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A rapid assessment of cave occupancy for Pacific sheath-tailed bats (fanihin ganas, *Emballonura semicaudata rotensis*) and Mariana swiftlets (chachaguak, *Aerodramus bartschi*) on Aguiguan, Mariana Islands[1]

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Abstract— Aguiguan is an uninhabited island in the Mariana archipelago that contains populations of four federally threatened or endangered species or subspecies endemic to the Mariana Islands. Although wildlife populations have been comprehensively surveyed in the past, the island does not receive consistent monitoring effort. We report here incidental observations from two expeditions to Aguiguan in 2021, including mammal, reptile, bird and invertebrate sightings, with a particular focus on cave occupancy by Mariana swiftlets (chachaguak, *Aerodramus bartschi*) and Pacific sheath-tailed bats (fanihin ganas, *Emballonura semicaudata rotensis*). In 2021, seven caves were surveyed; five were occupied by Mariana swiftlets and four by Pacific sheath-tailed bats. We counted a total of 322 Pacific sheath-tailed bats at East Black Noddy Cave, with small numbers of bats (n = 2-50) present at three other caves. A total of 111 Mariana swiftlets were counted at Guano Cave, and 29 at Pillar Cave. In addition to sheath-tailed bats and swiftlets, we documented observations of eight other forest bird species, two other mammal species, one lizard species, and three invertebrate species, including a suspected first record of paper wasp (*Ropalidia marginata sundaica*) on Aguiguan. Our observations can be used to inform future survey effort on this island, and provide evidence of persisting populations of common, threatened, and endangered species in this understudied region. Opportunistic observations of other taxa are included here as historical records of occurrence for an island that has, over time, received only sporadic biological survey effort.

Sumåria— Aguiguan, unu gi ti matåotåoguan na isla giya Marianas, låo guaha kuåttru na klåsin påpulasion gå'ga gi papa' i pruteksion fidirât na manlåla'la' solamenti guini giya Marianas. Guaha guinadduk kinimprendi manmakondukta put i påpulasion gå'ga' manmachålik gi alatcha na tiempu låo tumaigui i kontinuasion na istudiu gi tanu'. Estagui' i ripót i håfa manmaripåra gi dos na ekspidision (hinanåo) para Aguiguan gi halum 2021 na såkkan. Mañåsåonåo guini na lini'i' siha, chå'ka, fanihi, guali'ik, paluma (påharu), ayuyu, sasata, yan iskopio. Låo i pattikulåt na atinsion gumaigi gi liyang ni maninokukupa nu i chachaguak yan i fanihin Gånas. Gi halum 2021 na såkkan, sietti na liyang manma'eksamina ya masodda' singku maninokukupa nu i chachaguak yan kuåttru maninokukupa nu i fanihin Gånas. In tifung gi put todu 322 na fanihin Gånas gi halum i sanhaya na liyang fåhang åttilung yan unus kuåntus grånu ni manprisenti gi halum ottru tres na liyang. Gi tutåt put todu, 111 na chachaguak manmatufung gi halum Liyang Guåno yan 29 gi halum Liyan Pillar. Engkuenta i Fanihin Gånas yan Chachaguak, in dukumentu otchu difirentis paluman

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halum tånu', dos klåsin gå'ga' tånu', unu na guali'ik, dikiki' na iskopion håyu, ayuyu, yan lokkui' sasatan påppit, ni masuspetcha na estagui' primet biåhi nai madukumentu giya Aguiguan. I rinipåran-måmi siña ma'usa para u infotma i futtura na istudiu yan u guaha ebidensia para i gumaigin påpulasion todu gå'ga' ni manmaprutetehi guini na lugåt. Todu rinipåran kuatkuet gå'ga' på'gu na tiempu dumanña' guini na tinigi' yan dukumentu ginin mås tatti na tiempu put esti i håssan yan atchagu' ma'istudia na tånu'.

Introduction

Aguiguan, also known locally as Goat Island, is uninhabited by humans and located south of Tinian in the Commonwealth of the Northern Mariana Islands (CNMI). Despite its relative proximity to the populated and developed islands of Tinian and Saipan, expeditions to Aguiguan are costly and logistically difficult; thus, they are conducted infrequently. Comprehensive landbird surveys were completed on Aguiguan in 1982 (Engbring et al. 1986), 1992 (Craig et al. 1993), 1995 (Amidon et al. 2014), 2000 (Cruz et al. 2000), 2002 (Esselstyn et al. 2003), 2008 (Amidon et al. 2014), and 2016 (Liske-Clark et al. 2018). Surveys of Pacific sheath-tailed bats have also been conducted infrequently but regularly since the mid-1980s (see Lemke 1986, Cruz et al. 2000, Wiles et al. 2011, Liske-Clark et al. 2018). Systematic surveys and even opportunistic occurrence records for other fauna are found much less frequently in the literature, though Rodda et al. (1991) report information on reptiles and amphibians from targeted professional herpetological surveys completed over two years on thirteen of the Mariana Islands, including Aguiguan. Miscellaneous reports of faunal occurrence on Aguiguan are also available in technical reports from the Commonwealth of the Northern Mariana Islands (CNMI) Division of Fish and Wildlife (DFW) (see Reichel & Glass 1988, Rice & Taisican 1993, Cruz et al. 2000, Esselstyn et al. 2003, Liske-Clarke et al. 2018).

Aguiguan is home to three federally endangered species or subspecies endemic to the Marianas: Mariana swiftlet (chachaguak, *Aerodramus bartschi*), Micronesian megapode (sasangat, *Megapodius laperouse laperouse*), and Pacific sheath-tailed bat (fanihin ganas, *Emballonura semicaudata rotensis*); and one federally threatened endemic subspecies: Mariana fruit bat (Fanihi, *Pteropus mariannus mariannus*). All four species are also locally listed as “threatened and endangered” within the CNMI. The island was formerly home to the Aguiguan reed warbler (*Acrocephalis nijoi*) and Langford’s Tree Snail (*Partula langfordi*), but neither species has been detected there since the early to mid-1990s (Craig et al. 1993, USFWS 1998, Cruz et al. 2000, Esselstyn et al. 2003, USFWS 2015, Liske-Clark et al. 2018). The island faces substantial ecological challenges, including large-scale habitat degradation due to browsing from feral goats (*Capra hircus*) and colonization of the invasive shrub *Lantana camara*. A project to restore habitat for the Micronesian megapode is currently underway, with the goal of removing *Lantana* and fencing portions of the island to protect habitat from goat browse (USFWS 2020).

While the Mariana subspecies of Pacific sheath-tailed bat once occurred on Guam, Rota, Aguiguan, Tinian, and Saipan, with possible sightings on Anatahan and Maug (Lemke 1986), the species has been extirpated from much of its historic range (Steadman 1999, Lemke 1986, Wiles et al. 2011). Currently the only known persisting population of this subspecies is on Aguiguan, with an estimated population of 359-466 individuals total in 2008 (Wiles et al. 2011). Similarly, Mariana swiftlets were once found on each of the southernmost islands in the Mariana archipelago (from Guam to Saipan), but have been extirpated from Rota and Tinian (Johnson et al. 2018). Mariana swiftlets were also introduced in the 1960s to the island of O’ahu in the Hawaiian Islands and a small population persists there (Johnson et al. 2018). The total global population for Mariana swiftlets was estimated to be 5,500-6,500 individuals in 2018 (Johnson et al. 2018).

The CNMI DFW conducted two expeditions to Aguiguan in 2021, on February 23-26 and July 16-20 to explore cave complexes and determine Pacific sheath-tailed bat and/or Mariana swiftlet

occupancy. We also sought to obtain abundance estimates of Pacific sheath-tailed bats at three caves with known or suspected occupancy, and abundance estimates of Mariana swiftlets at two caves with known occupancy. This work was conducted as one component of a feasibility assessment for potential future translocations to reintroduce both Mariana swiftlets and Pacific sheath-tailed bats to the island of Rota. Characteristics of occupied caves on Aguiguan will be compared to cave characteristics of previously-occupied caves on Rota to determine whether caves on Rota still present suitable habitat for both species/subspecies. We report here our cave occupancy findings, and additional incidental observations from the 2021 expeditions.

Methods

Study Area

Aguiguan (14.85 N, 145.55 E) is a small island approximately 9 km southwest of Tinian, and 77 km northeast of Rota (Figure 1). It has an area of only 7 km^2, formed from raised limestone karst. The topography of the island consists of a central plateau, surrounded by steep terraced layers that descend to the ocean, with caves found in the escarpment walls throughout the island (Stafford 2003, Wiles et al. 2011). Access to the island is complicated by steep drop-offs to the ocean around the vast majority of the island's perimeter, though there is one commonly used boat access point. The island was used for sugar cane production in the mid-20th century, which caused large scale habitat alteration. Native limestone forest remains on approximately half of the island, with little ground cover and an open understory due to goat browse.

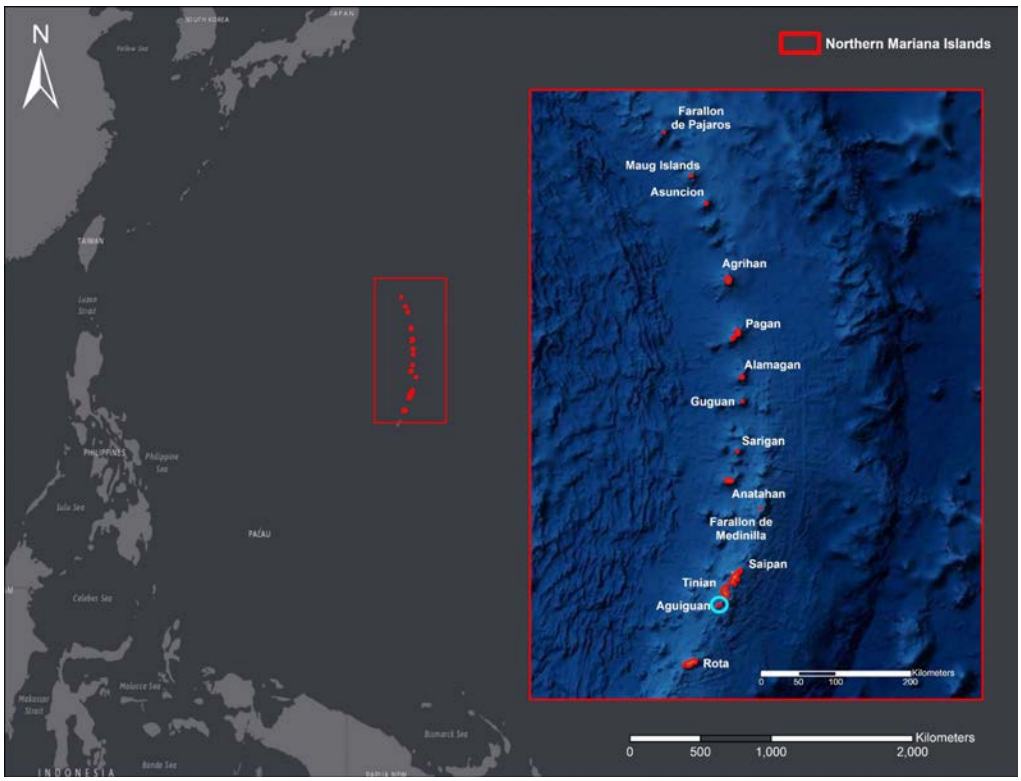

Figure 1: Map depicting the location of the Commonwealth of the Northern Mariana Islands in relation to the Asia-Pacific region and the location of Aguiguan (blue circle) within the archipelago. Sources: Basemaps: Esri, The General Bathymetric Chart of the Oceans, National Oceanic and Atmospheric Administration, National Geographic, DeLorme, HERE, Geonames.org, Garmin, United States Geological Survey, Earthstar Geographics.

EVENING ARRIVAL/EMERGENCE SURVEYS

Evening arrival counts for the Mariana swiftlet were conducted at Guano and Pillar Caves in February (Figure 2). Each location was counted once, on a single night by at least two observers (JG, EK, LS, CM). No formal arrival counts were conducted on the July expedition. We did not have enough personnel to conduct simultaneous swiftlet and sheath-tailed bat counts at East Black Noddy Cave, even though both species were present. Arrival surveys were conducted from outside the cave beginning at 17:00 hrs and continuing until it was too dark for observers to reliably detect or identify the species (~19:00 hrs) (Cruz et al. 2008, Brindock 2013, Radley 2013, Johnson et al. 2018). Observers did not enter the caves to count roosting birds before surveys began in order to minimize the disturbance to birds. Observers recorded the number of swiftlets entering and exiting cave entrances (one observer counted entering birds and one counted exiting birds) in 10 minute increments. The number of exiting swiftlets was subtracted from the number of entering swiftlets, and the difference of each 10-minute interval was summed. When the light levels were low, aural detection of the swiftlet's echolocation clicks (a rapid series of accelerating clicks as they enter the cave) was used in combination with visual observation to count individuals. No night vision or thermal imaging equipment was available for these surveys.

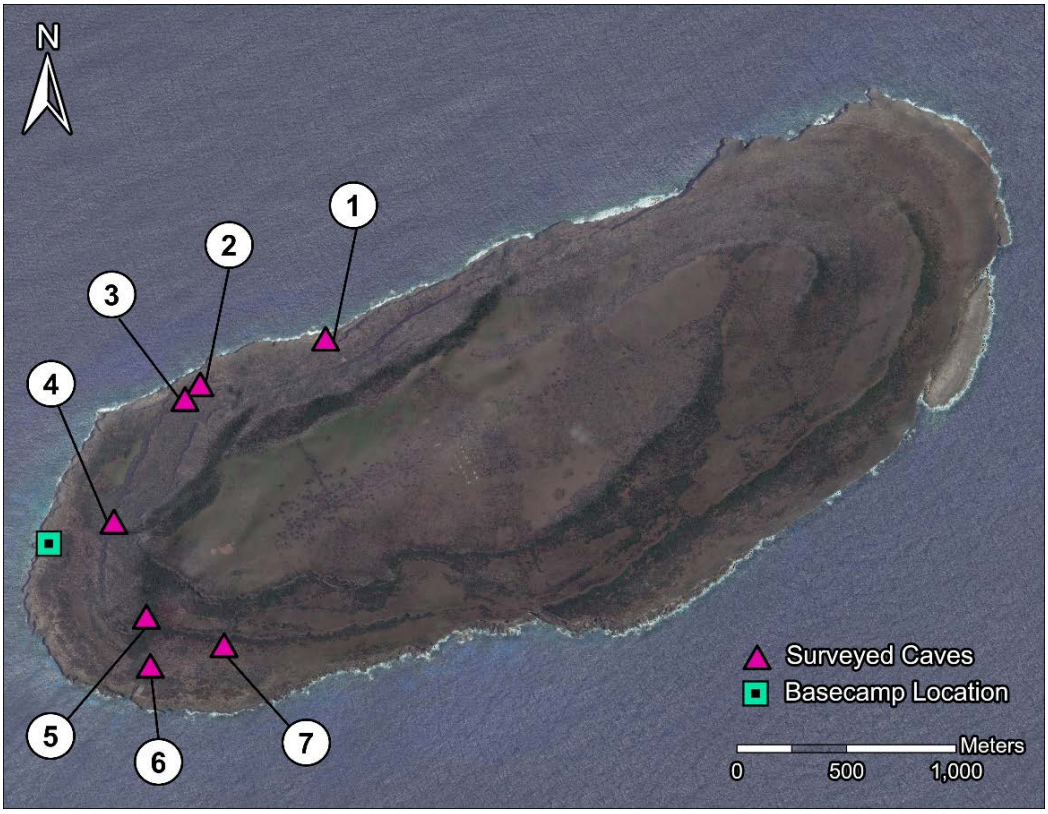

Figure 2: Locations of caves surveyed for Pacific sheath-tailed bat and Mariana swiftlet occupancy by the Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife in 2021, with WorldView-2 satellite imagery (dated April 14, 2019) for reference. Surveyed caves are labeled: 1 – East Black Noddy Cave; 2 – Cliff Cave; 3 – Pillar Cave; 4 – Guano Cave; 5 – New Cave Complex; 6 – Southern Cave Complex; 7 – Crevice Cave

Evening emergence counts for Pacific sheath-tailed bat were conducted at Guano and Pillar Caves in February. In July, counts were conducted at Guano and East Black Noddy Caves, and three entrances of the New Cave complex. We attempted to perform an emergence count at Cliff Cave, but were not able to successfully complete the count because we were unable to see the cave entrance well enough from our vantage point. Future counts at this location could be conducted by observers laying down and looking up at the cave entrance, with volant swiflets or bats silhouetted against the sky. Each location we successfully surveyed was counted once, by at least two observers (February: JG, EK, LS, CM; July: JG, ER, EK, JA). The July count of the New Cave complex was conducted on a single night, with one observer at each of two entrances, and two observers at the largest entrance, for a total of four observers at three entrances. Emergence counts took place outside the cave beginning at 17:00 hrs, when no bats were observed outside of the cave, and continued until the species could no longer reliably be detected due to nightfall (~19:00 hrs). No night vision, thermal imaging or ultrasonic detector equipment was used during surveys, due to equipment unavailability. Observers recorded the number of bats entering and exiting cave entrances (one observer counted entering bats and one counted exiting bats) every 10 minutes. The number of entering bats was subtracted from the number of exiting bats, and the difference of each 10-minute interval was summed.

General Cave Occupancy Surveys

To determine whether caves were occupied by either swiftlets or sheath-tailed bats, we conducted diurnal scouting trips to known cave locations documented in previous studies. In February, these occupancy surveys were conducted at Cliff and East Black Noddy Caves. In July, these were conducted at the New Cave and Southern Cave complexes, and Crevice Cave. To evaluate whether swiftlets or sheath-tailed bats were roosting in the cave, we entered caves when feasible without technical climbing equipment. Using red light, and listening for swiftlet echolocation clicks, or other signs of occupation, we searched the interior of caves for a duration of 5-30 minutes. When swiftlets were observed regularly flying in and out of the cave entrance over a period of more than 20 minutes, we assumed the cave was occupied by swiftlets, even if we were unable to enter the cave. If we were unable to enter the cave but observed no swiftlets, we did not consider it effectively surveyed for swiftlet or bat occupation. In one case (the New Cave complex), where we were unable to enter the cave, we conducted an evening emergence count to check for bat occupancy.

Incidental Observations

Expedition biologists opportunistically recorded the date, time and location of additional species sightings. Sightings were opportunistic and do not represent a comprehensive list of all wildlife encountered during the expedition. Particular attention was paid to threatened/endangered species, and to forest bird species. Where possible, behavioral observations were also noted.

A Malaise trap was deployed at one location, on the north edge of base camp (Figure 2), for ten hours on one night during the February expedition (Malaise 1937). The trap collection bottle was filled with 95% ethanol solution. Arthropods collected with the Malaise trap were identified to species.

Results

Mariana Swiftlet

Mariana swiftlets were observed roosting in or regularly entering and emerging from Cliff, East Black Noddy, Pillar, Guano caves, and two entrances of the New Cave Complex. We were able to enter both Crevice Cave and the Southern Cave Complex, but neither location revealed any evidence of swiftlet occupation. Swiftlet counts resulted in an estimated 111 volant individuals at Guano Cave and 29 volant individuals at Pillar Cave (Table 1).

PACIFIC SHEATH-TAILED BATS

Pacific sheath-tailed bats were observed during emergence counts at East Black Noddy, Guano, and Pillar caves. An emergence count was attempted at Cliff Cave, but the entrance was too high from our vantage point to accurately count individuals. Estimated occupancy at Cliff Cave was less than 50 individuals. General cave occupancy surveys of Crevice and the Southern Cave complex revealed no evidence of bat occupation. The majority of sheath-tailed bats were observed at East Black Noddy Cave, with our count resulting in a total of 322 individuals across the two entrances to that cave (Table 1). Only two sheath-tailed bats were detected at both Guano Cave and Pillar Cave (Table 1).

Table 1: Pacific sheath-tailed bat and Mariana swiftlet detections by cave location during two expeditions in 2021. Numerals indicate that an evening arrival or emergence count was conducted at that location. Present/Absent indicates that a general cave occupancy survey was conducted at that location. NA indicates that the location was not surveyed during the expedition.

Cave location	**Pacific sheath-tailed bat**		**Mariana swiftlet**	
	February	*July*	*February*	*July*
East Black Noddy	Present	322	Present	Present
Guano	2	0	111	Present
Pillar	2	NA	29	NA
Crevice	NA	Absent	NA	Absent
Cliff	Present	NA	Present	NA
New Cave Complex	NA	0	NA	Present
Southern Cave Complex	NA	Absent	NA	Absent

MICRONESIAN MEGAPODE

In July, the expedition team recorded five megapode detections throughout the western region of the island, from East Black Noddy Cave, to basecamp, to the Southern Cave Complex (Figure 2). Four of these detections were taken on the same day, July 17, at least 200 m apart from each other, as the team were hiking through the area. The other observation was taken nearly 1 km northeast of basecamp, near East Black Noddy Cave. All megapode detections were made in native limestone forest. Three detections included visual observation in addition to aural observation; all other detections were aural only.

MARIANA FRUIT BAT

We observed individuals and also small groups of less than 5 bats flying at various locations throughout the western region of the island on both expeditions. A colony with an estimated 100-200 individuals was located in February. In July, the colony was abandoned and several shotgun shells were located nearby, suggesting a poaching event may have occurred.

INCIDENTAL BIRD OBSERVATIONS

No systematic landbird or seabird surveys were conducted during the expeditions. However, the following species were detected in the forested area around basecamp during the July expedition. This habitat is largely dominated by fingersop (paipai, *Meiogyne cylindrocarpa*) and cyanometra (gulos, *Cyanometra ramiflora*). Observations were submitted to eBird (Roark 2021a, Roark 2021b), including details about numbers of individuals and behavior.

Philippine collared dove (paluman senesa, *Streptopelia dusumieri*)
Mariana fruit dove (tottot, *Ptilinopus roseicapilla*)
Mariana kingfisher (sihek, *Todiramphus albicilla*)
Micronesian myzomela (egigi, *Myzomela rubratra*)

rufous fantail (na'aback, *Rhipidura rufifrons*)
golden white-eye (canario, *Cleptornis marchei*)
bridled white-eye (nosa, *Zosterops conspicillatus*)

Other Taxa

Monitor lizard (hilitai, *Varanus tsukamotoi*) – Five documented detections during the July expedition, with three detections occurring near the basecamp kitchen (14.8481 N, 145.5391 E), and two occurring during the approach to East Black Noddy Cave. Species identification presumed based on Weijola et al. (2020), but not confirmed with morphological evidence.

Dwarf wood scorpion (*Liocheles australasiae*) - One individual observed clinging to a team member's backpack at basecamp. Specimen collected and in the CNMI DFW collection (specimen number 001A-H-D).

Paper wasp (*Ropalidia marginata sundaica*) - Three individuals captured in a malaise trap near basecamp. One specimen collected and in the CNMI DFW collection (specimen number 001A-M-D). This species is not documented on Aguiguan in Bourquin (2002), and is a suspected first record for the island.

Coconut crab (ayuyu, *Birgus latro*) - At least four individuals observed on or near a steep rock descent to East Black Noddy Cave.

Goat (*Capra hircus*) – More than 10 detections per day of individuals of all ages, including very young goats and nursing mothers. Encountered in all habitats, but mostly seen in limestone forested areas. Especially commonly encountered in open forest patches on the southwest side of the central terrace of the island.

Discussion

Surveys of Pacific sheath-tailed bats on Aguiguan have employed varying count methods over the years, including both direct roost counts, and emergence counts (Wiles et al. 2011). While the emergence counts conducted in 2021 provide important data about the observable number of sheath-tailed bats present at particular caves, it is difficult to draw robust conclusions about the overall abundance of sheath-tailed bats on Aguiguan based on data from the expeditions described here. Any sheath-tailed bats that emerged from the caves after dark were likely not detected. For caves that do not have large populations of bats, it is possible that they would be considered empty despite having bats present. When both sheath-tailed bats and swiftlets were present, as at East Black Noddy Cave, there was considerable overlap between the swiftlets arriving at the cave for evening roosting and the sheath-tailed bats emerging for evening foraging. The two species are easily differentiated when light is adequate, but become more difficult to distinguish as night falls. Additional survey effort will likely be required to adequately account for these difficulties.

The addition of other count methods could provide evidence to confirm the results of our emergence counts, or provide more robust population estimates than our emergence counts. To this end, we have partnered with US Geological Survey (USGS) researchers to pilot thermal imaging camera counting methods to identify and count both bats and swiftlets (Goldenberg et al. 2021, Dell et al. 2014). Thermal infrared imaging technology has been shown to produce population estimates that are more accurate and reproducible than human visual emergence counts (Brown et al. 2008, Betke at al. 2008). Data from these thermal imaging cameras may also allow for fewer person-hours in the field to conduct counts, which would help to increase survey effort.

Variation in counting methods, observers, and survey effort all make it difficult to draw robust conclusions from the available literature about how sheath-tailed bat populations are changing over time. However, the relatively low abundance we found at Pillar, Guano, and Cliff caves compared to East Black Noddy Cave (Table 1) is consistent with the results of previous studies (Wiles et al. 2011). East Black Noddy Cave appears to consistently serve as a main roosting site for Pacific sheath-

tailed bats on Aguiguan. Our emergence counts at East Black Noddy Cave produced very similar results to emergence counts reported in Wiles et al. (2011), which reported a count of a total of 333 bats encompassing both entrances, and Liske-Clark et al (2018), which reported a count of 323 bats across both entrances.

The reported abundances in Wiles et al. (2011) for 2008 roosting surveys of Guano cave of 55 bats is very high compared to our emergence counts of zero and two bats at the same location in July and February, respectively (Table 1). This 2008 roosting count, where observers conducted roosting bats inside the cave, rather than volant individuals emerging from the cave, is also high compared to emergence counts from the same location, even from the same observers (25-35 bats counted in September 2003, Wiles et al. 2011). This suggests that survey method may play a large role in variation between point estimates. A subsequent visit by the DFW team to Guano Cave in April 2022 with an ultrasonic bat detector provided anecdotal evidence that there may be far more bats present at the cave than were counted in 2021, though no formal count was conducted at Guano Cave in April 2022. It should be noted that our lack of roost counts may limit our ability to make generalizations about the bat and swiftlet populations at the caves we surveyed. We limited entry to caves primarily to minimize disturbance to sensitive listed species, but for several caves (East Black Noddy, Cliff, and New Cave) roosting counts may never be feasible because of the technical climbing and/or rappelling that would be required to enter the cave.

Liske-Clark et al. (2018) documented counts of 311 Mariana swiftlets at Guano Cave, and 23 at Pillar Cave. While our counts at both locations are in the same order of magnitude, our count of 111 swiftlets at Guano cave in 2021 would suggest that fewer swiftlets were present at that time than in 2016. However, we cannot infer a swiftlet population decline based on this count alone, and count method limitations without supplemental night vision or thermal imaging should cause us to treat this cave occupancy estimate with caution. Additionally, the number of swiftlets in any particular cave may fluctuate over time as birds change nesting and roosting locations. A suite of additional methods, including roost counts, thermal imaging camera deployments, and utilizing night vision assistance equipment would all be helpful and important techniques to employ to improve the robustness of our population estimates for each cave.

An additional obstacle to robust population estimates for both sheath-tailed bats and swiftlets is that even caves with known or suspected occupancy receive sporadic survey effort. For example, East Black Noddy cave, which holds the highest population of sheath-tailed bats known to date, was not initially surveyed until 1995. Following this first survey, it was not revisited until 2003. However, assumptions about continued occupancy at known roosting caves may also bias population estimates. Wiles et al (2011) reported 101 caves with known locations on the island. Of these, only 11 have received concerted survey effort from multiple expeditions. If sheath-tailed bat or swiftlet populations are moving between caves, large portions of the population may be missed when expeditions tend to survey only caves with well-documented historical occupancy; sampling bias in favor of historically occupied caves could therefore lead to mistaken impressions of population decline (Buckland et al. 2017, Fournier et al. 2019). Our 2021 expeditions were the first DFW expeditions to the island since 2016, and the first visits to the island since typhoon Yutu in 2018. We selected a mix of caves that had been visited in 2016 and had known populations of bats and swiftlets, and caves that had not been visited or surveyed in a long time, with particular attention to the southwest portion of the island.

While our incidental observations of other taxa do not represent a systematic or exhaustive list of non-target wildlife sightings, we include them here because of the scarcity of biological records from Aguiguan. Previous studies have illustrated the value of biological records over long time scales, even when not collected as part of an organized sampling scheme (Fariñas-Franco et al. 2018, Gaul et al. 2020). The ongoing *Lantana* removal project also represents substantial habitat modification on the island, which may increase the long-term value of even very sparse biological records from this time period on Aguiguan.

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