STATUS OF THE LAND AND WETLAND AVIFAUNA OF PAGAN, MARIANA ISLANDS

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Collared Kingfisher. Photograph by Dan Clark

Pacific Reef Heron. Photograph by Dan Clark

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Executive Summary

Avian surveys were conducted on the island of Pagan in June 2010 by the U.S. Fish and Wildlife Service to provide density and abundance estimates for the native forest birds. In addition, focused surveys were conducted to determine if the endangered Mariana common moorhen and nightingale reed-warbler were present on the island. Both species were thought to have been extirpated by the 1970s. Sufficient detections of white terns, white-throated ground-doves, collared kingfishers, Micronesian starlings, and Micronesian honeyeaters were recorded to estimate densities. Based on available forested habitat, we estimate there are 2,920 (± 916 SE) white terns, 602 (± 173 SE) white-throated ground-doves, 725 (± 127 SE) collared kingfishers, 11,158 (± 2,768 SE) Micronesian starlings, and 5,468 (± 1,964 SE) Micronesian honeyeaters on Pagan. Nightingale reed-warblers and Mariana common moorhens were not detected during surveys. Additional searches are needed to infer extirpation of the nightingale reed-warbler and Mariana common moorhen on Pagan. We recommend removing feral ungulates and restoring the wetlands and native forests on the island to promote long-term native bird conservation in the region.

Introduction

Pagan is the largest of the islands of the Commonwealth of the Northern Mariana Islands (CNMI) north of Saipan (Ohba 1994). It is around 48 sq. km and consists of distinctive northern and southern sections connected by a narrow isthmus (Figure 1). The larger northern section of the island is dominated by an active volcano, Mt. Pagan, which was smoking throughout the survey period. Because of the last major eruption in 1981, there are large areas of lava fields with volcanic ash and little vegetation. The vegetation in the northern part of the island is predominantly ironwood (*Casuarina equisetifolia*) forest (Ohba 1994). There is a large flat area at the southern foot of Mt. Pagan still retains the runway built during World War II (Ohba 1994). The runway is still used for landing small planes and helicopters and for sling loading equipment, and the neighboring shoreline area is used for housing by temporary residents. The isthmus is dominated by swordgrass (*Miscanthus floridulus*), typical of areas where native forest has been degenerated by grazing pressure from feral goats (*Capra hircus*) (Ohba 1994). The southern section of Pagan contains three old volcanoes and still includes large areas of native forest. However, grazing pressure is having adverse impacts on the native vegetation here as well (Ohba 1994).

Chamorros (the indigenous people of the Mariana Islands) are believed to have developed long-term settlements on the northern islands around 1,000 years ago (Russell 1998). Radiocarbon analysis at a latte village site on Pagan indicated that the site was probably occupied by A.D. 1300 (Egami and Saito 1973). Pagan was inhabited in historical times but people were evacuated due to the 1981 eruption, and since then, the island been only sporadically inhabited for short periods of time.

There are two lakes located on the island, Lake Sanhiyong, an approximately 16-ha saltwater lake on the western shore (locally known as Lower Lake) and Lake Sanhalom, an 11-ha, somewhat brackish/freshwater lake farther north (called Upper Lake or Inner Lake) at the foot of Mt. Pagan (Figures 2 and 3). Two endangered species, which are now apparently extirpated from the island, once occurred on Pagan in association with these lakes: the Mariana common moorhen (*Gallinula chloropus guami*) and the nightingale reed-warbler (*Acrocephalus luscinia yamashinae*). The wetland habitat was drastically altered and reduced in the last century due to development by the Japanese, as well as the presence of feral goats, pigs (*Sus scrofa*) and cows (*Bos taurus*), and volcanic eruptions (Corwin *et al*. 1957, Marche 1889, Reichel *et al*. 1992, Tenorio and Associates 1979). The vegetation around the upper lake was virtually eliminated during the 1981 and subsequent eruptions and in 1992, Reichel *et al*. (1992) estimated that there was less than a one percent vegetative ground cover bordering both lakes and no emergent vegetation in either.

The Mariana common moorhen was first recorded on Pagan in 1932 (Stinson *et al*. 1991). Both lakes apparently supported populations of the Mariana common moorhen, though it was less numerous at the Lower Lake (20+ compared to over 50 at the upper lake recorded in the 1960s) due to less emergent vegetation, higher salinity, and being subject to more human impacts (Corwin *et al*. 1957, Stinson *et al*. 1991). The last observation of a Mariana common moorhen on Pagan was one bird in 1979, subsequent trips to the island resulting in no sightings (Stinson *et al*. 1991, Tenorio and Associates 1979).

The Pagan subspecies of the nightingale reed-warbler is primarily known from specimens collected in 1887 and 1931 that indicate it may have been locally common in wetlands (Reichel *et al*. 1992). Residents of the island indicate the species was present until at least the 1960s but occurred only in

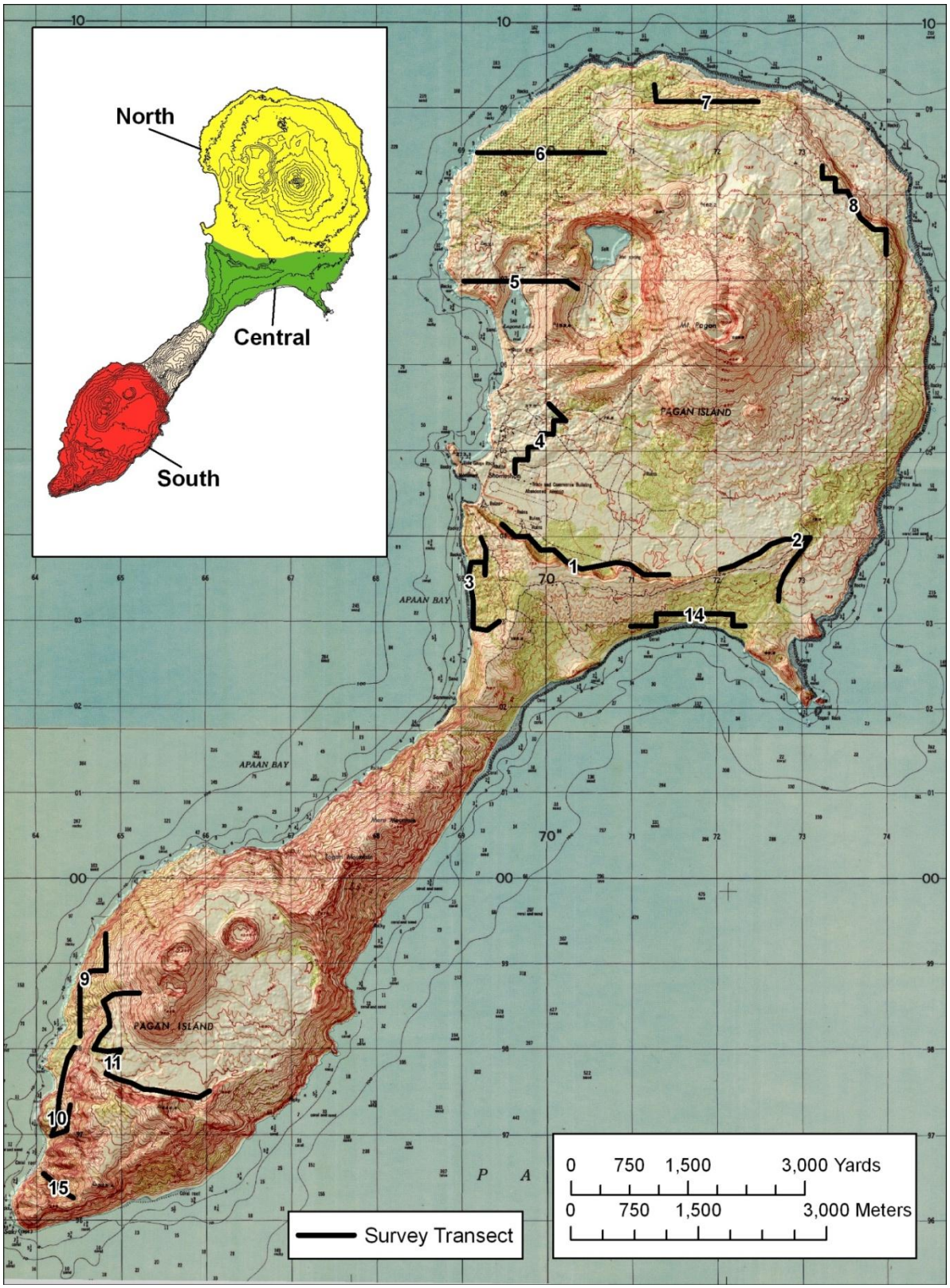

Figure 1. Island of Pagan showing the location of forest bird survey transects sampled in 2010.

wetlands near the Upper, or possibly both, of the island's lakes. Nightingale reed-warblers have not been observed on Pagan since the 1960s despite surveys made in the late 1970s, six trips (including intensive surveys in the vicinity of both lakes) made to the island between 1983 and 1989, and surveys in 1999 and 2000 (Division of Fish and Wildlife (DFW) 2000, Reichel *et al*. 1992, Tenorio and Associates 1979).

Native forest birds that occur on Pagan include the endangered Micronesian megapode (*Megapodius laperouse laperouse*), the Micronesian starling (*Aplonis opaca*), Micronesian honeyeater (*Myzomela rubratra*), collared kingfisher (*Todiramphus chloris*), and white-throated ground-dove (*Gallicolumbra xanthonura*) (DFW 2000). Early surveys primarily focused on the presence or absence of species from the island. However, in 1999 and 2000, the DFW conducted point-transect surveys on the island to estimate native bird populations. Unfortunately, due to poor weather they were only able to conduct surveys on the northern and southern half of the island in separate years (DFW 2000).

In June 2010, the U.S. Fish and Wildlife Service (USFWS) coordinated forest bird and wetland bird surveys on the island of Pagan as part of the "Marianas Expedition Wildlife Survey 2010" (MEWS 2010), funded through a contract with the Department of Defense -U.S. Marines through the Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawaii. The local DFW and staff from the Northern Islands Mayor's Office assisted with the project. The goals of these surveys were to estimate populations of native forest birds on the island by habitat type and determine whether Mariana common moorhen and nightingale reed-warblers were present on the island. Micronesian megapode surveys were also undertaken as part of this survey effort. The methods and results of the latter surveys are presented in a separate report.

Methods

Point-Transect Surveys - To estimate forest bird population size we conducted island-wide point-transect surveys on Pagan from June 19 to 25, 2010. We sampled a total of 144 stations on 13 transects (Figure 1; there are no transects 12 or 13). All transects were placed in accessible forested areas across the island. We did not sample open field and coastal habitats because the object of the survey was to estimate forest bird populations. In addition, the narrow isthmus connecting the northern and southern sections of the island and the southern half of the south part of the island were not sampled due to the steep terrain and limited access. The starting point for each transect was determined by randomly selecting a points on a 150-m grid placed over the island using Geographic Information Systems (GIS). A transect composed of stations spaced 150 m apart was then established to maximize coverage of forested areas.

All surveys were conducted by one observer and followed standard point-transect methods, consisting of 8-minute counts and estimation of horizontal distances to all birds heard and/or seen (see Engbring *et al*. 1986 or Reynolds *et al.* 1980 for details). Rangefinders were used during the surveys to assist with distance estimation. The direction, based on compass reading, and time of detection were also recorded. Sampling conditions recorded included cloud cover, rain, wind, understory openness, habitat type, canopy height, and canopy cover. These parameters were later used as covariates in density calculations. Counts commenced at sunrise and continued until completed (typically prior to 1100 hours) and were conducted only under favorable weather conditions.

The point-transect technique requires 75-100 detections to model the detection function for each species effectively (Buckland *et al*. 2001). To achieve the minimum number of detections for collared

kingfishers and white-throated ground-doves we pooled all observations from the 1999 and 2000 DFW surveys, and included observations from a 2010 USFWS secondary counter (survey effort on stations counted twice was adjusted appropriately). Therefore, we used 434 collared kingfisher and 120 white-throated ground-dove detections to model the detection function (Appendix 1). Densities were calculated using the program DISTANCE version 6.0 release 2 (Thomas *et al*. 2010) following procedures detailed in Camp *et al*. (2009a, b).

Lake Surveys- Surveys at the two lakes were conducted over 2 days, June 20 and June 21, 2010. On June 20, observers first established stations and conducted counts at Lower Lake. For Mariana common moorhen counts, three observers were stationed at 3 points along the west side of the lake (Stations 1, 2, 3; Figure 2). Counts were 30 minutes long and were divided into six 5-minute periods. During each 5-minute period, observers scanned and listened for Mariana common moorhens. Any birds located during each 5-minute period were to be transcribed on a map of the lake as per procedures previously established for Mariana common moorhen counts (USFWS 1996). Also, a species list all birds seen or heard was recorded at each Mariana common moorhen station. Mariana common moorhen surveys began around 0630 hours (hrs) and ended around 0725 hrs for stations 1, 2, 3.

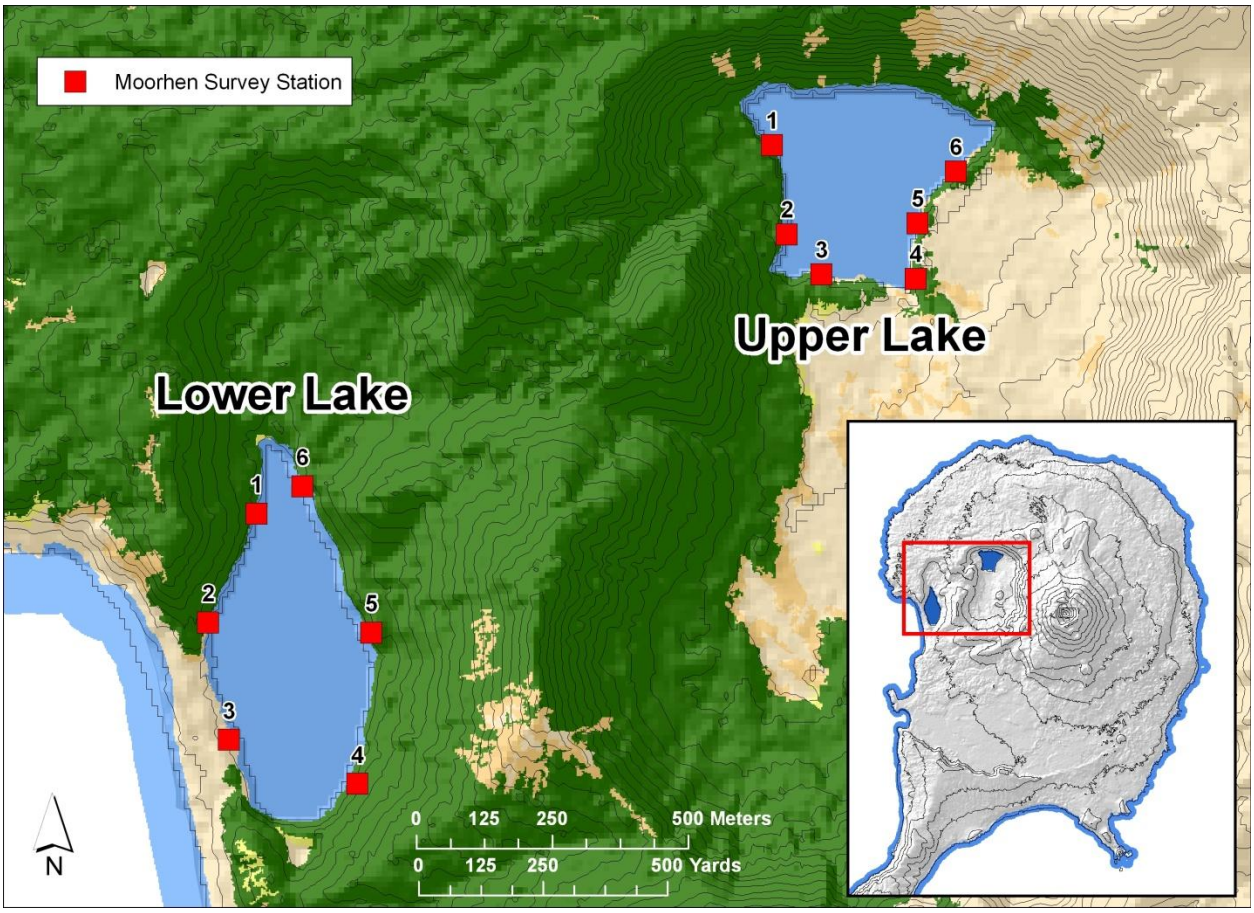

Figure 2. Island of Pagan showing the Mariana common moorhen survey stations around lower and upper lakes.

At Lower Lake, once the Station 1 observer was finished with his or her 30-minute Mariana common moorhen survey count, he or she began a playback survey for nightingale reed-warblers. Station 1 for the Mariana common moorhen was also station 1 for nightingale reed-warblers. Playback surveys consisted of digitally recorded nightingale reed-warblers from the Cornell Lab of Ornithology obtained

by Doug Pratt from Saipan. The call was played on an electronic game caller (Foxpro NX3™) for 30 seconds at each station. The observer listened for nightingale reed-warblers during the three minute survey period (30 seconds of playbacks and 2 minutes and 30 seconds of observation) and were to record the horizontal distances of any nightingale reed-warblers heard and/or seen. Rangefinders were to be used to assist with distance estimation and direction, based on compass bearing, and time of detection were to be recorded. All counts were conducted under favorable weather conditions. The observer then walked 150 m (using a GPS) for the next nightingale reed-warbler station (2), conducted the next playback and continued around the rest of the lake to the east side (picking up and dropping off (at Mariana common moorhen stations 4 and 5) the other 2 observers along the way) to finish at station 10 (station 6 for the Mariana common moorhen) (Figures 2 and 3). Nightingale reed-warbler counts started at 0705 hrs (station 1) and ended at 0819 hrs (station 10). The 3 observers began their 30-minute counts for Mariana common moorhens on the west side (stations 4, 5, 6) between 0800 hrs and 0820 hrs and ended by 0850 hrs.

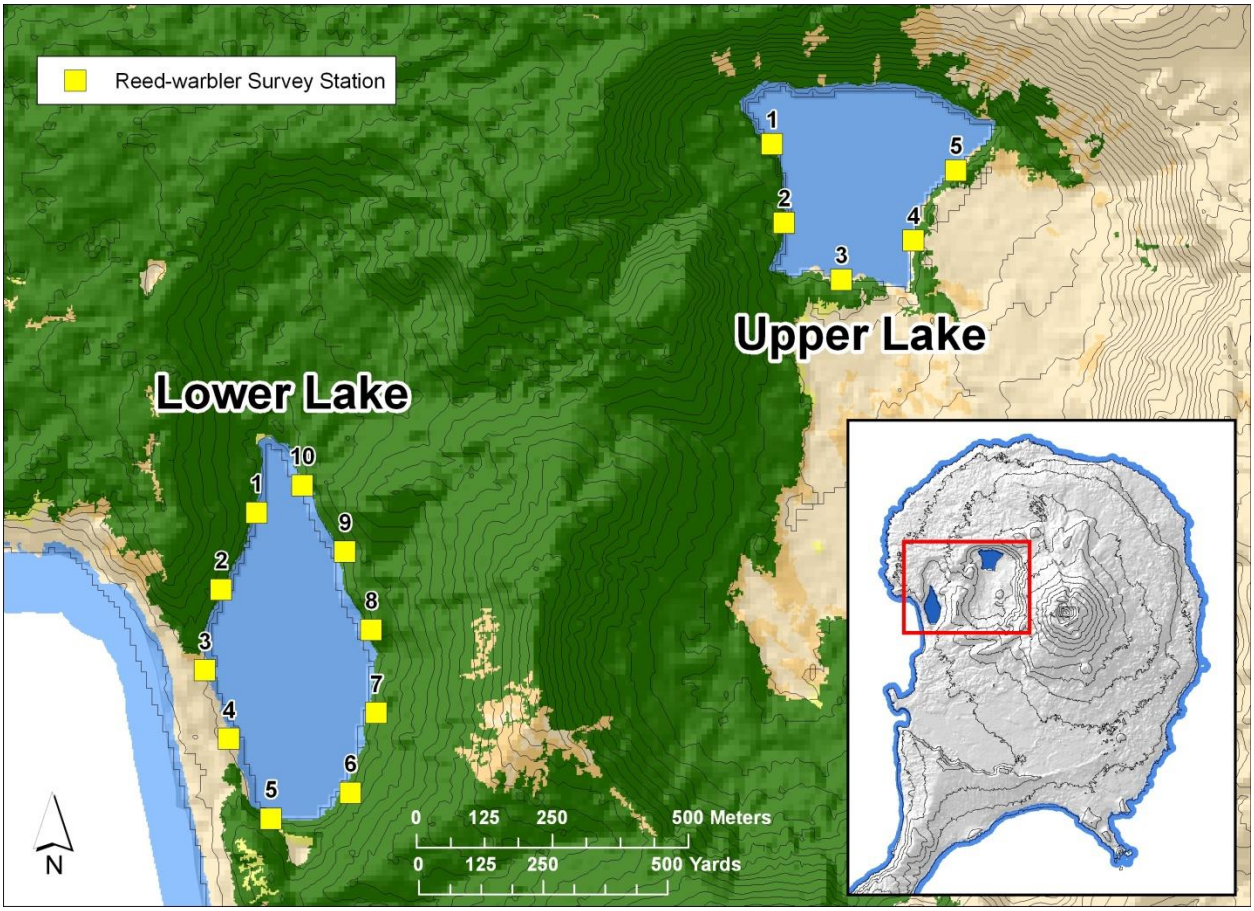

Figure 3. Island of Pagan showing the nightingale reed-warbler survey stations around lower and upper lakes.

Observers then walked to Upper Lake and followed the same protocol establishing stations starting on the west side of the lake and ending on the east side (Figures 2 and 3). Mariana common moorhen counts for stations 1, 2, 3 started by 1020 hrs and ended by 1050 hrs and counts for stations 4, 5, 6 started by 1130 hrs and ended by 1219 hrs. Nightingale reed-warbler counts started at 1100 hrs (station 1) and ended at 1148 hrs (station 5).

On June 21, 2010, observers started at Upper Lake for the first survey, following the same protocol as the first day (including using 3 observers), starting again on the west side of the lake. Surveys for Mariana common moorhen stations 1, 2, 3 began by 0730 hrs and ended by 0805 hrs. Nightingale reed-warblers counts started at 0806 hrs (station 1) and ended at 0841 hrs (station 5). Surveys for Mariana common moorhen stations 4, 5, 6 began by 0845 hrs and ended by 0915 hrs. Observers then moved to Lower Lake and started Mariana common moorhen surveys on the east side (stations 4, 5, 6) around 1100 hrs ended by 1145 hrs. Nightingale reed-warbler counts started at 1146 hrs (starting at station 6 to station 10, then stations 1 to 5) and ended at 1256 hrs (station 5). Surveys for Mariana common moorhen stations 1, 2, 3 began by 1230 hrs and ended by 1325 hrs (See Appendix 2 for UTM coordinates for Mariana common moorhen and nightingale reed-warbler survey stations).

Nightingale Reed-warbler Extirpation Analysis – Following Reynolds and Snetsinger (2001), we calculated detection probabilities to estimate the likelihood of extirpation of the nightingale reed-warbler on Pagan. Scott *et al*. (1986) calculated the probability (*p*) of detecting one bird from a randomly distributed population of *n* individuals as:

$$p = 1 - \left(1 - \frac{a}{A}\right)^n$$

The effective search area (*a*; lake and forest = 34.4 ha; lake only = 1.8 ha) was approximated by calculating the area for the effective detection radius (EDR) of the nightingale reed-warbler on Alamagan (36 meters; See Appendix 1 – Nightingale Reed-warbler Surveys on Alamagan in Status of the Micronesain megapode in the Commonwealth of the Northern Mariana Islands (Amidon *et al*. 2010)). Detection probabilities were calculated for lake and forest, and lake only searches. For lake and forest searches, *A*, the range of the nightingale reed-warbler on Pagan was estimated as 1,981.5 ha (lake habitat = 10.5 ha, and forested habitat = 1,971.0 ha). Suitable lake habitat was estimated as 10.5 ha. We started with 20 birds as the hypothetical population size, *n*, as 20 was the last estimated number of birds on Pagan (Reichel *et al*. 1992).

Using Reed's (1996) modification of Guyann *et al*.'s (1985) statistical methods to infer extinction, we also calculated the minimum number of visits,

$$N_{min} = \frac{\ln \alpha}{\ln(1-p)}$$

N_{min} needed for 95% (α=0.05) and 99% (α=0.01) probability of detection. *N* is the number of independent visits made to search for the species. We defined one visit as 10 hours of search effort.

Results

Point-Transect Surveys – A total of eight species were detected on Pagan during point-transect surveys (Table 1). Sufficient numbers of individuals were detected for calculating density and abundance estimates for Micronesian starlings, Micronesian honeyeaters, and white terns (*Gygis alba*) without data pooling. Density and abundance estimates for collared kingfishers and white-throated ground-doves were calculated by pooling data from this survey and data collected by DFW on Pagan in 1999 and 2000 (DFW 2000). There were insufficient detections of Pacific reef-herons (*Egretta sacra*), red-tailed tropicbirds (*Phaethon rubricauda*), and brown noddies (*Anous stolidus*) to calculate densities.

Table 1. List of birds detected during point-transect surveys on 144 stations along 14 transects on Pagan. The number of stations occupied and birds detected, indices of percent occurrence, and birds per station were calculated for each species.

Species	# Stations Occupied	Number Detected	Percent Occurrence	Birds per Station
Pacific Reef Heron	1	2	0.7	0.01
Brown Noddy	2	3	1.4	0.01
Red-tailed Tropicbird	3	3	0.7	0.01
White Tern	53	113	35.4	0.67
White-throated Ground-dove	27	40	16.7	0.21
Collared Kingfisher	65	95	41.7	0.41
Micronesian Honeyeater	104	220	69.4	1.33
Micronesian Starling	121	364	83.3	2.33

Micronesian starlings were the most common species recorded on Pagan. Micronesian starlings had the highest reported densities (5.66 (± 1.40 SE) birds per hectare; Figure 4) and were recorded at a larger percentage of the stations than any other species (Table 1). However, the average number detected per station in the Mount Pagan region was lower than in the in the Central and Southern regions of the islands (Table 2). Micronesian honeyeaters (2.77 (± 1.00 SE) birds per hectare) were the next most common terrestrial species followed by collared kingfishers (0.37 (± 0.06 SE) birds per hectare) and white-throated ground-doves (0.31 (± 0.09 SE) birds per hectare). Micronesian honeyeater detections per station were higher in North Pagan then in South Pagan while white-throated ground-dove detections were higher in South Pagan than in Central and North Pagan (Table 2). Collared kingfisher detections were similar across all three regions (Table 2). White terns, the only seabird with sufficient detections to estimate densities, were detected equally throughout the three regions of the island (Table 2). The density estimate for white terns was 1.48 (± 0.46 SE) birds per hectare.

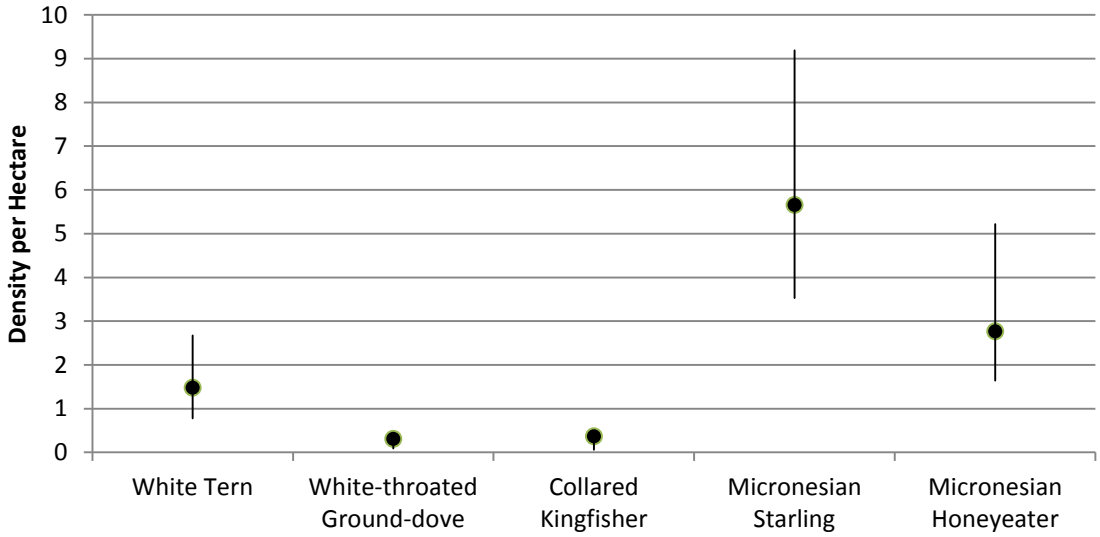

Figure 4. Estimated densities (with 95% confidence interval) of one seabird and four forest birds on the island of Pagan in 2010.

Based on the density estimates and available forested habitat on the island (1,917 hectares; Appendix 3), we estimate that there are approximately 11,158 (6,965-18,111) Micronesian starlings, 5,468 (3,229-10,298) Micronesian honeyeaters, and 2,923 (1,540-5,258) white terns on the island of Pagan. In addition, we estimate that there is a population of approximately 725 (485-1,010) collared kingfishers and 602 (312-970) white-throated ground-doves on the island.

Table 2. Mean detections per station (with 95% confidence interval) for five native species in three regions of Pagan in 2010. See Figure 1 for location of regions and corresponding transects.

Species	North Pagan (n=52)	Central Pagan (n=48)	South Pagan (n=44)
White Tern	0.64 (0.22-1.05)	0.48 (0.12-0.84)	1.23 (0.84-1.61)
White-throated Ground-dove	0.04 (-0.01-0.09)	0.13 (0.01-0.24)	0.59 (0.33-0.86)
Collared Kingfisher	0.71 (0.45-0.98)	0.46 (0.24-0.68)	0.66 (0.44-0.88)
Micronesian Honeyeater	2.12 (1.66-2.57)	1.40 (0.98-1.81)	0.89 (0.58-1.19)
Micronesian Starling	1.46 (1.09-1.84)	3.06 (2.51-3.61)	3.05 (2.58-3.51)

Lake Surveys – No Mariana common moorhens or nightingale reed-warblers were seen or heard during survey efforts at the lakes nor were nightingale reed-warblers detected during point-transect surveys (see above). The only wetland birds observed at the lakes were several intermediate egrets (*Egretta intermedia*), one or two gray herons (*Ardea cinerea*), and several Pacific reef-herons. Intermediate egrets are an uncommon winter visitor to the Mariana Islands and gray herons are a rare winter straggler to Micronesia (Pratt *et al*. 1987). Pacific reef-herons are a common resident for most of the southern Mariana Islands (Guam to Saipan), but are listed as uncommon residents on Pagan (Reichel and Glass 1991). Birds recorded at the Lower Lake included: Gray heron, Pacific reef-heron, white tern, collared kingfisher, Micronesian starling, and Micronesian honeyeater. Birds recorded at the Upper Lake included: white-tailed tropicbird (*Phaethon lepturus*), red-tailed tropicbird, intermediate egret, Pacific reef-heron, white tern, collared kingfisher, Micronesian starling, and Micronesian honeyeater.

As noted above, no nightingale reed-warblers were detected during the 2010 FWS point-transect or playback surveys, or during the directed lake searches on Pagan. The total time spent searching on the lake and forest surveys equaled 42.3 hrs and covered 34.4 ha, whereas 1.5 hrs were spent during the lake only searches and covered 1.8 ha. The likelihood of detecting one reed-warbler ranged from slightly better than 3% to almost 98%, depending on the survey and the starting population (Table 3). If a population of two individuals persisted about the lakes, an additional eight searches would be needed to achieve a 95 percent likelihood of detecting an individual. Whereas, if two individuals occurred in suitable habitat anywhere on Pagan (about the lakes or in the forest), 86 additional searches would be needed to achieve a 95% detection probability. Therefore, we cannot infer extirpation of reed-warbler on Pagan based on the 2010 surveys.

Table 3. Detection probability (DP) for one nightingale reed-warbler from a population of *n* birds randomly distributed across the known Pagan Island range in lake and forest habitat, and lake habitat only. The number of visits (N_{min}) needed to be 95% and 99% confident that the species is extinct are also provided. Area searched was based on a 36 m detection radius; based on the effective detection radius of reed-warbler on Alamagan.

	Lake and Forest			Lake		
Population *(n)*	**DP (%)**	**N_{min} for DP = 95%**	**N_{min} for DP = 99%**	**DP (%)**	**N_{min} for DP = 95%**	**N_{min} for DP = 99%**
20	29.7	8.51	13.08	97.7	0.80	1.22
18	27.2	9.45	14.53	96.6	0.89	1.36
16	24.6	10.63	16.35	95.1	1.00	1.53
14	21.8	12.15	18.68	92.8	1.14	1.75
12	19.0	14.18	21.80	89.5	1.33	2.04
10	16.1	17.01	26.16	84.7	1.59	2.45
8	13.1	21.27	32.69	77.8	1.99	3.06
6	10.0	28.36	43.59	67.6	2.66	4.08
4	6.8	42.54	65.39	52.9	3.98	6.12
2	3.5	85.07	130.78	31.3	7.97	12.24

In addition, no Mariana common moorhen were detected during the 2010 FWS directed lake searches on Pagan. The total time spent searching on the lake equaled 12 hrs and covered 27 ha. Based on the survey station locations and lack of shoreline vegetation we believe that all potential moorhen habitat on the island was viewable during counts. Therefore, the likelihood of detecting one moorhen was estimated to be 100%. As no moorhen were detected, we infer that the Mariana common moorhen was not present during the 2010 surveys.

Discussion

Previous Surveys – In 2000, CNMI DFW estimated there were 1,205 (95% CI = 981-1,430) collared kingfishers, 5,273 (2,867-7,680) Micronesian honeyeaters, 9,482 (3,326-15,637) Micronesian starlings, and 379 (348-411) white-throated ground-doves on Pagan based on data collected in 1999 and 2000 (DFW 2000). Our 2010 estimates for collared kingfishers, Micronesian honeyeaters, and Micronesian starlings were very similar to the 2000 estimates, which could indicate stable populations of these species. Our estimates for white-throated ground-dove were higher than those reported in 2000 and could reflect a population increases as was reported for Saipan, Tinian, and Aguiguan (Camp *et al.* 2009 a,b).

Comparisons Across Islands – The densities estimated from this survey were similar to previously reported density estimates on other islands in the archipelago surveyed in the last five years (Figures 5-

8; Martin *et al*. 2008; Camp *et al.* 2009 a,b; Williams et al. 2009). Micronesian honeyeater densities were lower on Pagan compared to the two other northern islands with density estimate (Asuncion and Sarigan; Figure 6). However, it was higher than the estimate for Tinian. Micronesian honeyeaters forage on nectar and the high percentage of ironwood (*Casuarina equisetifolia*) dominated forest on Pagan may be related to the lower densities (see Appendix 3; Jenkins 1983).

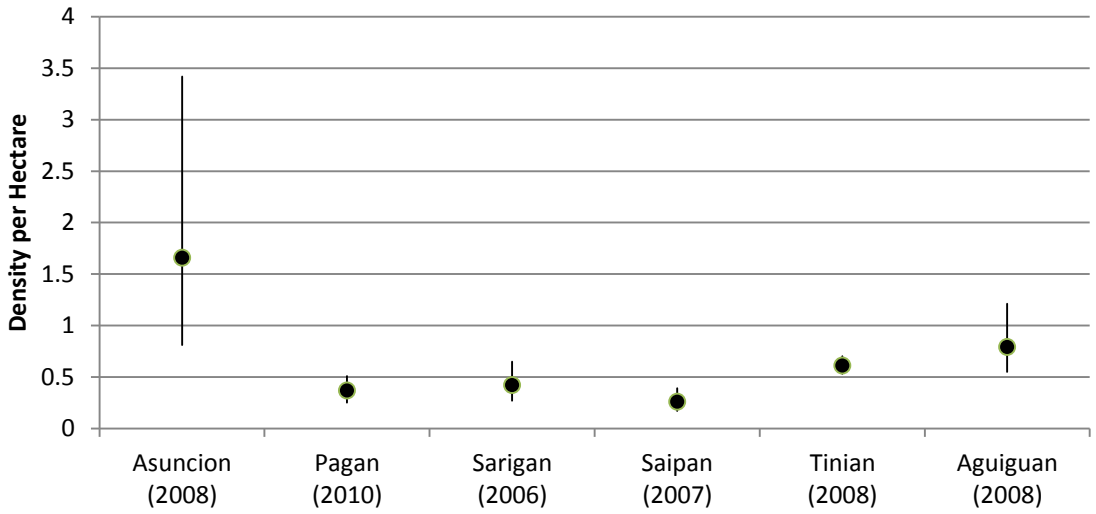

Figure 5. Estimated densities (with 95% confidence interval) for collared kingfishers on the island of Pagan and other islands recently surveyed in the CNMI.

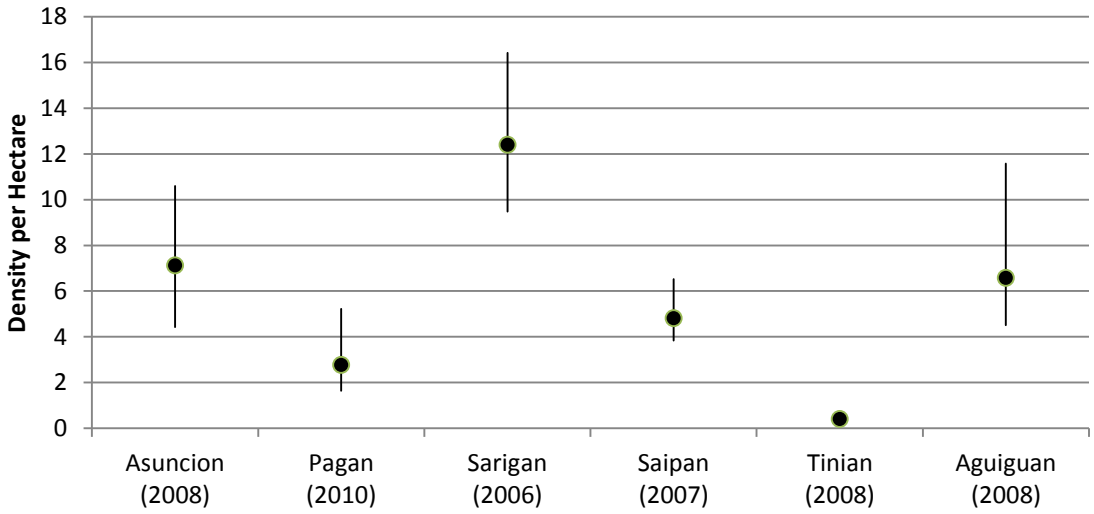

Figure 6. Estimated densities (with 95% confidence interval) for Micronesian Honeyeaters on the island of Pagan and other islands recently surveyed in the CNMI.

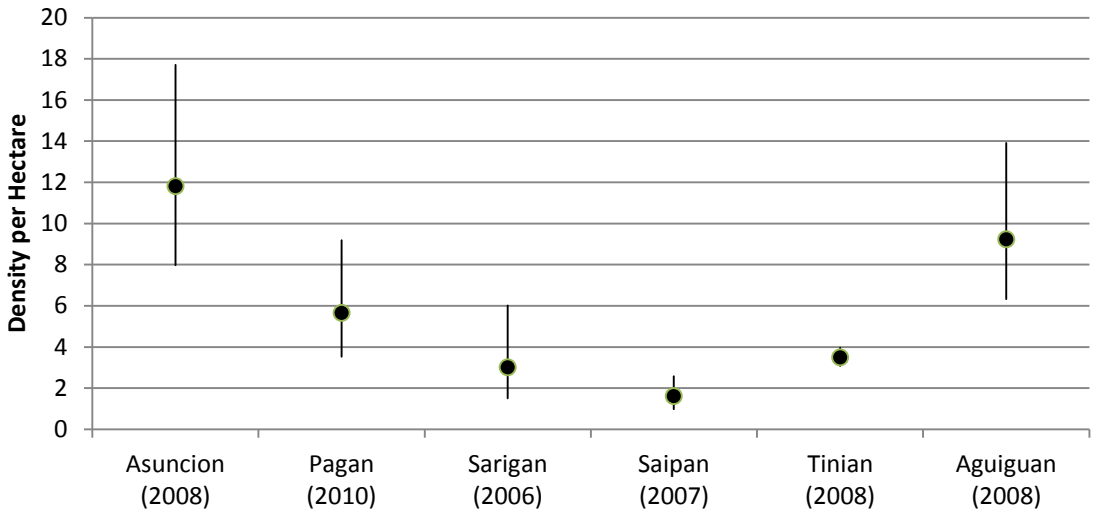

Figure 7. Estimated densities (with 95% confidence interval) for Micronesian Starlings on the island of Pagan and other islands recently surveyed in the CNMI.

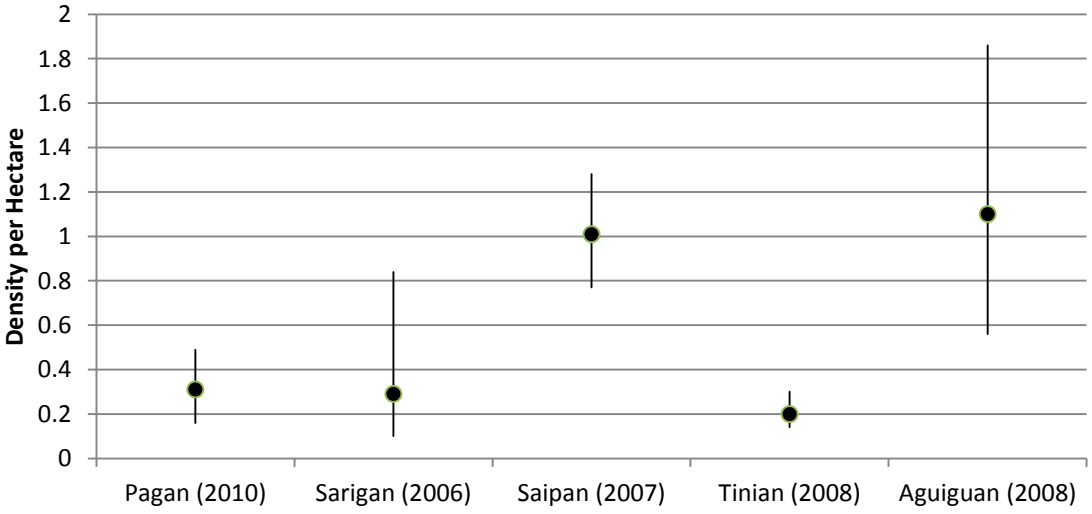

Figure 8. Estimated densities (with 95% confidence interval) for White-throated Ground-doves on the island of Pagan and other islands recently surveyed in the CNMI.

Species of Special Interest – These surveys corroborate previous findings that the Mariana common moorhen and nightingale reed-warbler are extirpated from Pagan. Biologists have looked for birds since the 1981 eruption, however no Mariana common moorhens have been observed since 1979 and no nightingale reed-warblers have been seen since the 1960s (DFW 2000, Reichel *et al*. 1992, Stinson *et al*. 1991, Tenorio and Associates 1979).

The Mariana common moorhen is recorded occurring on five islands, Guam, Rota, Tinian, Saipan, and Pagan. Prehistoric evidence suggests that Marian common moorhens once occurred on Rota but were possibly extirpated due to human-related loss of wetlands, elimination of wetlands due to sea-level

changes, hunting, or introduced predators (Becker and Butler 1988, Steadman 1992, Stinson *et al*. 1991). In 1995, up to 5 Mariana common moorhens were observed at an artificial wetland created at a golf resort and have been periodically recoded there at least until 2002 (Takano and Haig 2004, Worthington 1998). The lack of wetlands on Rota suggests that a self-sustaining population is not likely there. Although the Mariana common moorhen is extant on three islands in the Mariana Archipelago (Guam, Tinian, and Saipan), little management occurs, numbers appear to have declined in many wetlands across the islands, and the major threats to this species, including habitat loss and predation by introduced species, have not been addressed (USFWS 2009).

The Mariana common moorhen is an obligate wetland species and utilizes most types of wetlands (Stinson *et al*. 1991). The presence of Mariana common moorhens at wetlands on Guam was shown to be influenced by the percent of emergent cover and open water, such that birds frequented small wetlands that supported emergent cover of non-persistent vegetation (Ritter and Savidge 1999). Another predictor is the presence or absence of tilapia (*Oreochromis mossambuicus*) which are believed to degrade wetland habitat by depleting the prey base and competing with Mariana common moorhens for food, and the highest densities of Mariana common moorhens on Saipan and Tinian were recorded at wetlands with no tilapia (Marshall and Worthington 1996, Stinson 1993, Stinson *et al*. 1991, USFWS 2005).

Few native sedges or grasses were recorded at the lakes during recent surveys (Pratt 2010). With little emergent vegetation and the presence of tilapia fish in both lakes, it will likely take more work to restore habitat here for the Mariana common moorhen. Although translocating Mariana common moorhen birds to Pagan is not a goal in the recovery plan (USFWS 1991), it may be prudent to consider this as an option given the continued degradation, loss, and fragmentation of habitat, continued predation, and decline in birds on Guam, Tinian, and Saipan.

Nightingale reed-warblers are currently extant on two islands (Saipan and Alamagan). The nightingale reed-warbler has been extirpated from three islands historically, Guam, Aguigaun, and Pagan (Engbring *et al*. 1986, Reichel *et al*. 1992, Tenorio and Associates 1979). 2008 surveys on Saipan show that nightingale reed-warbler densities have decreased by more than half between 1982 and 2007 (Camp *et al*. 2009a). One of the goals in the recovery plan for the nightingale reed-warbler, focusing on its reduced distribution, is to translocate birds onto at least three additional islands; and Pagan is one of the islands proposed as a possible site (USFWS 1998). The historic habitation of the nightingale reed-warbler on Pagan makes Pagan particularly favorable as a future translocation site. The 1981 and subsequent volcanic eruptions killed all the herbaceous and most of the woody vegetation around the upper lake and was a factor in altering the vegetation around the lower lake (Reichel *et al*. 1992). However, 2010 vegetation surveys indicate that the vegetation around the lakes is recovering to some degree and both native trees and herbaceous species were observed (Pratt 2010). It is possible that with additional focused habitat restoration, including ungulate removal, the nightingale reed-warbler could be reestablished on Pagan in the future.

Management Recommendations – Pagan has several key features which are important to bird conservation in the Mariana Islands. First, it has the only naturally occurring wetlands north of Saipan which makes them important to waterbird, especially Mariana common moorhen, conservation in the region. Second, Pagan is the largest island north of Saipan and the fourth largest island in the CNMI. It therefore has the potential to support larger populations of many native species which is important for long-term viability. Lastly, it's located approximately two thirds the way up the archipelago which means it's effectively buffered from potential catastrophic events in the southern part of the chain and it serves as important link in bird movements up and down the chain. Therefore, improving the quality

and quantity of the forests and quality of the wetlands on the island is extremely important to long-term avian conservation. We therefore recommend the following priority management measures:

- Remove feral cattle, pig, and goat populations from the island to promote recruitment of native vegetation on the island.
- Restore the wetland vegetation at the upper and lower lakes to provide cover, nesting, and foraging habitat for native waterbird species.
- Develop and implement a native forest restoration plan involving native plant outplanting and weed control to increase the available native forest on the island.
- Explore the feasibility of reintroduction of nightingale reed-warblers and Mariana common moorhens to Pagan and, if feasible, develop and implement reintroduction plans.

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Appendix 1. Model selection statistics for A) 12 models of white tern abundance, Micronesian starling and Micronesian honeyeater, and 4 models of white-throated ground-dove and collared kingfisher on Pagan, and B) histograms of the best-fit models.

A)

Model	*k*	*L*	AIC_c	ΔAIC_c	w_i
White Tern					
H-norm Key DectType	2	-369.83	743.80	0.00	0.459
H-norm Key Clutter	3	-369.02	744.32	0.52	0.354
H-norm Key Gust	7	-365.75	746.85	3.05	0.100
H-norm Key Hab	3	-371.58	749.44	5.64	0.027
H-norm Key	1	-373.73	749.50	5.70	0.027
H-norm Key CanCov	4	-370.91	750.29	6.49	0.018
H-rate Key	2	-373.28	750.69	6.89	0.015
H-norm Cos [1]					
H-rate Cos [1]					
H-norm Key Cloud [2]					
H-norm Key Wind [2]					
H-norm Key CanHgt [3]					
White-throated Ground-dove [4]					
H-norm Key	1	-407.23	816.49	0	0.662
H-rate Key	2	-406.85	817.83	1.34	0.338
H-norm Cos [2]					
H-rate Cos [2]					
Collared Kingfisher [4]					
H-norm Key	1	-1028.03	2058.08	0	0.868
H-rate Key	2	-1028.89	2061.84	3.76	0.132
H-norm Cos [2]					
H-rate Cos [2]					
Micronesian Starling					
H-rate Key DectType	3	-1202.13	2410.35	0.00	1.000
H-rate Key Hab	5	-1220.57	2451.34	40.99	<0.001
H-rate Key CanCov	5	-1228.54	2467.28	56.93	<0.001
H-norm Key	1	-1236.29	2474.60	64.25	<0.001
H-rate Key	2	-1236.39	2476.81	66.46	<0.001
H-rate Key Wind	6	-1234.26	2480.80	70.45	<0.001
H-rate Key CanHgt	3	-1237.69	2481.46	71.11	<0.001
H-rate Key Clutter	5	-1235.65	2481.51	71.16	<0.001
H-rate Key Gust	8	-1233.04	2482.57	72.22	<0.001
H-norm Cos [1]					
H-rate Cos [2]					

H-rate Key Cloud [2]

Micronesian Honeyeater

H-rate Key DectType	3	-716.47	1439.08	0.00	1.000
H-rate Key Hab	5	-724.77	1459.89	20.81	<0.001
H-norm Key	1	-728.97	1459.96	20.88	<0.001
H-rate Key	2	-728.96	1461.98	22.90	<0.001
H-rate Key CanHgt	3	-727.99	1462.11	23.03	<0.001
H-rate Key CanCov	5	-726.58	1463.51	24.43	<0.001
H-rate Key Gust	8	-724.77	1466.37	27.29	<0.001
H-rate Key Clutter	6	-727.26	1467.00	27.92	<0.001
H-rate Key Wind	6	-727.51	1467.51	28.43	<0.001
H-norm Cos [1]					
H-rate Cos [1]					
H-rate Key Cloud [2]					

Detection function models: H-norm Key = half normal; H-rate Key = hazard-rate; Cos = cosign adjustment term; H-poly = hazard polynomial adjustment term; S-poly = simple polynomial adjustment term; covaraites: CanCov = canopy cover; CanHgt = canopy height; Cloud = cloud cover; Clutter = understory closure; DectType = detection type; Gust = gust speed; Habitat = habitat type; Island = island of survey; Obs = observer; Wind = wind speed.

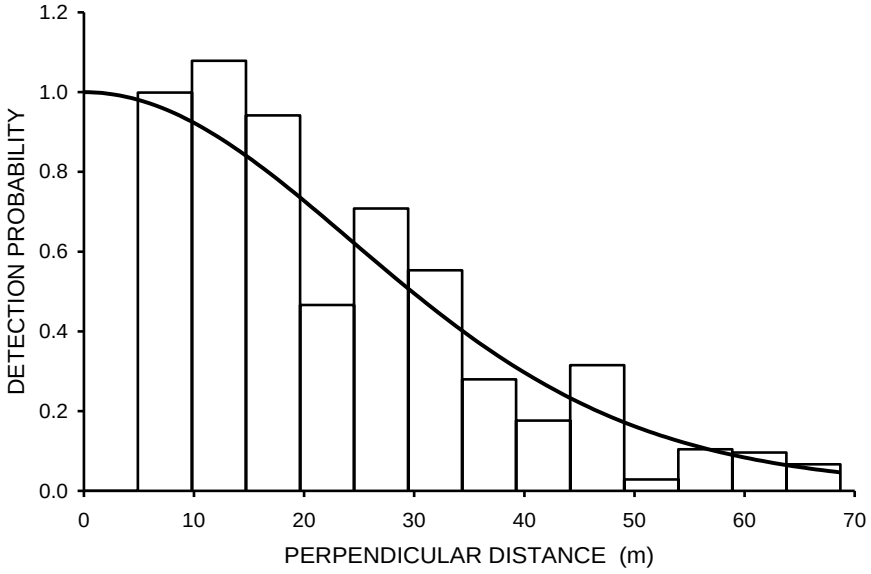
[1] Key model selected.

[2] Parameters highly correlated.

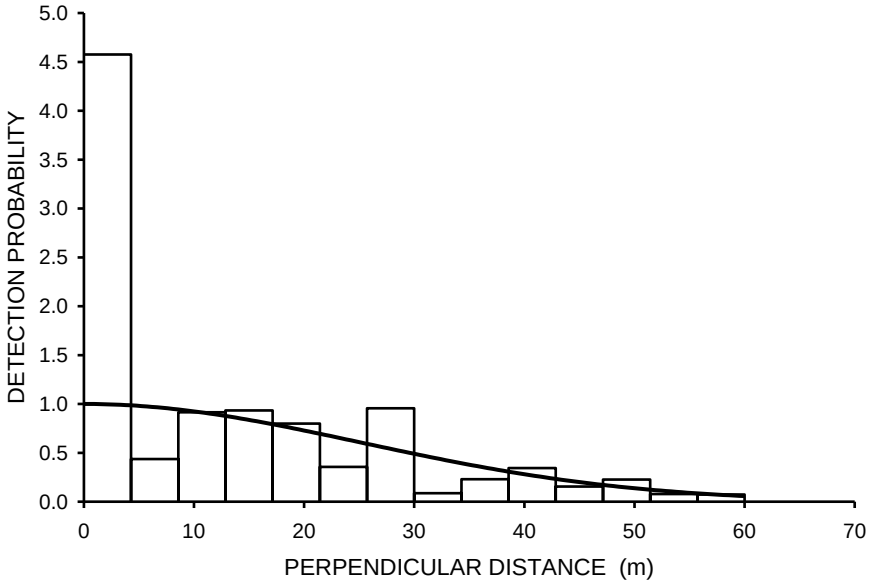
[3] Model failed to converge.

[4] Models incorporating covariates not tested because of small numbers of detections.

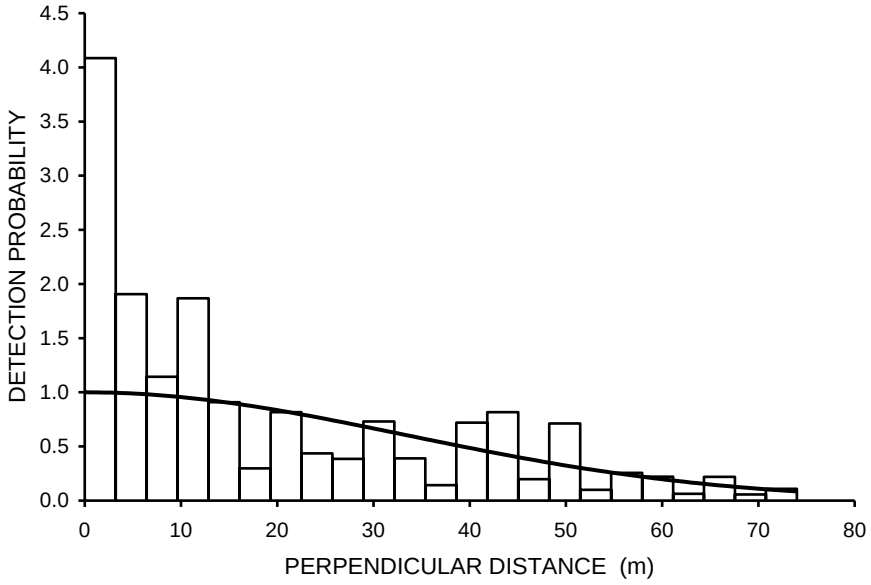
B)



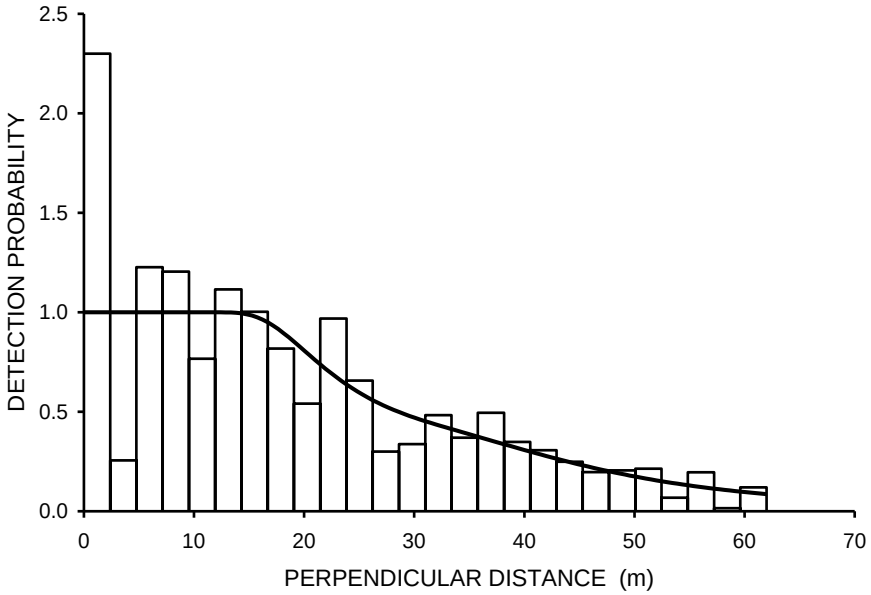
Histogram of the half normal detection function with covariate detection type fitted to white tern detections from Pagan. Truncation was set to 68.7 m.



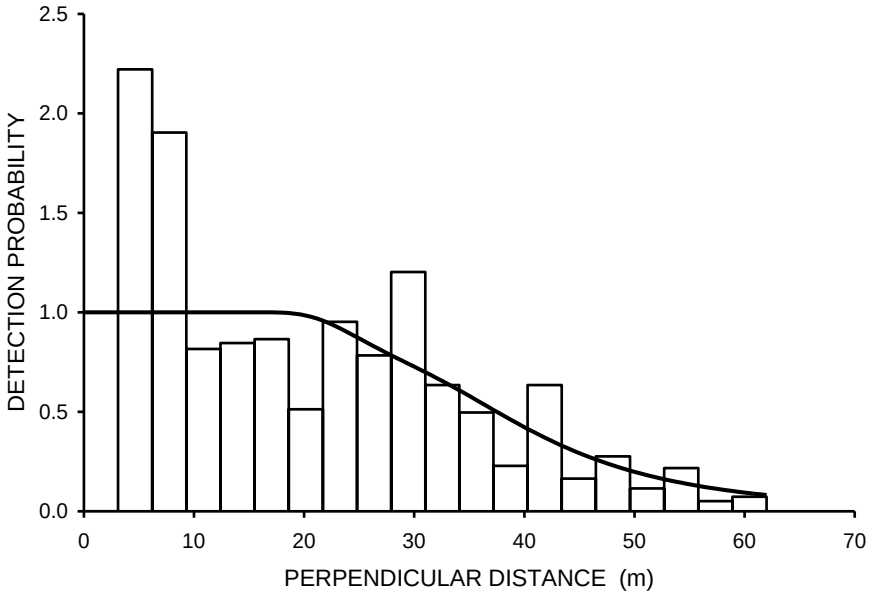
Histogram of the half normal detection function fitted to white-throated ground-dove detections from Pagan. Truncation was set to 60.0 m.



Histogram of the half normal detection function fitted to collared kingfisher detections from Pagan. Truncation was set to 74.0 m.



Histogram of the hazard-rate detection function with covariate detection type fitted to Micronesian starling detections from Pagan. Truncation was set to 62.0 m.



Histogram of the hazard-rate detection function with covariate detection type fitted to Micronesian honeyeater detections from Pagan. Truncation was set to 62.0 m.

Appendix 2. UTM coordinates for Mariana Common Moorhen and Nightingale Reed-warbler survey stations on Pagan. All coordinates are in WGS84 UTM Zone 55 North.

Nightingale Reed-warbler Stations				Mariana Common Moorhen Stations			
Lake	**Station**	**X**	**Y**	**Lake**	**Station**	**X**	**Y**
Lower	1	369113	2006574	Lower	1	369113	2006574
Lower	2	369048	2006432	Lower	2	369025	2006373
Lower	3	369018	2006283	Lower	3	369063	2006157
Lower	4	369063	2006157	Lower	4	369300	2006076
Lower	5	369140	2006010	Lower	5	369325	2006354
Lower	6	369287	2006058	Lower	6	369198	2006624
Lower	7	369335	2006205	Upper	1	370065	2007253
Lower	8	369325	2006358	Upper	2	370092	2007088
Lower	9	369277	2006502	Upper	3	370157	2007015
Lower	10	369198	2006624	Upper	4	370330	2007007
Upper	1	370065	2007253	Upper	5	370334	2007109
Upper	2	370088	2007108	Upper	6	370405	2007204
Upper	3	370194	2007003				
Upper	4	370326	2007075				
Upper	5	370405	2007204				

Appendix 3. Landcover mapping of the island of Pagan, Mariana Islands, 2010.

Author: Haldre Rogers, University of Oregon

Map Creation Date: April 2010
Update: June 2010
Ground-truth: June to July 2010
Finalized: October 2010

Satellite data for Pagan

There were several options for satellite data of Pagan. I based this landcover map primarily off of a 2003 Quickbird image obtained from Fred Amidon (US Fish and Wildlife Service). The image is split into two files, entitled "Pagan_North" and "Pagan_South", each showing about half of the island.

Other satellite data: Digital Globe has a January 2010 image taken from the WorldView satellite that is used in Google Earth. This is a clear, recent image of Pagan. However, WorldView is a commercial satellite, so the image is likely to be very expensive. The Ikonos satellite has an image from 2005 that has 0% cloud cover. This image is of lower resolution than the 2003 Quickbird image. There are many LandSat images available for this region, however, they are of lower resolution than the commercial images.

Process for developing landcover map

I began with the 2003 Quickbird image, then used ERDAS Image Analysis extension for ArcGIS to perform a supervised classification on each image. I trained the program using my best guess at each forest type, and this produced a highly pixelated map. I used this classified map alongside the original Quickbird image and the Google Earth image to determine the identity and boundaries of each landcover polygon.

Landcover categories: Below are the categories I used in the final map, after consultation with Laura Williams and Eric Cook after they visited Pagan.

<u>Non-forests</u>

- Sand- this category was rarely used. Only occurs on beaches.
- Lava/Cinder- Lava and/or Cinder is primarily found in the northern half of Pagan. The "Lava/Cinder" category was used exclusively for land that was dark in color and completely covered by volcanic material, with no visible grass, shrubs or trees.
- Lava scrub- Any lava interspersed with grass, shrubs or trees.
- Scrub- open land with a small amount of shrub or tree cover. Discontinuous canopy cover.
- Bare ground- Land with no vegetative cover.
- Grass- I could not confidently separate sword grass from short grass, so there is only one category for grass. Much of the grass category may also be grass/*Chromolaena* fields.

Forests

- *Casuarina*
- Casuarina-mixed: This category includes forest dominated by *Casuarina*, but not in pure stands.
- Coconut
- Native forest- This category includes much of the forest in the ravines in the southern half of the island as well as forest along clifflines. There is limited native forest remaining on Pagan.
- Mixed forest- Catch-all category for forest that didn't fall within another category.

Groundtruthing

I selected polygons representing each of the forest classes, as well as the scrub and cloud classes, for groundtruthing, and created a random point within each polygon. These points were spread out across the island. Laura Williams (DFW) traveled to as many points as possible and collected the following information along with a photograph:

- Number and Species ID of trees within 2 meters of groundtruthing point
- Dominant tree type (most common large tree in the region.)
- Height of canopy (estimated in meters)
- Percent canopy cover (estimated)
- Understory composition (top 3 most common understory plants)
- Substrate (red dirt, organic soil, lava, karst, sand, etc.)

For difficult to access sites, Laura attempted to view the location with binoculars and estimate the landcover type. She also traveled along the shore by boat and recorded forest type.

Finalizing the map

I used Laura's groundtruthing to identify major errors in my classification, and to correct specific polygons visited during groundtruthing. I also conferred with Eric Cook to clarify several confusing landcover types including grass/bare ground and ravine forest/native forest/coconut. Eric Cook viewed the amended version of the map and offered one last round of changes before the map was finalized.

Results

The landcover map of Pagan is presented below (Figure 1). Acreage estimates based on the landcover map indicate that over half of Pagan is un-forested (Figure 2), with the majority of this being lava/cinder fields (Figure 3). Approximately 42 percent of the island was forested (Figure 2), the most abundant forest type being *Casuarina* forest (Figure 4). The lava/cinder fields are believed to be part of the 1981 eruption on the island. In addition, the abundance of *Casuarina* forest on the island is also believed to be related to the 1981 eruption. Native forest was predominately found on the southern end of the island and along the clifflines of the northeastern part of the island and southern end of the northern part of the island.

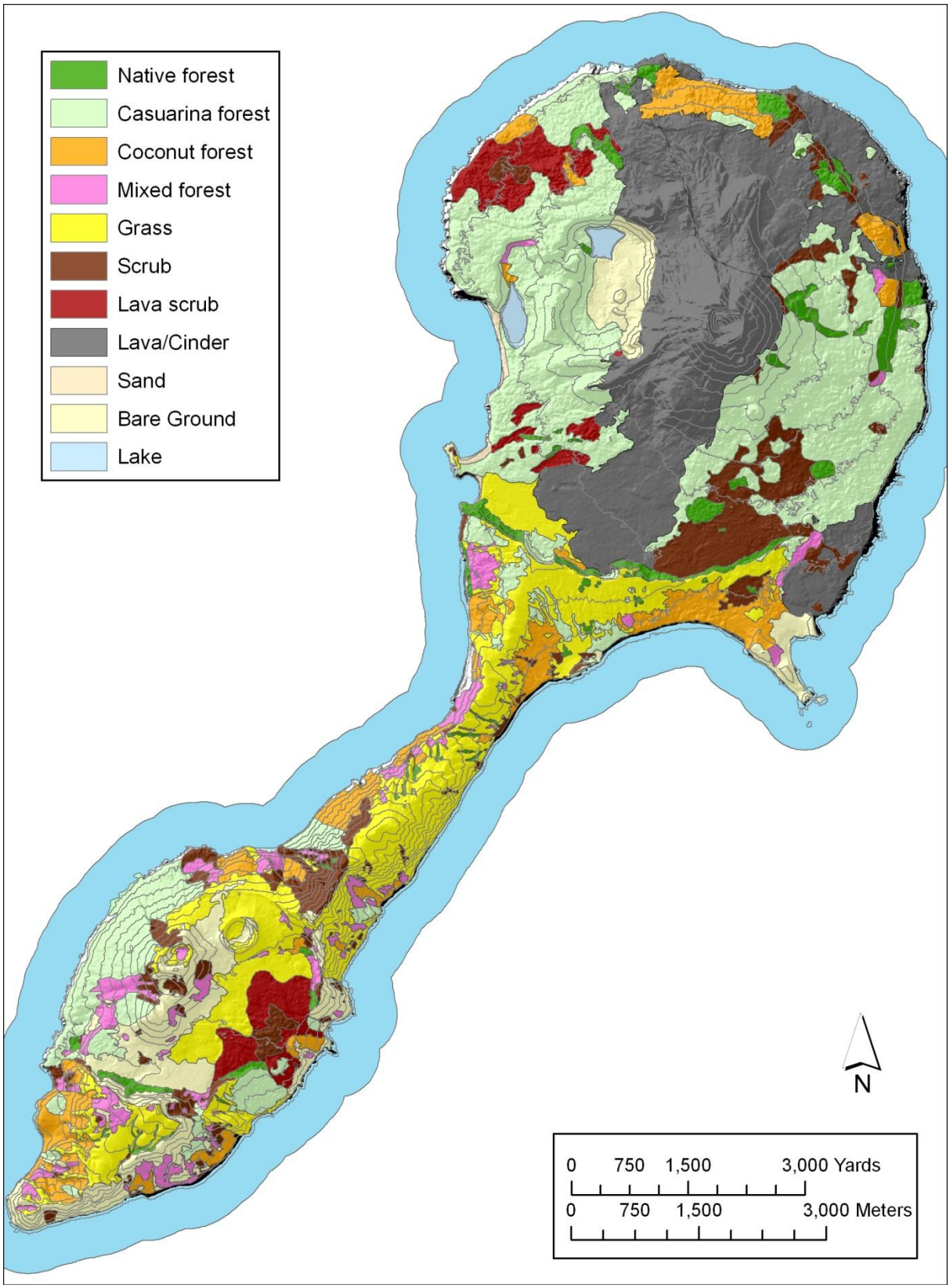


Figure 1. Landcover map of the island of Pagan.

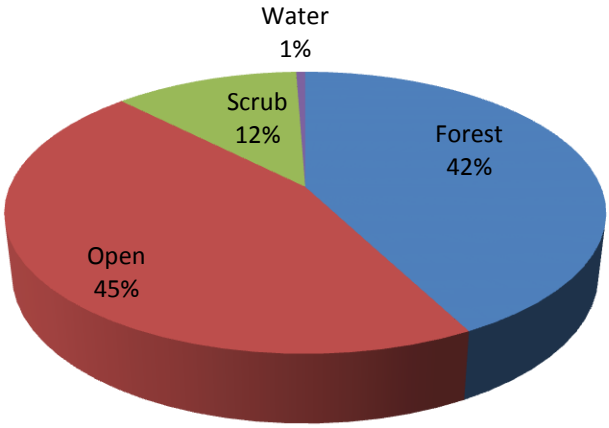


Figure 2. Percentage of land category type on the island of Pagan.

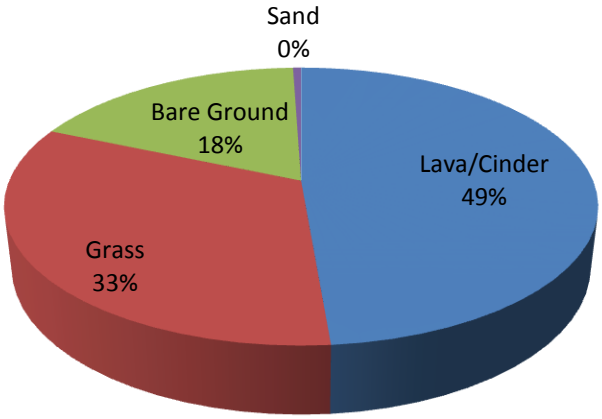


Figure 3. Percentage of land cover types in the open landcover category on the island of Pagan.

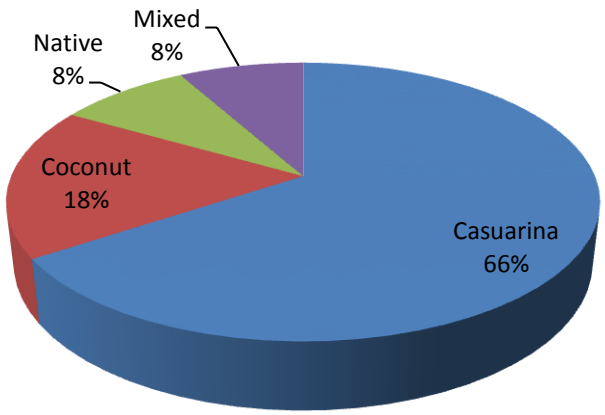


Figure 4. Percentage of land cover types in the forest landcover category on the island of Pagan.