequently, the extirpation of the Pacific sheath-tailed bat from some islands, particularly from the largest islands, may in the long-term result in the permanent regional extinction of the species, even if suitable environmental conditions persist on some islands (Palmeirim et al. 2005, p. 36). The continued decline of the only significant source population of Pacific sheath-tailed bat in the Fijian archipelago may greatly diminish the likelihood of recolonization throughout the remainder of the bat’s range where it is extirpated or nearly so.

Species that undergo severe population declines and range reductions are inherently highly vulnerable to extinction from catastrophes such as severe storms, disease outbreaks, climate change, inbreeding depression, or demographic stochasticity (Shaffer 1981, p. 131; Gilpin and Soule´ 1986, pp. 24–34; Pimm et al. 1988, p. 757; Mangel and Tier 1994, p. 607; Lacy 2000, pp. 40, 44–46). Conditions leading to this level of vulnerability are often reached by island species that face numerous non-historic threats derived from human occupation of previously uninhabited islands. Synergistic interactions among ongoing threats and natural disturbances such as storms or random demographic and genetic fluctuations further magnified the impacts to these species (Lacy 2000, pp. 45–47).

*Climate Change*

There are no climate-change studies on impacts to Pacific sheath-tailed bats or their habitat. There are, however, climate change studies that address potential changes in the tropical Pacific, including Samoa, Tonga, Fiji, and Vanuatu (Australian BOM and CSIRO 2011 Vol. 1, p. 15). Information on Samoa (13°S and 171°E) may be used as a proxy for American Samoa (14°S and 170°W). The annual average temperature in these island states is projected to increase by 1.0 to 1.9°C by 2055 and 1.5 to 3.3°C by 2090, with small differences depending on regions and emissions scenario. Change in precipitation is less certain but an overall increase in rainfall is expected along with drier dry seasons and wetter wet seasons and more extreme rainfall days. These projected changes will lead to alterations of current climate conditions (Loope and Giambelluca 1998, pp. 514–515; Pounds et al. 1999, pp. 611–612; IPCC AR4 2007, p. 48; Emanuel et al. 2008, p. 365; U.S. Global Change Research Program (US–GCRP) 2009, pp. 145–

149, 153; Keener et al. 2010, pp. 25–28; Sturrock et al. 2011, p. 144; Townsend et al. 2011, pp. 14–15; Finucane et al. 2012, pp. 23–26; Keener et al. 2012, pp. 47–51). The impacts on Pacific sheath-tailed bat are unknown but they will likely create additional stresses on the bats in the form of changes to roost habitats and food resource availability.

## Conservation Actions

### Habitat protection

A multinational coalition of non-governmental conservation and academic organizations and natural resource managers called the Fiji Bat Conservation Initiative and led by NatureFiji-MareqetiViti is working to conserve the Pacific sheath-tailed bat and other cave-dwelling bats in Fiji (Waldien 2019a, in litt.). These collaborators have been collating data on historic and new roosts and conducting surveys with bat detectors. Through these and visual roost assessment methods they located two new roost caves on Taveuni Island since the species was listed in 2016. They are also working through government conservation officers and with local partners to increase awareness of the urgency of Fijian bat conservation and species needs for land management in roost areas.

The National Park of American Samoa (NPSA) was established to preserve and protect the tropical forest and archaeological and cultural resources, to maintain the habitat of flying foxes, to preserve the ecological balance of the Samoan tropical forest, and, consistent with the preservation of these resources, to provide for the enjoyment of the unique resources of the Samoan tropical forest by visitors from around the world (American Samoa Government and National Park Service of America 100–571). Under a 50-year lease agreement between local villages, the American Samoa Government, and the Federal Government, approximately 8,000 ac (3,240 ha) of forested habitat on the islands of Tutuila, Ta'u, and Ofu are protected and managed, including suitable foraging habitat for the Pacific sheath-tailed bat (NPSA Lease Agreement 1993).

The American Samoa Government may also designate Unique Areas for conservation. The only Unique Area designated to date is the Ottoville Rainforest (American Samoa Coastal Management Program 2011, p. 52), on the Tafuna Plain on the south side of Tutuila, which may provide foraging habitat for Pacific sheath-tailed bats. It is a small parcel of land in the middle of the heavily developed Tafuna Plain (Trail 1993, p. 4), far from the last known roost sites of the bat.

As of 2014, a total of approximately 58,176 ac (23,543 ha), roughly 8 percent of the total land area of Samoa (285,000 ha) was enlisted in terrestrial protected areas, with the majority located in five national parks covering a total of 50,629 ac (20,489 ha), overlapping several sites known to be previously occupied by the bat (Tarburton 2002, pp. 105–107; Tarburton 2011, pp. 43–46).

Fiji currently has 23 terrestrial protected areas covering 188 sq mi (488 sq km) or 2.7 percent of the nation’s land area (Fiji Department of Environment 2014, pp. 20–21). Most notably, on

Taveuni Island, the Bouma National Heritage Park (3,500 ac (1,417 ha)), Taveuni Forest Reserve (27,577 ac (11,160 ha)), and Ravilevu Reserve (9.934 ac (4,020 ha)) may contain caves and could provide important foraging habitat for the Pacific sheath-tailed bat (Fiji Department of Environment 2011; Naikatini 2015, in litt.; Scanlon 2015a, in litt.). Additional areas of remnant forest and important bat habitat are also managed informally under traditional custodial management systems (Scanlon 2015a, in litt.).

Controlling invasive predators

We are unaware of any conservation actions planned or implemented at this time to abate the threats of predation by feral cats or rats to the Pacific sheath-tailed bat.

Resilience to tropical cyclones

We are not aware of any conservation efforts to increase resilience to tropical cyclones through protection and enhancement of cave sites. Alternate roost sites with a suitable microclimate and healthy forest ecosystems would increase bat resilience to more intense storms.

Reducing the threat of disease

We are unaware of any conservation actions planned or implemented at this time to abate the threats of disease to the Pacific sheath-tailed bat. Cleaning and sanitation of boots and equipment and outreach to the tourism community on appropriate decontamination procedures for those entering caves would reduce the threat of disease.

# Resiliency, Representation, and Redundancy of the Species

## Resiliency

Population size and population growth rates show that the current resilience of the Pacific sheath-tailed bat is low. The overall trend has been one of decline, including loss of individuals and populations (measured as number of active roosts and total abundance of animals), and extirpation from entire island chains distant from the current center of the species distribution in Fiji. There are, however, data gaps in species resilience due to lack of monitoring and population data. Since 1990, the loss of several known roost sites has been documented (Grant 1993, p. 52). However, there have been no comprehensive studies of population status and trends in these locations. Small and isolated populations may be resilient enough to grow in the absence of predators and with adequate forest management. On Aguiguan, a small island in the Marianas, a population of congener species *E.s. rotensis* was documented to be growing ($\lambda = 1.10$ and 1.13 in two populations; Wiles et al. 2011, p. 304).

The sheath-tailed bat's forest and cave habitat will likely continue to be lost or degraded on all islands, predators are not likely to be effectively controlled, and predators continue to be introduced to new islands. Degradation of forest habitat due to clearing and the introduction of invasive plants and ungulates are ongoing. Overall, bat populations continue to decline in size and become locally extirpated. Based on the available information, we estimate that the resiliency of sheath-tailed bats in Samoa, American Samoa, Fiji, Tonga, and Vanuatu is low to none.

## Representation

Species representation for the Pacific sheath-tailed bat is very low, and it has been in decline since the middle of the last century. The historic range has greatly contracted and foraging and roosting habitats have been destroyed and lost. The species has almost certainly lost genetic and phenotypic diversity through this range contraction, although no data are currently available. Moreover, individual bat colonies rely on metapopulation dynamics, which are more difficult to sustain when connectivity is lost due to increased distance between remaining populations. Representation is currently very low.

## Redundancy

The Pacific sheath-tailed bat has lost redundancy since the middle of the last century and is currently found only in Fiji; these Fijian populations appear to be declining. Populations from Samoa, Tonga, Vanuatu, and American Samoa are considered extirpated. These extirpations have resulted in a range contraction towards the current center in Fiji, and this contraction has occurred concurrent with loss of many individual Fiji roost populations. These losses have interfered with the metapopulation structure of the species, leaving the smaller and more thinly spread populations vulnerable to stochastic events. Tropical storms are predicted to occur less frequently, but with greater intensity and thus potential for greater damage to the bat's roosting and foraging habitat. The best evidence implicates several strong tropical storms in the early 1990s as the cause of extirpation of the bat from Samoa and American Samoa. Populations have been extirpated from the edges of the range, thus reducing redundancy. However, data gaps persist because survey effort has been sparse; the current species status in Tonga or Vanuatu is uncertain. In American Samoa and Samoa, bats have not been detected in recent years but survey effort has not been comprehensive (Miles 2019, in litt., and Fraser et al. 2009, p. 9), especially in remote locations such as the outer islands of American Samoa. Based on the available information, the redundancy of the Pacific sheath-tailed bat is low and will likely drop further if current conditions persist. Currently, Fiji is the only location with extant populations of the Pacific Sheath-tailed bat, thus redundancy of this species is very low.

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