STATUS OF THE MICRONESIAN MEGAPODE IN THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

Fred A. Amidon, Ann P. Marshall, and Curt C. Kessler

U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Honolulu, Hawaii

July 2011

Micronesian Megapode – Photo by Michael Lusk

Table of Contents

Executive Summary 4
Introduction 4
Methods 12
Results 28
Discussion 35
Acknowledgements 39
References 40

List of Figures

Figure 1. Location and composition of the Mariana archipelago 6
Figure 2. Island of Guguan 8
Figure 3. Island of Alamagan 9
Figure 4. Island of Pagan looking south from the north end of the island 9
Figure 5. Southern end of the island of Pagan 10
Figure 6. Island of Saipan showing the location of survey transects sampled in 2010 13
Figure 7. Island of Anatahan showing the location of survey transects sampled in 2010 14
Figure 8. Island of Sarigan showing the location of survey transects sampled in 2010 15
Figure 9. Island of Guguan showing the location of survey transects sampled in 2010 16
Figure 10. Island of Alamagan showing the location of survey transects sampled in 2010 17
Figure 11. Island of Pagan showing the location of survey transects sampled in 2010 18
Figure 12. Island of Agrihan showing the location of survey transects sampled in 2010 19
Figure 13. Island of Asuncion showing the location of survey transects sampled in 2010 20
Figure 14. Island of Maug showing the location of survey transects sampled in 2010 21
Figure 15. Unobserved movement of Micronesian megapodes by island 23
Figure 16. Unobserved movement of megapodes by understory clutter and detection type 24
Figure 17. Island of Uracus showing the location of survey transects sampled in 2010 27

List of Tables

Table 1. Number of transects and stations sampled by island……12

Table 2. Parameter coefficients from the model used to predict unobserved movement……24

Table 3. Measures of Micronesian megapode indices by island……..28

Table 4. Population size estimates of Micronesian megapode by island……29

Table 5. Population size estimates of Micronesian megapode by habitat…… 29

Table 6. Selection of models describing the relation of Micronesian megapode occurrence……31

Table 7. Summary of Micronesian megapode detection probability estimates……33

Table 8. Summary of Micronesian megapode occupancy estimates……33

Table 9. Summary of Micronesian megapode population estimates for the islands of the CNMI……36

List of Appendices

Appendix 1. Nightingale reed-warbler surveys on Alamagan…….. 47

Appendix 2. Forest bird surveys on Maug ……..55

Appendix 3. Bird list northern Mariana Islands surveys 2010 ……58

Appendix 4. Micronesian megapode survey assessment: Aguiguan 2009……60

Appendix 5. UTM coordinates for point-transect, playback, and occupancy stations……..100

Appendix 6. Model selection statistics……104

Appendix 7. SAS code to model unobserved movement ……106

Executive Summary

Micronesian megapode surveys were conducted in the Commonwealth of the Northern Mariana Islands in 2009 (Aguiguan) and 2010 (Saipan, Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracas) by the U.S. Fish and Wildlife Service to estimate the population in the Mariana archipelago. A combination of point-transect, playback, and occupancy sampling was used on islands known to have extant megapode populations and that were not surveyed in recent years. The islands of Tinian and Farallon de Medinilla were both surveyed in 2008 and not included in this survey. Megapodes were thought to have been extirpated from Anatahan and transient on Uracas so presence/absence surveys were conducted on those islands. Megapodes were detected during surveys on all islands except Agrihan and Uracas; however, one bird was detected off count on Agrihan. In general, population estimates were higher than previous estimates and ranged from a low of around 150 birds on Pagan and Saipan to over 5,000 birds on Asuncion. The total estimated population of megapodes in the northern islands was 10,727 individuals (95% CI: 6,682—15,445), with the majority of the population found on the islands of Asuncion, Sarigan and Guguan. We believe the increased estimates are, in part, due to increased survey effort. Many of the previous island surveys were limited in time and scope due to logistical constraints. However, other factors, like the ungulate eradication on Sarigan and volcanic eruption on Anatahan, also affected the population estimates from this study. We found that ungulate-free islands had the largest densities of megapodes and that the likelihood of detecting a megapode on ungulate-free islands was 84% compared to 37% on an island with ungulates. We also found that, on islands with ungulates, megapodes were more likely to be found in native forest and in areas with thick understory vegetation then in other habitats. We recommend removing feral ungulates and restoring the native forests on islands important to the long-term conservation of the megapode.

Introduction

Goal of Surveys:

In 2009 and 2010, the U.S. Fish and Wildlife Service (USFWS) coordinated Micronesian megapode (*Megapodius laperouse laperouse*) surveys in the Commonwealth of the Northern Mariana Islands (CNMI) 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 CNMI Division of Fish and Wildlife (DFW) and staff from the Northern Mayor's Office assisted with the project. The goals of these surveys were to estimate megapode populations by island and, if feasible, by habitat type. Micronesian megapodes were thought to have been extirpated from Anatahan and transient on Uracas so presence/absence surveys were planned for those islands. Tinian has a very small, and potentially transient, megapode population and was surveyed in 2008 (Kessler and Amidon 2009). We determined that additional surveys would provide minimal new information on the population for the effort and decided not resurvey the island. Farallon de Medinilla was surveyed extensively by the U.S. Navy in 2008 (Vogt 2009). Due to restricted access to the island and safety issues, part of the island is a live-fire range, we decided to not resurvey this island. Surveys of forest birds and wetland birds on Pagan, of nightingale reed-warblers (*Acrocephalus luscinia*) on Alamagan (Appendix 1) and of forest birds on Maug (Appendix 2) were also undertaken as part of this survey effort. The methods and results of the Pagan surveys are presented in a separate report in this volume (Marshall and Amidon 2010). A list of all incidental bird observations was also maintained (Appendix 3).

Background and Protected Status:
The Micronesian megapode, known as *sasangat* in Chamorro and *sasangal* in Carolinian, is a pigeon-sized bird of the forest floor that was once found throughout the Mariana archipelago (USFWS 1998). It has been extirpated from two of the large southern Mariana Islands (Guam and Rota; USFWS 1998). In addition, larger populations occur only on a few of the uninhabited northern islands (Sarigan, Guguan, and Asuncion) and it was recently believed extirpated from Anatahan (Martin *et al.* 2008; DFW 2000, unpublished data; C. Kessler, USFWS, pers. obs.). The Micronesian megapode was federally listed as endangered in 1970 (USFWS 1970). In 1991, the Commonwealth of the Northern Mariana Islands (CNMI) published their endangered species list, which included the Micronesian megapode (CNMI 2000). It is also listed as endangered according to the 2010 IUCN Red List (BirdLife International 2010).

The main threats affecting this species are the loss and degradation of habitat, mainly due to forest clearing, browsing by feral ungulates, and predation by introduced species, including but not limited to monitor lizards (*Varanus indicus*), dogs (*Canus familiarus*), cats (*Felis cattus*), and pigs (*Sus scrofa*; USFWS 1998). An additional concern is the possibility of brown treesnake (*Boiga irregularis*) introductions to the other Mariana Islands from Guam. The accidental introduction of the brown treeesnake to Guam resulted in the extirpation or extinction of 13 of Guam's 22 native breeding birds (Rodda and Savidge 2007).

Basic Life History: Glass and Aldan (1988) found that megapodes on Saipan appear to remain together throughout the year in territories that they advertise (through vocalizations, including pair duetting) and defend at least part of the year. Duetting in birds is correlated with year-round territories and prolonged monogamous pair bonds (Farabaugh 1982). Megapodes are often called incubator birds because they rely on alternative heat sources for incubation, including solar energy, volcanic activity, or microbial decomposition (Clark 1964). Nesting may occur year round and may be seasonal, depending on the island and the source of heat used for incubation (USFWS 1998). For instance, Glass and Aldan (1988) found that megapodes on Guguan lay eggs in dark, solar-heated cinders at a communal nesting area. Females dig the burrows and are not, or only rarely, accompanied by the male (Glass and Aldan 1988). It is unknown how many eggs a female may lay in a given time period, but they lay a very large egg and the chicks are considered super precocial when they hatch, as they are completely independent and able to fly upon emergence (USFWS 1998).

In general, the Micronesian megapode is a forest bird and has been reported in native forests and in dense coconut (*Cocos nucifera*) forests (Stinson 1993). Megapodes are omnivorous and eat a variety of plant and animal food, including seeds, beetles, ants, other insects, and plant matter (Stinson 1993). It is believed that Micronesian megapodes are capable of moving between the islands (USFWS 1998). The Palau subspecies (*Megapodius laperouse senex*) has been observed flying between islands (Pratt *et al*. 1980) and Olson (1980) states that based on the distribution of the Megapodiidae, megapodes are quite capable of flying over water for great distances. Although no megapodes have been observed flying over the ocean in the Mariana Islands, anecdotal information regarding fluctuations in numbers on Tinian and the apparent recolonization of Anatahan post-eruption suggests that they do fly between islands (Stinson 1993; Vogt 2008; Kessler, pers. comm. 2010).

Study Area and Previous Surveys

The Mariana archipelago is a chain of 15 islands located in the western Pacific Ocean (Figure 1). The southernmost island of Guam is a U.S. Territory and the remaining 14 islands make up the CNMI. All of the islands are volcanic in origin, however the islands south of Farallon de Medinilla (Saipan, Tinian, Aguiguan, Rota, and Guam) are older and have extensive deposits of uplifted marine limestone. The

islands north of Farallon de Medinilla (Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracus) are generally referred to as the northern islands while the islands to the south are considered the southern islands.

Micronesian megapodes were once found throughout the Mariana archipelago (USFWS 1998). However, they have not been reported on the islands of Guam and Rota in the last 50 years, except for an anecdotal observation of a megapode on Rota in 2010 (USFWS 1998; S. Faegre, University of Washington, pers. comm. 2010). Therefore, the remainder of this section will focus on the remaining islands of the archipelago. For additional information on Guam and Rota and megapode populations on those islands please refer to USFWS (1998) and Fosberg (1960).

Aguiguan (7 km^2) – Aguiguan is approximately 5 km long and 1.5 km wide and is located at 14° 51' North and 145° 34' East (Figure 1). The island is composed of a series of limestone plateaus and approximately 69 % of the island is forested (Amidon 2009). The island is currently uninhabited but was inhabited in the 1930s and 1940s when the Japanese developed the island for agriculture (Butler 1994). Most of the areas developed by Japanese are now fields of *Lantana camara* (lantana) or secondary forest (tangantangan (*Leucaena leucocephala*), etc.; Amidon 2009, Cruz *et al*. 2000). However, approximately half of the island is still covered with native forest (49%; Amidon 2009), though the presence of feral goats (*Capra hircus*) on the island since the early 1800s (Butler 1994) is impacting recruitment and regeneration of the forest (Cruz *et al*. 2000).

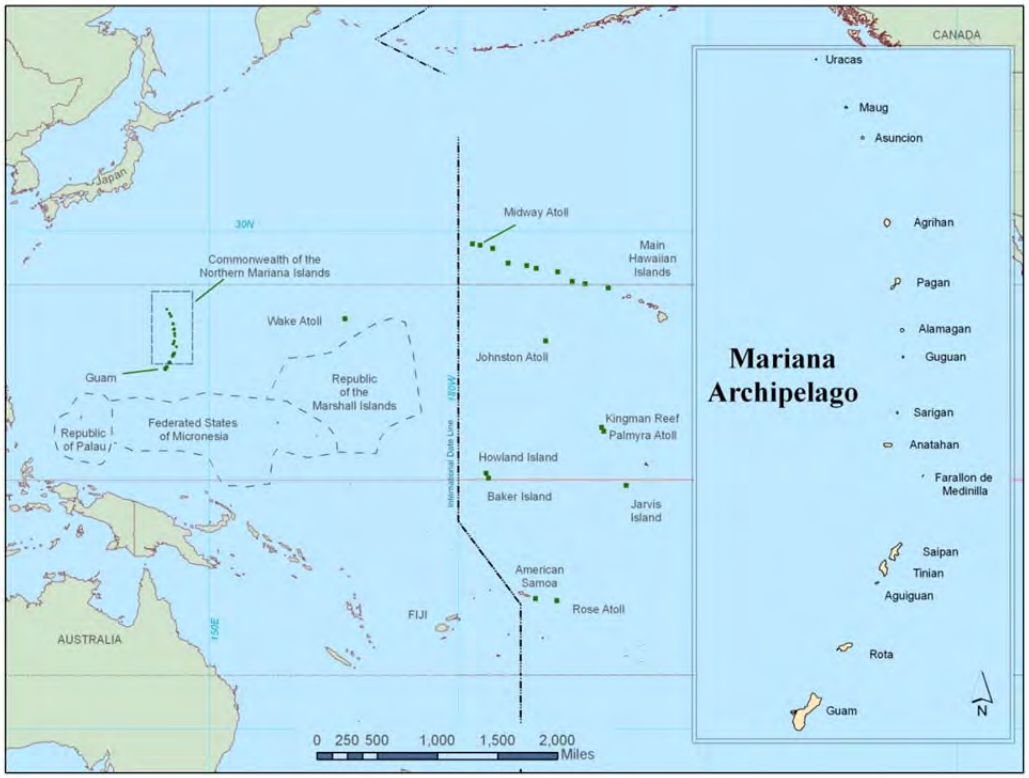


Figure 1. Location and composition of the Mariana archipelago.

Megapodes have been consistently observed in small numbers on Aguiguan based on reports from the 1930s, 1950s, 1980s, 1990s, and 2000s (Craig and Chandran 1992, Craig *et al*. 1992, Engbring *et al*. 1986, Owen 1974 (cited in Glass and Aldan 1988), Takatsukasa 1932-1938). Juvenile megapodes have been observed on the island but no nests have been confirmed (Appendix 4). Recent data (Camp *et al*. 2009a, Appendix 4) indicate megapodes may be more numerous there than previously believed.

Tinian (100 km^2) – Tinian is approximately 20 km long and 8 km wide and is located at 15° North and 145° 38' East (Figure 1). The island is generally flat and low (maximum elevation of 179 m) with upraised areas in the south and central parts of the island. Approximately 3,500 people were reported to live on the island in 2000 (U.S. Census Bureau 2001), all of whom are located in the southern third of the island. The remaining northern two thirds of the island are leased by the U.S. Navy for training purposes. The island has undergone a wide range of habitat modifications over the last century. One of the most dramatic was the conversion of almost the entire island into agriculture by the Japanese in the 1930s and the invasion and development of the island by U.S. forces in 1944 (Bowers 2001, Farrell 1992). After Tinian was captured by the U.S. from the Japanese in 1944, it was transformed into the busiest airbase of the war and supported a 40,000-personel installation (Wikipedia 2010). Currently, the island is dominated by secondary vegetation, especially tangantangan (Falanruw *et al*. 1989). However, remnant native forest makes up approximately 7% of the island and can be found along cliff-line areas (Falanruw *et al*. 1989).

Megapodes have been reported as rare on Tinian since first collected in 1820 (Quoy and Gaimard 1824-1826, cited in Baker 1951). Despite regular surveys, Megapodes have been observed infrequently (Engbring *et al*. 1986, Kessler and Amidon 2009, O'Daniel and Kreuger 1999, Pratt and Bruner 1978, Vogt 2008). It seems likely, based on the inconsistent observations, that the recent observations may be birds dispersing from other islands.

Saipan (120 km^2) – Saipan is approximately 22 km long and 3-10 km wide and is located at 15° 12' North and 145° 45' East (Figure 1). The island is dominated by a limestone ridge that runs along the center of the island with Mt. Takpochao being the highest point on the island (436 m). The central government for the CNMI is located on Saipan and it has the largest human population (62,392; U.S. Census Bureau 2001) in the Commonwealth. Like Tinian, Saipan was also heavily developed by the Japanese in the 1930s and subsequently invaded and developed by U.S. Forces (Bowers 2001). Approximately 75% of the island is forested. However, only 4% of the island is native forest (Falanruw *et al*. 1989).

Megapodes are believed to have been common on Saipan at one time and were hunted incessantly (Oustalet 1896). By 1945 birds were rare and thought extirpated (Baker 1951). However, Pratt and Bruner (1978) reported a small population on the northern part of Saipan, which has persisted to this day (USFWS 1998; A. Marshall and F. Amidon, USFWS, pers. obs.).

Farallon de Medinilla (0.9 km^2) – Farallon de Medinilla or FDM is approximately 2.6 km long and 0.4 km wide and is located at 16° 1' North and 146° 4' East (Figure 1). The island is an upraised limestone plateau with a maximum elevation of 82 m. Approximately 11% of the island is forested (NOAA 2009a), the majority of which is composed of low *Pisonia grandis* (umumu, Lusk *et al*. 2000). There are no records of habitation or feral ungulates on the island, and it is currently leased by the U.S. Military for use as a live-fire range (Lusk *et al*. 2000).

Megapodes were not reported on FDM until 1996 (Lusk *et al*. 2000) but it is unknown to what degree the island was previously surveyed by naturalists (USFWS 1998). Recent information suggests a small

megapode population of a minimum of 12 pairs and an unknown number of individual birds (chicks, juveniles, and presumably adult males) are found on the island (Lusk *et al*. 2000, Vogt 2009).

Anatahan (32 km^2) – Anatahan is approximately 3 km long and 9 km wide and is located at 16° 22' North and 145° 40' East (Figure 1). The first eruption of the island occurred in 2003 and the last was reported in 2008 (Smithsonian 2010). Less than 8 % of the island was considered forested (NOAA 2009b) and the 2003 eruption caused drastic alterations to the remaining forest. Currently, the majority of the forest is composed of thickets of *Hibiscus tiliaceus* (pago), though remnants of coconut forest and *Casuarina equisetifolia* (ironwood) groves remain (Kessler, pers. comm. 2010). The island is uninhabited and a small population of feral pigs is believed to still be persisting on the island (Kessler, pers. comm. 2010). One cat was also recently observed there (A. Marshall, USFWS, pers. obs., 2010)

Megapodes were reported on Anatahan in the 1940s (Ludwig 1979), however it is unknown to what degree the island was surveyed by naturalists prior to the 1970s (USFWS 1998). Since first being recorded on Anatahan, megapodes have been reported there regularly (USFWS 1998, DFW 2000a). However, they were believed extirpated as a result of the recent volcanic eruptions (Kessler, pers. obs., 2007).

Sarigan (5 km^2) – Sarigan is approximately 3 km long and 2.2 km wide and is located at 16° 42' North and 145° 47' East (Figure 1). The island consists of a central volcanic cone (549 m elevation) with steep slopes to the south and east and a more gradual slope to the north and northwest. Approximately 38% of the island is forested (NOAA 2009c). A large coconut forest dominates the northwestern half of the island and a native *Pisonia grandis* forest is found along a ridge that runs to the north (Ohba 1994). The coconuts were planted as part of copra (dried meat of the coconut used for coconut oil extraction and animal feed) production around 1900 (Spennemann 1999) which continued into the Japanese administration (1914-1944; Russell 1998). The last eruption on the island probably occurred in the Holocene but off gassing was observed in 2010 (Smithsonian 2010). Currently the island is uninhabited. Feral pigs and goats were once found on the island but were removed in 1998 (Kessler 2002). Feral cats are still found on the island (Kessler, pers. obs.).

Figure 2. Island of Guguan.

Megapodes were not reported on Sarigan until the early 1970s (Falanruw 1975) but it is unknown to what degree the island was surveyed by naturalists prior to the 1970s (USFWS 1998). Since then megapodes have been consistently reported as common there (Clapp 1983, Ludwig 1979, Reichel *et al*. 1989, Rice and Stinson 1992) and observations of megapode chicks indicates nesting is occurring (Glass and Aldan 1988). Fancy *et al*. (1999) estimated a population of 545 to 810 birds in 1998 and Martin *et al.* (2008) estimated a population of 1,772 in 2006.

Guguan (4 km^2) – Guguan is approximately 2.7 km long and 2.2 km wide and is located at 17° 19' North and 145° 51' East (Figure 1, 2). The island consists of two volcanoes, one older and one more recent. The newer volcano dominates the northern half of the island and has a maximum elevation of 248 m. The slopes of the northern half of the island are covered with ash fields and strand plant communities (Ohba 1994). The older volcano makes up the southern half of the island and has a maximum elevation of 301 m. Native forest, composed of *Terminalia catappa* (Pacific almond) and *Pisonia grandis*, dominates the areas along the old crater wall and the ravines formed along the slopes of the old

volcano. Approximately 40% of the island is forested (NOAA 2009d). The only known historical eruption of the island occurred between 1882 and 1884 (Smithsonian 2010) and the island is uninhabited. No feral ungulate populations are reported for the island and the island was designated a conservation island by the CNMI in the early 1980s (Commonwealth Constitution Article XIV).

Megapodes were not reported on Guguan until the early 1970s (Falanruw 1975) but it is unknown to what degree the island was surveyed by naturalists prior to the 1970s (USFWS 1998). Guguan was then believed to support the largest megapode population in the Mariana Islands (USFWS 1998) and Glass and Aldan (1988) reported on a large nesting area in the cinder fields on the island. In 2000, DFW (2000b) estimated there were 832 birds by determining densities in cover types and extrapolating over the amount of forest cover.

Figure 3. Island of Alamagan.

Alamagan (11 km^2) – Alamagan is approximately 4.4 km long and 3.9 km wide and is located at 17° 35' North and 145° 51' East (Figure 1, 3). It is composed of a single active volcanic cone with a maximum elevation of 744 m. There are no known historical eruptions on the island and the last known eruption was estimated to have occurred in 870 AD (± 100 years) based on radio carbon data (Smithsonian 2010). The island is approximately 37% forested (NOAA 2009e) with the majority consisting of coconut forest. Native forests consisting of *Elaeocarpus joga* (yoga) and *Hibiscus tiliaceus* are found in the ravines and at higher elevations on the island (Ohba 1994). The majority of the non-forested areas consist of swordgrass, *Miscanthus floridulus* (Ohba 1994).

Copra production on Alamagan began around 1900 (Spennemann 1999) and occurred up to the 1970s (Russell 1998). Villages were once found on the southern and northern coasts. The island is currently uninhabited but was regularly populated up until 2009 when residents were evacuated from the island after super typhoon Choi-Wan passed over the island (de la Torre 2009). Populations of feral goats, pigs, and cattle (*Bos taurus*) are currently found on the island. A dog and some cats also occur there (Marshall, pers. obs. 2010).

Megapodes were first collected on Alamagan in the 1930s (Takatsukasa and Yamashina 1932). Nesting grounds were reported on the northeastern and southeastern parts of the island in the 1950s by local residents (Reichel *et al*. 1988). The population of megapodes on Alamagan has been reported as low since the 1970s due to human presence and feral ungulates, although it may have recovered somewhat with the lack of permanent residents since the 2009 evacuation (DFW 2000c, USFWS 1998).

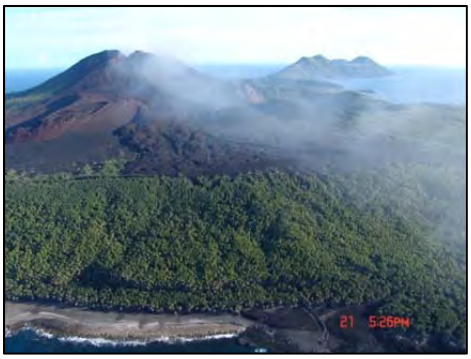


Figure 4. Island of Pagan looking south from the north end of the island.

Pagan (48 km^2) – Pagan is approximately 16 km long and 6 km wide and is located at 18° 06' North and 145° 46' East (Figure 1). The northern end of the island is dominated by Mount Pagan (570 m), an active volcano which last erupted in 2006 (Smithsonian 2010; Figure 4). The southern end of the island is dominated by a dormant volcano with active steam vents (Figure 5). The maximum elevation of the southern end of the island is 550 m. Connecting the northern and southern ends of the island is a narrow

isthmus with steep slopes. The maximum elevation along the isthmus is 572 m.

Approximately 42% of the island is forested (Rogers 2010). The dominant forest types include *Casuarina equisetifolia*, coconut, and native forest. The majority of the ironwood forest is found on the northern end of the island while the majority of the native forest, in particular *Geniostoma rupestre* var. *glaberrimum* (majlocjayo) and *Aidia cochinchinensis* (sumac), is found in the south (Pratt 2010, Rogers 2010). The remainder of the island is composed of *Miscanthus floridulus* (swordgrass) and other scrubby species (Pratt 2010).

Pagan was an important part of copra production in the northern islands since the mid-1800s (Russell 1998). During the Japanese administration the island was also used as a military base and approximately 2,200 personnel were stationed on the island (Richard 1957, as cited in Russell 1998). Pagan was bypassed by U.S. Military forces and no major military operations occurred on Pagan except for bombing and machine gunning by U.S. Military aircraft (Russell 1998). In 1981, a major eruption of Mount Pagan created two large lava flows, one on the northern end and one on the southern end of Mount Pagan. This eruption lead to the evacuation of the island and Pagan has remained largely unpopulated. Currently, there are feral populations of goats, pigs, and cattle on the island (Kessler 2010).

Figure 5. Southern end of the island of Pagan.

Megapodes were first collected on Pagan in 1887 (Oustalet 1896). Megapodes were reported common in the 1950 and 1960s (Glass and Aldan 1988). However, at least one nesting area was buried during the 1981 volcanic eruption (Glass and Aldan 1988) and since then, megapode populations have been reported as low (DFW 2000d).

Agrihan (44 km^2) – Agrihan or Agrigan is approximately 9.7 km long and 6.6 km wide and is located at 18° 46' North and 145° 40' East (Figure 1). Agrihan has the highest elevation of the Mariana Islands (965 m). A large crater dominates the center of volcanic cone and numerous steep ravines run along the slopes. The last historical eruption on the island occurred in 1917 (Smithsonian 2010) though active steam vents are found throughout the island. Approximately 35 % of the island is forested (NOAA 2009f). The majority of the forest is coconut forest but *Elaeocarpus joga* forest is found in the ravines and at higher elevations on the slope (Ohba 1994). Most of the ridge lines and upper slopes are covered with *Miscanthus floridulus*, which is thought to be maintained with regular burning by people on the island (Ludwig 1979, Ohba 1994). The coconut forests, which dominate the lower slopes of the island, were likely first established for copra production around 1900 (Spennemann 1999) and expanded during the Japanese Administration (1914-1944) and after WWII (Russell 1998). Agrihan currently has no long-term residents, though efforts to reestablish long-term settlement are underway (David 2010). Prior to the end of copra production on the island in the mid-1970s, a population of over 150 people was reported for the island (Ludwig 1979). Currently the island has feral populations of goats, pigs, and, potentially, cattle (Ludwig 1979). Feral dogs and cats were also observed on the island (Amidon, pers. obs. 2010).

Megapodes were first collected on Agrihan in 1889 (Oustalet 1896). Egg collection was apparently common and local residents noted that monitor lizards, cats, and dogs preyed on nests (Ludwig 1979). No megapodes were observed in searches from 1987 to 1992, although local residents indicated they

were still present (USFWS 1998). Surveys in 2000 only detected 7 megapodes on one transect, located away from the village (DFW 2000e).

Asuncion (7 km^2) – Asuncion is approximately 3.4 km long and 3 km wide and is located at 19° 40' North and 145° 24' East (Figure 1). The island is essentially an active volcanic cone with a maximum elevation of 891 m. The last confirmed eruption was in 1906 (Smithsonian 2010). Approximately 41 % of the island is forested (NOAA 2009g). The majority of the forest on the island is composed of natives, *Pandanus tectorius* (pahong) and *Terminalia catappa* (Ohba 1994). However, a coconut forest, likely planted as part of copra production in the 1890s (Spennemann 1999), is located on the southern coast. Asuncion is currently uninhabited and no feral ungulates are recorded for the island. The CNMI government designated the island as a conservation area in the early 1980s (Commonwealth Constitution Article XIV) and the waters and submerged land surrounding the island were included in the Marianas Trench National Monument in 2009 (White House 2009).

Megapodes were first reported on Asuncion by Yamashina (1940). Few birds were detected on the island during visits in 1987 to 1995 (USFWS 1998). However, more recent surveys of Asuncion by DFW (Radley 2009) found that megapodes were breeding based on the observations of chicks and relatively common with higher densities there than other islands surveyed (Agrihan, Sarigan, Saipan, and Aguiguan).

Maug (2 km^2) – Maug is located at 20° 01' North and 145° 13' East and is comprised of three islets which make up the wall of a sunken volcano (Figure 1). The maximum elevation is 227 m and the sides of islet which face the crater of the sunken volcano are comprised of steep cliffs. Approximately 22% of the island is forested (NOAA 2009h). Coconut forest and mixed *Pisonia grandis* and *Terminalia catappa* forest is found on the east and north islets while the remainder is covered in grass and shrubs (Ohba 1994). The island was briefly inhabited by the Japanese during their administration (1914-1944) and used for fish processing and as a weather station (Russell 1998). The island does not have feral ungulates and was designated a conservation area by the CNMI in the early 1980s (Commonwealth Constitution Article XIV). In 2009 the waters and submerged land surrounding the island became part of the Marianas Trench National Monument (White House 2009).

Megapodes were first recorded on Maug in the early 1970s (Falanruw 1975). Prior to this time there are no written records, however it is unknown to what degree the island was surveyed by naturalists prior to the 1970s (USFWS 1998). Most recent trips have found megapodes common on all of the three islets in both forest and scrub habitat (Clapp 1983, Reichel *et al*. 1987, Rice and Stinson 1992). Evidence of breeding was also reported by Reichel et al. (1987), who observed a megapode digging a nest tunnel in 1987.

Uracas (2 km^2) – Uracas or Farallon de Pajaros is approximately 1.8 km long and 1.6 km wide and is located at 20° 32' North and 144° 54' East (Figure 1). The maximum elevation of the island is 334 m and approximately 70% of the island is unvegetated due to recent lava flows (Ohba 1994). The majority of the vegetated areas are covered by *Fimbristylis cymosa*, a sedge (Ohba 1994). Uracas has an active volcano which last erupted in 1967 (Smithsonian 2010). However, regular eruptions were reported for every decade from the turn of the century to the 1950s which resulted in the nickname "Lighthouse of the Pacific." The island was designated a conservation area by the CNMI government in the early 1980s (Commonwealth Constitution Article XIV) and the waters and submerged lands surrounding it became part of the Marianas Trench Marine National Monument (White House 2009).

Megapodes were not reported on Uracus until the early 1970s (Falanruw 1975) but it is unknown to what degree the island was surveyed by naturalists prior to the 1970s (USFWS 1998). Megapodes have not been recorded on trips since the Falanruw (1975) trip during which only one adult was observed (USFWS 1998). There is no forest and only sparse vegetation on Uracas. Given the lack of appropriate vegetation, the island may not support a resident population of megapodes and the single observation may have been of a dispersing individual.

Methods

Point-Transect Surveys - To estimate the current megapode population size we conducted island-wide point-transect surveys on Saipan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug in 2010. Point-transect surveys were not utilized on Anatahan due time constraints and preliminary sampling which indicated that detections from point-transect sampling would be insufficient for estimating densities. Therefore, playback surveys were only utilized on Anatahan (see below). Aguiguan and Tinian were previously sampled in 2009 (Appendix 4) and 2008 (Kessler and Amidon 2009), respectively, and reported elsewhere.

We sampled a total of 516 stations on 60 transects over all of the islands (Table 1; Figures 6-14; see Appendix 5 for station UTM coordinates). Two of the transects on Saipan included stations that were established for monitoring the Saipan Upland Mitigation Bank (Cruz and Williams 2003; Appendix 5). Five transects on Sarigan overlapped and included stations from survey transects established by DFW (DFW 2000f, Martin *et al*. 2008; Appendix 5). The remaining transects and stations were established as part of this survey effort and were placed specifically in forested habitat to maximize the likelihood of megapode detections and provide coverage of all habitats in which megapode were likely to occur. The starting point for all newly established transects was determined by overlaying a 150-m grid over each island using a Geographic Information System (GIS) and randomly selecting points. A transect composed of stations spaced 150 m apart was then established to maximize coverage of forested areas. In addition, all stations were spaced a minimum of 150 meters apart on the previously established transects.

Table 1. Number of transects and stations sampled during point-transect and playback surveys by island and total acreage of each island.

		Point-Transect		Playback	
Island	**Acreage (km^2)**	**Transects**	**Stations**	**Transects**	**Stations**
Saipan	120	11	82	11	82
Anatahan	32	-	-	6	21
Sarigan	5	6	41	6	41
Guguan	4	5	32	5	32
Alamagan	11	10	72	10	72
Pagan	48	13	144	13	144
Agrihan	44	9	93	9	97
Asuncion	7	4	38	4	38
Maug	2	2	14	2	14
Total	*273*	*60*	*516*	*66*	*541*

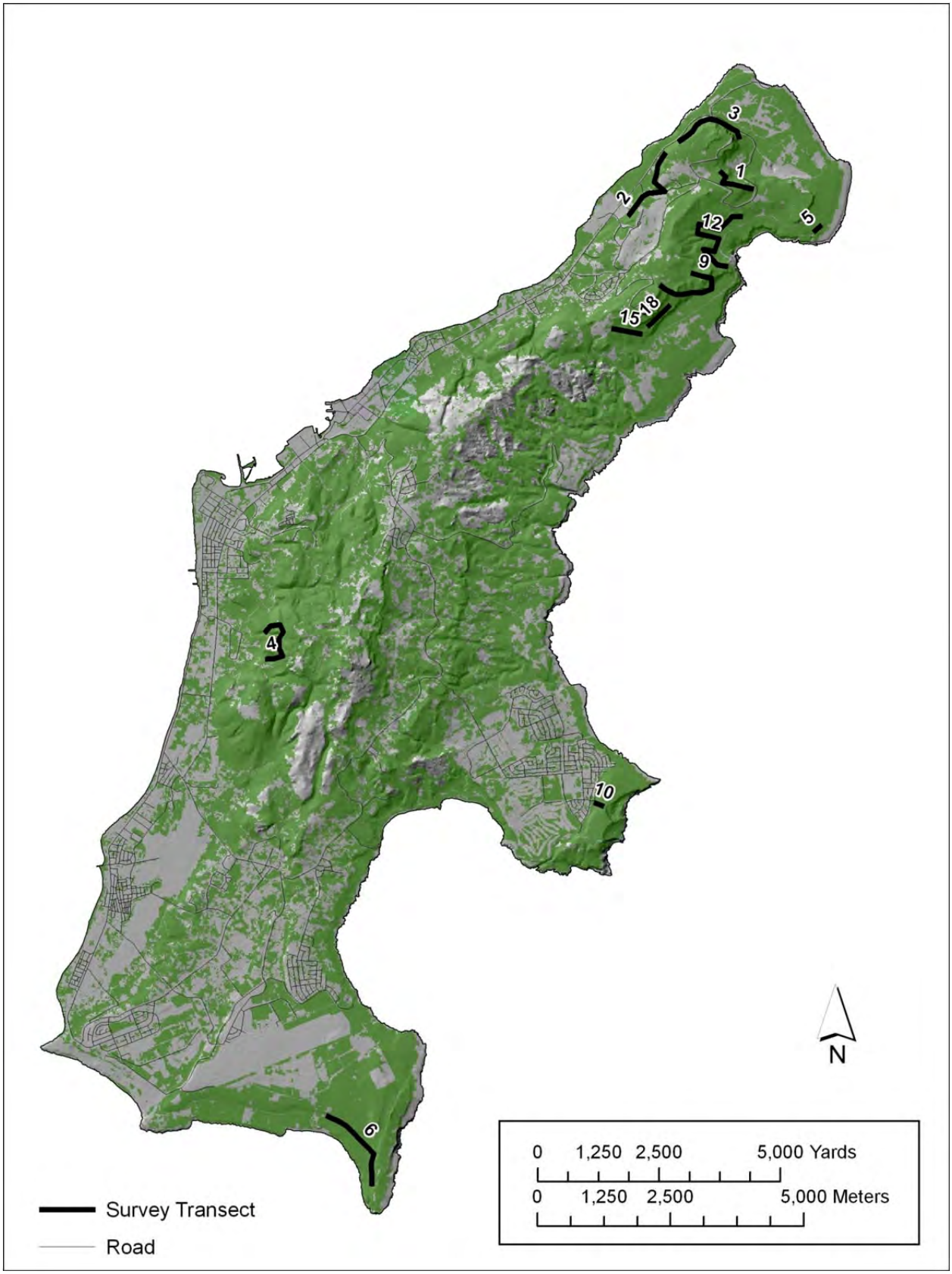


Figure 6. Island of Saipan showing the location of survey transects sampled on January 29 to February 3, 2010.

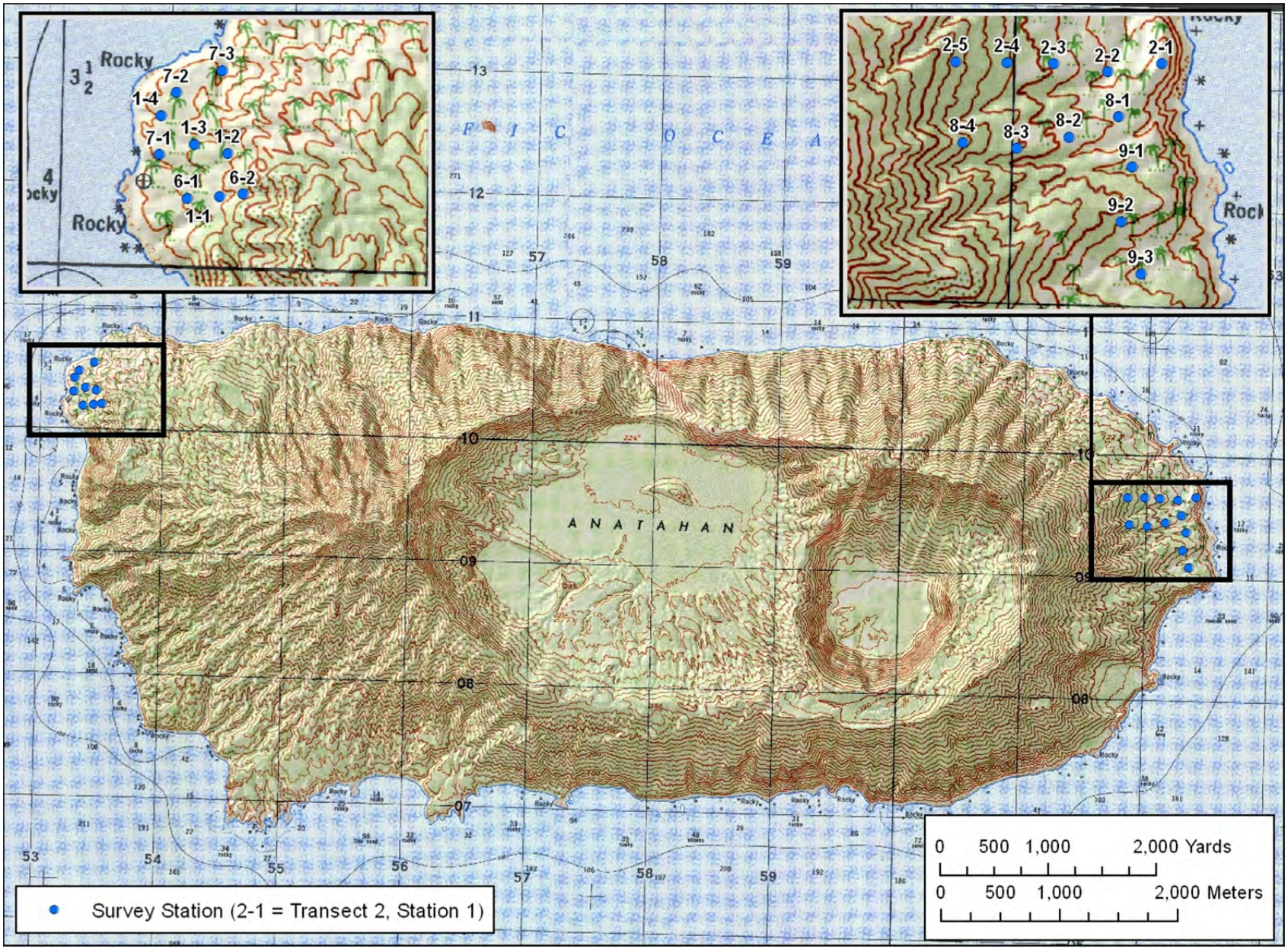


Figure 7. Island of Anatahan showing the location of survey transects sampled on 7-9 December 2010.

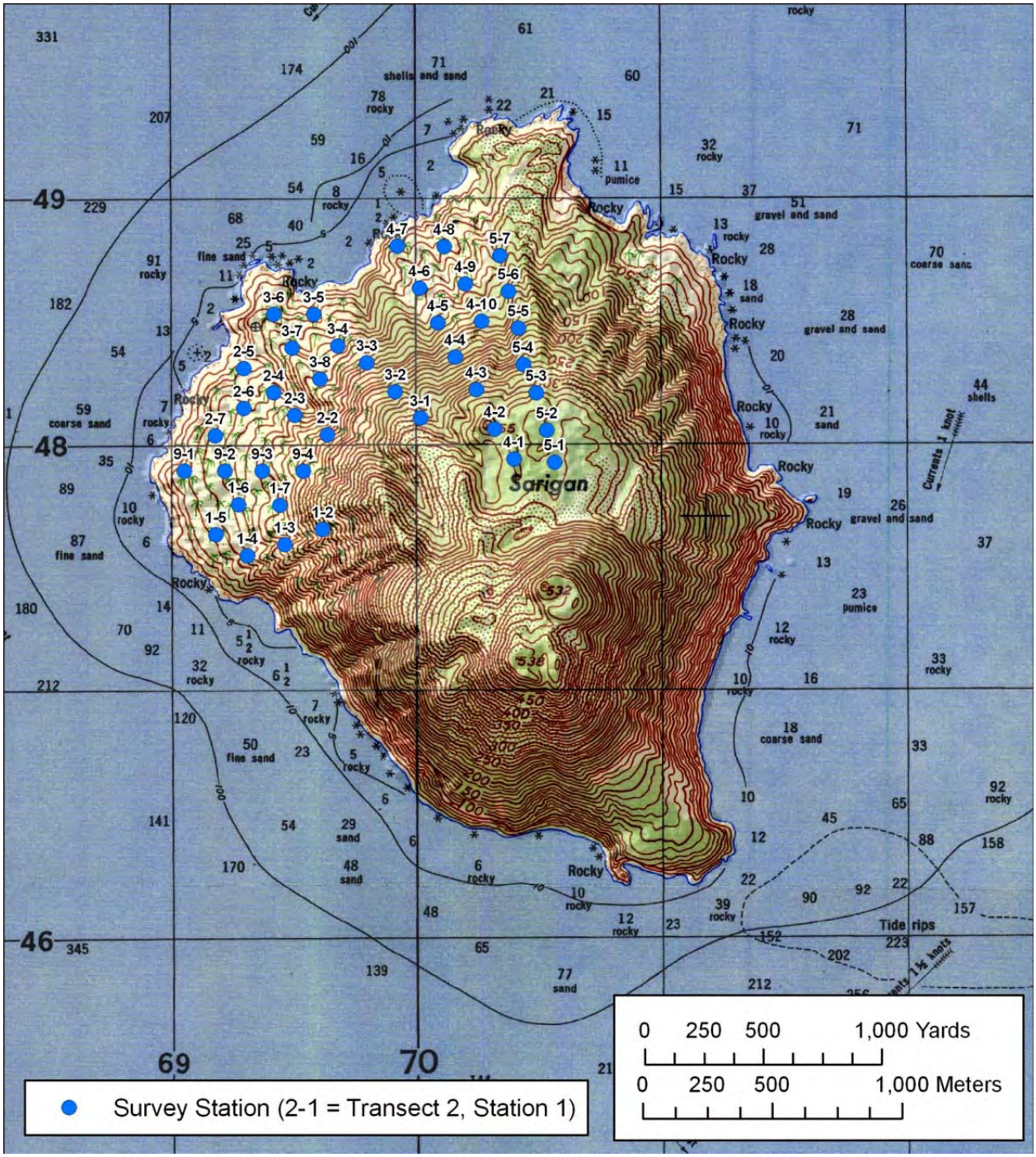


Figure 8. Island of Sarigan showing the location of survey transects sampled on 18-22 May 2010.

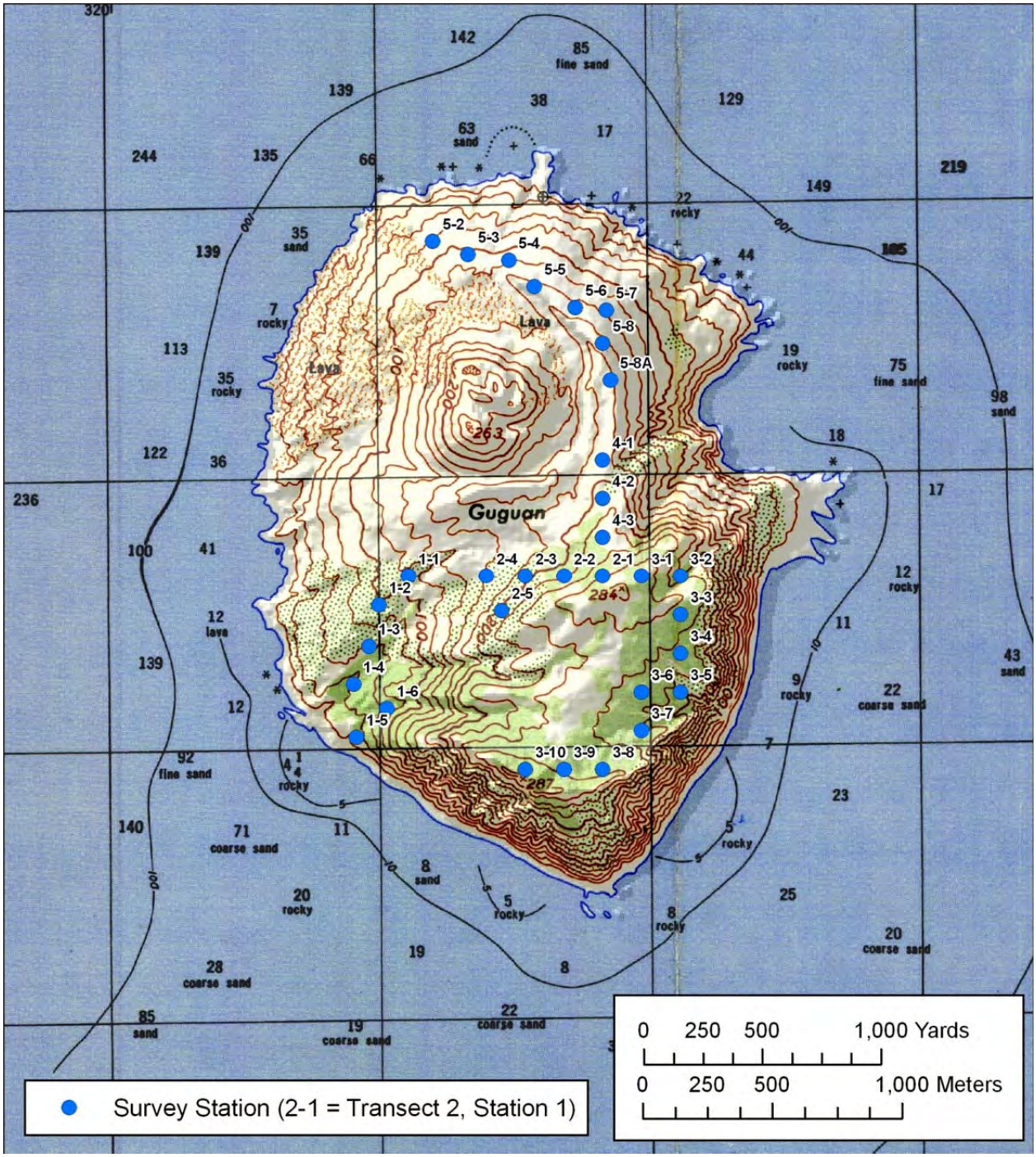


Figure 9. Island of Guguan showing the location of survey transects sampled on 17-18 May 2010.

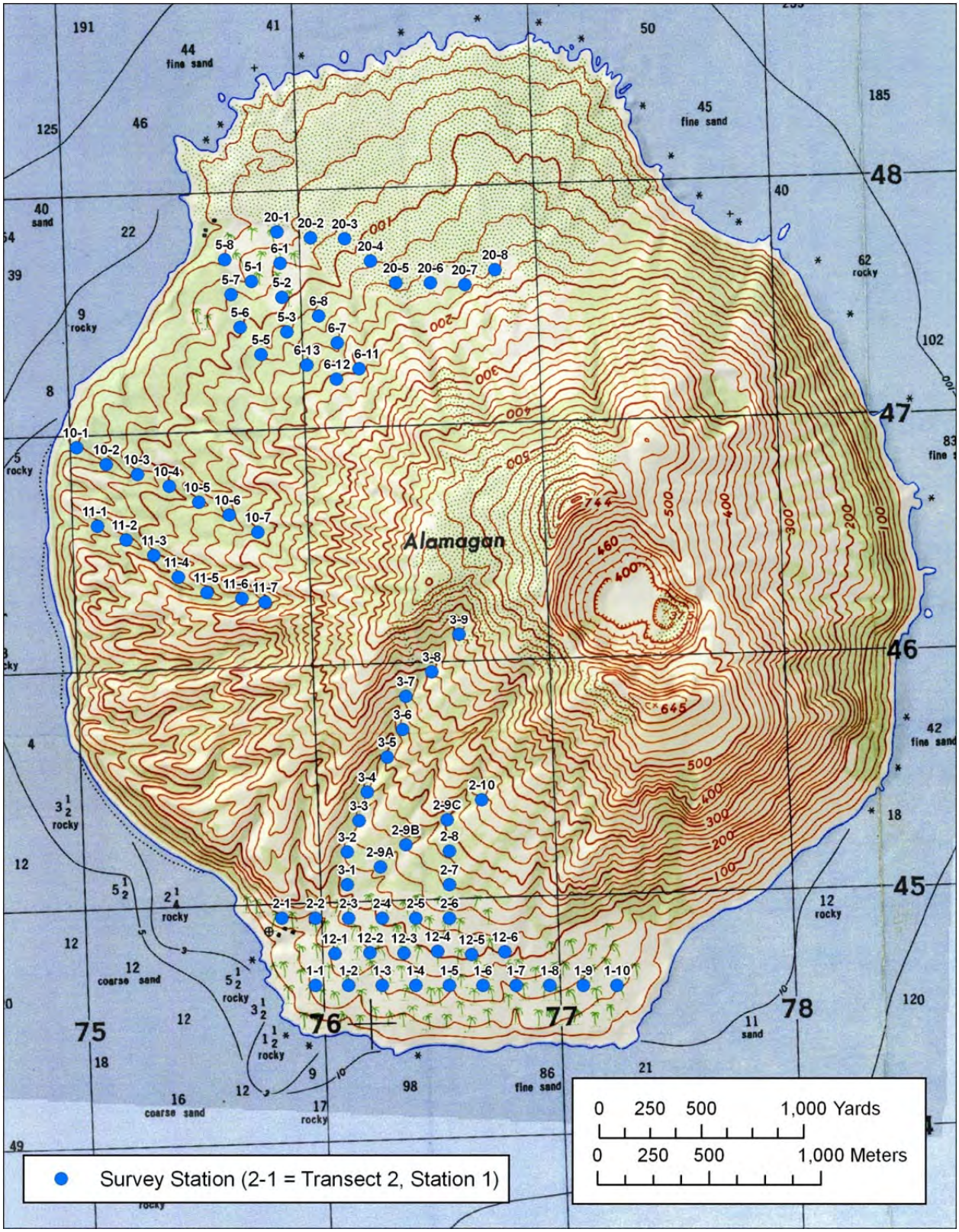


Figure 10. Island of Alamagan showing the location of survey transects sampled on 17-24 May 2010.

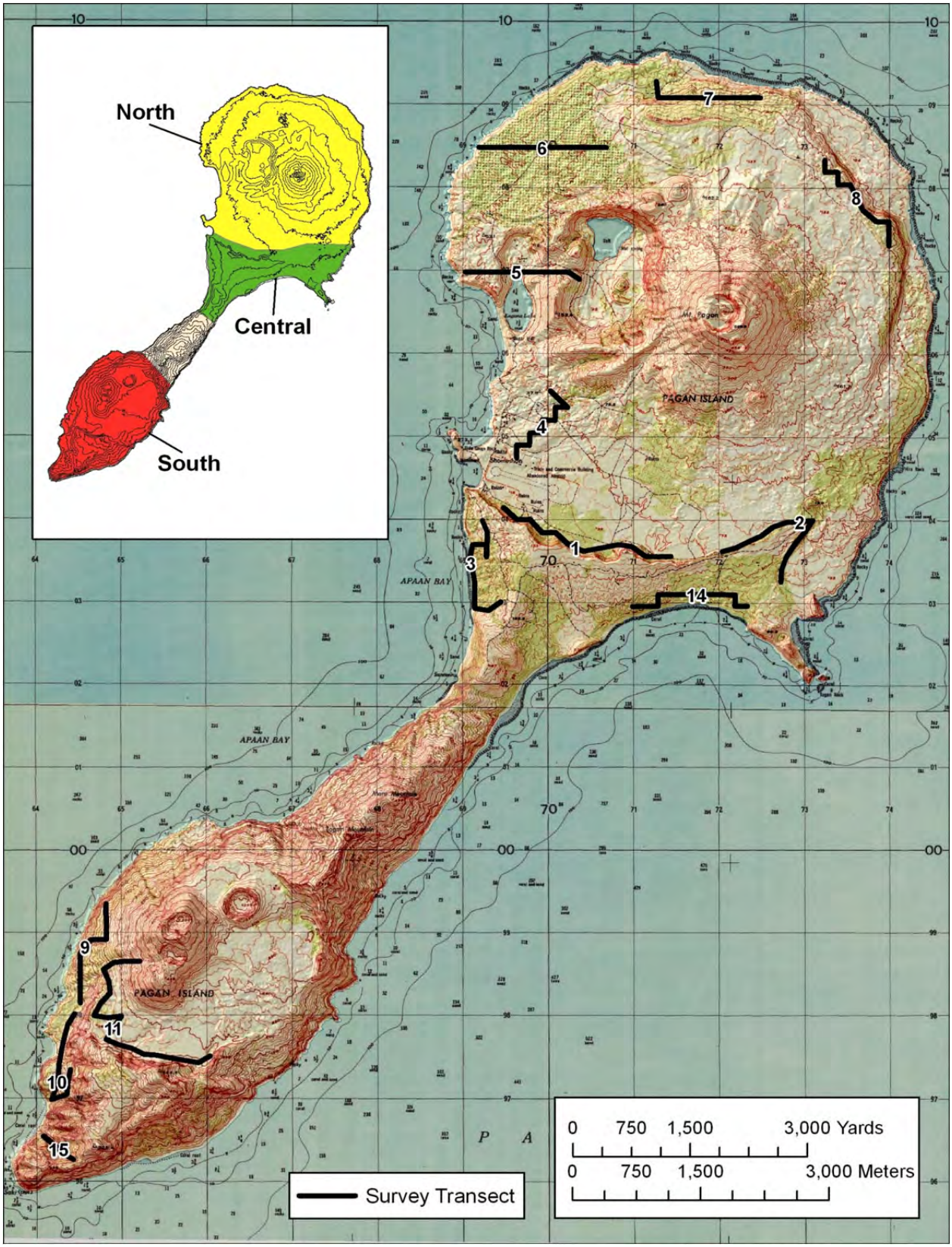


Figure 11. Island of Pagan showing the location of survey transects sampled in 19-25 June 2010.

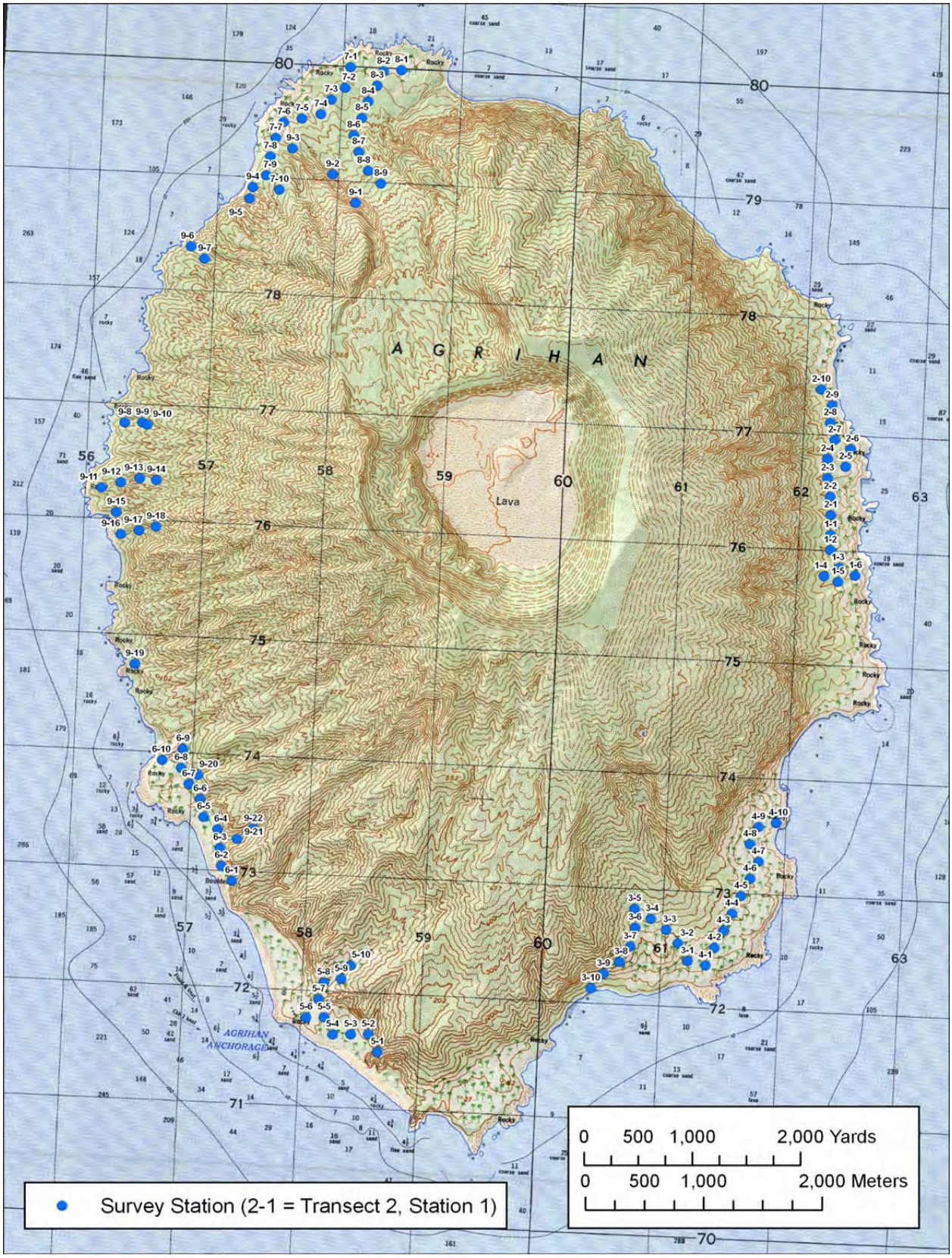


Figure 12. Island of Agrihan showing the location of survey transects sampled on June 28 to July 7, 2010.

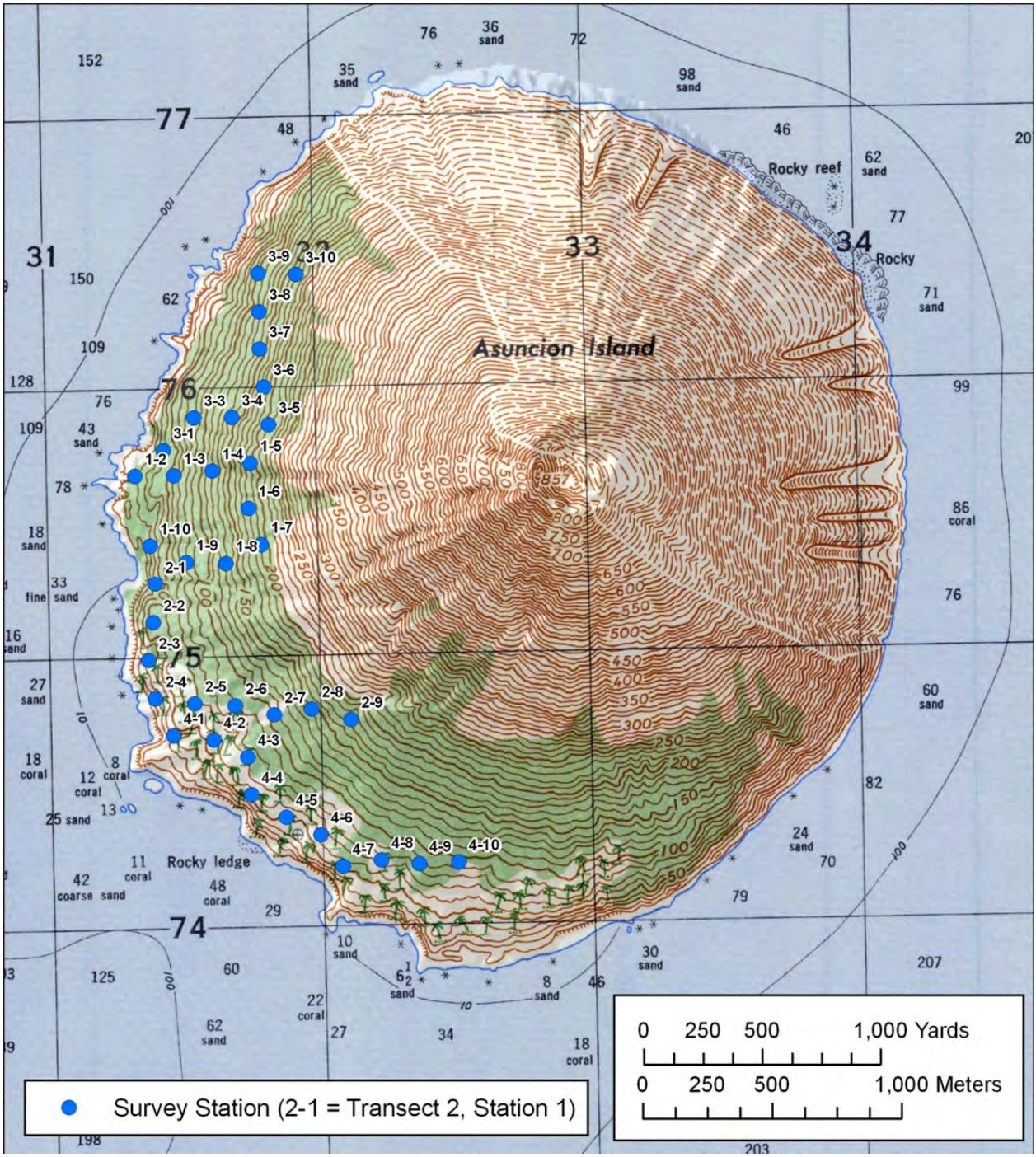


Figure 13. Island of Asuncion showing the location of survey transects sampled on 25-30 June 2010.

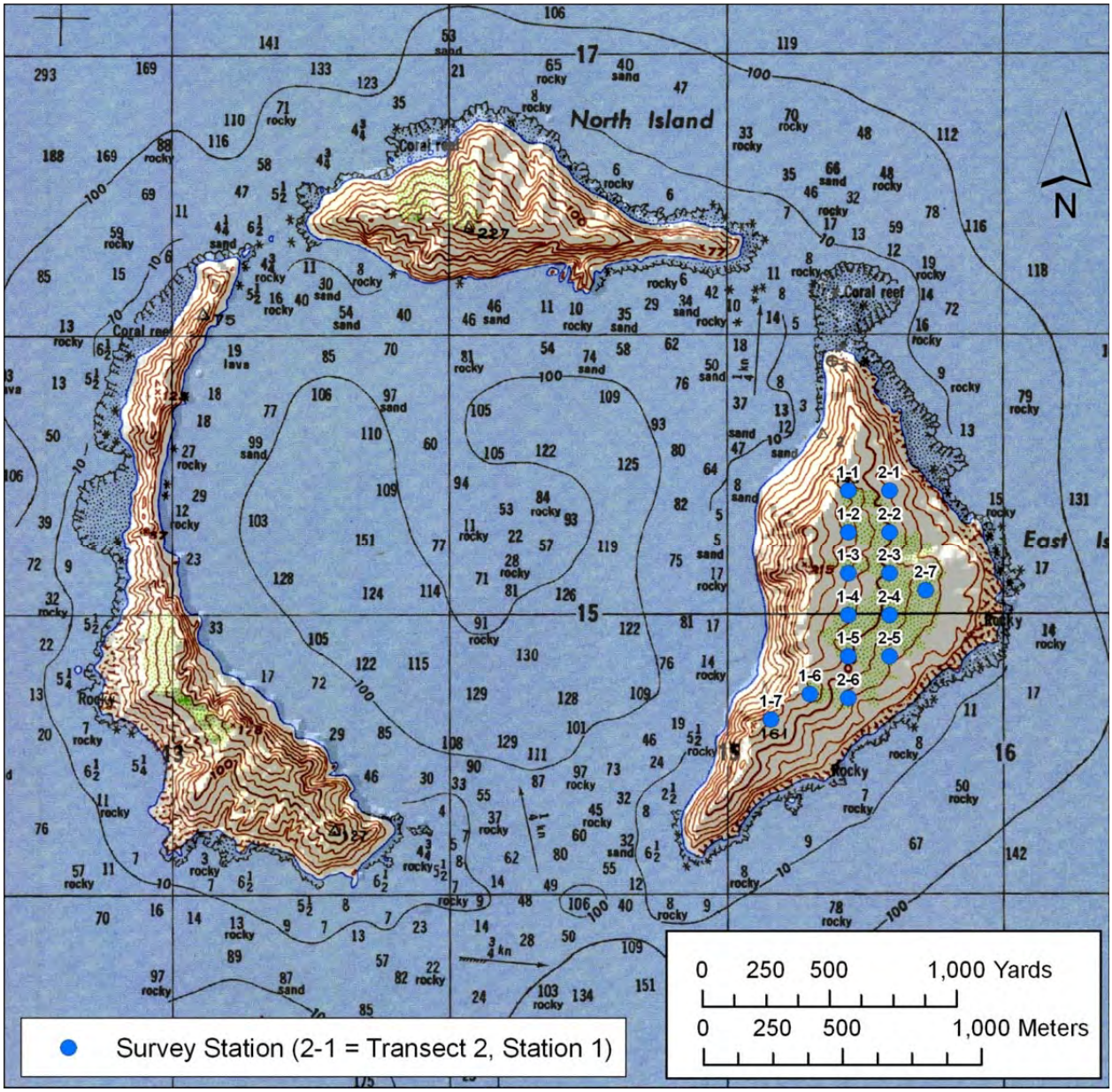


Figure 14. Islets of Maug showing the location of survey transects sampled on 26-27 May 2010.

All surveys were conducted by one observer and followed standard point-transect methods, consisting of 5 or 8-minute counts (5-minute counts were conducted on Saipan, all other islands used 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 (note: canopy height and canopy cover were only recorded on Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug), and these 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). Sufficient numbers of detections were made from the point-transect surveys on the islands without ungulates (Asuncion 151, Guguan 74, and Sarigan 127) to reliably model the detection function. Maug (41 detections) was also modeled with this group even though the recommended minimum number of detections was not achieved. An additional 46 detections were recorded during playback surveys, however, response to playback (see *Playback Surveys* below) data were not collected from Maug and combining the uncorrected playback data with the point-transect would confound the analyses. Thus, we used 393 detections to model the detection function. Island-specific densities were calculated using post-stratification methods in program DISTANCE version 6.0 release 2 (Thomas *et al*. 2010) following procedures detailed in Camp *et al*. (2009b) (Appendix 6). We also calculated the densities by habitat (coconut and native forests) on Asuncion and Sarigan. Density by habitat was not calculated for Guguan and Maug because only native forest was sampled on those islands. Methods for estimating population sizes for each island are outlined under *Playback Surveys* below.

Playback Surveys - Because megapodes can occur at low densities on some islands, it is difficult to obtain sufficient numbers of detections for reliable estimates of population size. The broadcast of recorded vocalizations ("playbacks") are often necessary to effectively sample species with cryptic behavior and low detection probabilities (e.g., the Hawaiian hawk (*Buteo solitarius*); Klavitter and Marzluff 2007, Gorresen *et al*. 2008). Playback surveys were conducted on Saipan (January 29 to February 3), Anatahan (December 7-9), Sarigan (May 18-22), Guguan (May 17-18), Alamagan (May 17-24), Pagan (June 19-25), Agrihan (June 28 to July 7), Asuncion (June 25-30), and Maug (June 26-27) in 2010. A total of 541 stations along 66 transects were sampled (Table 1; Figures 2-10; see Appendix 5 for station UTM coordinates). In general, all transects were previously sampled during the point-transect surveys (see above for description). However, only playback surveys occurred on Anatahan due to time constraints and concerns regarding megapode detection sample sizes.

All playback surveys were conducted by a single observer. During the survey, digitally recorded Micronesian megapode calls obtained on Sarigan in 2005 were broadcast. Pair duet calls were played on an electronic game caller (Foxpro NX3 or FX5 ™) for 30 seconds at each station on all islands. The observer then measured and recorded the horizontal distances of all Micronesian megapodes heard and/or seen during a three minute survey period (30 seconds of playbacks and 2 minutes and 30 seconds of observation). Rangefinders were used to assist with distance estimation. Direction, based on compass bearing, and time of detection were also recorded. Also, weather and habitat conditions were recorded at each station (see Point-Transect Surveys above). Counts commenced at sunrise and continued until completed (typically prior to 1100 hours) and were conducted only under favorable weather conditions.

Similar to the point-transect technique above, playback surveys require 75-100 detections to model the detection function for each species effectively (Buckland *et al*. 2001). In addition, preliminary testing of the technique on Aguiguan in 2009 indicated that megapodes can move in response to playbacks (Amidon et al. 2010; Appendix 4). Because responsive birds may move towards an observer before being detected, the use of playbacks without correcting for unobserved movement can result in the underestimation of actual observer-to-bird distances and inflate estimated densities (Buckland *et al*. 2006). Once the correction for unobserved movement was performed densities were calculated using the program DISTANCE (Thomas *et al*. 2010) following procedures detailed in Camp *et al*. (2009b).

To estimate a correction factor for megapode movement we conducted focal bird searches using pairs of observers to ascertain the amount of movement megapodes make in response to playbacks. When an observer visually detected a bird he or she would note its exact location, then radio the other observer who would initiate a playback survey and record his or her distance to the bird (if detected). The difference between the actual and observed distances yielded the distance moved prior to detection ("unobserved movement").

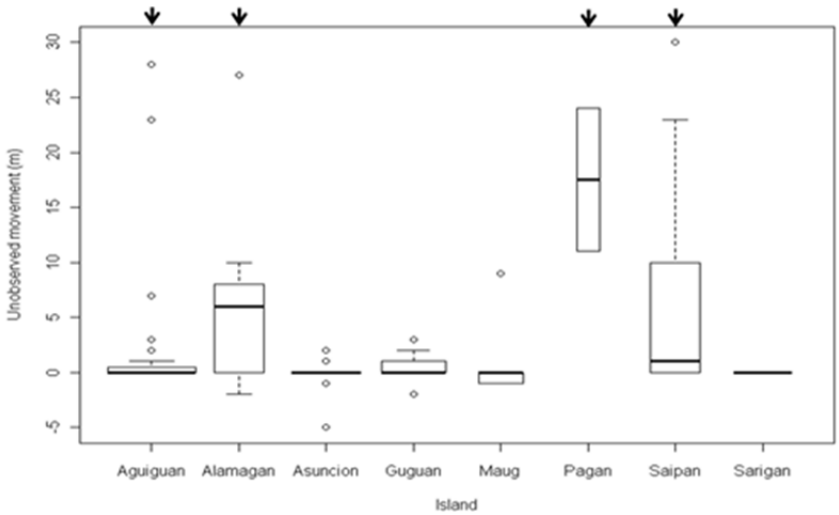


Figure 15. Unobserved movement of Micronesian megapodes by island (n = 100). Islands with low megapode densities are indicated with arrows.

A total of 100 paired records of unobserved movement and detection distances were acquired on Aguiguan in 2009 (see Appendix 4) and all other islands in 2010. Preliminary assessment of the data showed that mean unobserved movement differed significantly among islands with or without regular human visitation (e.g., hunting on Aguiguan) or current or recent human populations (e.g., Saipan, Alamagan, Pagan), hereby referred to as high human presence islands (Figure 15; paired 2-sided t-test; t = 2.988, df = 99, p-value = 0.0035). That is, on islands where human presence was low (e.g., conservation islands) there was very little or no unobserved movement by megapodes (mean = 0.15 m; 95%CI = -0.32 to 0.63 m, max = 9 m) whereas there was modest to marked unobserved movement on islands with high human presence (mean = 4.79 m; 95%CI = 2.28 to 7.31 m, max = 30 m). It should be noted, however, that other factors besides human presence may be influencing megapode repsonses to playbacks. Saipan, Pagan, Alamagan, and Aguiguan all have populations of feral ungulates while Asuncion, Guguan, Maug, and Sarigan do not. So feral ungulate damage to the vegetation may be a contributing factor, though evidence of feral ungulate impacts to the vegetation on Saipan is limited compared to the other islands. In addition, Maug, Asuncion, Guguan, and Sarigan have had generally large megapode populations for their size (USFWS 1998). So, megapode densitiesmay also be influencing megapode response to playbacks.

Unobserved movements on islands with high human presence was only apparent in situations where birds were either visually detected or were heard in a dense and highly cluttered forest understory (Figure 16; panels a, c and d). An exception to this was noted on Aguiguan where little or no unobserved movement was recorded for birds heard in low understory clutter conditions (Figure 16; panel b).

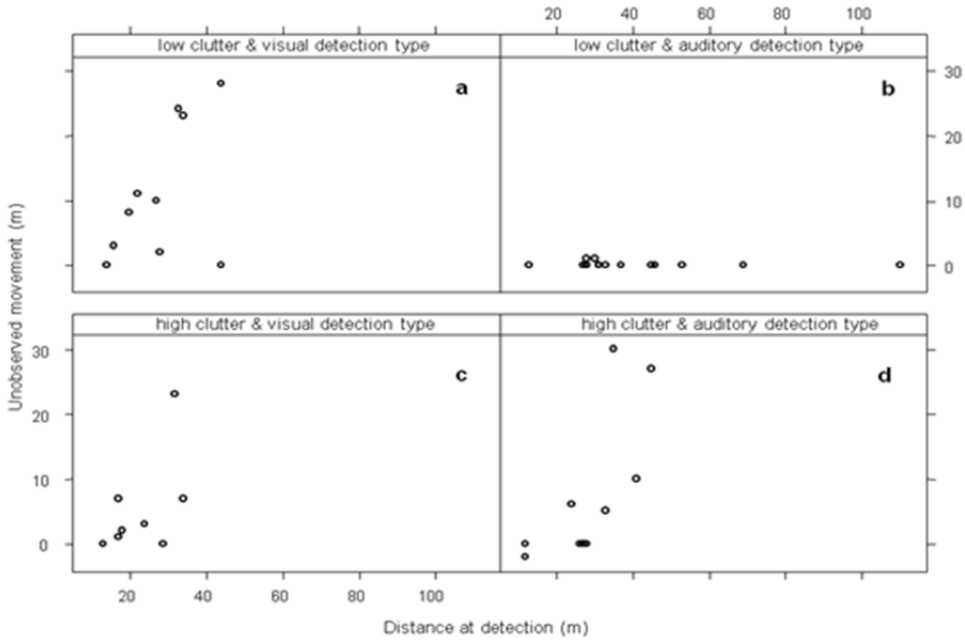


Figure 16. Unobserved movement of megapodes by understory clutter (low or high) and detection type (visual or auditory) for islands with high human presence (n = 48).

A generalized linear model (Table 2) was fit to the subset of records (*n* = 29) where unobserved movement was apparent (i.e., islands with high human presence and conditions exclusive of low clutter and auditory detection types.) The predictor variables used in the model included the observed distance at detection, detection type and island identity (Table 2). The variable indicating the degree of understory clutter was not significant (p = 0.0834) in the initial model development and was excluded from the final model. Observed and unobserved movement values were log-transformed to ensure that model predictions were not less than zero. To permit the use of records where unobserved movement equaled zero, 0.5 was added to all values. The log-normal regression models of unobserved movement were developed with PROC GENMOD in SAS (version 9.1; SAS Institute Inc., Cary, NC).

Table 2. Parameter coefficients from the model used to predict unobserved movement for all survey observations. Predictor variables included the observed distance at detection ("DIST") detection type ("DETTYPE") and island ("ISLAND"). Variables were determined to be significant if p≤ 0.05. Intercept refers to the value of the response variable when all predictor variables in the model are evaluated at zero. Scale refers to the degree to which standard errors are corrected for over-dispersion (i.e., higher than expected variance) in the observed data.

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	P- Value
Intercept	1	-7.7710	1.8403	-11.378	-4.1641	17.83	<0.0001
DIST	1	2.4703	0.5339	1.4239	3.5167	21.41	<0.0001
DETTYPE	1	-1.1189	0.4258	-1.9534	-0.2844	6.91	0.0086
ISLAND	1	0.7041	0.2091	0.2943	1.1139	11.34	0.0008
Scale	1	1.0832	0.1422	0.8375	1.4012		

The objective of modeling unobserved movement is to include the effects of this behavior in the subsequent estimation of bird densities. This is accomplished by adding predicted unobserved movement to that of the distance to a bird detected by an observer. However, there is some variability in megapode responses to playback, and the use of predicted mean values does not fully incorporate the uncertainty from modeling this process. To account for this uncertainty we developed a simulation procedure that generated a set of 1,000 predicted values for megapode detection and its associated

covariates (Appendix 6). The simulated values were drawn from a log-normal distribution centered on the predicted mean and delimited by the variance specified by the model's scale parameter (Table 2). Bird densities were calculated from the resulting set of simulated "total" distances.

Density estimation for islands with high human presence (i.e., Saipan, Alamagan, and Pagan) required combining the point-transect and playback counts to increase the numbers of detections for reliable modeling, and the analysis was conducted in two stages. In the first stage the density, confidence intervals, and variance associated with the unobserved movement model were estimated. For each island, a detection function was determined from the first 100 simulated data sets (Appendix 7). Processing restrictions in program DISTANCE precluded fitting a detection function to the entire 999 simulations. This detection function model was then applied to the remaining 899 simulations in sets of 100. Density was calculated as the mean of the entire set of 999 simulations. The variance associated with modeling unobserved movement was calculated from the simulated density estimates. Standard distance sampling procedures were applied during the second stage to determine the variability due to detection function modeling. The island-specific detection function model was applied to the pooled unadjusted data and the island-specific modeling uncertainty was determined using post-stratification and bootstrap procedures. The variances from the first and second stage models were combined to calculate the total uncertainty due to the density estimation and playback correction procedures, and the 95% CIs were calculated based on two standard deviations.

Abundance or population estimates for each island were calculated by multiplying estimated densities per forest type by estimates of available forest cover, by type, for each island. Megapode densities were calculated for three forest types: native, coconut (*Cocos nucifera*), and ironwood (*Casuarina equisetifolia*) forest. Native forest was defined as forest dominated by native tree species in the understory and canopy and included both *Hibiscus tiliaceus* (pago) and *Pandanus tectorius* (kafu) dominated thickets. Coconut and ironwood forests were forests dominated by each species. These forest types did include some native species. However, the overall forest was dominated by either coconut or ironwood trees.

Whenever possible we used the most recent landcover estimates (e.g., National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover maps) for each island to estimate available forest cover. However, not all available land cover estimates provided estimated coverage for each forest type. Therefore, we either used an older land cover estimate, if it was available, or derived forest cover estimates using heads-up digitizing of imagery in ArcGIS 9.3.

We used NOAA land cover mapping to estimate that 40 and 170 ha of Maug and Guguan, respectively, were native forest (NOAA2009 d,h). The NOAA data does not break down the forest cover into forest types. However, station notes from each island indicated that all forest cover could be classified as native forest so we utilized the total forest cover estimates for each island. Estimates for forest cover on Asuncion (Native: 260 ha, Coconut: 56 ha) and Pagan (Native: 237 ha, Coconut: 390 ha, and Ironwood: 1,344 ha) were based on estimates from Falanruw (1989) and Rogers (2010; Appendix 3 of the Status of Land and Wetland Avifauna of Pagan, Mariana Islands report), respectively. As noted above, the NOAA land cover estimated did not break out forest cover estimates by type. Therefore, we used more detailed assessments from Falanruw (1989) and Rogers (2010) Forest cover estimates for Alamagan (485 ha) and Sarigan (179 ha) were based on NOAA land cover estimates (NOAA 2009 c,e). However, these estimates included both native and coconut forest. Therefore, we estimated the acreage of coconut forest on Alamagan (55 ha) and Sarigan (109 ha) on Alamagan using 2007 and 2006 satellite imagery, respectively, and subtracted this from NOAA's total forest cover estimate to estimate native forest cover (430 and 70 ha, respectively). Megapode sampling on Saipan was primarily focused in native

(limestone) forest so we used native forest estimates (148 ha) from Falanruw *et al.* (1989) to estimate available habitat. Also, because the megapode sampling did not provide even coverage of all native forest on Saipan we limited the available native habitat to areas of the island that were sampled (e.g., northern Saipan, Naftan, Kagman, and Gualo Rai). We did not use the Forest Service's 2006 (USFS 2006) estimates of native (limestone) forest on Saipan because their estimates did not include small patches of known native forest on Saipan (e.g., the limestone forest along the slopes of the Marpi cliffs) which are utilized by megapodes. Therefore, since the Falanruw *et al.* estimate is from the 1980s it may overestimate the amount of limestone forest currently available on Saipan.

Total megapode population size, across all the Mariana Islands sampled in 2010, excluding Anatahan, was calculated by summing the island-specific abundances. That is, the bootstrap estimates from islands with high megapode densities were added to the simulation estimates from islands with low megapode densities by iteration. From these combined estimates, the total abundance and confidence intervals were calculated based on 1.96 standard deviations.

Occupancy surveys – Occupancy analysis provides a complementary or alternate metric to that of estimates of population abundance or vital rates. As a spatial metric it describes the proportion of area, habitat, or sample units within which a species occurs (MacKenzie *et al.* 2006). Surveys for megapodes occupancy were conducted in conjunction with the point-transect and playback surveys described above. On all islands, except Anatahan, Agrihan, and Maug, all stations were sampled four times with sampling distributed across two time periods (0600-1100 and 1400-1800). On Anatahan, all stations were sampled a minimum of two times (one morning and one afternoon) while eight stations along two transects (1 and 2) were sampled four times (two mornings and two afternoons). On Agrihan, stations along transect 9 were only sampled one to two times over the two time periods noted above due to time constraints. The remaining stations on Agrihan were sampled four times. On Maug, all stations were only sampled one or two times due to equipment problems and time constraints. All surveys were conducted by one observer and followed playback methods described above. As noted above, rangefinders were used to assist with distance estimation and direction, based on compass bearing, and time of detection were also recorded.

Occupancy models included site covariates describing vegetation type, understory closure/openness, canopy height, and canopy cover, and a sampling covariate indicative of the time of day (morning or afternoon). These covariates are referred to in the tabulations of results as "veg", "understory", "canhght", "cancov", and "time", respectively. A covariate for island identity was not used because of the low number of observations on several islands. Occupancy models were first ranked according to Akaike Information Criterion (AIC) values as adjusted for small sample size (i.e., AICc; Burnham and Anderson 2002). Model goodness-of-fit statistics ($\hat{c}$) were assessed with a parametric bootstrap procedure (MacKenzie and Bailey 2004) in which a Pearson X^2 test statistic p-value $\geq$0.05 indicated an adequate model fit. The global model (i.e., one which includes all covariates) describing occupancy on ungulate-free islands had a $\hat{c} > 1$; therefore, AICc values were subsequently adjusted by the model fit statistic to derive quasi-AICc values (i.e., QAICc) and re-ranked accordingly. Interpretive results are presented only for the top-ranked models. Occupancy (denoted with the symbol ψ) is given in units ranging from 0 to 1.0, and indicates the mean proportion of stations in which megapodes are present (i.e., a value of 0.5 is equivalent to 50%). Detection probability (denoted with the symbol p) is given in units ranging from 0 to 1.0, and indicates the likelihood of observing megapodes.

Presence/Absence Surveys –The only recorded observation of a Micronesian megapode on Uracus was by Falanruw (1975) and subsequent surveys of the island failed to detect the species (USFWS 1998). Due to the low likelihood of obtaining sufficient detections for density and abundance estimates, we

conducted presences/absence surveys on Uracus on July 17, 2010 using a walking survey technique (Forsman *et al.* 1977). Pair duet calls were played on an electronic game caller (Foxpro NX3 or FX5 ™) at regular intervals, followed by a listening period, along a walking route by one observer (Figure 19). Sampling occurred from 1000 to 1700 on July 17, 2010. The number of megapodes which responded to the playback were recorded along with any incidental observations outside the survey.

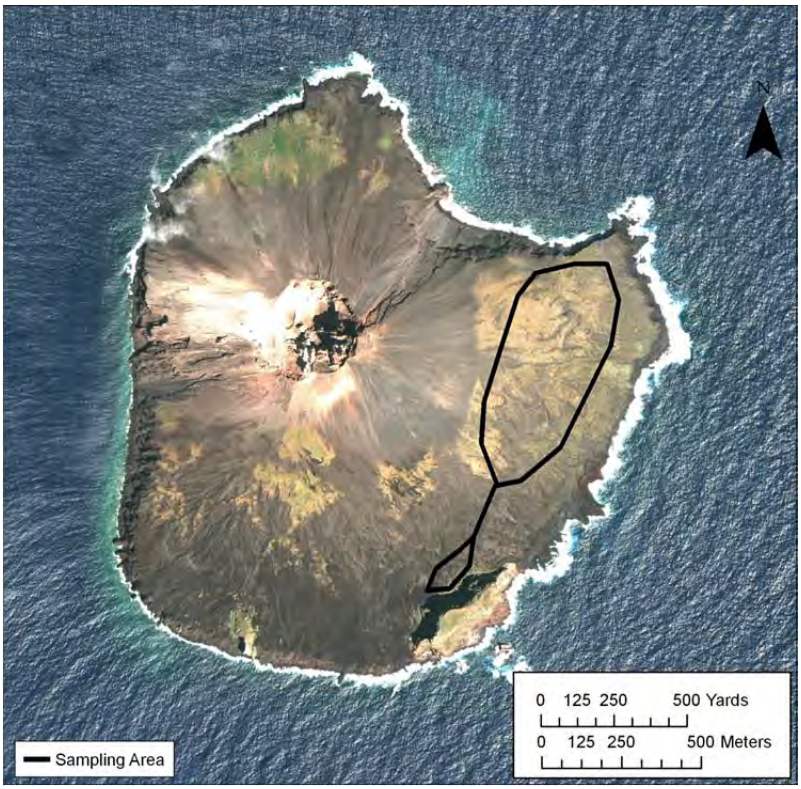


Figure 17. Island of Uracus showing the location of areas sampled with playbacks on July 17, 2010.

Results

Abundance analysis – A total of 415 megapodes was detected during the point-transect surveys, and 625 megapodes were detected during the playback surveys (Table 3). Megapodes were detected during surveys on all islands except Agrihan (where one bird was observed off count on the north end of the island). Densities ranged from low of about 0.07 birds per ha on Pagan to a high of 18.08 birds per ha on Asuncion (Table 4). The total abundance of megapodes on the islands of Saipan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug equaled 10,727 individuals (95% CI: 6,682—15,445). Density estimates for Anatahan were not calculated because the playback surveys occurred after the contract for data analysis had expired. Sufficient megapode detections were made on Asuncion and Sarigan to estimate densities by habitat type. Megapodes were more abundant in coconut forest than native forest on both islands (Table 5). However, the differences were not statistically significant (i.e., the 95 percent confidence intervals bracketed the means).

Table 3. Measures of Micronesian megapode indices by island from the point-transect and playback surveys. For both the numbers of stations (No. Stations) and numbers of samples (No. Samples) [1] indices of occupancy (Rel Occup and Smpl Occup, respectively) and abundance (Rel Abund and Smpl Abund, respectively) were calculated for each survey type. A station (No. Stns Occup) or sample (No. Smpl Occup) was considered occupied when one or more megapodes were detected during the counts. The numbers of megapodes detected (No. Detections) is presented by survey type and island.

Island	No. Stations	No. Stns Occup	No. Detections	Rel Occup	Rel Abund	No. Samples	No. Smpl Occup	Smpl Occup	Smpl Abund
point-transect									
Saipan	80	6	8	0.08	0.10	159	6	0.04	0.05
Sarigan	41	33	127	0.80	3.10	82	54	0.66	1.55
Guguan	32	27	74	0.84	2.31	61	38	0.62	1.21
Alamagan	72	6	10	0.08	0.14	72	6	0.08	0.14
Pagan	144	3	4	0.02	0.03	153	3	0.02	0.03
Agrihan	67	0	0	0.00	0.00	134	0	0.00	0.00
Asuncion	38	34	151	0.89	3.97	76	55	0.72	1.99
Maug	14	12	41	0.86	2.93	28	20	0.71	1.46
Totals	488	121	415	0.25	0.85	765	182	0.24	0.54
playbacks									
Saipan	81	17	27	0.21	0.33	322	23	0.07	0.08
Anatahan	21	10	23	0.48	1.10	58	16	0.28	0.40
Sarigan	41	41	182	1.00	4.44	160	141	0.88	1.14
Guguan	32	32	115	1.00	3.59	124	89	0.72	0.93
Alamagan	72	23	44	0.32	0.61	288	37	0.13	0.15
Pagan	144	13	28	0.09	0.19	565	28	0.05	0.05
Agrihan [2]	182	0	0	0.00	0.00	728	0	0.00	0.00
Asuncion	38	38	174	1.00	4.58	152	128	0.84	1.14
Maug	14	13	30	0.93	2.14	21	20	0.95	1.43
Totals	625	187	623	0.30	0.99	2418	482	0.20	0.26

[1] The number of samples is equal to the number of times the stations were sampled. For example, 38 stations on Asuncion were sampled over two mornings resulting in 76 samples.
[2] One megapode was detected after the surveys on Agrihan.

Table 4. Population size estimates of Micronesian megapode by island. Density (D; birds ha^{-1}) and abundance (N; density * area) with variance estimates were calculated using bootstrap procedures. Total abundance equaled 10,727 megapode (95% CI: 6,682—15,445). Density estimates for Anatahan were not calculated because the analysis contract had expired before the surveys were completed.

Island [1]	Mean	Percent Coefficient of Variation	Standard Error	Lower 95% Confidence Interval [2]	Upper 95% Confidence Interval
Alamagan [3]					
D	1.09	42.19	0.46	0.19	1.99
N	529	42.18	223	92	966
Asuncion					
D	18.08	25.94	4.69	9.92	27.92
N	5,714	25.94	1,482	3,135	8,821
Guguan					
D	8.86	27.87	2.47	4.85	14.41
N	1,507	27.87	420	824	2,449
Maug					
D	13.60	24.94	3.39	7.69	20.84
N	544	24.94	136	308	834
Pagan [3]					
D	0.07	57.01	0.04	0.01	0.16
N	147	57.03	84	28	312
Saipan [3]					
D	0.59	74.13	0.44	0.01	1.44
N	151	74.13	112	27	370
Sarigan					
D	11.93	24.56	2.93	7.05	18.16
N	2,135	24.56	524	1,261	3,250

[1] Area (ha) equaled 485 on Alamagan, 316 on Asuncion, 170 on Guguan, 40 on Maug, 1,971 on Pagan, 256 on Saipan, and 179 on Sarigan.
[2] The lower 95% CI for Pagan and Saipan were set to the minimum number of birds detected.
[3] Data adjusted for response to playback, and CIs calculated based on 1.96 standard deviations.

Table 5. Population size estimates of Micronesian megapode by habitat type (CF coconut forest; NF native forest) on Asuncion and Sarigan islands. Density (birds per hectare) with variance estimates were calculated for the 2010 survey using bootstrap procedures. Estimates were produced from the global model using post-stratification procedures with strata of island and habitat type.

Island-Habitat	Density	Percent Coefficient of Variation	Standard Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Asuncion-CF	26.60	26.83	7.14	14.79	43.64
Asuncion-NF	15.13	29.19	4.42	9.14	25.24
Sarigan-CF	13.08	26.33	3.44	7.43	20.54
Sarigan-NF	9.19	32.90	3.02	4.45	15.88

Occupancy analysis – Preliminary models collectively describing megapode occupancy on all islands did not converge; therefore, separate models were developed for islands with or without regular human presence (i.e., recent or current human populations or regular visitation). The top-ranked models for islands with high human presence included the site covariates understory closure/openness and vegetation type (Table 6, panel *a*). Models that included the time of day during which surveys were conducted also emerged as highly ranked candidates.

Top-ranked models for islands with low human presence (e.g., conservation islands) only included the covariate for understory closure/openness and a null model without covariates (i.e., $\psi(\cdot)p(\cdot)$ where occupancy and detection probabilities are both treated as constants; Table 5, panel *b*). That is, other site (habitat) covariates did not appear to be significantly associated with megapode occurrence.

The probability of detecting megapodes was markedly different among islands with and without high human presence. On islands where human presence was high, detection probability (p) averaged 0.37 (95% CI = 0.29 – 0.45) for the top ranked model ψ(understory)p(.) (Table 6, panel *a*). On islands with low human presence the same model yielded a mean p of 0.84 (95% CI = 0.80 – 0.87) (Table 5, panel *b*). In other words, on any one visit there is an 84% chance of detecting megapodes on islands with low human presence, whereas there is less than half that likelihood on islands with high human presence.

The time of day during which a survey was conducted appeared to have a moderate effect on megapode detectability. For example, although confidence intervals overlap, the model ψ(understory)p(time) showed a slightly higher mean in the morning (p = 0.40; 95% CI = 0.30 – 0.50) than in the afternoon (p = 0.34; 95% CI = 0.25 – 0.44) (Table 7). Time of day was not a top-ranked model on islands without ungulates, which may indicate that bird response is high throughout the day where habitat conditions are good.

Overall, megapode occupancy on islands with high human presence was fairly low and ranged from a mean of 0.04 (95% CI = 0.01 – 0.13) where the understory was open, up to 0.36 (95% CI = 0.26 – 0.48) where the understory was closed and dense. In contrast, occupancy was 1.00 (i.e., 100%) on islands with low human presence regardless of habitat composition at the survey stations. That is, megapodes were detected at every station sampled on Guguan, Asuncion and Maug. The association of megapodes abundance to vegetation type is examined in more detail in the section "Abundance Analysis" presented above .

Vegetation type emerged an important variable on islands with high human presence. Habitats dominated by coconut or ironwood vegetation had low levels of megapode occurrence which averaged about 0.10 (i.e., 10% occupancy; Table 8). Sites classed as native forest had about 3 times the occupancy of coconut or ironwood dominated areas. Vegetation type interacted with understory such that more closed and dense sites had higher levels of megapode occurrence.

Presence/Absence Surveys – A total of five hours was spent surveying the eastern slope of Uracas and no megapodes were detected.

Table 6. Selection of models describing the relation of Micronesian megapode occurrence to site and sampling covariates. Results for islands with high or low human presence are shown separately (panels *a* and *b*, respectively). Covariates are indicated in parentheses following the occupancy symbol "ψ" and detection probability symbol "*p*". Site covariates "veg", "understory", "canhgt", "cancov", and "time", refer to vegetation type, understory closure/openness, canopy height, and canopy cover, respectively. The sampling covariate "time" indicates the time of day (morning or afternoon) at which the observation was made. The term "global" refers to a model that includes all covariates. Column *k* is the number of model parameters; *L* is the -2*log likelihood; ΔAIC_c is the relative difference in AIC_c values from the model with the smallest value; *w* is the AIC_c model weight; ĉ is the estimated average over-dispersion parameter; and X^2 *p*-value is the probability of observing a X^2 greater than or equal to the test statistic based upon 999 parametric bootstraps. Where the global model has a ĉ < 1, calculation of QAICc is not necessary and ranking is performed on AICc. Shaded rows are top-ranked models for which occupancy estimates are provided in Table 7.

Panel *a*. Model results for islands with high human presence.

Model	*k*	*L*	ΔAICc	*w*	Ĉ	X^2 p-value
ψ(understory)*p*(.)	3	565.68	0.0	0.43	1.18	0.337
ψ(understory)*p*(time)	4	564.72	1.1	0.25	1.20	0.356
ψ(understory,veg)*p*(.)	6	562.19	2.7	0.11	1.15	0.337
ψ(veg)*p*(.)	5	564.49	2.9	0.10	0.92	0.465
ψ(understory,veg)*p*(time)	7	561.23	3.9	0.06	1.08	0.396
ψ(veg)*p*(time)	6	563.53	4.1	0.06	0.96	0.455
ψ(.)*p*(.)	2	577.93	10.2	0.00	1.16	0.366
ψ(.)*p*(time)	3	576.99	11.3	0.00	1.10	0.366
ψ(understory,canhgt)*p*(.)	4	1320.58	757.0	0.00	0.66	0.158
ψ(understory,canhgt)*p*(time)	5	1319.97	758.4	0.00	0.90	0.248
ψ(understory,cancov,canhgt)*p*(.)	5	1320.57	759.0	0.00	0.94	0.218
ψ(understory,cancov,canhgt)*p*(time)	6	1319.96	760.5	0.00	0.92	0.228
ψ(understory,cancov)*p*(.)	4	1326.33	762.7	0.00	1.18	0.287
ψ(canhgt)*p*(.)	3	1328.78	763.1	0.00	0.83	0.238
ψ(understory,cancov)*p*(time)	5	1325.72	764.2	0.00	0.84	0.257
ψ(canhgt)*p*(time)	4	1328.17	764.5	0.00	1.04	0.297
ψ(cancov,canhgt)*p*(.)	4	1328.22	764.6	0.00	0.88	0.257
ψ(global)*p*(.)	8	1320.22	765.0	0.00	0.71	0.178
ψ(cancov,canhgt)*p*(time)	5	1327.61	766.1	0.00	1.22	0.356
ψ(canhgt,veg)*p*(.)	6	1325.82	766.3	0.00	0.99	0.267
ψ(global)*p*(time)	9	1319.61	766.5	0.00	0.82	0.188
ψ(understory,cancov,veg)*p*(.)	7	1325.04	767.7	0.00	0.89	0.287
ψ(canhgt,veg)*p*(time)	7	1325.21	767.8	0.00	0.99	0.267
ψ(cancov,canhgt,veg)*p*(.)	7	1325.63	768.3	0.00	0.82	0.257
ψ(understory,cancov,veg)*p*(time)	8	1324.43	769.2	0.00	0.87	0.257
ψ(cancov,canhgt,veg)*p*(time)	8	1325.02	769.8	0.00	0.72	0.248
ψ(cancov,veg)*p*(.)	6	1334.49	775.0	0.00	0.85	0.347
ψ(cancov,veg)*p*(time)	7	1333.89	776.5	0.00	0.72	0.347
ψ(cancov)*p*(.)	3	1346.64	781.0	0.00	0.80	0.406
ψ(cancov)*p*(time)	4	1346.04	782.4	0.00	0.86	0.465

Table 6. Continued.

Panel *b*. Model results for islands with low human presence.

Model	*k*	*L*	ΔAICc	*w*	$\hat{C}$	X^2 p-value
ψ(understory)p(.)	3	398.65	0.0	0.76	1.95	0.050
ψ(.)p(.)	2	398.65	3.1	0.16	1.90	0.059
ψ(canhgt)p(.)	3	398.65	6.7	0.03	1.89	0.079
ψ(understory,cancov)p(.)	4	398.65	8.2	0.01	1.90	0.069
ψ(cancov,veg)p(.)	4	398.65	8.3	0.01	1.89	0.069
ψ(understory,cancov,canhgt)p(time)	6	390.84	8.5	0.01	1.89	0.059
ψ(canhgt)p(time)	4	390.84	9.1	0.01	1.85	0.069
ψ(veg)p(time)	4	390.84	10.1	0.00	1.84	0.059
ψ(global)p(time)	7	390.84	10.7	0.00	1.90	0.069
ψ(cancov)p(.)	3	398.65	12.3	0.00	1.84	0.069
ψ(cancov)p(time)	4	390.84	14.4	0.00	1.80	0.099
ψ(veg)p(.)	3	398.65	16.5	0.00	1.81	0.099
ψ(understory,canhgt)p(.)	4	398.65	18.9	0.00	1.80	0.099
ψ(cancov,canhgt)p(.)	4	398.65	19.0	0.00	1.80	0.089
ψ(understory,canhgt)p(time)	5	390.84	21.3	0.00	1.77	0.069
ψ(understory,cancov,veg)p(time)	6	390.84	21.4	0.00	1.78	0.059
ψ(global)p(.)	6	398.65	22.2	0.00	1.81	0.040
ψ(understory,cancov,canhgt)p(.)	5	398.65	24.4	0.00	1.78	0.069
ψ(understory)p(time)	4	390.84	26.3	0.00	1.71	0.079
ψ(understory,cancov,veg)p(.)	5	398.65	27.9	0.00	1.75	0.129
ψ(canhgt,veg)p(time)	4	390.84	29.6	0.00	1.69	0.139
ψ(.)p(time)	3	390.84	30.4	0.00	1.67	0.119
ψ(cancov,veg)p(time)	5	390.84	41.6	0.00	1.62	0.109
ψ(understory,veg)p(time)	5	390.84	41.6	0.00	1.62	0.109
ψ(understory,cancov)p(time)	5	390.84	41.6	0.00	1.62	0.089
ψ(cancov,canhgt)p(time)	5	390.84	48.0	0.00	1.58	0.178
ψ(cancov,canhgt,veg)p(time)	6	390.84	54.1	0.00	1.55	0.129

Table 7. Summary of Mariana megapode detection probability (*p*) estimates and 95% confidence limits (lower and upper) for the sampling covariate describing the time of day during which a survey was conducted. Results for islands with high or low human presence are shown separately (panels *a* and *b*, respectively). Results are shown only for the top-ranked subset of models as indicated by shading in Table 6.

Panel *a*. Model results for islands with high human presence.

Model	*P*	95%CI lower	95%CI upper	Sampling Covariate
ψ(understory)*p*(.)	0.37	0.29	0.45	None
ψ(understory)*p*(time)	0.40	0.30	0.50	Morning
	0.34	0.25	0.44	afternoon
ψ(understory,vegetation)*p*(.)	0.37	0.29	0.45	None
ψ(vegetation)*p*(.)	0.37	0.29	0.45	None
ψ(understory,vegetation)*p*(time)	0.40	0.30	0.50	Morning
	0.34	0.25	0.44	afternoon

Panel *b*. Model results for islands with low human presence.

Model	*P*	95%CI lower	95%CI upper	Sampling Covariate
ψ(understory)*p*(.)	0.84	0.80	0.87	None
ψ(.)*p*(.)	0.84	0.80	0.87	None

Table 8. Summary of Micronesian megapode occupancy (ψ) estimates and 95% confidence limits (lower and upper) for existing combinations of site covariate values. Estimates are presented only for islands with high human presence (occupancy for islands with low human presence is 1.0; that is, 100%). Results are shown only for the top-ranked subset of models as indicated by shading in Table 5. Results are sorted by ascending occupancy estimate within each model. Habitat variable "Understory" is ranked from 1 (closed/dense) to 5 (open/sparse) and "Vegetation" categories are coconut forest (CF) ironwood forest (IRON) secondary forest (including tangantangan forest; SF) and native forest (NF).

Model	Ψ	95%CI lower	95%CI upper	Site Covariates
ψ(understory)*p*(.)				Understory
	0.04	0.01	0.13	5
	0.08	0.04	0.17	4
	0.14	0.09	0.21	3
	0.23	0.18	0.30	2
	0.36	0.26	0.48	1
ψ(understory)*p*(time)				Understory
	0.04	0.01	0.13	5
	0.08	0.04	0.17	4
	0.14	0.09	0.21	3
	0.23	0.18	0.30	2

Table 8. Continued.

Model	ψ	95%CI lower	95%CI upper	Site Covariates	
	0.36	0.26	0.48	1	
ψ(understory,vegetation)p(.)				Understory	Vegetation
	0.05	0.01	0.16	5	CF
	0.06	0.01	0.23	5	IRON
	0.07	0.03	0.17	4	CF
	0.09	0.03	0.24	4	IRON
	0.10	0.04	0.20	3	CF
	0.12	0.04	0.28	3	IRON
	0.12	0.01	0.57	3	SF
	0.13	0.06	0.28	2	CF
	0.16	0.05	0.38	4	NF
	0.16	0.06	0.38	2	IRON
	0.18	0.06	0.43	1	CF
	0.21	0.11	0.36	3	NF
	0.22	0.03	0.73	1	SF
	0.28	0.20	0.37	2	NF
	0.36	0.25	0.48	1	NF
ψ(vegetation)p(.)					Vegetation
	0.10	0.04	0.20		CF
	0.12	0.05	0.29		IRON
	0.17	0.02	0.64		SF
	0.30	0.23	0.39		NF
ψ(understory,vegetation)p(time)				Understory	Vegetation
	0.05	0.01	0.16	5	CF
	0.06	0.01	0.23	5	IRON
	0.07	0.03	0.17	4	CF
	0.09	0.03	0.24	4	IRON
	0.09	0.04	0.20	3	CF
	0.12	0.04	0.28	3	IRON
	0.12	0.01	0.57	3	SF
	0.13	0.06	0.28	2	CF
	0.16	0.05	0.38	4	NF
	0.16	0.06	0.38	2	IRON
	0.18	0.06	0.43	1	CF
	0.21	0.11	0.36	3	NF
	0.22	0.03	0.73	1	SF
	0.28	0.20	0.37	2	NF
	0.36	0.25	0.48	1	NF

Discussion

We compiled the population estimates from this study with the results of previous surveys in the CNMI, including the 2008 estimates from Tinian and FDM (Table 9). In general, archipelago-wide Micronesian megapode numbers are much higher than previously reported. The previous archipelago-wide estimate was between 1,440 to 1,975 megapodes, with the majority of the megapodes on Sarigan (41%), Guguan (25%), and Anatahan (15%; USFWS 1998). We estimated between 6,682 and 15,445 megapodes in the northern islands alone. Over half (52%) of the total megapodes were on the island of Asuncion with approximately 20% on Sarigan and 14% on Maug. Interestingly, our 2010 abundance estimates were similar to those previously reported for Sarigan in 2008 (Martin *et al.* 2008), Guguan in 1986 (Glass and Villagomez 1986), and Pagan in the 1990s and 2000 (DFW 2000d, USFWS 1998). However, overall, there was an increase in estimates over almost all islands over the years.

We believe this increase is, in large part, due to the increased survey coverage and survey effort. The majority of the northern islands are remote and difficult to access so previous surveys have largely consisted of short trips that included surveys of a sub-section of each island. During this survey we were able to systematically sample most of the available forested habitat on each island over a several day period. The use of playbacks, as well as repeat surveys of the majority of the survey stations, allowed us to increase our overall detections to allow for improved density estimates. An excellent example of this is the island of Aguiguan (Appendix 4). The number of megapode detections along the four transects surveyed since 1982 have been similar over the years (Craig and Chandran 1992, Cruz *et al.* 2000, Esselstyn *et al.* 2003, Engbring *et al.* 1986). However, increases in the number of survey stations, the use of playbacks, as well as the compilation of detections over repeated surveys provided sufficient detections for population estimation in later years. We therefore believe that the increased population on Aguiguan is primarily related to survey effort. This is also likely the case for Saipan, Guguan, Alamagan, and Maug (see below). However, other factors may have also played a role in the resulting density estimates and changing status for the remaining islands.

Survey results show higher megapode densities on islands with low human presence, which were also islands without ungulates (i.e., Maug, Asuncion, Guguan, and Sarigan). In fact, these islands account for approximately 90% of the total megapode population and approximately 2% of the total land area in the archipelago. Feral ungulates impact habitats by browsing on plants, causing erosion, inhibiting plant growth and regeneration, and facilitating the establishment of invasive plants, which can impede forest regeneration by displacing or smothering native species (Aplet *et al.* 1991, Cuddihy and Stone 1990, Loope *et al.* 2001, Perry and Morton 1999, Ritter and Naugle 1999, Stone 1985, Wiles 2005, Wiles *et al.* 1996). This, in turn, can negatively impact the availability of foraging, breeding, and roosting resources for other species, like the Micronesian megapode. Megapode hunting and collection of their eggs has been documented in the past but current levels of collection are unknown (Oustalet 1896, Ludwig 1979, USFWS 1998). Collection of eggs would reduce recruitment while hunting would lower the number of individuals available for breeding which would result in reduced populations. We found that, on islands with high human presence, which in general also had feral ungulate populations (feral ungulates occur on Saipan but the populations may be small), megapodes were more likely to occur in areas with dense understories which could indicate that heavily browsed areas are not preferred habitats. Megapodes are ground foragers (USFWS 1998) and understory browsing by ungulates may affect microclimate for ground insects, which may impact food availability for megapodes. Dense understories may also provide protective cover from predators, like feral cats and dogs, monitor lizards, and humans. Ungulates (goats and pigs) were removed from Sarigan in 1998 (Kessler 1998, 2002). The increase in megapodes shown by surveys on Sarigan pre- (5.25 birds per ha, Fancy *et al.* 1999) and post-ungulate removal (11.93 birds per hectare, this study) could be related to increases in understory which provides

additional habitat for the species. The lack of a human population on the island since at least the 1970s (Russell 1998) could also explain why the island had a relatively large megagpode population prior to ungulate eradication.

Table 9. Summary of Micronesian megapode population estimates for the islands of CNMI. Population estimates are presented with 95% confidence intervals if available.

Island	Size (ha)	Estimate	Year	Source
Aguiguan	700	11	1982	Engbring *et al*. 1986
		72 (34-149)	2002	Esselstyn *et al*. 2003
		112 (61-206)	2009	Amidon *et al*. 2010
Tinian	10,200	0	1982	Engbring *et al*. 1986
		<10	1994-1995	O'Daniel and Krueger 1999
		<10	2008	Kessler and Amidon 2009
Saipan	12,200	40	1982	Engbring *et al*. 1986
		<30	1997	USFWS 1998
		151 (130-174)	2010	This Study
FDM	73	<10	1996	USFWS 1998
		28	2008	Vogt 2009
Anatahan	3,395	300	1988	Reichel and Glass 1988
		423 (340-505)	2000	DFW 2000a
		>20	2010	This Study
Sarigan	452	545-810	1998	Fancy *et al.* 1999
		360 (183-537)	2000	DFW 2000f
		1,772 (1,202-2,604)	2006	Martin *et al*. 2008
		2,135 (1,261-3,250)	2010	This Study
Guguan	423	1,500-2,200	1986	Glass and Villagomez 1986
		305 (172-438)	2000	DFW 2000b
		1,507 (824-2,449)	2010	This Study
Alamagan	1,297	< 30	1990s	USFWS 1998
		Not Estimated	2000	DFW 2000c
		529 (499-564)	2010	This Study
Pagan	4,772	50-150	1990s	USFWS 1998
		134 (128-141)	2000	DFW 2000d
		147 (131-162)	2010	This Study
Agrihan	4,388	395 (305-484)	2000	DFW 2000e
		<10	2010	This Study
Asuncion	784	25	1990s	USFWS 1998
		1,757 (1,123-2,487)	2008	Radley 2009
		5,714 (3,135-8,821)	2010	This Study
Maug	211	150-300	1987	Reichel *et al*. 1987
		50-150	1992	USFWS 1998
		544 (308-834)	2010	This Study
Uracus	225	1	1975	Falanruw 1975
		0	2010	This Study

In addition to ungulates, natural catastrophic events like volcanic eruptions impacted megapode populations in the archipelago. Anatahan had a relatively large Megapode population (DFW 2000a) and

it's believed that they were extirpated from the island after the volcanic eruptions starting in 2003. These eruptions covered the island, and the available habitat, in ash and no incidental observations of megapodes were noted on the island after 2005 despite at least seven trips to Anatahan for ungulate control by one of the authors. However, surprisingly, birds were detected on the island using playbacks during this study and a small population is believed to be present, at least 20 individuals based on the number of detections (Table 3). If megapodes were extirpated from Anatahan due to the volcanic eruption it's possible that Anatahan may have been recolonized from the neighboring islands of Sarigan and FDM. This potential movement highlights the importance of connectivity between the islands and the importance of maintaining suitable habitat for the species on all islands to allow inter-island movement and to reduce the effect of catastrophic events, like volcanic eruptions.

The apparent population increase on Asuncion may also be related to survey coverage, as noted above. The 2008 DFW survey was cut short due to poor weather conditions (L. Williams, U.S. Navy, pers. comm. 2011). The island also contains thick stands of *Pandanus tectorius* which are difficult to move through and limits access to all areas of the island. At least one transect established for the 2008 DFW survey was hampered by these thickets (P. Radley, DFW, pers. comm. 2009). Maps from survey reports prior to 2008 also indicate that only a portion of the island was surveyed at any one time (Stinson 1993). Interestingly, we detected birds in all surveyed habitats, including fern vegetation, and observed birds in camp and foraging under *Scaevola* outside of the forests. In addition detections on transects 2 and 4 were so frequent that it was hard to keep track of them. If the species was as common during previous surveys in the 1980s and 1990s it would seem that it would have been noted. However, very few individuals were reported during those surveys (Stinson 1993, USFWS 1998). Even the number of detections per station in 2008 (1.75; Radley 2009) were lower than the estimates from the point-transect surveys in this study (3.97; Table 3). However, megapodes were still commonly encountered in camp and in different habitats in 2008 (P. Radley, pers. comm. 2009). Therefore, the apparent increase in megapodes does not appear to be related to survey effort alone. The 2008 survey occurred in May while this survey occurred in late June two years later. It's possible that the time of year may have some influence on numbers if it's related to breeding. However, we know too little about the breeding biology of the species to be certain. In addition, the island is so infrequently visited that we have no information available to lead us to believe that anything has changed on the island over the last several decades. Clearly additional surveys and research on the species is needed to assess what could be happening on Asuncion. However, currently, the island of Asuncion is the most important island in the archipelago for megapode conservation.

One unexpected result of the survey was the apparent lack of megapodes on Agrihan. Agrihan is a large island with forested areas that appeared suitable for megapodes, based on observations of habitat use of megapodes on other islands, even though it is heavily impacted by introduced ungulates and other species. Previous observations indicate megapodes were at least somewhat common on Agrihan and several nesting areas were know of and described by locals (USFWS 1998). However, egg collection was also common and eggs were still being collected in 1978, when the megapode population appeared to start declining dramatically (Ludwig 1979). In addition to the loss of nesting areas (one of which was destroyed by village construction during the Japanese period), locals also observed nests being preyed on by monitor lizards, cats, and dogs (Ludwig 1979, USFWS 1998). The loss of nesting areas combined with predation appears to have taken their toll on this island. Our surveys covered all of the areas described in previous accounts of the species and included focused searches of various valleys and other areas that appeared potentially suitable for megapodes. However, as noted above, only a single megapode was observed throughout our time on the island. We were not able to survey the crater and

many of the remote valleys found at higher elevations on the island due to logistical constraints. Therefore, megapodes may be present in these areas.

We believe the increased abundance of megapodes on the island of Saipan is largely related to survey effort, as mentioned above. However, there were several interesting outcomes of the survey which makes it's worthwhile to elaborate further on the island. First, the survey effort was focused on the northern half of Saipan so the population estimate does not account for all available habitat on the island and the calculated density estimate may be higher than an island-wide estimate. Second, almost all megapode observations were associated with native limestone forest, including small remnant patches. Many of these patches were not mapped by the Forest Service previously (Falanruw *et al.* 1989, Liu and Fischer 2006), however, they were discernable on 1945 imagery of the island. In addition, comparisons of mapped locations of megapodes from this survey with previously mapped location dating back to the 1980s indicates that megapodes are using many of the same areas of the island. One of the more startling comparisons was with the megapode home range map for the Marpi region prepared by Glass and Aldan (1988, Figure 6) for period between 1986 and 1987. Estimated megapode locations from this study, based on offsets from survey stations, all fell within estimated home ranges from that study indicating strong site fidelity. Though the megapode population on Saipan is low, the ease of accessibility for megapode areas on the island makes Saipan an ideal location for further research on the biology of the species and additional surveys.

We were unable to survey the north and west islets of Maug due to logistical constraints (i.e., lack of suitable helicopter landing areas). However, we did have good survey coverage of the larger, east islet. Previous surveys of the island noted that megapodes were present on all three islands. Therefore, our population estimate is likely an underestimate. However, the majority of the forested habitat on the island was found on the east islet, so megapode densities on the remaining two islets may be lower. Our population estimate was much higher than previous estimates. We believe this is largely due to survey effort and methods. The previous surveys of the islands included short visits to portions of each islet. Though we were restricted to the east islet, we were able to sample all available forested habitat on that islet over a two day period, which resulted in detections at almost all stations (Table 3).

As noted earlier, the population estimates for Pagan where similar to those reported in 2000 and in the 1990s (Table 8). Megapodes were predominately detected in the southern half of the island for all surveys (DFW 2000d, USFWS 1998). The 2000 survey detected a megapode in the central part of the island along the cliffline near the runway. This area contains some remnant native forest (Pratt 2010). However, despite repeated surveys, we did not detect any megapodes in this area. Patches of potential megapode habitat were also noted in the northeastern part of the island. However, no megapodes were detected in this area during the surveys. We believe the heavy ungulate browsing in the northern half of the island is likely related to the megapodes limited distribution on the island.

The islands of Alamagan and Guguan were both surveyed extensively in 2000 (DFW 2000b,c). However, our population estimates from this study were much higher than reported during those surveys (Table 8). On Alamagan we noted that most of the megapode detections were in ravine habitats, where ungulate browsing was thought to be reduced. Based on the distribution of transects, this study appears to have sampled the ravine habitats and other forested habitats, especially in the southern half of the island, more extensively then the 2000 survey resulting in increased detections. The same is also likely true for Guguan. The 2000 survey sampled all habitat types while this study focused on forested habitats.

Finally, the low numbers of megapodes on the larger islands of the archipelago, especially Agrihan, is of concern. Currently, the majority of the megapode population is located on small islands that, due to their size, are extremely susceptible to catastrophic events. The larger islands of the archipelago have the potential for larger megapode populations and contain varied topography and larger areas which could potentially reduce the impacts of catastrophic events. These islands also provide important connectivity between the smaller islands. Increased emphasis on the management of some or all of the large islands should be undertaken to improve the status of the megapode population in the archipelago.

Based on these surveys, improving the quality and quantity of the forests is extremely important to the long-term conservation of this species. We therefore recommend the following priority management measures:

- Remove feral animals (dogs, cats, cattle, pig, and goats) from Agrihan, Pagan, and Alamagan.
- Develop and implement a native forest restoration plan involving native plant outplanting and weed control to increase the available native forest on islands where loss and fragmentation of habitat has occurred.
- Continue monitoring megapodes.
- Research nesting needs and habitat use.
- Continue protection of the established refuge islands.
- Develop an archipelago-wide management plan which addresses connectivity between the populations on the different islands.

Removing feral ungulates will aid megapode recovery by decreasing habitat degradation and fragmentation and reducing disturbances to birds. The main threat to the megapode continues to be the loss and degradation of habitat due to feral ungulates and clearing (USFWS 1998). The conversion of forest habitat to non-native monocultures, such as swordgrass, also likely affects the amount and diversity of food available (USFWS 1998). The native forest is also important to other birds indigenous to the Mariana Islands, including the Micronesian starling and the collared kingfisher. The second greatest threat to the megapode is predation by introduced mammals as well as monitor lizards (USFWS 1998). Restoring forest habitat and removing predators will help recover the species.

Monitoring megapodes allows us to assess their status, to ensure the stability of the population, and to determine if restoration efforts (including ungulate and predator removal) are aiding recovery. In addition, understanding nesting needs and habitat use of the species could help us manage habitat to increase reproductive success and for foraging respectively. Protection of the refuge islands will help maintain important source populations for megapodes, decrease the possibility of poaching, and reduce forest degradation. Managing the population archipelago-wide is important in order to maintain dispersal corridors between the islands and to maintain gene flow.

Acknowledgements

Analyses were conducted by the U.S. Geological Survey – PIERC under Cooperative Agreement No.: 03WRAG0036 by Richard Camp and Marcos Gorresen. Thanks are due Major Brad Adams, Angela Anders, James Bradley, Richard Camp, Antonio Castro, Lenny Corin, Cari Eggleston, Chris Eggleston, Howard Ferguson, Joshua Fisher, Marcos Gorresen, Samantha Hudson, Jiny Kim, Jaan Lepson, Michael Lusk, Theresa Mathis, Paul Radley, Tim Robert, Christina Rockwell, Rachel Rounds, Rick Spaulding, and Laura Williams for data collection. We are incredibly grateful to Paul Wagner, Tom McCall, Benny

Myhre, Greg Camacho, Gus Castro, Sandy Castro, Jess Omar, Jon Manygoats, Lerins Stole, Ben Mettao, Frank Kaipat, and Elvin Masga for their support on the islands, Sarigan, Guguan, Alamagan, Pagan, Agrihan, and Asuncion. We are also grateful to Ben Camacho, Craig Clark, Howard Ferguson, and Curt Kessler for support and logistics on Saipan. We also thank Americopters, the owners, Captain and crew of the Micronesian, The U.S. Navy, particularly Vanessa Pepi and Scott Vogt, The U.S. Geologic Survey (for volcano monitoring), The U.S. Coast Guard (for support), The Northern Islands Mayor's Office, Dr. Ignacio T. dela Cruz, CNMI Department of Lands and Natural Resources Secretary, and the former Director of DFW, Sylvan Igisomar. At the USFWS Office, we thank Karen McCurry, Pam Kringel, Roxanne Anderson, Jimmy Breedan, Dean Mark, Paulette Reyes, Dave Castro, Chanse Aoki, and Elaine McHale. We also thank Earl Campbell, Marilet Zablan, Gina Shultz, and Loyal Mehrhoff for their support of these surveys.

References

Amidon, F. 2009. Vegetation surveys on Tinian and Aguiguan. Pages 8-18 *in* Terrestrial resource surveys of Tinian and Aguiguan, Mariana Islands, 2008. Final report to MARFORPAC and NAVFAC. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Amidon, F., R. Camp, A. Marshall, C. Kessler, P. Radley, K. Buermeyer, and M. Gorresen. 2010. Micronesian megapode survey assessment: Aguiguan 2009. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Aplet, G.H., S.L. Anderson, and C.P. Stone. 1991. Association between feral pig disturbances and the composition of some alien plant assemblages in Hawaii Volcanoes National Park. Vegetation 95:55-62.

Baker, R.H. 1951. The avifauna of Micronesia, its origin, evolution, and distribution. Univ. Kansas Publ., Mus. Nat. Hist. 3: 1-359.

BirdLife International. 2010. Species factsheet: Micronesian megapode, Megapodius laperouse. Downloaded from http://www.birdlife.org/datazone/speciesfactsheet.php?id=125&m=1.

Bowers, N.M. 2001. Problems of resettlement on Saipan, Tinian, and Rota, Mariana Islands. Occasional Historical Papers Series No. 7. CNMI Division of Historic Preservation, Saipan, MP.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford: Oxford University Press.

Buckland, S. T., R. W. Summers, D. L. Borchers, and L. Thomas. 2006. Point transect sampling with traps and lures. Journal of Applied Ecology 43: 377-384.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, second edition. Springer-Verlag, NY, 496 pp.

Butler, B. 1994. An archeological survey of Aguiguan (Aquijan), Northern Mariana Islands. Micronesian Archaeological Survey Report No. 29, CNMI Division of Historic Preservation, Saipan, MP.

Camp, R. J., T. K. Pratt, F. Amidon, A. P. Marshall, S. Kremer, and M. Laut. 2009a. Status and trends of the land bird avifauna on Tinian and Aguiguan, Mariana Islands. Appendix 3.1 *in* Terrestrial

Resource surveys of Tinian and Aguiguan, Mariana Islands, 2008. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Camp, R.J., T.K. Pratt, A.P. Marshall, F. Amidon, and L.L. Williams. 2009b. Recent status and trends of the land bird avifauna on Saipan, Mariana Islands, with emphasis on the endangered Nightingale Reed-warbler *Acrocephalus luscinia*. Bird Conservation International 19: 323-337.

Clapp, R.B. 1983. [letter to T.K. Pratt, dated 3 October 1983]. On file at CNMI Division of Fish and Wildlife, Saipan, MP.

Clark, G.A. 1964. Life histories and the evolution of megapodes. Living Bird 3: 149-167.

Commonwealth of the Northern Mariana Islands (CNMI). 2000. Division of Fish and Wildlife Non-commercial fishing and hunting regulations. Commonwealth Register 22 (4):17165-17199.

Craig, R.J. and R. Chandran. 1992. Wildlife Species recorded during the Aguiguan expedition: 20-25 May, 1992. Pp. 1-7 *in* The Aguiguan Expedition (R.J. Craig, editor). Proceedings of the Mariana Research Symposium, Volume 1. College of the Northern Mariana Islands, Saipan, MP.

Craig, R.J., R. Chandran, and A. Ellis. 1992. Bird populations of Aguiguan: a ten year update. Pp. 8-15 *in* The Aguiguan Expedition (R.J. Craig, editor). Proceedings of the Mariana Research Symposium, Volume 1. College of the Northern Mariana Islands, Saipan, MP.

Cruz, J. and L. Williams. 2003. Baseline avian and vegetation surveys of the Saipan Upland Mitigation Bank 1999-2003. Technical Report #13 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife Wildlife Section and Tinian Department of Lands and Natural Resources Fish and Wildlife and Conservation Sections. Saipan, MP. 49 pp.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000. Wildlife and Vegetation surveys Aguiguan 2000. Technical report #2 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife Wildlife Section and Tinian Department of Lands and Natural Resources Fish and Wildlife and Conservation Sections. Saipan, MP. 30 pp.

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of native Hawaiian vegetation: effects of humans, their activities and introductions, University of Hawaii, Honolulu, HI. 138 pp.

David, C. 2010. Survey equipment donated to Northern Islands residents. Saipan Tribune 26 November 2010.

De la Torre, F. 2009. 8 Alamagan residents evacuated, four Agrihan residents opt to stay. Saipan Tribune 30 September 2009.

Division of Fish and Wildlife (DFW). 2000a. Wildlife and Vegetation surveys Anatahan 2000. Technical report #6 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Wildlife Section, with assistance from The Northern Mayor's Office. Saipan, MP. 48 pp.

Division of Fish and Wildlife (DFW). 2000b. Wildlife and Vegetation surveys Guguan 2000. Technical report #3 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Wildlife Section, with assistance from The Northern Mayor's Office. Saipan, MP. 42 pp.

Division of Fish and Wildlife (DFW). 2000c. Wildlife and Vegetation surveys Alamagan 2000. Technical report #4 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Wildlife Section, with assistance from The Northern Mayor's Office. Saipan, MP. 39 pp.

Division of Fish and Wildlife (DFW). 2000d. Wildlife and Vegetation surveys Pagan 2000. Technical report #7 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Wildlife Section with assistance from The Northern Mayor's Office. Saipan, MP. 68 pp.

Division of Fish and Wildlife (DFW). 2000e. Wildlife and Vegetation surveys Agrihan 2000. Technical report #8 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Wildlife Section, with assistance from The Northern Mayor's Office. Saipan, MP. 46 pp.

Division of Fish and Wildlife (DFW). 2000f. Wildlife and Vegetation surveys Sarigan 2000. Technical report #5 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Wildlife Section, with assistance from The Northern Mayor's Office. Saipan, MP. 59 pp.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Aguijan, and Rota. U.S. Fish and Wildlife Service Report. 143pp.

Esselstyn, J., J.B. Cruz, L.L. Williams, and N. Hawley. 2003. Wildlife and Vegetation surveys, Aguiguan 2002. Technical report #9 CNMI-DFW. Unpublished report by Division of Fish and Wildlife Wildlife Section, Saipan, MP. 55 pp.

Falanruw, M.C. V. 1975. Distribution of the Micronesian megapode *Megapodius laperouse laperouse* in the Northern Mariana Islands. Micronesica 11: 149-150.

Falanruw, M.C.V. 1989. Vegetation of Asuncion: A volcanic northern Mariana Island. Resource Bulletin PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. 14 pp.

Falanruw, M.C., T.G. Cole, and A.H. Ambacher. 1989. Vegetation survey of Rota, Tinian, and Saipan, Commonwealth of the Northern Mariana Islands. Resource Bulletin PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. 11 pp.

Fancy, S.G., R.J. Craig, and C.W. Kessler. 1999. Forest bird and fruit bat populations on Sarigan, Mariana Islands. Micronesica 31: 247-254.

Farabaugh, S.M. 1982. The ecological and social significance of duetting. Pp. 85-124 *in* Acoustic Communication in Birds, Vol. 2 (D.E. Kroodsma and E.H. Miller, eds.). New York: Academic Press.

Farrell, D.A. 1992. Tinian. Tinian, MP: Micronesian Productions.

Forsman, E.D., E.C. Meslow, and M.J. Strub. 1977. Spotted owl abundance in young versus old-growth forests, Oregon. Wildlife Society Bulletin 5: 43-47.

Fosberg. F.R. 1960. The vegetation of Micronesia. Bull. American Museum Natural History. 119 pp.

Glass, P.O. and E.C. Villagomez. 1986. Trip report: Guguan, 8-20 September. CNMI Division of Fish and Wildlife, Saipan, MP.

Glass, P.O. and D.T. Aldan. 1988. Micronesian megapode surveys and research. Pp. 131-153 *in* Division of Fish and Wildlife Research and Management Progress Report: 1982-1987. CNMI Division of Fish and Wildlife, Saipan, MP.

Gorresen, P.M., R.J. Camp, J.L. Klavitter, and T.K. Pratt. 2008. Abundance, distribution and population trend of the Hawaiian Hawk: 1998-2007. Hawai`i Cooperative Studies Unit Technical Report HCSU-009. University of Hawai`i at Hilo. 53 pp. + 1 appendix.

Kessler, C.C. 1998. Report on the eradication of feral ungulates from Sarigan Island, Commonwealth of the Northern Mariana Islands, USA. Unpublished report by Zoology Unlimited, LLC, Flagstaff Arizona to U.S. Fish and Wildlife Service, Honolulu, HI. 29 pp. + appendices.

Kessler, C.C. 2002. Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands. *Turning the tide: the eradication of invasive species*, 132-140, Veitch, C.R. and Clout, M.N. (eds.). Gland, Switzerland and Cambridge, U.K.: IUCN SSC Invasive Species Specialist Group.

Kessler, C.C. 2010. Status of feral ungulates on Pagan, CNMI. *In* Mariana Expedition Wildlife Report, 2010: Final Draft, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Kessler, C. and F. Amidon. 2009. Micronesian megapode on Tinian and Aguiguan. Pages 201 to 218 *in* Terrestrial resource surveys of Tinian and Aguiguan, Mariana Islands, 2008. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Klavitter, J.L. and J.M. Marzluff. 2007. Methods to correct for density inflation biases in Hawaiian hawk surveys using attractant calls. Journal of Raptor Research 41:81-89.

Liu, Z. and L. Fischer. 2006. Commonwealth of the Northern Mariana Islands Vegetation Mapping Using Very High Spatial Resolution Imagery: Methodology. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Forest Health Protection, McClellan, California. 14 pp.

Loope, L.L., F.G. Howarth, F. Kraus, and T.K. Pratt. 2001. Newly emergent and future threats of alien species to Pacific landbirds and ecosystems. Stud. Avian Biol. 22:291-304.

Ludwig, G.M. 1979. Fish and wildlife concerns and recommendations for Northern Marianas Islands based on July 1978 field trip. Unpublished report, U.S. Fish and Willidfe Serice, Honolulu, Hawaii.

Lusk, M.R., P. Bruner, and C. Kessler. 2000. The avifauna of Farallon de Medinilla, Mariana Islands. Journal of Field Ornithology 71: 22-33.

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier Publishing, Amsterdam.

Marshall, A., and F. Amidon. 2010. Status of the land and wetland avifauna of Pagan, Mariana Islands. *In* Mariana Expedition Wildlife Report, 2010: Final Draft, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Martin, G., L.L. Williams, J.B. Cruz, N.B. Hawley, S. Vogt, B.D. Smith, O. Bourquin, S. Kremer, and C. Kessler. 2008. Wildlife and Vegetation surveys of Sarigan Island, April 13-25, 2006. Technical report #14 CNMI-DFW. Unpublished report by Division of Fish and Wildlife, Wildlife Section, Saipan, CNMI. 138 pp.

MacKenzie, D. I. and L. L. Bailey. 2004. Assessing the fit of site-occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9: 300-318.

National Oceanic and Atmospheric Administration (NOAA). 2009a. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Farallon de Medinilla, 2004. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration (NOAA). 2009b. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Anatahan, 2005. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration(NOAA) . 2009c. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Sarigan, 2006. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration(NOAA) . 2009d. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Guguan, 2004. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration(NOAA) . 2009e. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Alamagan, 2007. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration(NOAA) . 2009f. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Agrihan, 2001. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration(NOAA) . 2009g. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Asuncion Island, 2004. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

National Oceanic and Atmospheric Administration. 2009h. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Maug Islands, 2003. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. < http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

O'Daniel, D. and S. Krueger. 1999. Recent sightings of the Micronesian megapode on Tinian, Mariana Islands. Micronesica 31:301-307.

Ohba, T. 1994. Flora and vegetation of the northern Mariana Islands, Micronesia. Pages 13-70 in Biological expedition to the Northern Mariana Islands, Micronesia (A. Asakura and T. Furuki, eds.). Natural History Research, Special Issue, Number 1.

Olson, S.L. 1980. The significance of the distribution of the Megapodiidae. Emu 80:21-24.

Oustalet, E. 1896. Les mammiferes et les oiseaux des Iles Mariannes. Nouv. Archives Museum Natural History, Paris 8(1896): 24-74.

Owen, B. 1974. Environmental impact study on the terrestrial fauna and flora of Tinian with respect to the prposed establishment of a U.S. military base on that island. Unpublished report, Trust Territory Conservation Office.

Perry, G. and J. M. Morton. 1999. Regeneration rates of the wood vegetation of Guam's Northwest Field following major disturbance: land use patterns, feral ungulates, and cascading effects of the brown treesnake. Micronesica 31:125-142.

Pratt, H.D. and P.L. Bruner. 1978. Micronesian megapode rediscovered on Saipan. `Elepaio 39: 57-59.

Pratt, H.D., J. Engbring, P.L. Bruner, and D.G. Berrett. 1980. Notes on the taxonomy, natural history, and status of the resident birds of Palau. Condor 82:117-131.

Pratt, L.W. 2010. Vegetation assessment of forests of Pagan Island, Commonwealth of the Northern Mariana Islands. *In* Mariana Expedition Wildlife Report, 2010: Final Draft, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Quoy, J.R.C. and P.J. Gaimard. 1824-1826. Voyage autour du monde. Enterpres par ordre du roi. Execute sur les corvettes de S.M. l'Uranie et la Physicienne, pendant les annees 1817, 1818, 1819, et 1820. Par M. Louis de Freycinet, Capitaine de Vaisseax. Zoologie. Paris, Chez Pillet Aine, Imprimeur-Libraire. 712 pp.

Radley, P. 2009. Survey of birds on Asuncion. Pp. 21-33 *in* Wildlife and Vegetation surveys of Asuncion Islands 16-25 May, 2008. Technical report #15 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife, Department of Lands and Natural Resources, Saipan, MP. 49 pp.

Reichel, J.D. and P.O. Glass. 1988. Field trip report: Anatahan, 27-29 September. Unpublished report by CNMI Division of Fish and Wildlife, Saipan, MP.

Reichel, J.D., C.G. Rice, and D.W. Stinson. 1989. Field trip report, Sarigan and Pagan, 25-27 April. Unpublished report by CNMI Division of Fish and Wildlife, Saipan, MP.

Reichel, J.D., S. Taisacan, and P.O. Glass. 1988. Field trip report, Northern Islands, 22-31 Mar. Unpublished report by CNMI Division of Fish and Wildlife, Saipan, MP.

Reichel, J.D., S. Taisacan, S.C. Villigomez, P.O. Glass, and D.T. Aldan. 1987. Field trip report, Northern Islands, 27 May 5 June. Unpublished report by CNMI Division of Fish and Wildlife, Saipan, MP.

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309-313.

Rice, C.G. and D.W. Stinson. 1992. Field trip report: Chiba Institute Northern Islands Trip, 11-20 May, 24 May-9 June. CNMI Division of Fish and Wildlife, Saipan, MP.

Richard, D. 1957. Administration of the Trust Territory of the Pacific Islands, Vol 2. Washington, D.C.: Office of the Chief of Naval Operations.

Ritter, M.W. and C. M. Naugle. 1999. Population characteristics, germination and proposed management of Elaeocarpus joga Merr. on Guam: A regionally endemic tree. Micronesica 31:275-281.

Rodda, G.H. and J.A. Savidge. 2007. Biology and impacts of Pacific Island invasive species. 2 *Boiga irregularis*, the brown tree snake (Reptilia: Colubridae). Pacific Science 61: 307-324.

Rogers, H. 2010. Landcover mapping of the island of Pagan, Mariana Islands, 2010. Appendix 3 *in* A. Marshall and F. Amidon, Status of the land and wetland avifauna of Pagan, Mariana Islands. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Russell, S. 1998. Gani revisited: a historical overview of the Mariana archipelago's northern islands. Pacific Studies 21: 83-105.

Smithsonian. 2010. Global volcanism program: volcanoes of Japan, Taiwan, and the Marianas. < http://www.volcano.si.edu/world/region.cfm?rnum=0804> Accessed 30 December 2010.

Spenneman, D.H.R. 1999. Aurora Australis: The German period in the Mariana Islands 1899-1914. Occasional Historical Papers Series No. 5, Division of Historic Preservation, Saipan, MP.

Stinson, D.W. 1993. Micronesian megapode research. Pp. 217-233 *in* Division for Fish and Wildlife Research and Management Program, Progress Report: 1998-1992. CNMI Division of Fish and Wildlife, Saipan, MP.

Stone, C.P. 1985. Alien animals in Hawaii's native ecosystems: toward controlling the adverse effects of introduced vertebrates. Pp. 251-297 *in* Hawaii's Terrestrial Ecosystems: Preservation and Management, C.P. Stone and J.M. Scott (eds.), Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu, HI.

Takatsukasa, S. 1932-1938. The birds of Nippon. London: H.F. & G. Witherby.

Takatsukasa, S. and Y. Yamashina. 1932. Second report on the birds of the South Seas. Dobutsu. Zasshi 44: 221-226.

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J. R.B. Bishop, T.A. Marques, and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

U.S. Census Bureau. 2001. Census bureau releases census 2000 population counts for the Commonwealth of the Northern Mariana Islands. News release from the U.S. Census Bureau, Public Information Office, Department of Commerce (www.census.gov).

U.S. Fish and Wildlife Service (USFWS). 1970. Conservation of endangered species and other fish and wildlife. Federal Register 35(106): 8491-8498.

U.S. Fish and Wildlife Service (USFWS). 1998. Recovery plan for the Micronesian megapode (*Megapodius laperouse laperouse*). U.S. Fish and Wildlife Service, Portland, OR. 65 + pp.

Vogt, S. 2008. Micronesian megapode (*Megapodius laperouse laperouse*) surveys on Tinian and Aguijan, Commonwealth of the Northern Mariana Islands. Unpublished draft report (April 2008) U.S. Navy, NAVFAC Pacific, Honolulu, HI. 12 pp.

Vogt, S. 2009. Micronesian megapode (*Megapodius laperouse laperouse*) surveys on Farallon de Medinilla, Commonwealth of the Northern Mariana Islands. Unpublished report U.S. Navy, NAVFAC Pacific, Pearl Harbor, HI. 12 pp.

White House. 2009. Marine National Monuments. Office of the Press Secretary, The White House, January 6, 2009.

Wikipedia. 2010. Tinian. http://en.wikipedia.org/wiki/Tinian

Wiles, G.J. 2005. Decline of a population of wild seeded breadfruit (*Artocarpus mariannensis*) on Guam, Mariana Islands. Pacific Science 59:509-522.

Wiles, G.J., I. H. Schreiner, D. Nafus, L. K. Jurgensen, and J. C. Manglona. 1996. The status, biology, and conservation of *Serianthes nelsonii* (Fabaceae), and endangered Micronesian tree. Biological Conservation 76:229-239.

Yamashina, Y. 1940. Some additions to the "List of the birds of Micronesia." Tori 10: 673-679.

Appendix 1 – Nightingale Reed-warbler Surveys on Alamagan

Annie Marshall[1], Fred Amidon[1], and Paul Radley[2]

[1]U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Honolulu, Hawaii
[2]Division of Fish and Wildlife, P.O. Box 10007, Lower Base
Saipan, Commonwealth of the Northern Mariana Islands

Introduction

Surveys for the endangered nightingale reed-warbler (*Acrocephalus luscinia*) were conducted on Alamagan during the recent U. S. Fish and Wildlife (USFWS) surveys of the Micronesian megapode (*Megapodius laperouse laperouse*) in the Northern Mariana Islands. Extant populations of the nightingale reed-warbler are believed to occur only on Saipan and Alamagan. The last avifauna surveys on Alamagan occurred in 2000 (Division of Fish and Wildlife (DFW) 2000) and in 2007 on Saipan (Camp *et al*. 2009b). In order to recover the nightingale reed-warbler, it is important to understand its status archipelago-wide.

Methods

Point-Transect Surveys - To estimate nightingale reed-warbler population sizes we conducted island-wide point-transect surveys on Alamagan between May 17 and 24, 2010. We sampled a total of 72 stations on 10 transects (Figure 1). 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. The starting point for each transect was determined by randomly selecting 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 nightingale reed-warblers (and Micronesian megapodes) 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 and 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, and these were later used as covariates in density calculations. Counts commenced at sunrise and continued until completed (typically prior to 1100 hours) and were conducted under favorable weather conditions.

The point-transect technique requires 75-100 detections to effectively model the detection function for each species (Buckland *et al*. 2001). To achieve the minimum number of detections for Alamagan we pooled observations from the DFW surveys of Alamagan (40 detections; DFW 2000) and the Saipan Upland Mitigation Bank (46 detections; Cruz and Williams 2003). The detections were predominately of males holding territories (singing males). However, some unknown number of females and unknown floating birds were also counted. We included the covariate survey to account for different detection

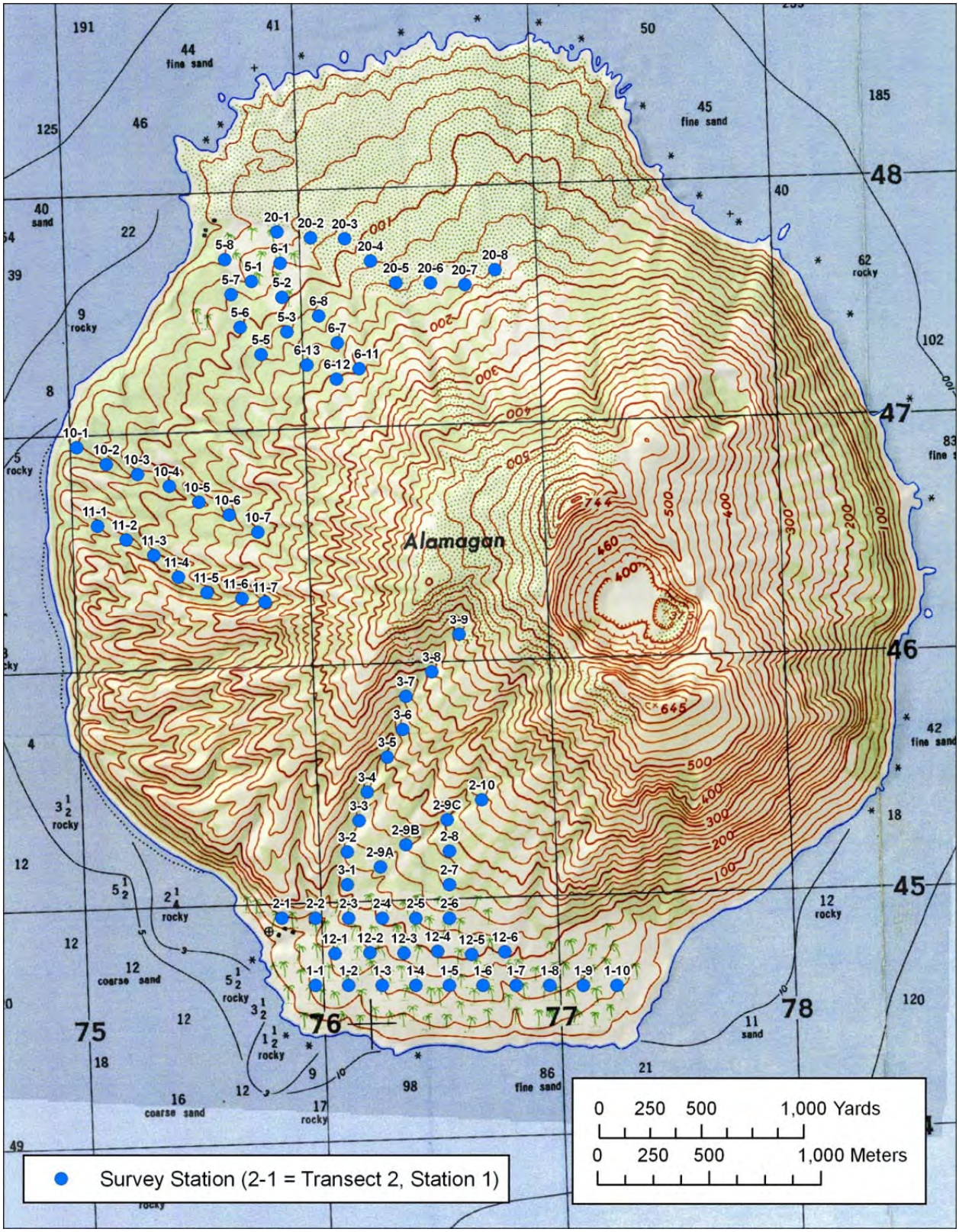


Figure 1. Location of transects and stations surveyed for nightingale reed-warblers on the island of Alamagan in 2010.

functions among the three data sets. Densities (birds/ha) were calculated using the program DISTANCE version 6.0 release 2 (Thomas *et al*. 2010) following procedures detailed in Camp *et al*. (2009b). This density was therefore a conservative estimate of the total population and an over estimate of the number of males on territories.

DFW surveyed Alamagan for birds (as well as other resources) in 2000 but did not estimate densities using program DISTANCE. They instead presented island-wide estimates based on the number of birds detected within a fixed radius of each station and extrapolated out for each habitat type. We therefore calculated the density estimates for the 2000 data (DFW 2000) to compare to the 2010 estimates. The estimated available habitat (485 ha) on the island was obtained from the NOAA (2009) landcover map of the island, which was based on 2004 imagery. This area estimate was then used to calculate both the 2000 and 2010 estimates of the number of nightingale reed-warbler abundances on the island. It should be noted, however, that the vegetation on the island may have changed after the 2004 imagery was collected so the population estimates are based on the assumption that the vegetation was consistent between years.

Occupancy surveys –Surveys for reed-warbler occupancy were conducted in conjunction with the point-transect survey described above. All stations were sampled four times with sampling distributed across two time periods (0600-1100 and 1400-1800 hours). Occupancy models included site covariates describing vegetation type, understory closure/openness, canopy height, and canopy cover, and a sampling covariate indicative of the time of day (morning or afternoon). Occupancy models were first ranked according to Akaike Information Criterion (AIC) values as adjusted for small sample size (*i.e.*, AICc; Burnham and Anderson 2002). Model goodness-of-fit statistics ($\hat{c}$) were assessed with a parametric bootstrap procedure (MacKenzie and Bailey 2004) in which a Pearson X^2 test statistic p-value $\geq$0.05 indicated an adequate model fit. Occupancy modeling followed the procedures detailed in Status of the Micronesian Megapode in the Commonwealth of the Northern Mariana Islands (Amidon *et al*. 2010).

Results

Abundance analysis – A total of 60 nightingale reed-warblers was detected during the 2010 point-transect survey from 72 stations on Alamagan. Because insufficient numbers of detections were made to reliably model a detection function, we added an additional 40 detections from the 2000 DFW survey of Alamagan and 46 detections from Saipan surveys. The count length of the DFW surveys was only 5 min; therefore, we included detections from the first 5 min of the 2010 survey (53), yielding a total of 139 detections to model the detection function. Truncation was set at 55.3 m; leaving 124 detections for modeling. The hazard-rate detection function was the best-fit model, and the covariate survey further improved the model fit (Table 1, Figure 2). Estimates for both the 2000 and 2010 Alamagan surveys

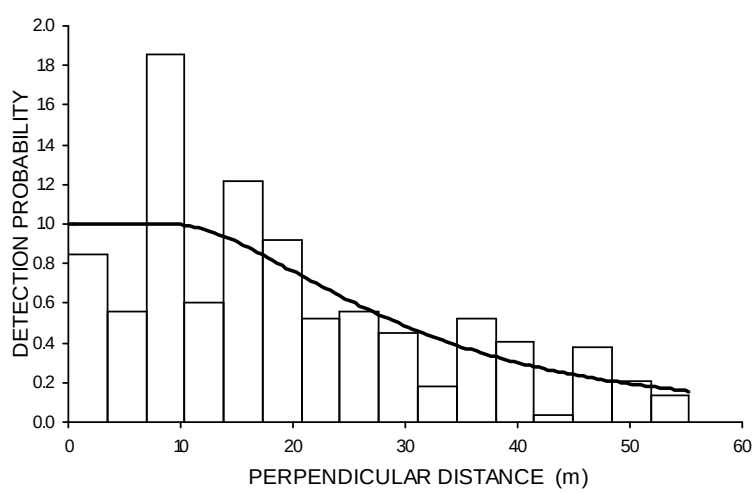


Figure 2. Histogram of Nightingale Reed-warbler detections used to derive the detection function and population estimates via distance sampling. A best fit line of these data were modeled using the hazard-rate detection function with the covariate survey.

were calculated using post-stratification procedures. Although not statistically significant because the confidence intervals overlap, nightingale reed-warblers decreased from 1,125 to 946 individuals between 2000 and 2010 (Table 2).

Table 1. Point-transect sampling model selection results for the Nightingale Reed-warbler data. Models are half-normal (H-norm) and hazard-rate (H-rate) key detection functions. Except for a covariate representing Survey (FWS 2010 Alamagan, DFW 2000 Alamagan, and DFW Saipan) no series expansion adjustment terms or sampling and site covariates were modeled because of over-fitting concerns due to the small numbers of detections. *K* is the number of estimated parameters, *L* is the estimate of the log-likelihood, AIC_c is the 2nd-order Akaike's Information Criterion corrected for small sample sizes, ΔAIC_c is the difference among the AIC_c values, and w_i is the Akaike model weight that the likelihood that model is the best model (of the 3 models evaluated).

Model	*k*	*L*	AIC_c	ΔAIC_c	w_i
H-rate Key Survey	3	-487.10	980.40	0.00	0.836
H-rate Key	2	-490.42	984.94	4.54	0.086
H-norm Key	1	-491.56	985.16	4.76	0.077

Table 2. Population size estimates of Nightingale Reed-warbler on Alamagan. Density (birds ha^{-1}) and abundance (density * area) with variance estimates were calculated for the 2000 DFW and 2010 FWS surveys. Area for both surveys equaled 485 ha.

Survey	Estimate	% Coefficient of Variation	Standard Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
2000					
Density	2.32	43.19	1.00	1.04	3.17
Abundance	1,125	43.19	486	504	1,539
2010					
Density	1.95	34.80	0.68	0.88	3.63
Abundance	946	34.80	329	428	1,762

Occupancy analysis – The top-ranked models included the site covariates canopy height and vegetation type (Table 3). Although the confidence intervals overlapped considerably because of small sample sizes among habitat strata, occupancy of the nightingale reed-warbler appeared to be tentatively correlated with vegetation type (Table 4). Mean estimates ranged from a low of 0.19 (95% CI = 0.09 – 0.35) in native forest (n = 58), up to 0.49 (95% CI = 0.17 – 0.83) in coconut forest (n = 10) and 0.69 (95% CI = 0.02 – 1.00) in secondary forest (n = 2). Nightingale reed-warbler occurrence also appeared associated with canopy height, with higher mean occupancy in taller vegetation.

Occupancy models also identified the time of day during which surveys were conducted as having a moderate effect on nightingale reed-warbler detectability. Although confidence intervals overlapped, the model ψ(canopy height-vegetation)p(time) showed a slightly higher mean in the morning (p = 0.43; 95% CI = 0.21 – 0.68) than in the afternoon (p = 0.31; 95% CI = 0.14 – 0.56) (Table 5).

Table 3. Selection of models describing the relation of Nightingale Reed-warbler occurrence to site and sampling covariates. Covariates are indicated in parentheses following the occupancy symbol "ψ" and detection probability symbol "p". Site covariates "veg", "understory", "canhgt", "cancov", and "time", refer to vegetation type, understory closure/openness, canopy height, and canopy cover, respectively. The sampling covariate "time" indicates the time of day (morning or afternoon) at which the observation was made. The term "global" refers to a model that includes all covariates. Column k is the number of model parameters; L is the -2*log likelihood; $\Delta QAIC_c$ is the relative difference in $QAIC_c$ values from the model with the smallest value; w is the $QAIC_c$ model weight; $\hat{c}$ is the estimated average over-dispersion parameter; and X^2 p-value is the probability of observing a X^2 greater than or equal to the test statistic based upon 999 parametric bootstraps. Shaded rows are top-ranked models for which occupancy estimates are provided in Table 4.

Model	k	L	ΔQAICc	w	$\hat{c}$	X^2 p-value
ψ(canhgt-veg),p(time)	6	111.12	0.0	0.74	1.406	0.139
ψ(veg),p(time)	5	111.86	2.7	0.19	1.332	0.139
ψ(global),p(time)	8	100.74	6.0	0.04	1.252	0.198
ψ(veg),p(.)	4	112.66	7.7	0.02	1.236	0.228
ψ(canhgt-veg),p(.)	5	111.90	8.6	0.01	1.245	0.149
ψ(understory-veg),p(.)	5	112.63	10.3	0.00	1.229	0.238
ψ(cancov-veg),p(.)	5	107.32	12.1	0.00	1.149	0.238
ψ(global),p(.)	7	101.54	12.7	0.00	1.135	0.287
ψ(understory-canhgt),p(.)	4	115.48	12.8	0.00	1.200	0.188
ψ(understory-veg),p(time)	6	111.82	13.0	0.00	1.214	0.208
ψ(understory-canhgt),p(time)	5	114.74	15.5	0.00	1.186	0.238
ψ(understory),p(time)	4	115.17	17.0	0.00	1.147	0.327
ψ(canhgt),p(.)	3	115.90	20.3	0.00	1.095	0.347
ψ(.),p(time)	3	115.83	20.3	0.00	1.094	0.317
ψ(canhgt),p(time)	4	115.18	22.2	0.00	1.091	0.356
ψ(cancov-canhgt-veg),p(time)	7	103.32	22.2	0.00	1.043	0.366
ψ(understory),p(.)	3	115.93	22.5	0.00	1.072	0.297
ψ(understory-cancov-canhgt),p(time)	6	106.64	24.0	0.00	1.035	0.396
ψ(understory-cancov-veg),p(.)	6	103.95	24.2	0.00	1.007	0.455
ψ(cancov),p(time)	4	112.75	24.7	0.00	1.043	0.356
ψ(understory-cancov-canhgt),p(.)	5	107.45	25.8	0.00	1.004	0.475
ψ(cancov-canhgt),p(.)	4	111.44	26.8	0.00	1.011	0.436
ψ(.),p(.)	2	116.58	27.1	0.00	1.016	0.446
ψ(cancov-canhgt-veg),p(.)	6	104.01	27.9	0.00	0.972	0.347
ψ(cancov-veg),p(time)	6	106.55	29.1	0.00	0.985	0.436
ψ(understory-cancov-veg),p(time)	7	103.12	30.2	0.00	0.964	0.406
ψ(understory-cancov),p(time)	5	108.19	37.3	0.00	0.913	0.564
ψ(cancov-canhgt),p(time)	5	110.75	38.1	0.00	0.928	0.545
ψ(understory-cancov),p(.)	4	109.02	39.0	0.00	0.891	0.634
ψ(cancov),p(.)	3	113.47	42.8	0.00	0.884	0.624

Table 4. Summary of Nightingale Reed-warbler occupancy (ψ) estimates and 95% confidence limits (lower and upper) for existing combinations of site covariate values. Results are shown only for the top-ranked subset of models as indicated by shading in Table 3. Results are sorted by ascending occupancy estimate within each model. Habitat variable "Canopy Height" is ranked from 1 (short; < 3 m), 2 (mid; 3 - 10 m) and 3 (tall; ≥ 10 m), and "Vegetation" categories are coconut forest (CF), secondary forest (SF), and native forest (NF).

Model	ψ	SE	95%CI lower	95%CI upper	Site Covariates	
ψ(canhgt-veg),p(time)					Canopy Height	Vegetation
	0.10	0.09	0.02	0.43	1	NF
	0.19	0.07	0.09	0.36	2	NF
	0.33	0.21	0.07	0.77	3	NF
	0.49	0.20	0.17	0.82	2	CF
	0.53	0.50	0.02	0.98	1	SF
	0.70	0.40	0.05	0.99	2	SF
ψ(veg),p(time)						Vegetation
	0.19	0.07	0.09	0.35		NF
	0.49	0.20	0.17	0.83		CF
	0.69	0.50	0.02	1.00		SF

Table 5. Summary of Nightingale Reed-warbler detection probability (p) estimates and 95% confidence limits (lower and upper) for the sampling covariate describing the time of day during which a survey was conducted. Results for islands with and without ungulates are shown separately (panels *a* and *b*, respectively). Results are shown only for the top-ranked subset of models as indicated by shading in Table 3.

Model	p	SE	95%CI lower	95%CI upper	Sampling Covariate
ψ(canhgt-veg),p(time)	0.43	0.13	0.21	0.68	morning
	0.31	0.11	0.14	0.56	afternoon
ψ(veg),p(time)	0.43	0.13	0.21	0.68	morning
	0.31	0.11	0.14	0.55	afternoon

Discussion

Although the estimated number of nightingale reed-warblers on Alamagan in 2010 is lower than the number estimated in 2000, the confidence intervals overlap, indicating no significant difference between years. This implies that the population may have been relatively stable over the past 10 years. However, The 2007 population estimate for nightingale reed-warblers on Saipan was 2,742 pairs (Camp *et al*. 2009b). Thus, the Alamagan population is about 25 percent of the total population of nightingale reed-warblers remaining. Nightingale reed-warblers no longer occur on Guam or Tinian and are believed extirpated from Aguiguan and Pagan (Camp *et al*. 2009a, Marshall and Amidon 2010, USFWS 1998). This means that the Alamagan population is very important to the recovery of this species.

Nightingale reed-warblers occur in about one-fifth (19 percent) of the native forest, in almost half (49 percent) of the coconut forest, and in slightly more than two-thirds (69 percent) of the secondary forest

on Alamagan. The low numbers of detections make monitoring densities difficult (requires pooling with other surveys/islands, and wide confidence intervals). However, the occupancy analysis is reliable and more nuanced and allows for tracking changes by habitat and canopy height. Increasing the number of stations surveyed among habitats would help to tighten up the CIs and allow for better monitoring. Although detectability is greatest in the morning, occupancy surveys can be conducted both in the morning and afternoon allowing more flexibility.

We therefore recommend the following priority management measures:

- Remove feral pig (*Sus scrofa*), goat (*Capra hircus*), and cattle (*Bos taurus*) populations from Alamagan to promote recruitment of native vegetation used by nightingale reed-warblers on the island.
- Develop and implement a forest restoration plan that includes native plant outplanting and weed control to improve habitat for nightingale reed-warblers.
- Continue monitoring the Alamagan nightingale reed-warbler population.
- Increase the number of stations for subsequent population surveys to make sampling more balanced among habitats.
- Conduct ecological research (*e.g.*, habitat use of nightingale reed-warblers on Alamagan compared to Saipan).

Feral ungulates cause loss and degradation of habitat by overgrazing, often leasing to erosion and further habitat loss. The first two above measures will help restore habitat used by the nightingale reed-warbler, thus improving the possibility of increasing the population on island. Monitoring will help us understand the status of the species, alert us to potential declines, and also allow us to determine the effects for habitat restoration on the population. Improving our surveys allows us to better estimate the status of the population. Research will help us better understand how to manage the species that currently occurs on two islands with different habitat availability. It will also aid in our ability to expand the population to other islands, an important recovery action in the recovery plan (USFWS 1998).

References

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford: Oxford University Press.

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, second edition. Springer-Verlag, New York, U.S.A., 496 pp.

Camp, R.J., T.K. Pratt, F. Amidon, A.P. Marshall, S. Kremer, and M. Laut. 2009a. Status and trends of the land bird avifauna of Tinian and Aguiguan, Mariana Islands. Appendix 3.1 *in* Terrestrial resource surveys of Tinian and Aguiguan, Mariana Islands, 2008. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI. 65 pp.

Camp, R.J., T.K. Pratt, A.P. Marshall, F. Amidon, and L.L. Williams. 2009b. Recent status and trends of the land bird avifauna on Saipan, Mariana Islands, with emphasis on the endangered Nightingale Reed-warbler *Acrocephalus luscinia*. Bird Conservation International 19: 323-337.

Cruz, J. de and L. Williams. 2003. Baseline avian and vegetation surveys, Saipan Upland Mitigation Bank 1999-2003. 2003 Technical report #13 by the CNMI Department of Lands and Natural resources, Division of Fish and Wildlife, Wildlife Section. 49 pp.

Division of Fish and Wildlife (DFW). 2000. Wildlife and Vegetation Surveys: Alamagan 2000. 2000 Technical Report #4 by the CNMI Division of Fish and Wildlife, Wildlife Section with assistance from The Northern Mayor's Office, 10-17 June 2000, Saipan, MP.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Aguijan, and Rota. U.S. Fish and Wildlife Service Report. 143pp.

MacKenzie, D. I., and L. L. Bailey. 2004. Assessing the fit of site-occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9:300-318.

Marshall, A.P. and F.A. Amidon. 2010. Status of the land and wetland avifauna of Pagan, Mariana Islands. Draft report, U.S. Fish and Wildlife Service to the U.S. Navy, 2010. 23 pp.

National Oceanic and Atmospheric Administration. 2009. C-CAP Land Cover, Commonwealth of the Northern Mariana Islands (CNMI), Alamagan, 2004. NOAA's Ocean Service, Coastal Services Center (CSC), Charleston, SC. <http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/index.html>

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309-313.

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J. R.B. Bishop, T.A. Marques, and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

U.S. Fish and Wildlife Service (USFWS). 1998. Recovery plan for the nightingale reed-warbler (*Acrocephalus luscinia*). U.S. Fish and Wildlife Service, Portland, Oregon. 62 pp.

Appendix 2 – Forest Bird Surveys on Maug

Fred Amidon and Ann P. Marshall

U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Honolulu, Hawaii

Introduction

Forest bird surveys were conducted on Maug during the Archipelago-wide surveys of the Micronesian megapode in the Northern Mariana Islands. All of the islands south of Maug had been previously surveyed by the Commonwealth of the Northern Mariana Islands' Division of Fish and Wildlife (DFW). However, Maug has never been systematically surveyed. Therefore, surveys on Maug were conducted to help determine the status of forest bird populations throughout the archipelago.

Methods

To estimate forest bird numbers we conducted island-wide point-transect surveys on the east island of Maug on June 26 and 27, 2010. We sampled a total of 14 stations on 2 transects (Figure 1). 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 sample forest bird populations. The starting point for each transect was determined by randomly selecting 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.

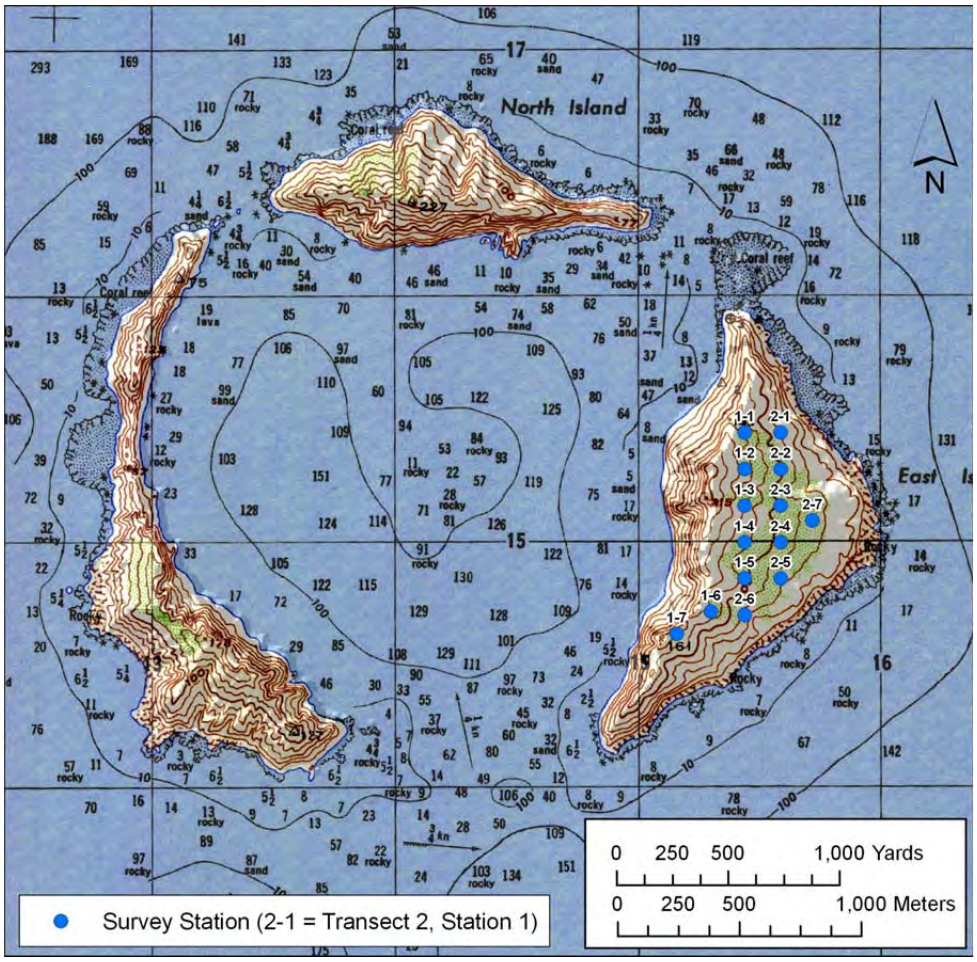


Figure 1. Location of survey transects and station sampled on the island of Maug in 2010.

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 Reynolds *et al.* 1980 or Engbring *et al*. 1986 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. Counts commenced at sunrise and continued until completed (typically prior to 1100 hours) and were conducted 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). Due to the limited sampling of the island we were unable to obtain sufficient detections for any species; therefore densities were not estimated. Instead, detections per station and percent of stations with detections were calculated.

Results and Discussion

A total of six species was detected on the Maug surveys, excluding Micronesian megapodes (Table 1). Insufficient individuals were detected to estimate densities. However, based on detections per station and number of stations with detections, the Micronesian starling was the most commonly detected species. This is consistent with results from the surveys of the other northern islands (DFW 2000a-c, Martin *et al*. 2008, Williams *et al*. 2009; see Forest and Wetland Bird report in this volume). The number of collared kingfishers and Micronesian honeyeaters was very low (Table 1) which could indicate very low populations of these species on the island. No white-throated ground-doves were detected during surveys on Maug, otherwise the species composition was similar to the other northern islands (DFW 2000a-c, Martin *et al*. 2008, Williams *et al*. 2009; see Forest and Wetland Bird report in this volume).

Table 1. List of birds detected during point-transect surveys on 14 stations along 2 transects on Maug. 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
Black Noddy	4	7	28.6	0.50
Collared Kingfisher	1	2	7.1	0.14
Micronesian Honeyeater	3	3	21.4	0.21
Micronesian Starling	8	18	57.1	1.29
Red-tailed Tropicbird	1	2	7.1	0.14
White Tern	3	8	21.4	0.57

References

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford: Oxford University Press.

Division of Fish and Wildlife (DFW). 2000a. Wildlife and Vegetation Surveys: Agrihan 2000. 2000 Technical Report #8. CNMI Division of Fish and Wildlife, Saipan, MP with assistance from the Northern Mayor's Office.

Division of Fish and Wildlife (DFW). 2000b. Wildlife and Vegetation Surveys: Alamagan 2000. 2000 Technical Report #4. CNMI Division of Fish and Wildlife, Saipan, MP with assistance from the Northern Mayor's Office.

Division of Fish and Wildlife (DFW). 2000c. Wildlife and Vegetation Surveys: Guguan 2000. 2000 Technical Report #3. CNMI Division of Fish and Wildlife, Saipan, MP with assistance from the Northern Mayor's Office.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Aguijan, and Rota. U.S. Fish and Wildlife Service Report. 143pp.

Martin, G. , L.L. Williams, J.B. Cruz, N.B. Hawley, S. Vogt, B.D. Smith, O. Bourquin, S. Kremer, and C. Kessler. 2008. Wildlife and Vegetation Surveys of Sarigan Island: April 13-25, 2006. 2008 Technical Report #14. CNMI Division of Fish and Wildlife, Saipan, MP.

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82: 309-313.

Williams, L.L., P. Radley, T. Castro, and S. Vogt. 2009. Wildlife and Vegetation Surveys of Asuncion Island: 16-25 May 2008. 2009 Technical Report #15. CNMI Division of Fish and Wildlife, Saipan, MP.

Appendix 3 – Bird List Northern Mariana Islands Bird Surveys, 2010

Compiled by: A.P. Marshall, P.A. Radley, J.E. Bradley, J. Lepson, C. Kessler, and F.A. Amidon.

During the 2010 surveys for Micronesian megapodes on the northern Mariana Islands, several observers also recorded all incidental observations of birds seen on the islands during surveys, between surveys, and while travelling between islands. The species are arranged in taxonomic or phylogenetic order following that adopted in 1983 by the American Ornithologists' Union for its checklist of North American birds (Pratt *et al*. 1987).

Species names and abbreviations:

Seabirds:

WTSH (Wedge-tailed Shearwater, *Puffinus pacificus*), SOSH (Sooty shearwater, *Puffinus griseus*), STSH (Short-tailed Shearwater, *Puffinus tenuirostris*), WNPE (White-naped Petrel, *Pterodroma cervicalis*), MSPE (Matsudaira's Storm-Petrel, *Oceanodroma matsudairae*), WTTB (White-tailed Tropicbird, *Phaethon lepturus*), RTTB (Red-tailed Tropicbird, *Phaethon rubricauda*), MABO (Masked Booby, *Sula dactylatra*), BRBO (Brown Booby, *Sula leucogaster*), RFBO (Red-footed Booby, *Sula sula*), GRFR (Great Frigatebird, *Fregata minor*), LEFR (Lesser Frigatebird, *Fregata ariel*), BNTE (Black-naped Tern, *Sterna sumatrana*), GBTE (Gray-backed Tern, *Sterna lunata*), SOTE (Sooty Tern, *Sterna fuscata*),BRNO (Brown Noddy, *Anous stolidus*), BLNO (Black Noddy, *Anous minutus*), WHTE (White Tern, *Gygis alba*).

Shorebirds/Waders:

GRHE (Gray Heron, *Ardea cinerea*), INEG (Intermediate Egret, *Egretta intermedia*), PRHE (Pacific Reef-Heron, *Egretta sacra*), CAEG (Cattle Egret, *Bubulcus ibis*), PGPL (Pacific Golden-Plover, *Pluvialis dominica fulva*), WATA (Wandering Tattler, *Heteroscelus incanus*), WHIM (Whimbrel, *Numenius phaeopus*), RUTU (Ruddy Turnstone, *Arenaria interpres*).

Terrestrial birds:

BLKI (Black Kite, *Milvus migrans*), WTEA (White-tailed Eagle, *Haliaeetus albicilla*), MIME (Micronesian Megapode, *Megapodius laperouse*), WTGD (White-Throated Ground-Dove (*Gallicolumba xanthonura*), MAFD (Mariana Fruit-Dove, *Ptilinopus roseicapilla*), COKI (Collared Kingfisher, *Halcyon chloris*), NIRW (Nightingale Reed-warbler, *Acrocephalus luscinia*), MIST (Micronesian Starling, *Aplonis opaca*), MIHO (Micronesian honeyeater, *Myzomela cardinalis*), BRWE (Bridled White-eye, *Zosterops conspicillatus*).

Birds observed by island:

Agrihan

Seabirds – WTTB, BRBO, GBTE, SOTE, BRNO, BLNO, WHTE.
Shorebirds/Waders – PRHE, PGPL, WATA.
Terrestrial birds – MIME, WTGD, COKI, MIST, MIHO.

Alamagan

Seabirds – WTSH, STSH, WTTB, RTTB, BRBO, RFBO, GRFR, BNTE, SOTE, BRNO, BLNO, WHTE.
Shorebirds/Waders – WATA, PRHE, COSA.
Terrestrial birds – MIME, WTGD, COKI, NIRW, MIST, MIHO.

Anatahan

Seabirds – WTTB, GBTE, BRNO, WHTE.
Shorebirds/Waders – PGPL, RUTU.
Terrestrial birds – MIME, MIHO.

Asuncion

Seabirds – WTSH, SOSH, WTTB, RTTB, BRBO, RFBO, GRFR, GBTE, SOTE, BRNO, BLNO, WHTE.
Shorebirds/Waders – GRHE, PRHE.
Terrestrial birds – MIME, WTGD, COKI, MIST, MIHO.

Guguan

Seabirds – WTSH, WTTB, RTTB, BRBO, MABO, RFBO, GRFR, GBTE, SOTE, BRNO, BLNO, WHTE.
Shorebirds/Waders – PRHE, INEG, WHIM.
Terrestrial birds – BLKI, MIME, WTGD, MIST, MIHO.

Maug

Seabirds – WTSH, STSH, WTTB, RTTB, MABO, BRBO, RFBO, GRFR (nesting), L EFR, SOTE, BRNO, BLNO, WHTE.
Terrestrial birds – MIME, COKI, MIST, MIHO.

Pagan

Seabirds – WTSH, STSH (seen from boat between Pagan and Alamagan),MSPE (seen from boat between Pagan and Alamagan),WTTB, RTTB, BRBO, GRFR, GBTE, SOTE, BRNO, BLNO, WHTE.
Shorebirds/Waders –GRHE, INEG, PRHE, CAEG, PGPL, WATA, RUTU.
Terrestrial birds – MIME, WTGD, COKI, MIST, MIHO.

Sarigan

Seabirds – WNPE (off Zealandia Banks), GBTE, BRNO, BLNO, WHTE.
Shorebirds/Waders –PRHE, CAEG.
Terrestrial birds – MIME, WTGD, MAFD, COKI, MIST, MIHO, BRWE.

Uracus (Farallon de Pajaros)

Seabirds – BRBO, MABO, SOTE, BRNO.
Shorebirds/Waders – CAEG, PGPL, WHIM, RUTU
Terrestrial birds – WTEA

References

Pratt, H.D., P.L. Bruner, and D.G. Berrett. 1987. A field guide to the birds of Hawaii and the Tropical Pacific. Princeton: Princeton University Press. 409 pp. + 45 plates.

Appendix 4

MICRONESIAN MEGAPODE SURVEY ASSESSMENT

AGUIGUAN 2009

Fred Amidon[1], Richard Camp[2], Ann Marshall[1], Curt Kessler[1], Paul Radley[3],
Karl Buermeyer[1], and Marcos Gorresen[2]

[1] U.S. Fish and Wildlife Service Pacific Islands Office
300 Ala Moana Boulevard, Honolulu, HI
[2] Hawai`i Cooperative Studies Unit, University of Hawai`i at Hilo,
Pacific Aquaculture and Coastal Resources Center, P.O. Box 44, Hawai`i National Park, HI
[3] Division of Fish and Wildlife, Wildlife Section,
P.O. Box 10007, Saipan, MP

January 2010

Introduction

The Micronesian megapode (*Megapodius laperouse laperouse*) known as *sasangat* in Chamorro and *sasangal* in Carolinian, is a pigeon-sized bird of the forest floor that was once found throughout the Mariana archipelago (USFWS 1998). It has been extirpated from two of the large southern Mariana Islands (Guam and Rota; USFWS 1998). In addition, larger populations occur only on a few of the uninhabited northern islands (Sarigan, Guguan, and Asuncion) and it was recently believed extirpated from Anatahan (Martin *et al.* 2008; DFW 2000, unpublished data; C. Kessler, pers. obs.). In 1970 the Micronesian megapode was listed as endangered (USFWS 1970). The main threats affecting this species are the loss and degradation of habitat, mainly due to volcanic activity, browsing by feral ungulates, and forest clearing, and predation by introduced species, including but not limited to monitor lizards (*Varanus indicus*), dogs (*Canus familiarus*), cats (*Felis cattus*), and pigs (*Sus scrofa*). An additional concern is the possibility of brown treesnake (*Boiga irregularis*) introductions to the other Mariana Islands from Guam. The accidental introduction of the brown treeesnake to Guam resulted in the extirpation or extinction of 13 of Guam's 22 native breeding birds (Wiles *et al*. 2003).

The current status of the Micronesian megapode is unclear. Surveys on the northern islands have been sporadic and several of the islands have not been thoroughly surveyed (USFWS 1998). In addition, the point-transect or variable circular plot (VCP) methodology used to count other forest birds does not appear to work well for megapodes, especially on islands where they are not common. During 2009, we conducted field work on Aguiguan, also known as Goat Island, to assess several methods to efficiently determine the status of the Micronesian megapode in the Mariana Islands.

Study Area

Aguiguan is a 7 km^2 uninhabited island located 9 km south of the coast of Tinian in the Commonwealth of the Northern Mariana Islands. The island is composed of a series of upraised limestone shelves with a maximum elevation of 163 meters. In the 1930's the Japanese cleared most of the level areas of the island for sugarcane production but the island has been abandoned since the end of the Second World War (Butler 1992). Currently the island consists of approximately 340 hectares of native forest and 158 and 139 hectares of open field and secondary forest, respectively (Amidon 2009). The major components of the native forest include *Pisonia grandis*, *Cynometra ramiflora*, and *Guamia mariannae* trees (Esselstyn *et al*. 2003). However, the understory of the native forest is heavily degraded by ungulate browsing and patches of *Lantana camara* are found growing in disturbed areas throughout the forest. The open fields primarily consist of *Lantana camara* but patches of *Chromolaena odorata* and *Miscanthus* spp. are also present. Secondary forest consisted primarily of forest dominated by *Delonix regia*, *Acacia confusa*, and *Casuarina equisetifolia* trees in the canopy.

Methods

Point-Transect Surveys - To estimate the current megapode population size we conducted island-wide point-transect surveys on Aguiguan between July 13 and 14, 2009. We sampled 74 stations on 6 transects (Figure 1). Four of these transects (transects 1-4) were previously surveyed in 1982 (Engbring *et al*. 1986), 1992 (Craig *et al*. 1992), 1995 (USFWS unpublished data), 2000 (Cruz *et al*. 2000), 2002 (Esselstyn *et al*. 2003), and 2008 (USFWS unpublished data). Two additional transects were established in 2009 (transects 8 and 10) to sample the territory mapping plots (see below). All stations were spaced 150 meters apart.

All surveys were conducted by at least one observer (the 1982 and 1995 surveys were conducted by teams of two observers) and followed standard point-transect methods, consisting of 8-minute counts

and estimation of horizontal distances to all birds heard and/or seen (see Reynolds *et al.* 1980 or Engbring *et al*. 1986 for details). Leupold 9x32 mm RXB-IV Range Finding Binoculars (Leupold, Beaverton, OR) were used during the 2009 survey to assist with distance estimation. Sampling conditions recorded included cloud cover, rain, wind, understory openness, and habitat type, and these were later used as covariates in density calculations. Counts commenced at sunrise and continued until 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 we added 28 observations from the 1982 and 2008 surveys to the 25 point transect detections. In addition, we included 40 auditory-based detections from the 2009 playback survey. We did not include the 6 visual detections from the playback survey because those birds may have moved in response to the playback prior to detection (see section *Playback Surveys* below). Therefore, we used 93 detections to model the detection function (Appendix 1). Densities were calculated using the program DISTANCE (Thomas *et al*. 2006) following procedures detailed in Camp *et al*. (2009).

Playback Surveys - Because megapodes occur at low densities, it is difficult to obtain sufficient numbers of detections for reliable estimates of population size. One method of augmenting the number of detections is to incorporate playback calls during the survey (Buckland *et al*. 2006). Playback surveys were conducted between July 17 and 20, 2009. A total of 111 stations along 11 transects were sampled (Figure 2; see Appendix 2 for station UTM coordinates). Six transects were previously sampled during the point-transect surveys (Figure 1) and five additional transects were established for this survey to increase survey coverage of the island. All stations were 150 meters apart and, in order to maximize the likelihood of detections, all new transects were established in native forest.

All surveys were conducted by a single observer. During surveys, digitally recorded Micronesian megapode calls obtained on Sarigan were broadcast. Pair duet calls were played on an electronic game caller (Foxpro FX5 ™) for one minute at each station. The observer then measured and recorded the horizontal distances of all Micronesian megapodes heard and/or seen during a four-minute survey period (one minute of playbacks and three minutes of observation). Range finding binoculars were used to assist with distance estimation. Weather and habitat conditions were recorded at each station. Counts commenced at sunrise and continued until completed (typically prior to 1100 hours) and were conducted only under favorable weather conditions.

Similar to the analysis of point-transect data, densities would be calculated from playback data using the program DISTANCE (Thomas *et al*. 2006) if sufficient detections (75 – 100) were recorded during the survey and if the movement in response to the playback calls could be accounted for during population estimation. Using playbacks without correcting for megapode movement can bias distance estimates because birds responding to playbacks typically move closer to the station before being detected, resulting in underestimates of actual observer-to-megapode distances and inflating the density estimates (Buckland *et al*. 2006).

We conducted focal bird searches using pairs of observers to ascertain the amount of movement megapodes make in response to playbacks and calculate a correction factor to account for this movement. When an observer detected a bird they would mark its location using a GPS (actual distance) and radio the other observer who would initiate a playback survey and record the distance and detection type once they detected the bird (observed distance). The difference between the actual and observed distances was calculated to obtain the distances moved prior to detection (unobserved movement). We found no movement for the birds that vocalized in response to the playbacks; that is,

these birds were detected at the actual distance. We fit a first order logarithmic regression to the visually detected data. Because we did not collect sufficient focal bird observations we could not calculate a correction factor for megapode response to playback calls and we did not use these data for estimating densities.

Occupancy – Occupancy surveys were conducted between July 13 and 16, 2009. A total of 35 stations, along 6 transects (Figure 3) were sampled ("visits") a minimum of 2 times (maximum 11 times) with sampling distributed across three time periods (0600-1000, 1000-1400, 1400-1800). 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 Reynolds *et al.* 1980 or Engbring *et al*. 1986 for details). Range finding binoculars were used to assist with distance estimation. Site and sampling conditions used as covariates in occupancy models included habitat type, exposure to prevailing weather, understory closure/openness, distance to the coast, and elevation.

Occupancy models were first ranked according to Akaike Information Criterion (AIC) values as adjusted for small sample size (i.e., AICc; Burnham and Anderson 2002). Models with a greater number of covariates were not considered because of the relatively small number of sampled sites (n = 35). Interpretive results are presented only for the top-ranked models. Model goodness-of-fit was assessed with a parametric bootstrap procedure (MacKenzie and Bailey 2004), in which a Pearson X^2 test statistic p-value $\geq$0.05 indicated adequate model fit. Model averaging of covariate coefficients was performed on the confidence set identified by a ΔAICc $\leq$ 4.0 (Burnham and Anderson 2002). A "global" model that included all covariates in the confidence set was added to the averaged models.

Spot Mapping - Between July 13 and 20, 2009, four study plots were established on Aguiguan and sampled to estimate Micronesian megapode territory densities (Figure 3). All four plots were established in native forest in areas where megapodes were observed previously to maximize the likelihood of recording megapodes. Each study plot consisted of a grid of points at 50-meter intervals developed using Hawth's Analysis Tools© 3.27 in ArcMap 9.3 (ESRI, Redlands, CA). All points were downloaded into Garmin 76CSx (Garmin International, Inc., Olathe, KS) Global Positioning System (GPS) units as waypoints to assist with mapping. GPS tracks from each unit were also recorded during each survey and downloaded into ArcMap 9.3 to identify the effective search area.

Each plot was surveyed in the morning (0600-1000), mid-day (1000-1400), and afternoon (1400-1800) over several days by one or several surveyors. All megapode detections were marked on a map of the study plot using symbols for movements and activities outlined by Bibby *et al.* (2000) and/or recorded in a field notebook with GPS waypoints. These locations were then transferred to a master map of each study plot in ArcMap 9.3. In addition, behavior, band combinations (if applicable), and other relevant information was recorded to help determine territories (see Appendix 3).

Megapode territory densities were determined by counting the number of pairs within each study plot and dividing the total number of territories by the size of the plot. Territories which overlapped the edge of the plot were included as half territories (Bibby *et al.* 2000). The presence of a territory was determined through a combination of visual observations of pairs and territorial behaviors. The boundary of each study plot was defined as the outer points in the study plot grid. These were typically associated with cliff lines and forest edges.

Island-wide Count – Finally, we compiled all of the locations of Micronesian megapodes detected during the 2008 and 2009 surveys into a GIS database to estimate the island-wide population of megapodes. The 2008 and 2009 location data included GPS locations of all Micronesian megapodes detected visually.

In addition, during 2009 we also estimated the distance and direction of all megapodes detected aurally which were then used to determine the approximate location of the bird from the GPS location of the survey point. The numbers of megapode pairs and individuals on the island was determined by placing all detections on a map of the island using ArcMap 9.3 with the type of detection (visual or aural), pair status (observed pair, single individual), and date and time of the detection noted. Only visual observations of pairs were counted as pairs but aural detections of individual megapodes were included in the total population estimate. In areas with multiple observations of pairs or individuals, we included multiple pairs or individuals only if there were simultaneous observations of multiple pairs or individuals in an area. Otherwise, clusters of observations were only counted as a single pair or individual to avoid double counting.

Results

Point-Transect Surveys – A total of 25 megapodes was detected during the 2009 Aguiguan point-transect survey from 80 counts at 74 stations along 6 transects. To model the detection function we added 68 detections from other surveys yielding 93 detections. The data were right tail truncated at 95 m, which left 78 detections for modeling. We fit a hazard-rate detection function with a simple polynomial series expansion of one order and the model fit was improved by including the covariate year (Table 1, Figure 4). Using post-stratification procedures and bootstrap methods we estimated megapode densities for the 2009 survey. We derived the megapode abundance estimate by multiplying the density and confidence interval estimates with the area of native habitat. The 2009 megapode density was 0.3288 birds per ha with a 95% confidence interval (CI) of 0.1789—0.6061 and a 41.23% coefficient of variation. Multiplying the 2009 density and CI estimates by the area of native habitat (340 ha) yielded a total of 112 individuals with a range of 61 to 206 birds.

Playbacks – During focal bird searches we located and elicited responses from 34 megapodes (19 vocal and 15 visual detections). All birds that responded vocally did not move before they were detected (unobserved distances = 0), and therefore their distance do not require adjusting to produce unbiased density estimates. In contrast, visually detected birds moved on average 8.7 m (SD = 12.6) and their response is described by a first order logarithmic equation $y = -12.777\text{Ln}(x) + 47.637$ with an R^2 of 0.33 (Figure 5). Although adjustments are not required for vocally detected birds, an adjusment is needed for birds that are detected visually. Additional observations of megapode responses to playbacks, focusing on obtaining visual detections, are needed to better model unobserved movement.

Occupancy – The results of occupancy model selection demonstrated that no single model accounted for a majority of AIC_c weight (Table 2). In fact, all models ranked below that of the null model (i.e., $\psi(\cdot)p(\cdot)$, where occupancy and detection probabilities are both constant). Seven habitat models (excluding the null model and the global model) comprised the confidence set used for model averaging. This set included all the habitat variables (understory, elevation, exposure, habitat and distance) under consideration. However, 3 models (with understory, elevation or both covariates) had a ΔAICc of less than 2 units, and this set of models together accounted for 44% of AICc model weight.

Occupancy estimates were higher than "naïve" estimates in which detection probability was not taken into account. That is, a calculation based simply on the proportion of stations with megapode detections produces an occupancy estimate of 0.57 (i.e., megapodes were recorded at 57% of stations). However, because detection probabilities are less than perfect we expect there to be megapode occurrence at a greater proportion of sites than that indicated by the naïve estimate. For example, mean occupancy for the model without habitat covariates (i.e., null model) was estimated at 0.69 (95%CI = 0.45-0.86; Table 3), an increase of 12% above the naïve estimate. Occupancy as estimated by

the next top-ranked model ranged from 0.58 (95%CI = 0.35-0.78) up to 0.83 (95%CI = 0.04-1.00) depending on the degree of understory closure or openness. Estimates for each station are provided in Appendix 4 and summarized in Table 3 for the 3 top-ranked habitat models. Megapode detections and covariates are listed in Appendix 5.

Sampling effort directly affects the precision of occupancy and detection probability estimates (Bailey *et al*. 2007). For example, a greater number of stations may be expected to narrow the broad confidence intervals currently observed around occupancy estimates (Table 3). However, sampling effort has a logistical cost that requires balancing spatial and temporal coverage. Given the sample size applied in the occupancy survey (35 stations; average of 7 visits, range = 2 – 11), the null model $\psi(\cdot)p(\cdot)$ produced an estimated $\psi = 0.69$ with a coefficient of variations (CV) = 0.16 and an estimated $p = 0.23$ with a CV = 0.17 (Table 4). In contrast, similar variance may be obtained by reducing the number of visits from 7 to 5 while doubling the number of stations sampled from 35 to 70. Although overall effort is increased, the range of habitat settings is broadened and performance of habitat models may improve.

Spot Mapping – One hundred eighty person hours were spent territory mapping in the four study plots, which translated to approximately four person hours per hectare. A total of 10 pairs were identified along with 16 potentially unpaired individuals. The average pair density per hectare was 0.21 ($\pm$ 0.09 Standard Deviation) (Table 5). Extrapolating across all native forest occupied by megapodes (280 ha; Amidon 2009) we estimated 58 Micronesian megapode pairs on Aguiguan in this habitat. This estimate excluded the native forest along the southeast coast of Aguiguan where no megapodes were detected during the 1982, 1995, 2000, 2002, 2008, and 2009 point-transect and 2008 and 2009 playback surveys, as well as secondary forest habitats, which are used by Micronesian megapodes, but were not sampled during the territory mapping.

Island-wide Count – A total of 225 megapode detections was recorded in 2009 and 24% (113 hectares) of the forested areas on the island (30% of the Native Forest and 8% of the Secondary Forest; Figure 6) were visited during surveys or in transit to and from survey sites. In addition, we also compiled into a database all of the megapode location information from June and August 2008 surveys to fill in gaps for areas that were not covered well in 2009. Based on all of the compiled data we estimate that there were 29 megapode pairs, 32 single adults, and 4 juvenile megapodes on the island which gives a total population estimate of 94 individuals (Figure 7).

Discussion

Comparison of methods

Population estimates – Most authorities consider spot mapping methods to produce an unbiased estimator and treat the estimates as truth for comparing among other methods. Remarkably, the abundance estimators produced similar numbers of megapodes for the 2009 Aguiguan surveys. The difference among the three approaches was only 22 birds, and the estimates ranged from 94 to 116 birds (58 pairs x 2) using island-wide counts and spot mapping searches, respectively. Although those estimators are without variance measurements and therefore not quantifiably comparable (Anderson 2001), they serve well as indices in as much as they produced similar results. The point-transect survey estimator, which includes estimates of precision, likewise produced a similar absolute abundance estimate. At 112 individuals its estimate was slightly closer to that from the spot mapping than the island-wide count methods. This was expected because the point-transect and spot mapping surveys were roughly carried out in the same areas of high megapode densities, whereas the island-wide counts sampled a larger area and included portions of the island with low megapode densities. The confidence

interval of the point-transect estimator was rather wide, almost 150 birds, and the variance to means ratio was large, CV>40%. Thus, it is difficult to say with much certainty what the actual density of megapodes is on Aguiguan. Additional sampling will be required to bring the precision down to a biologically relevant size (see *Sample size requirements* below).

Occupancy – The ranking of habitat covariate models below that of the null model (i.e., $\psi(\cdot)p(\cdot)$ may indicate either that the measured habitat attributes had little or no effect on megapode occurrence or they had more complicated relationships (e.g., curvilinearities or interactions) not included in the model suite. On the other hand, it may indicate that occupancy sampling was too "concentrated" in areas known to harbor megapodes and did not sufficiently span the range of habitat attributes necessary to establish a correlative relationship. Fewer station re-visits would permit a wider coverage of island habitats in future surveys with resulting improvements in the precision of occupancy estimates. Perhaps more importantly, the use of call playbacks during occupancy surveys may considerably increase megapode detection probability (p), thereby reducing bias and improving precision of parameter estimates. For example, a boost from the current value of p = 0.23 to 0.8 in native forest would yield a CV < 10% for p and ψ. Such gains in parameter estimation would greatly improve their use in tracking population status. Increased levels of p also permit the sampling effort to be reduced. For example, a p = 0.8 would allow the total frequency of station visits to be reduced to 3 without a substantial decrease in precision (and concomitant increase in CV).

Time and personnel requirements – We evaluated the relative efficiency of megapodes detected derived from four different survey methods for estimating megapode abundance and two methods for estimating megapode distribution. The ratio of survey time to detections varied widely among the four sampling methods to assess abundance (Table 6). Although playback call and point-transect surveys were most efficient (13 and 24 min per detection, respectively), insufficient numbers of detections were made using those methods to calculate reliable abundance estimates. Pooling data through time and across islands should yield sufficient numbers of detections to produce reliable estimates while maintaining efficient survey effort. Least efficient of the abundance estimators were the island-wide searches and spot mapping methods (> 72 minutes per detection). Both of those methods were time-intensive as they required canvassing suitable habitat to find and locate magapodes, plus record their behavior and interactions, to generate a composite map of individual territories. In summary, both point-transect and playback call surveys were far more efficient than spot mapping and island-wide counts because they required far less time per detection yet the point-transect produced comparable estimates of abundance. We conclude that conducting the time-intensive multiple island-wide and spot mapping methods to estimate megapode abundance is not logistically feasible for most monitoring efforts, and those methods lack estimates of precision making comparisons of abundance through time questionable.

We assessed megapode distribution using two survey methods, occupancy and island-wide searches, and the efficiency between the two methods was as markedly different as it was for assessing abundance (Table 6). The occupancy method was most efficient although it required multiple revisits at sampling locations to model the detection probability. In addition, the occupancy method also produced two metrics (detection probability and occupancy) with measures of precision. The island-wide search method was far less efficient, and as noted above, did not allow for comparisons through time.

Sample size requirements – Megapodes occur at low densities which results in low numbers of detections, even with pooling detections from other surveys and years. Obtaining sufficient numbers of detections (75-100 birds; Buckland *et al*. 2001) may be difficult if data from previous surveys are not available, or if the numbers of or repeated samples of stations are not adequate to yield large numbers of birds. Using the sample size equation from Buckland et al. (2001; p. 245) and a desired CV of 10%, the 25 birds detected from 74 stations surveyed in 2009 would require sampling more than 100 stations.

This may be feasible for Aguiguan and the larger islands, but it will not be possible to pack that many stations into the sampling frame of the smaller islands. Pooling data from previous years is an effective way of boosting the numbers of detections and the point-transect sampling estimator is not biased when data are combined (termed pooling robust; Buckland *et al*. 2001). However, not all of the Mariana Islands have been surveyed, and until the shape and scale of island-specific detection functions can be ascertained, pooling data among islands should be approached with caution. Another way to increase the numbers of detections is to incorporate playback calls with point-transect sampling. Megapodes aggressively respond to the playbacks either by vocalizing from their initial location or scurrying through the forest toward the "intruder" before being detected visually. For the point-transect and playback methods to be comparable, however, the duration of the counts should be the same (8 minutes with a playback during the first minute). Moreover, a correction factor for the attraction of visually detected birds needs to be further developed.

Recommended Survey Methods

Sampling Frame – The current sampling frame on Aguiguan includes most of the native forest and limited portions of the other habitat types (open field, secondary forest, and tangantangan thicket; total area 340 ha). Thus, inference from the current sampling frame is essentially restricted the native forest. There is ample evidence indicating that megapodes utilize only the forest habitat. The few detections in other habitat types may be of birds incidentally using or moving through those habitats, or misidentification of the bird's location. Therefore, the sampling frame for other islands needs to be carefully delineated and the inference explicitly stated.

Point-Transect Surveys – Standard point-transect sampling, where qualified observers conduct 8-min counts and record the sampling conditions, horizontal distance, direction, and type of detection to all megapodes heard or seen, yields valid estimates of absolute abundance (densities and total numbers of birds) when critical assumptions are met and sufficient numbers of birds are detected. A comprehensive treatment of the theoretical, analytical and applied aspects of distance sampling, in particular point-transect sampling, is presented in Buckland *et al*. (2001). Point-transect data are readily managed and analyzed in program DISTANCE (Thomas *et al*. 2006). Data from islands with previous point-transect surveys can be pooled together without problems, although as we did here survey year should be tested for and incorporated as a covariate. Obtaining sufficient numbers of detections becomes more of a problem for those islands without previous point-transect surveys. One possible solution is to revisit the sampling stations until sufficient sample sizes are obtained. This approach fits nicely with occupancy surveys which require revisiting sites to model detection probabilities (MacKenzie *et al*. 2006) and co-locating the two surveys will maximize the spatial and temporal coverage.

Playback Surveys – Megapodes respond readily to playback calls and using playbacks may be a good method for obtaining sufficient numbers of detections to estimate bird densities. However, we were unable to obtain sufficient visual detections to produce a reliable adjustment factor accounting for birds moving in response to the playbacks, and until a larger data set is available the playback survey data cannot be used to estimate reliable megapode densities.

Acknowledgements

We thank Elvin Masga, Tony Castro, Americopters, Laura Williams, Sylvan Igisomar, Jesse Omar, the Tinian Mayor, and our respective Administrative staffs for their assistance and support. We also thank Shelly Kremer and Gayle Berger for their assistance with data collection in 2008. Any use of trade,

product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Literature Cited

Bailey, L.L., J.E. Hines, J.D. Nichols, and D.I. MacKenzie. 2007. Sampling design trade-offs in occupancy studies with imperfect detection: examples and software. Ecological Applications, 17: 281-290.Bibby, C., N.D. Burgess, and D.A. Hill. 1992. Bird census techniques. London: Academic Press.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford: Oxford University Press.

Buckland, S. T., R. W. Summers, D. L. Borchers, and L. Thomas. 2006. Point transect sampling with traps and lures. Journal of Applied Ecology 43:377-384.

Burnham, K.P., and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, second edition. Springer-Verlag, New York, U.S.A., 496 pp.

Camp, R.J., T.K. Pratt, A.P. Marshall, F. Amidon, and L.L. Williams. 2009. Recent status and trends of the land bird avifauna on Saipan, Mariana Islands, with emphasis on the endangered Nightingale Reed-warbler *Acrocephalus luscinia*. Bird Conservation International 19:323-337.

Craig, R.J., R. Chandran, and A. Ellis. 1992. Bird populations of Aguiguan: a ten year update. Pages 8-15 *in* The Aguiguan Expedition (R.J. Craig, editor). Proceedings of the Mariana Research Symposium, Volume 1. College of the Northern Mariana Islands, Saipan, MI.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000. Wildlife and Vegetation surveys Aguiguan 2000. Technical report #2 CNMI-DFW. Unpublished report by CNMI Division of Fish and Wildlife Wildlife Section and Tinian Department of Lands and Natural Resources Fish and Wildlife and Conservation Sections. 30 pp.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Aguijan, and Rota. U.S. Fish and Wildlife Service Report. 143pp.

Esselstyn, J., J.B. Cruz, L.L. Williams, and N. Hawley. 2003. Wildlife and Vegetation surveys, Aguiguan 2002. Technical report #9 CNMI-DFW. Unpublished report by Division of Fish and Wildlife Wildlife Section, Saipan, CNMI. 55 pp.

Kessler, C. 2010. Micronesian megapode on Tinian and Aguiguan. Pages 110 to 123 *in* Terrestrial Resource surveys of Tinian and Aguiguan, Mariana Islands, 2008. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Martin, G., L.L. Williams, J.B. Cruz, N.B. Hawley, S. Vogt, B.D. Smith, O. Bourquin, S. Kremer, and C. Kessler. 2008. Wildlife and Vegetation surveys of Sarigan Island, April 13-25, 2006. Technical report #14 CNMI-DFW. Unpublished report by Division of Fish and Wildlife, Wildlife Section, Saipan, CNMI. 138 pp.

MacKenzie, D.I., and L.L. Bailey. 2004. Assessing the fit of site-occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9:300-318.

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309-313.

Thomas, L., J.L. Laake, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley, J.H. Pollard, J.R.B. Bishop, and T.A. Marques. 2006. Distance 5.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, U.K. <http://www.ruwpa.st-and.ac.uk/distance/>

USFWS. 1970. Conservation of endangered species and other fish and wildlife. Federal Register 35(106):8491-8498.

USFWS. 1998. Recovery plan for the Micronesian megapode (*Megapodius laperouse laperouse*). U.S. Fish and Wildlife Service, Portland, OR. 65 + pp.

Wiles, G.J., J. Bart, R.E. Beck Jr., and C.F. Aguon. 2003. Impacts of the brown tree snake: Patterns of decline and species persistence in Guam's avifauna. Conservation Biology 17:1350-1360.

Table 1. Point-transect sampling model selection results for the megapode data. Models are half-normal (H-norm) and hazard-rate (H-rate) key detection functions, and adjustment terms are cosine (Cos) hazard polynomial (H-poly) and simple polynomial series expansion of one order [S-poly(1)]. All covariate terms were continuous (con) except Time and Year were also treated as factor (fac) variables. *K* is the number of estimated parameters, *L* is the estimate of the log-likelihood, AIC_c is the 2nd-order Akaike's Information Criterion corrected for small sample sizes, ΔAIC_c is the difference among the AIC_c values, and w_i is the Akaike model weight that the likelihood that model is the best model (of the 11 models evaluated).

Model[1]	*k*	*L*	AIC_c	ΔAIC_c	w_i
H-rate S-poly(1) Year(fac)	6	-328.27	669.73	0.00	0.9981
H-rate S-poly(1) Gust	7	-333.35	682.31	12.58	0.0019
H-rate S-poly(1)	3	-346.18	698.68	28.95	<0.0000
H-rate S-poly(1) Detectability	5	-344.55	699.94	30.21	<0.0000
H-rate Key	2	-348.27	700.70	30.97	<0.0000
H-rate S-poly(1) Wind	6	-344.36	701.90	32.17	<0.0000
H-rate S-poly(1) Time(con)	4	-346.96	702.48	32.75	<0.0000
H-rate S-poly(1) Rain	4	-347.62	703.80	34.07	<0.0000
H-norm Key	1	-351.05	704.15	34.42	<0.0000
H-rate S-poly(1) Habitat	6	-346.35	705.89	36.16	<0.0000
H-rate S-poly(1) Detection Type	6	-346.95	707.08	37.35	<0.0000

[1] The H-norm Cos and H-rate Cos models were best fit by the key model, and parameters in the H-norm H-poly model were highly correlated. The H-rate S-poly(1) model with covariates representing Cloud, Observer and Year(con) failed to converge.

Table 2. Selection of models describing the relation of megapode occurrence to site habitat covariates. See Methods section for an explanation of site covariates indicated in parentheses following the occupancy symbol "ψ". Shaded models are those identified as the confidence set used in model averaging. The term "global" in model ψ(global)p(.) refers to the inclusion of all habitat variables. Column *k* is the number of model parameters; *L* is the -2*log likelihood; ΔAIC_c is the relative difference in AIC_c values from the model with the smallest value; *w* is the AIC_c model weight; $\hat{c}$ is the estimated average over-dispersion parameter; and X^2 *p*-value is the probability of observing a X^2 greater than or equal to the test statistic based upon 999 parametric bootstraps. Model fit is considered adequate or good when X^2 *p*-value ≥ 0.05. Minimum AIC and AIC_c values for model ψ(.)p(.) was 218.7 and 219.1, respectively.

Model	*k*	*L*	ΔAICc	*w*	$\hat{c}$	X^2 p-value
ψ(.),p(.)	2	214.74	0.0	0.26	1.84	0.091
ψ(understory)p(.)	2	215.18	0.4	0.21	1.92	0.107
ψ(understory, elevation)p(.)	3	213.93	1.6	0.12	1.51	0.130
ψ(elevation)p(.)	2	216.39	1.6	0.11	1.49	0.152
ψ(exposure)p(.)	3	214.68	2.3	0.08	2.08	0.087
ψ(habitat)p(.)	3	214.73	2.4	0.08	1.79	0.105
ψ(distance)p(.)	2	217.96	3.2	0.05	1.46	0.130
ψ(elevation, exposure)p(.)	4	213.61	3.8	0.04	1.66	0.109
ψ(understory, exposure)p(.)	4	214.68	4.9	0.02	1.77	0.098
ψ(habitat, understory)p(.)	4	214.72	4.9	0.02	1.77	0.118
ψ(habitat, exposure)p(.)	5	214.54	7.5	0.01	1.96	0.091
ψ(global)p(.)	8	212.91	15.3	0.00	0.46	0.997

Table 3. Summary of occupancy (ψ) estimates and 95% confidence limits (lower and upper) for existing combinations of covariate values. Results are shown only for a top-ranked subset of models (ΔAICc ≤ 2) from the confidence set (indicated in bold in Table 2). Results are sorted by ascending occupancy estimate within each model. The null model ψ(.)p(.) is included for comparative purposes. Habitat variable "Understory" is ranked from 1 (closed) to 5 (open)and "Elevation" is in meters above sea level.

Model	ψ	95%CI lower	95%CI upper	Understory	Elevation
ψ(.)p(.)	0.69	0.45	0.86	-	-
ψ(understory)p(.)	0.58	0.35	0.78	1	
	0.65	0.23	0.92	2	
	0.72	0.14	0.98	3	
	0.78	0.08	0.99	4	
	0.83	0.04	1.00	5	
ψ(understory, elevation)p(.)	0.54	0.04	0.97	2	40
	0.57	0.07	0.96	2	50
	0.60	0.10	0.95	2	60
	0.62	0.02	0.99	3	40
	0.62	0.15	0.94	2	70
	0.65	0.22	0.93	2	80
	0.66	0.01	1.00	4	30
	0.68	0.20	0.95	2	90
	0.69	0.01	1.00	4	40
	0.70	0.09	0.98	3	70
	0.70	0.16	0.97	2	100
	0.72	0.13	0.98	3	80
	0.73	0.14	0.98	1	140
	0.75	0.11	0.99	2	120
	0.77	0.10	0.99	2	130
	0.78	0.09	0.99	1	160
	0.79	0.08	0.99	2	140
	0.80	0.07	1.00	4	90
	0.84	0.04	1.00	3	140
	0.93	0.01	1.00	5	160
ψ(elevation)p(.)	0.35	0.09	0.74		30
	0.38	0.14	0.70		40
	0.41	0.20	0.66		50
	0.44	0.28	0.61		60
	0.47	0.38	0.56		70
	0.50	0.49	0.51		80
	0.53	0.45	0.60		90
	0.55	0.40	0.70		100
	0.61	0.31	0.85		120
	0.64	0.27	0.90		130
	0.67	0.23	0.93		140
	0.72	0.16	0.97		160

Table 4. Estimated variance in occupancy (ψ) and detection probability (p) as a function of sample size (i.e., number of station visits). The shaded row is the ψ and p as estimated from the null model $\psi(\cdot)p(\cdot)$ for the sample size applied in the occupancy survey (average = 7 visits; range = 2 – 11).

Visits	stations	ψ	SE	95%CI lower	95%CI upper	CV	p	SE	95%CI lower	95%CI upper	CV
avg 7	35	0.69	0.11	0.45	0.86	0.16	0.23	0.04	0.16	0.31	0.17
7	70	0.69	0.08	0.52	0.82	0.11	0.23	0.03	0.18	0.29	0.13
6	70	0.69	0.09	0.50	0.83	0.13	0.23	0.03	0.17	0.30	0.15
5	70	0.69	0.11	0.46	0.85	0.15	0.23	0.04	0.16	0.32	0.18
4	70	0.69	0.14	0.39	0.88	0.20	0.23	0.05	0.15	0.34	0.22
3	70	0.69	0.19	0.28	0.93	0.28	0.23	0.07	0.12	0.39	0.31

Table 5. Micronesian megapode densities (pairs/ha) in four forest plots on Aguiguan in July 2009.

Plot	Plot Size (ha)	Number of Pairs	Density
1	12.4	1	0.08
2	17.3	4	0.23
3	9.6	2	0.21
4	9.7	3	0.31
		Mean (± Standard Deviation)	0.21 (± 0.09)

Table 6. Efficiency of survey methods (total survey time/number of detections). A low value for indicates higher efficiency.

Metric and survey type	Number of stations	Number of revisits	Duration of count (min)	Total survey time (min)[1]	Number of detections	Efficiency
Abundance						
Point-transect	74	1	8	592	25	24
Playback	111	1	4	444	34	13
Spot mapping				10800	36	300
Island-wide search				16148	225	72
Distribution						
Occupancy	35	254	8	2032	40	51
Island-wide search				16148	225	72

[1] Total time spent searching for spot mapping and island-wide search surveys.

Figure 1. Location of point-transect survey transects and stations sampled in July 2009 on Aguiguan, Mariana Islands.

Figure 2. Locations of stations sampled during July 2009 Micronesian megapode playback surveys on the island of Aguiguan, Mariana Islands.

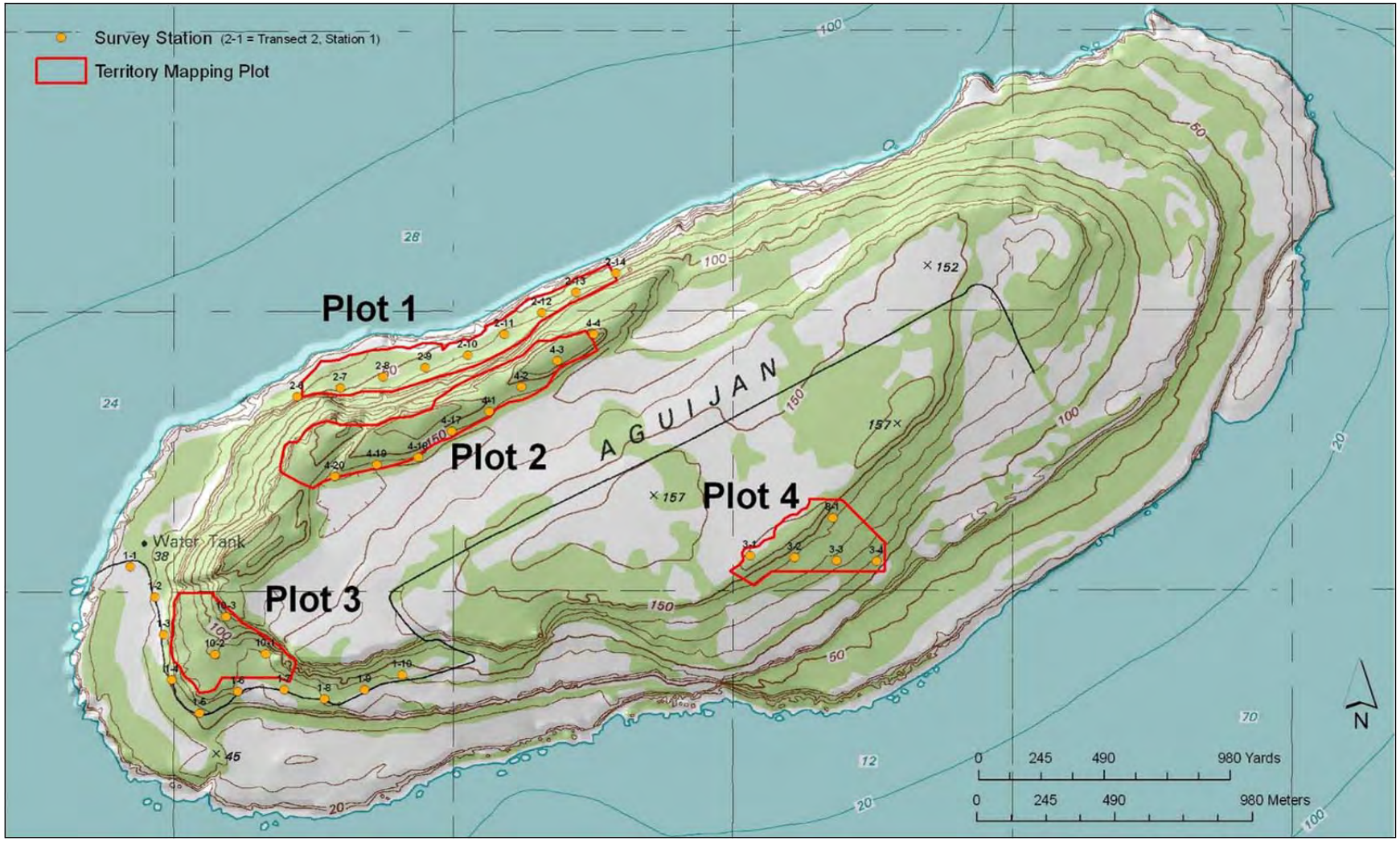


Figure 3. Location of stations and territory mapping plots sampled during occupancy and spot mapping surveys for Micronesian megapodes on the island of Aguiguan in July 2009.

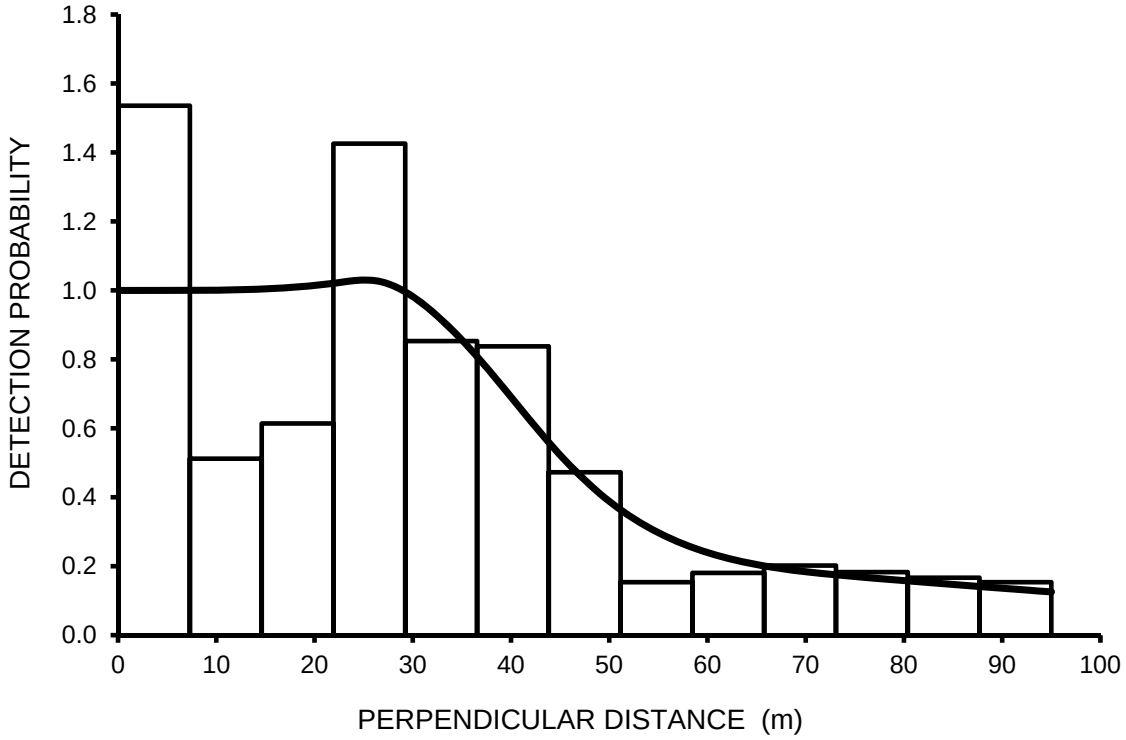


Figure 4. Histogram of megapode detections used to derive the detection function and a population estimate via distance sampling. A best fit line of these data were modeled using the hazard-rate detection function with a simple polynomial series expansion of one order and the covariate year.

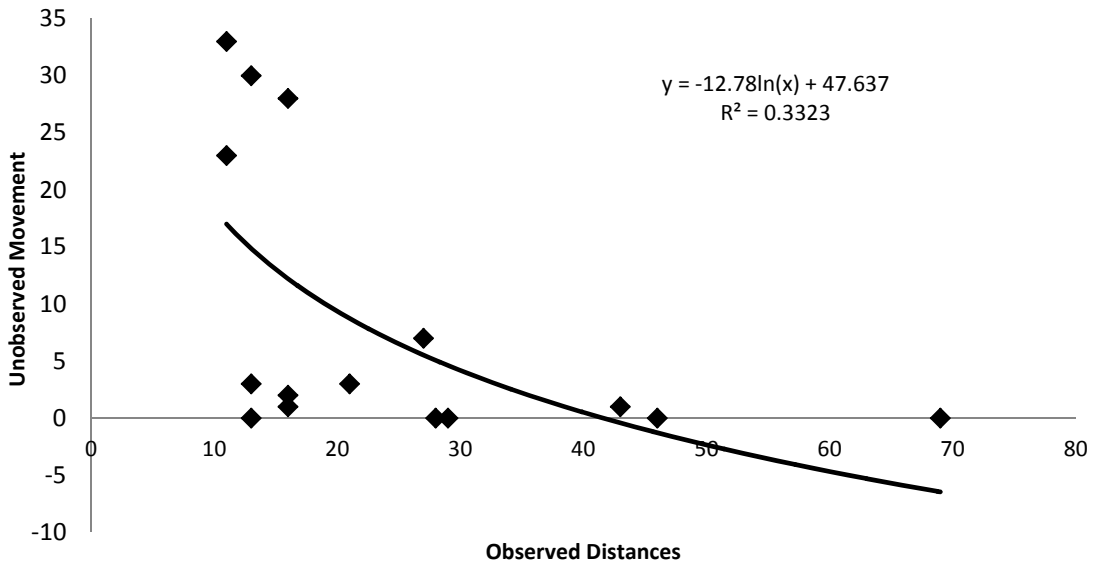


Figure 5. Response of megapodes to playback calls that were detected visually. The data were fit with a first-order logarithmic regression.

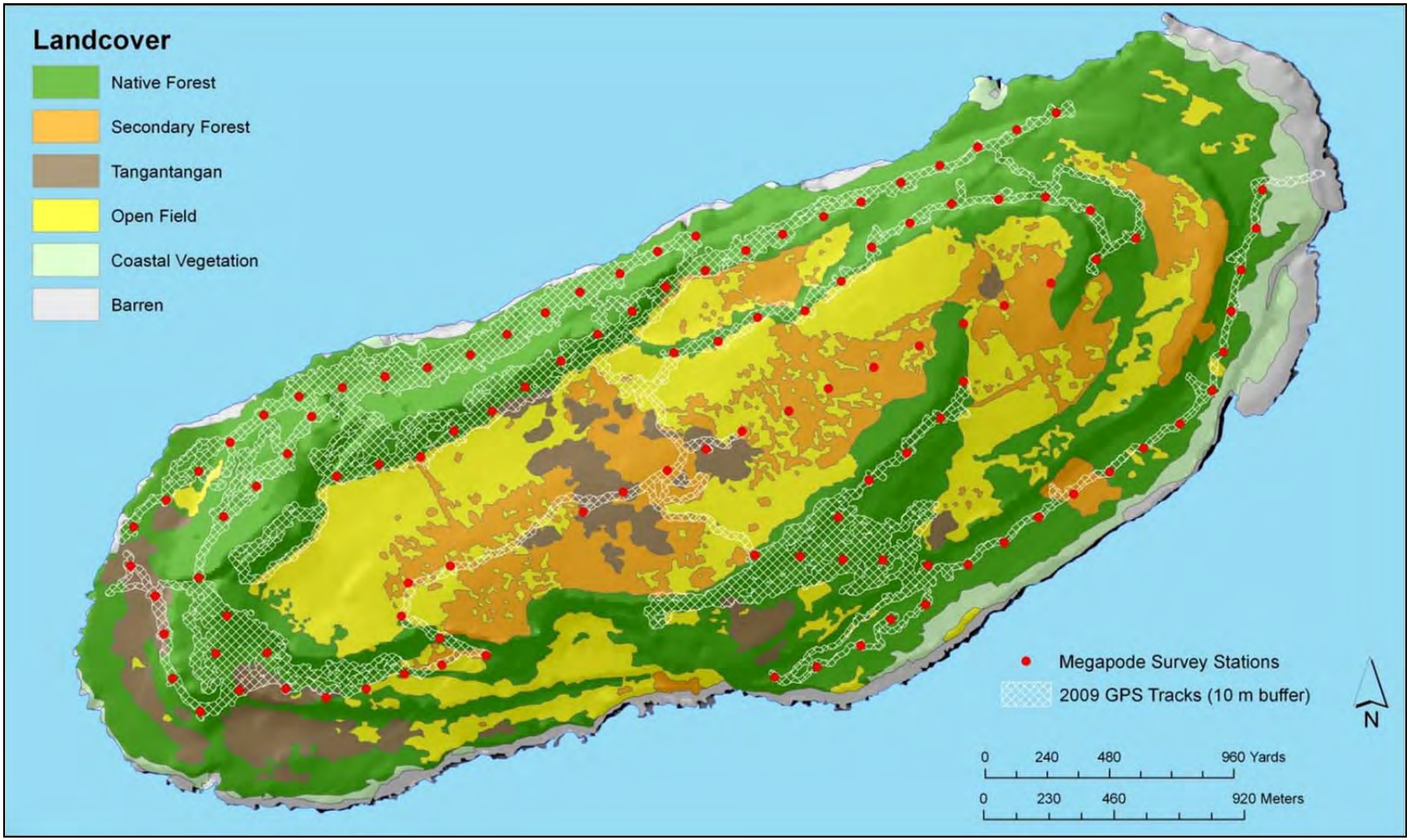


Figure 6. Regions and land cover types traversed during July 2009 Micronesian megapode surveys on the island of Aguiguan, Mariana Islands.

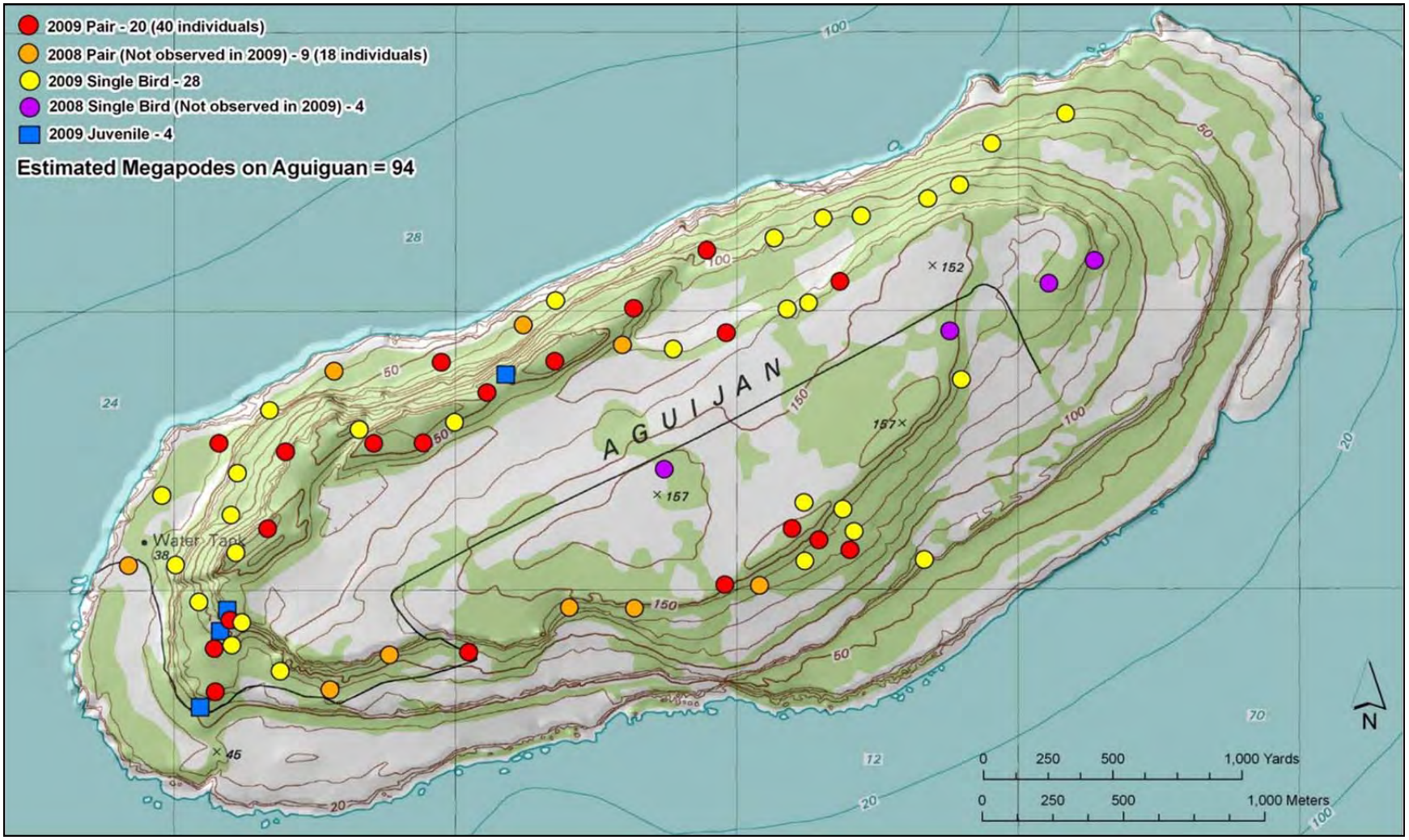


Figure 7. Locations of Micronesian megapode pairs and individuals detected during 2008 and 2009 surveys of the island of Aguiguan, Mariana Islands.

Appendix 1. Megapode detections by survey and associated sampling conditions. Headers year and survey type (Yr_Srvy) the number of times the station was sampled during a specific survey (Effort) the transect (Tran) and station (Stn) number, the observer (Obs) when the count was started (TStrt) the amount of cloud cover (C; to the nearest 10%; blank fields categorized as 110) rain (R; blank fields combined with 0) wind (W; blank fields changed to 1) gust (G; blank fields changed to 0) understory openness (O; categories 4 and 5 combined with 3) habitat type (Hab) radial distance to birds detected (Dist) and the type of detection (DTyp; C = vocal and V = visual detection).

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
1982-D	2	1	1	A	551	10	0	1	0	3	TT	90	C
1982-D	2	1	1	D	551	10	0	1	0	3	TT	250	C
1982-D	2	1	2	A	605	110	0	1	0	3	TT		
1982-D	2	1	2	D	605	110	0	1	0	3	TT		
1982-D	2	1	3	A	620	110	0	1	0	3	TT	80	C
1982-D	2	1	3	D	620	110	0	1	0	3	TT	80	C
1982-D	2	1	4	A	634	110	0	1	0	3	LI		
1982-D	2	1	4	D	634	110	0	1	0	3	LI		
1982-D	2	1	5	A	647	110	0	1	0	3	LI		
1982-D	2	1	5	D	647	110	0	1	0	3	LI		
1982-D	2	1	6	A	700	110	0	1	0	3	LI		
1982-D	2	1	6	D	700	110	0	1	0	3	LI		
1982-D	2	1	7	A	715	110	0	1	0	3	TT		
1982-D	2	1	7	D	715	110	0	1	0	3	TT		
1982-D	2	1	8	A	730	110	0	1	0	3	SF	60	C
1982-D	2	1	8	D	730	110	0	1	0	3	SF	90	C
1982-D	2	1	9	A	747	110	0	1	0	3	OF		
1982-D	2	1	9	D	747	110	0	1	0	3	OF	95	C
1982-D	2	1	10	A	804	110	0	1	0	3	SF		
1982-D	2	1	10	D	804	110	0	1	0	3	SF		
1982-D	2	1	11	A	820	110	0	1	0	3	OF		
1982-D	2	1	11	D	820	110	0	1	0	3	OF		
1982-D	2	1	12	A	835	110	0	1	0	3	SF		
1982-D	2	1	12	D	835	110	0	1	0	3	SF		
1982-D	2	1	13	A	853	110	0	1	0	3	LI		
1982-D	2	1	13	D	853	110	0	1	0	3	LI		
1982-D	2	1	14	A	909	110	0	1	0	3	OF		
1982-D	2	1	14	D	909	110	0	1	0	3	OF		
1982-D	2	1	15	A	924	110	0	1	0	3	SF		
1982-D	2	1	15	D	924	110	0	1	0	3	SF		
1982-D	2	1	16	A	938	30	0	3	0	3	SF		
1982-D	2	1	16	D	938	30	0	3	0	3	SF		
1982-D	2	2	1	B	554	110	0	1	0	3	SF		
1982-D	2	2	1	C	554	0	0	1	0	3	SF		
1982-D	2	2	2	B	608	110	0	1	0	3	LI		
1982-D	2	2	2	C	608	110	0	1	0	3	LI		
1982-D	2	2	3	B	622	110	0	1	0	3	LI	75	C
1982-D	2	2	3	B	622	110	0	1	0	3	LI	80	C
1982-D	2	2	3	C	622	110	0	1	0	3	LI	70	C
1982-D	2	2	3	C	622	110	0	1	0	3	LI	90	C
1982-D	2	2	4	B	634	110	0	1	0	3	LI		
1982-D	2	2	4	C	634	110	0	1	0	3	LI		
1982-D	2	2	5	B	647	110	0	1	0	3	LI		
1982-D	2	2	5	C	647	110	0	1	0	3	LI		
1982-D	2	2	6	B	700	110	0	1	0	3	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
1982-D	2	2	6	C	700	110	0	1	0	3	LI		
1982-D	2	2	7	B	715	110	0	1	0	3	LI		
1982-D	2	2	7	C	715	110	0	1	0	3	LI		
1982-D	2	2	8	B	728	110	0	1	0	3	LI		
1982-D	2	2	8	C	728	110	0	1	0	3	LI		
1982-D	2	2	9	B	742	110	0	1	0	3	LI		
1982-D	2	2	9	C	742	110	0	1	0	3	LI		
1982-D	2	2	10	B	756	110	0	1	0	3	LI		
1982-D	2	2	10	C	756	110	0	1	0	3	LI		
1982-D	2	2	11	B	809	110	0	1	0	3	LI		
1982-D	2	2	11	C	809	110	0	1	0	3	LI		
1982-D	2	2	12	B	822	110	0	1	0	3	LI		
1982-D	2	2	12	C	822	110	0	1	0	3	LI		
1982-D	2	2	13	B	837	110	0	1	0	3	LI		
1982-D	2	2	13	C	837	110	0	1	0	3	LI		
1982-D	2	2	14	B	852	110	0	1	0	3	LI		
1982-D	2	2	14	C	852	110	0	1	0	3	LI		
1982-D	2	2	15	B	905	110	0	1	0	3	LI		
1982-D	2	2	15	C	905	110	0	1	0	3	LI		
1982-D	2	2	16	B	924	30	0	2	0	3	LI		
1982-D	2	2	16	C	924	30	0	2	0	3	LI		
1982-D	2	3	1	B	557	80	0	2	0	3	TT		
1982-D	2	3	1	D	557	80	0	2	0	3	TT	85	C
1982-D	2	3	2	B	610	110	0	1	0	3	LI	110	C
1982-D	2	3	2	D	610	110	0	1	0	3	LI	60	C
1982-D	2	3	3	B	625	110	0	1	0	3	LI		
1982-D	2	3	3	D	625	110	0	1	0	3	LI		
1982-D	2	3	4	B	637	110	0	1	0	3	LI		
1982-D	2	3	4	D	637	110	0	1	0	3	LI		
1982-D	2	3	5	B	653	110	0	1	0	3	LI		
1982-D	2	3	5	D	653	110	0	1	0	3	LI		
1982-D	2	3	6	B	704	110	0	1	0	3	LI		
1982-D	2	3	6	D	704	110	0	1	0	3	LI		
1982-D	2	3	7	B	715	110	0	1	0	3	SF		
1982-D	2	3	7	D	715	110	0	1	0	3	SF		
1982-D	2	3	8	B	728	110	0	1	0	3	LI		
1982-D	2	3	8	D	728	110	0	1	0	3	LI		
1982-D	2	3	9	B	739	110	0	1	0	3	LI		
1982-D	2	3	9	D	739	110	0	1	0	3	LI		
1982-D	2	3	10	B	751	110	0	1	0	3	LI		
1982-D	2	3	10	D	751	110	0	1	0	3	LI		
1982-D	2	3	11	B	803	110	0	1	0	3	LI		
1982-D	2	3	11	D	803	110	0	1	0	3	LI		
1982-D	2	3	12	B	815	110	0	1	0	3	LI		
1982-D	2	3	12	D	815	110	0	1	0	3	LI		
1982-D	2	3	13	B	826	110	0	1	0	3	LI		
1982-D	2	3	13	D	826	110	0	1	0	3	LI		
1982-D	2	3	14	B	837	110	0	1	0	3	LI		
1982-D	2	3	14	D	837	110	0	1	0	3	LI		
1982-D	2	3	15	B	849	110	0	1	0	3	LI		
1982-D	2	3	15	D	849	110	0	1	0	3	LI		
1982-D	2	3	16	B	901	110	0	1	0	3	LI		
1982-D	2	3	16	D	901	110	0	1	0	3	LI		
1982-D	2	3	17	B	913	110	0	1	0	3	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
1982-D	2	3	17	D	913	110	0	1	0	3	LI		
1982-D	2	3	18	B	925	110	0	1	0	3	SF		
1982-D	2	3	18	D	925	30	0	2	0	3	SF		
1982-D	2	4	1	A	600	70	0	2	0	3	LI		
1982-D	2	4	1	C	600	70	0	2	0	3	LI		
1982-D	2	4	2	A	612	110	0	1	0	3	LI		
1982-D	2	4	2	C	612	110	0	1	0	3	LI		
1982-D	2	4	3	A	627	110	0	1	0	3	LI		
1982-D	2	4	3	C	627	110	0	1	0	3	LI		
1982-D	2	4	4	A	640	110	0	1	0	3	LI		
1982-D	2	4	4	C	640	110	0	1	0	3	LI		
1982-D	2	4	5	A	653	110	0	1	0	3	LI		
1982-D	2	4	5	C	653	110	0	1	0	3	LI		
1982-D	2	4	6	A	707	110	0	1	0	3	LI		
1982-D	2	4	6	C	707	110	0	1	0	3	LI		
1982-D	2	4	7	A	718	110	0	1	0	3	LI		
1982-D	2	4	7	C	718	110	0	1	0	3	LI		
1982-D	2	4	8	A	731	110	0	1	0	3	LI		
1982-D	2	4	8	C	731	110	0	1	0	3	LI		
1982-D	2	4	9	A	744	110	0	1	0	3	LI		
1982-D	2	4	9	C	744	110	0	1	0	3	LI		
1982-D	2	4	10	A	756	110	0	1	0	3	LI		
1982-D	2	4	10	C	756	110	0	1	0	3	LI		
1982-D	2	4	11	A	809	110	0	1	0	3	LI		
1982-D	2	4	11	C	809	110	0	1	0	3	LI		
1982-D	2	4	12	A	821	110	0	1	0	3	LI		
1982-D	2	4	12	C	821	110	0	1	0	3	LI		
1982-D	2	4	13	A	834	110	0	1	0	3	LI		
1982-D	2	4	13	C	834	110	0	1	0	3	LI		
1982-D	2	4	14	A	847	110	0	1	0	3	LI		
1982-D	2	4	14	C	847	110	0	1	0	3	LI		
1982-D	2	4	15	A	859	110	0	1	0	3	LI		
1982-D	2	4	15	C	859	110	0	1	0	3	LI		
1982-D	2	4	16	A	912	10	0	30	0	3	LI		
1982-D	2	4	16	C	912	10	0	3	0	3	LI		
2008-D	1	1	1	APM	619	110	0	0	0	1	TT		
2008-D	1	1	2	APM	605	30	0	0	0	2	TT		
2008-D	1	1	3	APM	552	20	0	0	0	2	TT		
2008-D	1	1	4	APM	641	40	0	0	1	1	LI	32	C
2008-D	1	1	4	APM	641	40	0	0	1	1	LI	21	C
2008-D	1	1	4	APM	641	40	0	0	1	1	LI	33	C
2008-D	1	1	5	APM	656	110	0	1	2	1	LI		
2008-D	1	1	6	APM	712	10	0	1	3	1	LI		
2008-D	1	1	7	APM	731	10	0	1	3	1	TT		
2008-D	1	1	8	APM	753	20	0	1	3	1	SF		
2008-D	1	1	9	APM	808	90	0	2	4	3	OF	45	C
2008-D	1	1	10	APM	827	70	0	1	3	2	SF		
2008-D	1	1	11	APM	846	50	0	2	4	3	OF		
2008-D	1	1	12	APM	903	50	0	1	3	1	SF		
2008-D	1	1	13	APM	920	30	0	1	3	1	LI		
2008-D	1	1	14	APM	939	30	0	2	4	3	OF		
2008-D	1	1	15	APM	955	60	0	1	4	2	SF		
2008-D	1	1	16	APM	1010	110	0	1	4	2	SF		
2008-D	1	2	1	SRK	601	30	0	1	3	2	SF		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2008-D	1	2	2	SRK	619	60	2	0	0	1	LI		
2008-D	1	2	3	SRK	636	60	0	1	2	1	LI		
2008-D	1	2	4	SRK	652	60	0	0	0	2	LI		
2008-D	1	2	5	SRK	708	50	0	1	2	2	LI		
2008-D	1	2	6	SRK	722	40	0	1	3	2	LI		
2008-D	1	2	7	SRK	737	60	0	2	3	2	LI		
2008-D	1	2	8	SRK	753	50	0	2	3	2	LI		
2008-D	1	2	9	SRK	811	60	0	1	2	2	LI		
2008-D	1	2	10	SRK	835	40	0	1	2	2	LI		
2008-D	1	2	11	SRK	857	40	0	1	2	2	LI		
2008-D	1	2	12	SRK	912	40	0	1	2	2	LI		
2008-D	1	2	13	SRK	932	40	0	1	0	2	LI		
2008-D	1	2	14	SRK	951	50	0	2	3	1	LI		
2008-D	1	2	15	SRK	1004	60	0	1	3	2	LI		
2008-D	1	2	16	SRK	1017	60	0	1	2	2	LI		
2008-D	1	3	1	SRK	603	50	0	1	2	3	TT		
2008-D	1	3	2	SRK	617	50	0	1	2	1	LI		
2008-D	1	3	3	SRK	631	50	0	0	1	1	LI		
2008-D	1	3	4	SRK	644	40	0	1	2	1	LI		
2008-D	1	3	5	SRK	706	40	0	0	1	1	LI		
2008-D	1	3	6	SRK	720	40	0	1	2	1	LI		
2008-D	1	3	7	SRK	735	50	0	1	2	2	SF		
2008-D	1	3	8	SRK	748	50	0	0	1	2	LI		
2008-D	1	3	9	SRK	802	50	0	0	1	1	LI		
2008-D	1	3	10	SRK	816	50	0	1	3	2	LI		
2008-D	1	3	11	SRK	831	50	0	1	3	2	LI		
2008-D	1	3	12	SRK	849	40	0	1	2	2	LI		
2008-D	1	3	13	SRK	905	40	0	1	2	2	LI		
2008-D	1	3	14	SRK	919	40	0	1	3	2	LI		
2008-D	1	3	15	SRK	936	60	0	0	2	2	LI		
2008-D	1	3	16	SRK	1032	100	0	0	0	2	LI		
2008-D	1	3	17	SRK	1043	80	0	0	0	2	LI		
2008-D	1	3	18	SRK	1053	70	0	0	0	1	SF		
2008-D	1	4	1	APM	554	90	0	1	3	2	LI		
2008-D	1	4	2	APM	612	80	0	1	3	2	LI		
2008-D	1	4	3	APM	632	70	0	1	3	1	LI	18	C
2008-D	1	4	3	APM	632	70	0	1	3	1	LI	14	C
2008-D	1	4	4	APM	652	40	0	2	4	1	LI		
2008-D	1	4	5	APM	721	50	0	1	3	1	LI	37	C
2008-D	1	4	6	APM	746	30	0	1	2	2	LI	24	C
2008-D	1	4	7	APM	802	30	0	1	3	2	LI		
2008-D	1	4	8	APM	820	20	0	1	2	2	LI	46	C
2008-D	1	4	9	APM	836	10	0	0	2	1	LI		
2008-D	1	4	10	APM	854	40	0	0	2	1	LI		
2008-D	1	4	11	APM	913	30	0	0	2	1	LI	28	C
2008-D	1	4	12	APM	932	50	0	0	2	2	LI	24	C
2008-D	1	4	12	APM	932	50	0	0	2	2	LI	33	C
2008-D	1	4	13	APM	640	20	0	0	1	2	LI		
2008-D	1	4	14	APM	656	0	0	0	2	1	LI	37	C
2008-D	1	4	15	APM	722	20	0	0	2	1	LI		
2008-D	1	4	16	APM	741	20	0	0	2	1	LI		
2008-D	1	5	1	SRK	640	30	0	0	0	3	SF		
2008-D	1	5	2	SRK	624	40	0	0	1	2	TT		
2008-D	1	5	3	SRK	610	30	0	0	1	1	SF	28	C

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2008-D	1	5	4	SRK	718	30	0	0	1	1	SF		
2008-D	1	5	5	SRK	706	40	0	1	2	1	SF		
2008-D	1	5	6	SRK	735	40	0	1	2	2	SF		
2008-D	1	5	7	SRK	748	40	0	1	2	1	SF		
2008-D	1	5	8	SRK	801	20	0	1	3	1	SF		
2008-D	1	5	9	SRK	817	20	0	1	3	1	SF		
2008-D	1	5	10	SRK	831	20	0	1	3	2	LI		
2008-D	1	5	11	SRK	844	10	0	0	1	1	SF		
2008-D	1	5	12	SRK	859	10	0	0	3	1	SF		
2008-D	1	5	13	SRK	920	60	0	2	3	2	LI		
2008-D	1	5	14	SRK	937	80	0	1	3	1	SF		
2009-P	4	1	1	FAA	845	30	0	2	3	3	TT		
2009-D	1	1	1	FAA	938	90	0	2	3	3	TT		
2009-P	4	1	1	FAA	1405	80	0	3	4	3	TT		
2009-P	4	1	1	FAA	1443	90	0	2	3	3	TT		
2009-P	4	1	1	RJC	719	30	0	1	0	3	TT	130	C
2009-P	7	1	2	APM	1746	100	0	1	3	3	TT	117	C
2009-P	7	1	2	APM	1746	100	0	1	3	3	TT	103	C
2009-P	7	1	2	FAA	833	20	0	1	2	3	TT		
2009-D	1	1	2	FAA	925	80	0	1	2	3	TT		
2009-P	7	1	2	FAA	1114	80	0	2	3	3	TT		
2009-P	7	1	2	FAA	1354	70	0	2	3	3	TT		
2009-P	7	1	2	FAA	1454	90	2	1	0	3	TT		
2009-P	7	1	2	FAA	1614	70	2	1	2	3	TT		
2009-P	7	1	2	RJC	731	40	0	1	0	3	TT		
2009-P	7	1	3	APM	1734	100	0	2	3	3	TT		
2009-P	7	1	3	FAA	821	50	0	1	2	3	TT		
2009-D	1	1	3	FAA	913	80	0	1	2	3	TT		
2009-P	7	1	3	FAA	1127	80	0	2	3	3	TT		
2009-P	7	1	3	FAA	1343	70	0	1	2	3	TT		
2009-P	7	1	3	FAA	1509	90	2	1	2	3	TT		
2009-P	7	1	3	FAA	1603	80	2	2	3	3	TT	83	C
2009-P	7	1	3	RJC	742	50	0	1	3	3	TT		
2009-P	7	1	4	APM	1721	100	0	0	2	1	LI		
2009-P	7	1	4	FAA	808	110	0	1	0	2	LI		
2009-D	1	1	4	FAA	900	80	0	1	2	2	LI		
2009-P	7	1	4	FAA	1140	90	0	2	3	2	LI		
2009-P	7	1	4	FAA	1332	90	0	2	3	2	LI		
2009-P	7	1	4	FAA	1522	20	0	0	1	2	LI		
2009-P	7	1	4	FAA	1543	30	0	2	3	2	LI		
2009-P	7	1	4	RJC	755	30	0	0	2	2	SF		
2009-P	7	1	5	APM	739	40	0	1	4	1	LI		
2009-P	7	1	5	FAA	754	60	0	1	2	2	LI	24	V
2009-D	1	1	5	FAA	847	70	0	1	2	2	LI		
2009-P	7	1	5	FAA	1157	90	0	2	3	2	LI		
2009-P	7	1	5	FAA	1321	80	0	2	4	2	LI	14	V
2009-P	7	1	5	FAA	1531	10	0	1	2	2	LI		
2009-P	7	1	5	FAA	1536	20	0	0	1	2	LI		
2009-P	7	1	5	RJC	1713	90	0	2	4	1	SF		
2009-P	7	1	6	APM	718	30	0	1	3	1	LI		
2009-P	7	1	6	FAA	741	70	0	2	3	2	LI		
2009-D	1	1	6	FAA	834	80	0	1	2	2	LI		
2009-P	7	1	6	FAA	1220	100	0	2	3	2	LI		
2009-P	7	1	6	FAA	1311	50	0	1	3	2	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2009-P	7	1	6	FAA	1549	50	0	1	2	2	LI		
2009-P	7	1	6	FAA	1639	80	0	2	3	2	LI		
2009-P	7	1	6	RJC	1724	100	0	2	4	1	LI	22	V
2009-P	7	1	7	APM	705	30	0	2	4	3	TT		
2009-P	7	1	7	FAA	729	60	0	2	3	3	TT		
2009-D	1	1	7	FAA	805	80	0	2	3	3	TT		
2009-P	7	1	7	FAA	1233	60	0	2	3	3	TT		
2009-P	7	1	7	FAA	1259	70	0	2	4	3	TT		
2009-P	7	1	7	FAA	1602	60	0	2	3	3	TT		
2009-P	7	1	7	FAA	1652	70	0	2	3	3	TT		
2009-P	7	1	7	RJC	1736	90	0	3	5	3	TT		
2009-D	1	1	8	FAA	818	80	0	2	3	2	TT		
2009-P	2	1	8	FAA	1248	50	0	2	3	2	TT		
2009-P	2	1	8	FAA	1705	50	0	2	3	2	TT		
2009-D	1	1	9	FAA	747	80	0	2	3	3	OF		
2009-P	2	1	9	FAA	1302	40	0	2	3	3	OF	212	C
2009-P	2	1	9	FAA	1717	70	0	1	2	3	OF		
2009-D	1	1	10	FAA	734	70	0	2	3	3	OF		
2009-P	2	1	10	FAA	1317	20	0	1	2	3	OF		
2009-P	2	1	10	FAA	1731	60	0	1	2	3	OF		
2009-D	1	1	11	FAA	722	60	0	2	3	3	SF		
2009-D	1	1	12	FAA	709	50	0	1	2	3	SF		
2009-D	1	1	13	FAA	654	50	0	2	3	2	LI	23	C
2009-D	1	1	14	FAA	641	40	0	2	3	3	OF	217	C
2009-D	1	1	15	FAA	630	70	0	2	3	3	OF	208	C
2009-D	1	1	16	FAA	619	90	0	2	3	3	OF		
2009-D	1	2	1	PMR	1025	100	0	1	2	2	SF		
2009-D	1	2	2	PMR	1005	100	0	2	3	1	SF		
2009-D	1	2	3	PMR	947	80	0	1	1	1	SF		
2009-D	1	2	4	PMR	912	90	0	1	0	2	LI	23	C
2009-D	1	2	4	PMR	912	90	0	1	0	2	LI	85	C
2009-D	1	2	5	PMR	853	100	0	1	0	2	LI	9	V
2009-P	7	2	6	APM	857	50	0	0	2	2	LI		
2009-P	7	2	6	APM	1320	40	0	1	2	2	LI		
2009-P	7	2	6	APM	1419	90	0	1	3	2	LI		
2009-P	7	2	6	FAA	733	20	0	1	2	2	LI		
2009-P	7	2	6	FAA	1104	10	0	1	3	2	LI		
2009-P	7	2	6	KB	1400	60	0	2	4	3	LI		
2009-D	1	2	6	PMR	839	100	0	2	3	3	LI		
2009-P	7	2	6	PMR	1127	100	0	2	3	3	LI		
2009-P	7	2	7	APM	827	30	0	1	3	2	LI		
2009-P	7	2	7	APM	1303	40	0	1	3	2	LI		
2009-P	7	2	7	APM	1438	20	0	2	3	2	LI		
2009-P	7	2	7	FAA	716	30	0	2	2	2	LI		
2009-P	7	2	7	FAA	1127	10	0	2	3	2	LI		
2009-P	7	2	7	KB	1424	50	0	3	4	3	LI		
2009-D	1	2	7	PMR	821	100	0	2	3	3	LI	47	C
2009-P	7	2	7	PMR	1225	90	0	1	0	3	LI		
2009-P	7	2	8	APM	748	20	0	2	3	2	LI		
2009-P	7	2	8	APM	1240	30	0	2	3	2	LI		
2009-P	7	2	8	APM	1500	10	0	1	2	2	LI		
2009-P	7	2	8	FAA	659	40	0	2	3	2	LI		
2009-P	7	2	8	FAA	1152	0	0	2	3	2	LI		
2009-P	7	2	8	KB	1500	30	0	2	4	2	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2009-D	1	2	8	PMR	805	100	0	2	2	2	LI		
2009-P	7	2	8	RJC	1235	100	0	1	2	1	LI		
2009-P	8	2	9	APM	729	20	0	1	2	2	LI		
2009-P	8	2	9	APM	1217	90	0	0	2	2	LI		
2009-P	8	2	9	APM	1519	10	0	2	3	2	LI		
2009-P	8	2	9	FAA	646	30	0	1	2	2	LI		
2009-P	8	2	9	FAA	1212	0	0	2	3	2	LI		
2009-P	8	2	9	KB	1532	100	0	3	4	2	LI		
2009-D	1	2	9	PMR	747	90	0	1	1	2	LI		
2009-P	8	2	9	RJC	1129	100	0	1	3	1	LI		
2009-P	8	2	9	RJC	1404	100	0	0	0	1	LI		
2009-P	8	2	10	APM	714	40	0	1	1	2	LI		
2009-P	8	2	10	APM	1147	90	0	1	3	2	LI		
2009-P	8	2	10	APM	1544	10	0	1	3	2	LI		
2009-P	8	2	10	FAA	1516	60	0	2	3	2	LI		
2009-P	8	2	10	KB	848	20	0	2	3	3	LI		
2009-P	8	2	10	KB	1300	0	0	2	3	3	LI	40	C
2009-D	1	2	10	PMR	731	90	0	2	2	2	LI	65	C
2009-P	8	2	10	RJC	1044	100	0	0	1	1	LI		
2009-P	8	2	11	APM	700	20	0	0	0	2	LI		
2009-P	8	2	11	APM	1110	90	0	1	0	2	LI		
2009-P	8	2	11	APM	1620	90	0	0	0	2	LI		
2009-P	8	2	11	FAA	1458	50	0	2	4	2	LI		
2009-P	8	2	11	KB	823	20	0	2	3	2	LI		
2009-P	8	2	11	KB	1204	0	0	3	4	2	LI		
2009-D	1	2	11	PMR	718	90	0	2	0	2	LI		
2009-P	8	2	11	RJC	959	90	0	0	2	1	LI		
2009-P	8	2	11	RJC	1511	100	0	0	0	1	LI		
2009-P	8	2	12	APM	644	40	0	0	1	2	LI	88	C
2009-P	8	2	12	APM	1049	50	0	1	3	2	LI		
2009-P	8	2	12	APM	1642	90	0	0	1	2	LI		
2009-P	8	2	12	FAA	1436	40	0	2	4	2	LI		
2009-P	8	2	12	KB	941	0	0	2	3	3	LI		
2009-P	8	2	12	KB	1119	0	0	3	4	3	LI		
2009-D	1	2	12	PMR	705	100	0	1	0	2	LI		
2009-P	8	2	12	RJC	837	100	1	0	0	1	LI		
2009-P	8	2	12	RJC	1557	100	0	0	0	1	LI	34	C
2009-P	8	2	13	APM	629	80	0	0	0	2	LI	41	C
2009-P	8	2	13	APM	1026	60	0	1	3	2	LI		
2009-P	8	2	13	APM	1658	90	0	0	1	2	LI		
2009-P	8	2	13	FAA	1421	20	0	2	4	2	LI		
2009-P	8	2	13	KB	741	100	0	2	3	2	LI		
2009-P	8	2	13	KB	1051	0	0	2	3	2	LI		
2009-D	1	2	13	PMR	649	100	0	1	0	2	LI		
2009-P	8	2	13	RJC	721	100	0	0	0	1	LI	6	V
2009-P	8	2	13	RJC	1629	100	0	0	0	1	LI		
2009-P	8	2	14	APM	612	50	0	0	0	2	LI		
2009-P	8	2	14	APM	1004	60	0	1	3	2	LI		
2009-P	8	2	14	APM	1716	60	0	0	0	2	LI		
2009-P	8	2	14	FAA	1405	20	0	2	4	2	LI		
2009-P	8	2	14	KB	629	70	0	0	1	2	LI		
2009-P	8	2	14	KB	1013	0	0	3	4	2	LI		
2009-D	1	2	14	PMR	631	100	0	1	0	3	LI		
2009-P	8	2	14	RJC	606	100	0	0	0	1	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2009-P	8	2	14	RJC	1708	100	0	0	0	1	LI		
2009-D	1	2	15	PMR	618	100	0	1	0	3	LI		
2009-D	1	2	16	PMR	606	100	0	1	0	3	LI		
2009-D	1	3	1	FAA	609	100	0	2	3	3	TT		
2009-P	7	3	1	KB	835	100	0	3	4	3	TT		
2009-P	7	3	1	KB	1209	100	3	2	3	3	TT		
2009-P	7	3	1	KB	1649	100	0	1	2	3	TT		
2009-P	7	3	1	PMR	619	60	0	2	3	3	TT	110	C
2009-P	7	3	1	PMR	631	90	0	2	4	3	TT	113	C
2009-P	7	3	1	PMR	631	90	0	2	4	3	TT	127	C
2009-P	7	3	1	PMR	1347	50	0	2	3	3	TT		
2009-P	7	3	1	PMR	1639	60	0	2	3	3	TT		
2009-D	1	3	2	FAA	623	100	0	1	2	2	LI	130	C
2009-D	1	3	2	FAA	623	100	0	1	2	2	LI	47	C
2009-P	7	3	2	KB	817	100	0	3	4	2	LI		
2009-P	7	3	2	KB	1228	90	0	3	5	2	LI		
2009-P	7	3	2	KB	1613	100	0	1	2	2	LI	40	C
2009-P	7	3	2	PMR	637	60	0	2	3	2	LI		
2009-P	7	3	2	PMR	648	100	0	2	3	3	LI	107	C
2009-P	7	3	2	PMR	1146	70	0	1	2	2	LI		
2009-P	7	3	2	PMR	1619	60	0	1	2	2	LI		
2009-D	1	3	3	FAA	635	100	0	1	2	2	LI	83	C
2009-P	7	3	3	FAA	1447	100	0	1	2	2	LI		
2009-P	7	3	3	KB	800	100	0	3	4	2	LI		
2009-P	7	3	3	KB	1246	100	2	4	5	2	LI		
2009-P	7	3	3	PMR	653	40	0	1	2	2	LI	46	C
2009-P	7	3	3	PMR	653	40	0	1	2	2	LI	46	C
2009-P	7	3	3	PMR	702	80	0	2	3	2	LI	37	C
2009-P	7	3	3	PMR	702	80	0	2	3	2	LI	37	C
2009-P	7	3	3	PMR	1200	70	0	1	2	2	LI		
2009-P	7	3	3	PMR	1603	70	1	2	3	2	LI		
2009-D	1	3	4	FAA	647	100	0	2	3	2	LI	68	C
2009-D	1	3	4	FAA	647	100	0	2	3	2	LI	146	C
2009-D	1	3	4	FAA	647	100	0	2	3	2	LI	54	C
2009-P	7	3	4	FAA	1600	100	0	2	3	2	LI		
2009-P	7	3	4	KB	742	100	0	2	3	2	LI		
2009-P	7	3	4	KB	1312	110	2	2	3	2	LI		
2009-P	7	3	4	PMR	716	40	0	1	3	3	LI		
2009-P	7	3	4	PMR	801	70	0	2	3	3	LI		
2009-P	7	3	4	PMR	1215	70	0	1	3	3	LI		
2009-P	7	3	4	PMR	1545	50	2	2	4	3	LI		
2009-D	1	3	5	FAA	707	100	0	2	3	2	LI		
2009-D	1	3	6	FAA	724	100	0	1	2	2	LI		
2009-D	1	3	7	FAA	735	100	0	2	3	2	LI		
2009-D	1	3	8	FAA	747	100	0	1	2	2	LI		
2009-D	1	3	9	FAA	759	100	0	2	3	2	LI		
2009-D	1	3	10	FAA	810	100	0	2	3	2	LI		
2009-D	1	3	11	FAA	822	100	0	2	3	2	LI		
2009-D	1	3	12	FAA	832	100	0	2	3	2	LI		
2009-D	1	3	13	FAA	846	100	1	2	3	2	LI		
2009-D	1	3	14	FAA	857	100	0	2	3	2	LI		
2009-D	1	3	15	FAA	909	100	0	2	3	3	LI		
2009-D	1	3	16	FAA	920	100	2	3	4	2	LI		
2009-D	1	3	17	FAA	938	100	2	2	3	2	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2009-D	1	3	18	FAA	950	100	2	2	3	2	LI		
2009-D	1	4	1	APM	600	100	0	0	0	2	LI	28	C
2009-P	11	4	1	APM	619	20	0	1	4	2	LI	29	C
2009-P	11	4	1	APM	1210	40	0	1	4	2	LI		
2009-P	11	4	1	APM	1412	100	2	1	1	2	LI		
2009-P	11	4	1	APM	1539	50	0	1	3	2	LI	29	C
2009-P	11	4	1	APM	1539	50	0	1	3	2	LI	27	C
2009-P	11	4	1	PMR	654	20	0	1	3	3	LI		
2009-P	11	4	1	PMR	1309	0	0	2	3	3	LI	52	C
2009-P	11	4	1	PMR	1710	80	0	2	4	3	LI		
2009-P	11	4	1	RJC	719	80	0	1	3	2	LI		
2009-P	11	4	1	RJC	948	70	0	2	3	1	LI		
2009-P	11	4	1	RJC	1012	50	0	1	3	2	LI	31	C
2009-P	11	4	1	RJC	1708	50	0	2	3	1	LI	38	C
2009-D	1	4	2	APM	615	100	0	1	3	2	LI		
2009-P	11	4	2	APM	635	20	0	1	3	2	LI		
2009-P	11	4	2	APM	1225	30	0	2	4	2	LI		
2009-P	11	4	2	APM	1423	100	0	1	3	2	LI		
2009-P	11	4	2	APM	1441	100	0	1	2	2	LI		
2009-P	11	4	2	PMR	1011	0	0	2	4	3	LI		
2009-P	11	4	2	PMR	1209	10	0	2	3	3	LI		
2009-P	11	4	2	PMR	1736	10	0	2	4	3	LI		
2009-P	11	4	2	RJC	745	20	0	1	3	2	LI		
2009-P	11	4	2	RJC	1002	80	0	2	4	1	LI		
2009-P	11	4	2	RJC	1024	40	0	1	2	2	LI		
2009-P	11	4	2	RJC	1719	30	0	1	3	1	LI		
2009-D	1	4	3	APM	631	100	0	2	4	1	LI		
2009-P	10	4	3	APM	652	40	0	2	4	1	LI		
2009-P	10	4	3	APM	1243	50	0	1	3	1	LI		
2009-P	10	4	3	APM	1440	90	0	1	3	1	LI		
2009-P	10	4	3	APM	1504	100	0	2	3	1	LI		
2009-P	10	4	3	PMR	1026	10	0	3	4	1	SF		
2009-P	10	4	3	PMR	1113	10	0	2	4	1	SF		
2009-P	10	4	3	RJC	759	50	0	2	4	1	LI		
2009-P	10	4	3	RJC	1017	60	0	3	4	1	LI	32	C
2009-P	10	4	3	RJC	1100	20	0	1	3	1	LI		
2009-P	10	4	3	RJC	1731	60	0	1	0	1	LI		
2009-D	1	4	4	APM	648	100	0	3	4	1	LI		
2009-P	10	4	4	APM	708	60	0	2	4	1	LI		
2009-P	10	4	4	APM	1301	60	0	2	4	1	LI		
2009-P	10	4	4	APM	1505	100	0	0	3	1	LI		
2009-P	10	4	4	APM	1532	100	0	1	3	1	LI	37	C
2009-P	10	4	4	PMR	1048	10	0	2	4	2	SF		
2009-P	10	4	4	PMR	1133	10	0	2	4	2	SF		
2009-P	10	4	4	RJC	813	40	0	3	4	1	SF		
2009-P	10	4	4	RJC	1031	60	0	3	4	1	LI		
2009-P	10	4	4	RJC	1042	20	0	1	3	1	SF		
2009-P	10	4	4	RJC	1742	80	0	2	4	1	LI		
2009-D	1	4	5	APM	716	100	0	2	4	1	LI		
2009-D	1	4	6	APM	734	90	0	1	3	2	LI		
2009-D	1	4	7	APM	746	90	0	1	3	2	LI	45	C
2009-D	1	4	8	APM	800	100	0	1	1	2	LI	39	C
2009-D	1	4	9	APM	812	100	0	1	2	2	LI		
2009-D	1	4	10	APM	824	100	0	0	2	2	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2009-D	1	4	11	APM	837	90	0	1	3	2	LI		
2009-D	1	4	12	APM	851	90	0	1	2	2	LI		
2009-D	1	4	13	APM	903	90	0	1	3	2	LI		
2009-D	1	4	14	APM	916	90	0	1	3	1	LI		
2009-D	1	4	15	APM	932	90	2	1	2	1	LI		
2009-D	1	4	16	APM	952	90	0	1	3	1	LI	41	C
2009-D	1	4	20	APM	752	20	0	0	2	2	LI	20	V
2009-P	8	4	20	APM	1146	0	0	2	4	2	LI		
2009-P	8	4	20	APM	1600	80	0	1	0	2	LI		
2009-P	8	4	20	PMR	714	40	0	2	3	3	LI		
2009-P	8	4	20	PMR	1357	10	0	3	4	3	LI		
2009-P	8	4	20	PMR	1722	100	0	3	4	3	LI		
2009-P	8	4	20	RJC	620	60	0	2	3	2	LI	68	C
2009-P	8	4	20	RJC	624	50	0	0	0	1	LI		
2009-P	8	4	20	RJC	1654	40	0	2	0	1	LI	80	C
2009-P	8	4	20	RJC	1654	40	0	2	0	1	LI	50	C
2009-D	1	4	21	APM	808	50	0	2	4	1	LI		
2009-P	6	4	21	APM	1132	0	0	2	5	1	LI		
2009-P	6	4	21	APM	1614	90	0	2	4	1	LI		
2009-P	6	4	21	PMR	1644	60	0	3	5	2	LI		
2009-P	6	4	21	RJC	633	90	0	2	3	2	LI		
2009-P	6	4	21	RJC	641	50	0	1	2	1	LI		
2009-P	6	4	21	RJC	1644	80	0	2	4	1	LI		
2009-D	1	4	22	APM	822	110	0	1	4	2	LI	27	C
2009-P	7	4	22	APM	1118	10	0	2	4	2	LI		
2009-P	7	4	22	APM	1627	80	0	0	2	2	LI		
2009-P	7	4	22	PMR	1436	40	0	3	4	2	LI		
2009-P	7	4	22	PMR	1629	60	0	3	5	2	LI		
2009-P	7	4	22	RJC	645	80	0	2	3	2	LI	34	C
2009-P	7	4	22	RJC	659	40	0	1	2	1	LI		
2009-P	7	4	22	RJC	1633	80	0	2	3	1	LI		
2009-D	1	4	23	APM	838	10	0	2	4	2	LI		
2009-P	7	4	23	APM	1102	10	0	2	4	2	LI		
2009-P	7	4	23	APM	1646	80	0	0	2	2	LI		
2009-P	7	4	23	PMR	1500	80	0	3	4	3	LI		
2009-P	7	4	23	PMR	1615	40	0	3	5	3	LI		
2009-P	7	4	23	RJC	657	100	0	2	4	2	LI		
2009-P	7	4	23	RJC	717	50	0	0	2	1	LI		
2009-P	7	4	23	RJC	1619	50	0	0	0	1	LI	83	C
2009-P	7	8	1	FAA	1421	100	0	1	2	2	LI		
2009-P	7	8	1	KB	941	90	2	1	0	2	LI		
2009-P	7	8	1	KB	1034	100	0	3	4	2	LI		
2009-D	1	8	1	PMR	751	70	0	1	3	3	LI		
2009-P	7	8	1	PMR	842	20	0	2	3	3	LI		
2009-P	7	8	1	PMR	1035	20	0	2	3	3	LI		
2009-P	7	8	1	PMR	1319	30	0	2	3	3	LI		
2009-P	7	8	1	PMR	1514	20	0	2	3	3	LI		
2009-P	7	10	1	APM	1422	0	0	2	4	2	LI		
2009-P	7	10	1	FAA	959	10	0	3	4	2	LI		
2009-P	7	10	1	FAA	1247	60	0	3	4	2	LI		
2009-D	1	10	1	KB	844	60	0	1	2	3	LI		
2009-P	7	10	1	KB	1158	80	0	2	3	2	LI		
2009-P	7	10	1	KB	1554	100	3	2	3	3	LI		
2009-P	7	10	1	RJC	923	0	0	1	2	2	LI		

Yr_Srvy	Effort	Tran	Stn	Obs	TStrt	C	R	W	G	O	Hab	Dist	DTyp
2009-P	7	10	1	RJC	1103	0	0	1	2	2	LI		
2009-P	7	10	2	APM	924	0	0	2	4	1	SF	119	C
2009-P	7	10	2	APM	1211	0	0	1	4	1	SF		
2009-P	7	10	2	FAA	942	20	0	2	4	1	LI	56	C
2009-P	7	10	2	FAA	1209	70	0	1	3	1	LI		
2009-D	1	10	2	KB	756	90	0	2	3	2	SF	2	V
2009-D	1	10	2	KB	756	90	0	2	3	2	SF	2	V
2009-P	7	10	2	KB	1043	60	0	2	3	2	SF		
2009-P	7	10	2	KB	1459	10	0	2	3	2	SF	30	C
2009-P	7	10	2	KB	1459	10	0	2	3	2	SF	30	C
2009-P	7	10	2	KB	1459	10	0	2	3	2	SF	60	C
2009-P	7	10	2	RJC	1400	20	0	2	4	1	SF	43	C
2009-P	7	10	2	RJC	1400	20	0	2	4	1	SF	29	C
2009-P	7	10	3	APM	941	0	0	0	2	2	LI	11	V
2009-D	1	10	3	APM	1116	0	0	0	2	2	LI	15	C
2009-D	1	10	3	APM	1116	0	0	0	2	2	LI	23	C
2009-D	1	10	3	APM	1116	0	0	0	2	2	LI	31	C
2009-P	7	10	3	FAA	934	110	0	1	0	2	LI		
2009-P	7	10	3	FAA	1129	20	0	1	4	2	LI	70	C
2009-P	7	10	3	FAA	1129	20	0	1	4	2	LI	19	V
2009-P	7	10	3	KB	921	90	0	1	2	3	LI		
2009-P	7	10	3	KB	1127	60	0	1	0	3	LI	70	C
2009-P	7	10	3	KB	1524	10	0	2	3	3	LI		
2009-P	7	10	3	RJC	1638	80	0	1	2	2	LI		

Appendix 2 – UTM coordinates for the point-transect and occupancy stations on the island of Aguiguan. All coordinates are in WGS84 UTM Zone 5 North. Transects 1 through 4 were established by Engbring *et al.* (1986) in 1982, transect 5 was established in 2008, and the remaining transects were established in 2009.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	342821.65	1642070.79	3	7	345909.87	1642154.48	5	7	345288.56	1642704.19
1	2	342908.96	1641962.31	3	8	346031.58	1642244.44	5	8	345449.04	1642780.42
1	3	342940.71	1641827.37	3	9	346155.94	1642326.46	5	9	345609.51	1642856.64
1	4	342969.82	1641668.62	3	10	346282.94	1642405.84	5	10	345765.97	1642936.88
1	5	343067.71	1641549.56	3	11	346401.47	1642490.79	5	11	345910.39	1643001.07
1	6	343205.30	1641626.28	3	12	346531.12	1642578.10	5	12	346074.87	1643081.30
1	7	343369.34	1641631.58	3	13	346644.89	1642697.17	5	13	346235.35	1643165.55
1	8	343512.21	1641599.83	3	14	346684.57	1642834.75	5	14	346375.76	1643241.77
1	9	343655.09	1641631.58	3	15	346711.03	1642980.27	7	1	345631.36	1641931.79
1	10	343790.03	1641684.49	3	16	346748.07	1643128.44	7	2	345509.83	1641880.18
1	11	343922.32	1641716.24	3	17	346800.99	1643276.60	7	3	345402.17	1641785.64
1	12	344078.42	1641750.64	3	18	346822.16	1643414.19	7	4	345247.31	1641709.01
1	13	343914.38	1641811.49	4	1	344099.59	1642623.12	7	5	345098.04	1641672.92
1	14	343779.44	1641890.87	4	2	344216.01	1642710.43	8	1	345323.51	1642244.38
1	15	343803.26	1642009.93	4	3	344343.01	1642803.04	8	2	345432.67	1642376.61
1	16	343951.42	1642070.79	4	4	344472.65	1642898.29	8	3	345565.76	1642474.12
2	1	342832.23	1642210.31	4	5	344594.36	1642980.31	8	4	345684.43	1642598.87
2	2	342948.65	1642305.56	4	6	344713.42	1643067.62	8	5	345765.57	1642730.30
2	3	343062.42	1642408.75	4	7	344853.65	1643125.83	10	1	343303.37	1641760.51
2	4	343173.55	1642511.94	4	8	344996.53	1643197.27	10	2	343122.78	1641757.77
2	5	343292.61	1642609.83	4	9	345126.17	1643255.48	10	3	343161.80	1641891.83
2	6	343416.96	1642675.98	4	10	345271.70	1643318.98	11	1	344742.62	1642832.68
2	7	343570.42	1642707.73	4	11	345403.99	1643371.89	11	2	344898.95	1642873.35
2	8	343721.23	1642747.42	4	12	345544.22	1643440.68	11	3	345038.24	1642958.31
2	9	343872.05	1642779.17	4	13	345681.80	1643501.54	11	4	345205.96	1642982.21
2	10	344022.86	1642824.14	4	14	345816.21	1643567.71	11	5	345333.26	1643087.17
2	11	344152.51	1642898.23	4	15	345953.79	1643628.56	11	6	345441.49	1643209.50
2	12	344287.71	1642974.96	4	16	346094.02	1643689.42	11	7	345576.38	1643295.98
2	13	344409.42	1643049.04	4	17	343965.34	1642553.18	11	8	345724.44	1643364.50
2	14	344552.29	1643115.19	4	18	343847.66	1642460.72	11	9	345890.64	1643380.83
2	15	344684.58	1643194.56	4	19	343700.29	1642434.21	11	10	346054.83	1643387.99
2	16	344819.79	1643249.86	4	20	343550.24	1642390.97	11	11	346214.14	1643341.24
3	1	345028.81	1642109.50	5	1	344422.02	1642262.90	20	1	343062.56	1642028.31
3	2	345187.56	1642104.21	5	2	344562.43	1642335.11	20	2	343150.72	1642247.20
3	3	345338.37	1642093.63	5	3	344718.89	1642411.33	20	3	343265.99	1642355.41
3	4	345481.25	1642090.98	5	4	344855.29	1642487.56	20	4	343375.81	1642470.80
3	5	345640.00	1642072.46	5	5	344983.67	1642551.75	20	5	343461.89	1642603.88
3	6	345782.87	1642075.11	5	6	345148.15	1642623.96				

Appendix 3 – Interesting Observations

Band Re-sighting

Of the 16 megapodes color banded in August 2008, only 1 re-sighting (RWRA) was confirmed in July 2009. The color banded megapode was band number 1096-96505, color combination Red over White (left leg) and Red over Aluminum (Right leg). It was observed with an unbanded bird and was recorded in the same area where it was banded in August 2008. This bird was paired with another banded bird in 2008 but this bird was not observed. At least two megapodes were observed with only aluminum bands indicating that some of the banded birds removed their plastic color bands. We believe that additional banded birds were also likely present on the island. However, evasive behaviors by the banded birds, and those thought to be banded but were unconfirmed, were regularly encountered during re-sighting efforts. These birds typically moved quickly away from the observer, once the presence of the observer was noted, or stayed in the thick brush limiting the ability to observe bands.

Based on the above observation we have several recommendations for future megapode banding. First, only metal or locking bands should be used for banding megapodes. Second, we recommend that all banding be conducted by personnel with their shapes disguised (e.g., covered in camouflage netting) so the banded birds don't associate the banding experience with humans. Finally, we recommend that all banding be conducted after population surveys for that year are completed and that different megapode recordings be used for audio lures for capturing megapodes than for surveys.

Juvenile Megapodes

Three juvenile megapodes were observed during the surveys. Two were observed in the southwestern part of the island on the bottom and middle terrace while the third was observed in the northwestern part of the island on the top terrace (see Figure 7 of the report for locations). All three birds appeared to be different ages based on size and plumage and all were observed in native forest. No interaction between juveniles and adults was noted, though at least one juvenile was observed in the territory of one pair. In addition, no obvious nest sites were observed in the areas around the juveniles.

Appendix 4. Estimated occupancy (ψ) and 95% confidence limits (lower and upper) for each sampled station the confidence set of models.

Model	Station	ψ	95%CI lower	95%CI upper
ψ(understory)p(.)	1-1	0.78	0.08	0.99
	1-2	0.78	0.08	0.99
	1-3	0.72	0.14	0.98
	1-4	0.65	0.23	0.92
	1-5	0.65	0.23	0.92
	1-6	0.65	0.23	0.92
	1-7	0.72	0.14	0.98
	1-8	0.65	0.23	0.92
	1-9	0.72	0.14	0.98
	1-10	0.78	0.08	0.99
	2-6	0.65	0.23	0.92
	2-7	0.65	0.23	0.92
	2-8	0.65	0.23	0.92
	2-9	0.65	0.23	0.92
	2-10	0.65	0.23	0.92
	2-11	0.65	0.23	0.92
	2-12	0.65	0.23	0.92
	2-13	0.65	0.23	0.92
	2-14	0.65	0.23	0.92
	3-1	0.83	0.04	1.00
	3-2	0.65	0.23	0.92
	3-3	0.65	0.23	0.92
	3-4	0.65	0.23	0.92
	4-1	0.65	0.23	0.92
	4-2	0.65	0.23	0.92
	4-3	0.58	0.35	0.78
	4-4	0.58	0.35	0.78
	4-20	0.65	0.23	0.92
	4-21	0.58	0.35	0.78
	4-22	0.65	0.23	0.92
	4-23	0.65	0.23	0.92
	8-1	0.72	0.14	0.98
	10-1	0.65	0.23	0.92
	10-2	0.65	0.23	0.92
	10-3	0.65	0.23	0.92
ψ(understory, elevation)p(.)	1-1	0.66	0.01	1.00
	1-2	0.69	0.01	1.00
	1-3	0.62	0.02	0.99
	1-4	0.57	0.07	0.96
	1-5	0.57	0.07	0.96
	1-6	0.62	0.15	0.94
	1-7	0.70	0.09	0.98
	1-8	0.65	0.22	0.93
	1-9	0.72	0.13	0.98
	1-10	0.80	0.07	1.00
	2-6	0.54	0.04	0.97
	2-7	0.54	0.04	0.97
	2-8	0.57	0.07	0.96

Model	Station	ψ	95%CI lower	95%CI upper
	2-9	0.57	0.07	0.96
	2-10	0.60	0.10	0.95
	2-11	0.60	0.10	0.95
	2-12	0.60	0.10	0.95
	2-13	0.60	0.10	0.95
	2-14	0.60	0.10	0.95
	3-1	0.93	0.01	1.00
	3-2	0.77	0.10	0.99
	3-3	0.75	0.11	0.99
	3-4	0.70	0.16	0.97
	4-1	0.79	0.08	0.99
	4-2	0.79	0.08	0.99
	4-3	0.78	0.09	0.99
	4-4	0.78	0.09	0.99
	4-20	0.79	0.08	0.99
	4-21	0.73	0.14	0.98
	4-22	0.79	0.08	0.99
	4-23	0.77	0.10	0.99
	8-1	0.84	0.04	1.00
	10-1	0.65	0.22	0.93
	10-2	0.68	0.20	0.95
	10-3	0.75	0.11	0.99
ψ(elevation)p(.)	1-1	0.35	0.09	0.74
	1-2	0.38	0.14	0.70
	1-3	0.38	0.14	0.70
	1-4	0.41	0.20	0.66
	1-5	0.41	0.20	0.66
	1-6	0.47	0.38	0.56
	1-7	0.47	0.38	0.56
	1-8	0.50	0.49	0.51
	1-9	0.50	0.49	0.51
	1-10	0.53	0.45	0.60
	2-6	0.38	0.14	0.70
	2-7	0.38	0.14	0.70
	2-8	0.41	0.20	0.66
	2-9	0.41	0.20	0.66
	2-10	0.44	0.28	0.61
	2-11	0.44	0.28	0.61
	2-12	0.44	0.28	0.61
	2-13	0.44	0.28	0.61
	2-14	0.44	0.28	0.61
	3-1	0.72	0.16	0.97
	3-2	0.64	0.27	0.90
	3-3	0.61	0.31	0.85
	3-4	0.55	0.40	0.70
	4-1	0.67	0.23	0.93
	4-2	0.67	0.23	0.93
	4-3	0.72	0.16	0.97
	4-4	0.72	0.16	0.97
	4-20	0.67	0.23	0.93
	4-21	0.67	0.23	0.93

Model	Station	ψ	95%CI lower	95%CI upper
	4-22	0.67	0.23	0.93
	4-23	0.64	0.27	0.90
	8-1	0.67	0.23	0.93
	10-1	0.50	0.49	0.51
	10-2	0.53	0.45	0.60
	10-3	0.61	0.31	0.85
ψ(exposure)p(.)	1-1	0.70	0.34	0.91
	1-2	0.70	0.34	0.91
	1-3	0.70	0.34	0.91
	1-4	0.70	0.34	0.91
	1-5	0.70	0.34	0.91
	1-6	0.70	0.34	0.91
	1-7	0.70	0.34	0.91
	1-8	0.61	0.17	0.93
	1-9	0.61	0.17	0.93
	1-10	0.61	0.17	0.93
	2-6	0.70	0.34	0.91
	2-7	0.70	0.34	0.91
	2-8	0.70	0.34	0.91
	2-9	0.70	0.34	0.91
	2-10	0.70	0.34	0.91
	2-11	0.70	0.34	0.91
	2-12	0.70	0.34	0.91
	2-13	0.70	0.34	0.91
	2-14	0.70	0.34	0.91
	3-1	0.61	0.17	0.93
	3-2	0.61	0.17	0.93
	3-3	0.61	0.17	0.93
	3-4	0.61	0.17	0.93
	4-1	0.70	0.34	0.91
	4-2	0.70	0.34	0.91
	4-3	0.70	0.34	0.91
	4-4	0.70	0.34	0.91
	4-20	0.70	0.34	0.91
	4-21	0.70	0.34	0.91
	4-22	0.70	0.34	0.91
	4-23	0.70	0.34	0.91
	8-1	0.61	0.17	0.93
	10-1	0.70	0.34	0.91
	10-2	0.70	0.34	0.91
	10-3	0.70	0.34	0.91
ψ(habitat)p(.)	1-1	0.69	0.30	0.92
	1-2	0.69	0.30	0.92
	1-3	0.69	0.30	0.92
	1-4	0.69	0.30	0.92
	1-5	0.69	0.30	0.92
	1-6	0.69	0.30	0.92
	1-7	0.73	0.16	0.98
	1-8	0.73	0.16	0.98
	1-9	0.69	0.30	0.92
	1-10	0.73	0.16	0.98

Model	Station	ψ	95%CI lower	95%CI upper
	2-6	0.69	0.30	0.92
	2-7	0.69	0.30	0.92
	2-8	0.69	0.30	0.92
	2-9	0.69	0.30	0.92
	2-10	0.69	0.30	0.92
	2-11	0.69	0.30	0.92
	2-12	0.69	0.30	0.92
	2-13	0.69	0.30	0.92
	2-14	0.69	0.30	0.92
	3-1	0.73	0.16	0.98
	3-2	0.69	0.30	0.92
	3-3	0.69	0.30	0.92
	3-4	0.69	0.30	0.92
	4-1	0.69	0.30	0.92
	4-2	0.69	0.30	0.92
	4-3	0.69	0.30	0.92
	4-4	0.69	0.30	0.92
	4-20	0.69	0.30	0.92
	4-21	0.69	0.30	0.92
	4-22	0.69	0.30	0.92
	4-23	0.69	0.30	0.92
	8-1	0.69	0.30	0.92
	10-1	0.69	0.30	0.92
	10-2	0.69	0.30	0.92
	10-3	0.69	0.30	0.92
ψ(distance)p(.)	1-1	0.46	0.16	0.78
	1-2	0.49	0.41	0.57
	1-3	0.50	0.47	0.54
	1-4	0.51	0.45	0.56
	1-5	0.50	0.49	0.51
	1-6	0.52	0.35	0.69
	1-7	0.54	0.23	0.82
	1-8	0.54	0.25	0.80
	1-9	0.53	0.27	0.77
	1-10	0.53	0.29	0.76
	2-6	0.46	0.15	0.79
	2-7	0.47	0.23	0.72
	2-8	0.47	0.26	0.70
	2-9	0.47	0.23	0.73
	2-10	0.47	0.21	0.74
	2-11	0.46	0.17	0.78
	2-12	0.46	0.17	0.78
	2-13	0.45	0.15	0.80
	2-14	0.45	0.13	0.82
	3-1	0.56	0.15	0.90
	3-2	0.57	0.12	0.93
	3-3	0.56	0.15	0.90
	3-4	0.54	0.24	0.81
	4-1	0.52	0.36	0.67
	4-2	0.51	0.44	0.58
	4-3	0.50	0.47	0.54

Model	Station	ψ	95%CI lower	95%CI upper
	4-4	0.50	0.46	0.53
	4-20	0.53	0.29	0.76
	4-21	0.55	0.19	0.86
	4-22	0.54	0.21	0.84
	4-23	0.53	0.25	0.80
	8-1	0.59	0.05	0.97
	10-1	0.56	0.14	0.91
	10-2	0.55	0.17	0.88
	10-3	0.55	0.16	0.89
ψ(elevation, exposure)p(.)	1-1	0.56	0.05	0.97
	1-2	0.59	0.08	0.96
	1-3	0.59	0.08	0.96
	1-4	0.62	0.12	0.95
	1-5	0.62	0.12	0.95
	1-6	0.67	0.24	0.93
	1-7	0.67	0.24	0.93
	1-8	0.61	0.16	0.93
	1-9	0.61	0.16	0.93
	1-10	0.64	0.14	0.95
	2-6	0.59	0.08	0.96
	2-7	0.59	0.08	0.96
	2-8	0.62	0.12	0.95
	2-9	0.62	0.12	0.95
	2-10	0.65	0.17	0.94
	2-11	0.65	0.17	0.94
	2-12	0.65	0.17	0.94
	2-13	0.65	0.17	0.94
	2-14	0.65	0.17	0.94
	3-1	0.80	0.04	0.71
	3-2	0.74	0.07	0.82
	3-3	0.72	0.08	0.99
	3-4	0.66	0.12	0.97
	4-1	0.82	0.13	0.99
	4-2	0.82	0.13	0.99
	4-3	0.86	0.09	1.00
	4-4	0.86	0.09	1.00
	4-20	0.82	0.13	0.99
	4-21	0.82	0.13	0.99
	4-22	0.82	0.13	0.99
	4-23	0.81	0.16	0.99
	8-1	0.76	0.06	0.99
	10-1	0.70	0.33	0.92
	10-2	0.72	0.30	0.94
	10-3	0.79	0.19	0.98

Appendix 5. Megapode detections and site covariates used in occupancy analysis. Zeroes and ones indicate whether megapodes were detected in station visits 1 through 11. Habitat covariates are as follows: A – native forest; B – non-native forest; C – high exposure; D – low exposure; E – understory closure/openness; F – distance from coast (standardized); and G – elevation (standardized).

Station	Megapode Detection by Visit											Habitat Covariate						
	1	2	3	4	5	6	7	8	9	10	11	A	B	C	D	E	F	G
1-1	1	0	0	0	-	-	-	-	-	-	-	1	0	0	1	4	-1.051	-1.319
1-2	0	0	0	1	0	0	0	-	-	-	-	1	0	0	1	4	-0.246	-1.062
1-3	0	1	0	0	0	0	0	-	-	-	-	1	0	0	1	3	0.099	-1.062
1-4	0	0	0	0	0	0	0	-	-	-	-	1	0	0	1	2	0.158	-0.804
1-5	0	0	0	0	1	1	0	-	-	-	-	1	0	0	1	2	-0.021	-0.804
1-6	0	0	0	1	0	0	0	-	-	-	-	1	0	0	1	2	0.517	-0.289
1-7	0	0	0	0	0	0	0	-	-	-	-	0	1	0	1	3	0.985	-0.289
1-8	0	0	-	-	-	-	-	-	-	-	-	0	1	1	0	2	0.890	-0.031
1-9	1	0	-	-	-	-	-	-	-	-	-	1	0	1	0	3	0.797	-0.031
1-10	0	0	-	-	-	-	-	-	-	-	-	0	1	1	0	4	0.735	0.226
2-6	0	0	0	0	0	0	0	-	-	-	-	1	0	0	1	2	-1.098	-1.062
2-7	0	0	0	0	0	0	0	-	-	-	-	1	0	0	1	2	-0.779	-1.062
2-8	0	0	0	0	0	0	0	-	-	-	-	1	0	0	1	2	-0.671	-0.804
2-9	0	0	0	0	0	0	0	0	-	-	-	1	0	0	1	2	-0.800	-0.804
2-10	0	0	0	0	0	1	0	-	-	-	-	1	0	0	1	2	-0.856	-0.547
2-11	0	0	0	0	0	0	0	0	-	-	-	1	0	0	1	2	-1.044	-0.547
2-12	0	1	1	0	0	0	0	0	-	-	-	1	0	0	1	2	-1.029	-0.547
2-13	1	0	1	0	0	0	0	0	-	-	-	1	0	0	1	2	-1.144	-0.547
2-14	0	0	0	0	0	0	0	0	-	-	-	1	0	0	1	2	-1.259	-0.547
3-1	0	0	0	1	0	0	1	-	-	-	-	0	1	1	0	5	1.436	2.030
3-2	0	0	1	0	0	0	1	-	-	-	-	1	0	1	0	2	1.655	1.257
3-3	0	0	0	1	0	0	1	-	-	-	-	1	0	1	0	2	1.410	0.999
3-4	0	0	0	0	0	0	0	-	-	-	-	1	0	1	0	2	0.951	0.484
4-1	0	0	1	0	1	0	1	0	1	0	1	1	0	0	1	2	0.455	1.514
4-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0.204	1.514
4-3	0	1	0	0	0	0	0	0	0	0	-	1	0	0	1	1	0.113	2.030
4-4	1	0	0	0	0	0	0	0	0	0	-	1	0	0	1	1	-0.110	2.030
4-20	0	1	0	0	0	1	1	0	0	-	-	1	0	0	1	2	0.728	1.514
4-21	0	0	0	0	0	0	0	-	-	-	-	1	0	0	1	1	1.164	1.514
4-22	0	0	0	0	1	1	0	0	-	-	-	1	0	0	1	2	1.080	1.514
4-23	0	1	0	0	0	0	0	0	-	-	-	1	0	0	1	2	0.879	1.257
8-1	0	0	0	0	0	0	0	0	-	-	-	1	0	1	0	3	2.329	1.514
10-1	0	0	0	0	0	0	0	0	-	-	-	1	0	0	1	2	1.511	-0.031
10-2	1	0	1	1	0	1	1	0	-	-	-	1	0	0	1	2	1.275	0.226

Station	Megapode Detection by Visit											Habitat Covariate						
	1	2	3	4	5	6	7	8	9	10	11	A	B	C	D	E	F	G
10-3	0	1	0	1	1	0	0	1	-	-	-	1	0	0	1	2	1.363	0.999

Appendix 5 – UTM coordinates for the point-transect, playback, and occupancy stations surveyed as part of the archipelago-wide survey of Micronesian megapodes. All coordinates are in WGS84, UTM Zone 55 North.

A – Saipan: Stations 1 through 4 on transects 15 and 18 were sampled as part of the Saipan Upland Mitigation Bank (SUMB; Cruz and Williams 2003). Transect 9, stations 1 through 3 were equivalent to SUMB transect 9, stations 4 through 6. Transect 12, stations 1-12 were equivalent to the following SUMB transects and stations (e.g., 4-8 is transect 4, station 8): 4-8, 4-7, 5-6, 5-5, 5-4, 6-6, 6-5, 6-4, 7-6, 7-5, 8-7, and 8-6. All the remaining transects and stations were establishing in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	371997	1688488	3	11	372315	1689329	9	7	371256	1686391
1	2	372195	1688458	4	1	363441	1679412	9	8	371098	1686381
1	3	372386	1688422	4	2	363593	1679428	9	9	370944	1686455
1	4	372046	1688597	4	3	363742	1679483	9	10	370817	1686562
1	5	371953	1688718	4	4	363664	1679629	10	1	369604	1676677
1	6	372572	1688370	4	5	363681	1679794	10	2	369756	1676617
2	1	370224	1687861	4	6	363729	1679958	12	1	372372	1687861
2	2	370317	1687979	4	7	363672	1680097	12	2	372186	1687865
2	3	370409	1688097	4	8	363511	1680058	12	3	371918	1687592
2	4	370503	1688214	4	9	363393	1679941	12	4	371737	1687663
2	5	370608	1688309	5	1	373699	1687566	12	5	371554	1687715
2	6	370773	1688309	5	2	373844	1687687	12	6	371933	1687448
2	7	370920	1688334	6	1	364555	1670739	12	7	371738	1687491
2	8	370732	1688514	6	2	364697	1670671	12	8	371542	1687538
2	9	370751	1688663	6	3	364830	1670613	12	9	371830	1687198
2	10	370800	1688803	6	4	364942	1670538	12	10	371653	1687247
2	11	370862	1688940	6	5	365041	1670448	12	11	372116	1686913
2	12	370934	1689071	6	6	365460	1670016	12	12	371911	1686932
3	1	371156	1689265	6	7	365401	1669829	15	1	369907	1685728
3	2	371325	1689380	6	8	365414	1669688	15	2	370107	1685694
3	3	371433	1689479	6	9	365428	1669526	15	3	370296	1685660
3	4	371506	1689582	6	10	365405	1669418	15	4	370486	1685611
3	5	371609	1689649	9	1	371413	1686781	18	1	370587	1685755
3	6	371743	1689703	9	2	371602	1686725	18	2	370746	1685885
3	7	371884	1689682	9	3	371778	1686671	18	3	370883	1686019
3	8	372017	1689618	9	4	371782	1686473	18	4	371019	1686168
3	9	372146	1689538	9	5	371624	1686395				
3	10	372267	1689461	9	6	371446	1686427				

B – Anatahan: All transects and stations were sampled in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	376390	1913972	2	4	377290	1913972	8	1	377140	1914122
1	2	376276	1913859	2	5	377440	1913972	8	2	377140	1914272
1	3	376237	1913699	6	1	377440	1913822	8	3	376484	1915266
1	4	376178	1913552	6	2	377440	1913672	8	4	376619	1915216
2	1	376189	1913346	7	1	377440	1913522	9	1	376777	1915194
2	2	376307	1913459	7	2	377290	1913522	9	2	376875	1915091
2	3	377140	1913972	7	3	377290	1913372	9	3	377033	1915011

C – Sarigan: The following stations were sampled in previous DFW surveys (the DFW transect and stations are noted in parenthesis): 1-3 (DFW 1-4), 2-2 (DFW 2-2), 2-4 (DFW 2-5), 3-1 (DFW 3-3), 3-3 (DFW 3-6), 3-5 (DFW 3-9), 4-1 (DFW 4-1), 4-3 (DFW 4-3), 4-5 (DFW 4-7), 4-7 (DFW 4-8), 5-1 (DFW 5-1), 5-3 (DFW 5-3), 5-5 (DFW 5-7), and 5-7 (DFW 5-10). All other transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	369144	1847138	3	2	369425	1847672	4	8	369614	1848232
1	2	368998	1847080	3	3	369315	1847783	4	9	369696	1848087
1	3	368853	1847037	3	4	369202	1847848	4	10	369759	1847944
1	4	368733	1847119	3	5	369109	1847970	5	1	370041	1847400
1	5	368820	1847235	3	6	368955	1847971	5	2	370009	1847522
1	6	368979	1847232	3	7	369026	1847841	5	3	369969	1847667
1	7	369144	1847138	3	8	369135	1847719	5	4	369918	1847776
2	2	369162	1847504	4	1	369884	1847411	5	5	369900	1847917
2	3	369036	1847580	4	2	369809	1847527	5	6	369861	1848059
2	4	368955	1847667	4	3	369737	1847679	5	7	369830	1848197
2	5	368839	1847760	4	4	369656	1847805	9	1	368610	1847364
2	6	368839	1847605	4	5	369589	1847938	9	2	368767	1847364
2	7	368730	1847500	4	6	369518	1848071	9	3	368911	1847364
3	1	369522	1847569	4	7	369433	1848234	9	4	369069	1847364

D – Guguan: All transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	376390	1913972	3	1	377290	1913972	4	2	377140	1914122
1	2	376276	1913859	3	2	377440	1913972	4	3	377140	1914272
1	3	376237	1913699	3	3	377440	1913822	5	2	376484	1915266
1	4	376178	1913552	3	4	377440	1913672	5	3	376619	1915216
1	5	376189	1913346	3	5	377440	1913522	5	4	376777	1915194
1	6	376307	1913459	3	6	377290	1913522	5	5	376875	1915091
2	1	377140	1913972	3	7	377290	1913372	5	6	377033	1915011
2	2	376990	1913972	3	8	377140	1913222	5	7	377153	1915001
2	3	376840	1913972	3	9	376990	1913222	5	8	377140	1914872
2	4	376690	1913972	3	10	376840	1913222	5	8a	377170	1914730
2	5	376750	1913837	4	1	377140	1914422				

E – Alamagan: All transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	375400	1944347	3	3	375596	1945085	10	5	374879	1946513
1	2	375550	1944347	3	4	375632	1945212	10	6	375014	1946456
1	3	375700	1944347	3	5	375722	1945368	10	7	375142	1946379
1	4	375850	1944347	3	6	375791	1945493	11	1	374427	1946405
1	5	376000	1944347	3	7	375806	1945641	11	2	374555	1946345
1	6	376150	1944347	3	8	375922	1945750	11	3	374677	1946275
1	7	376300	1944347	3	9	376043	1945920	11	4	374788	1946177
1	8	376450	1944347	5	1	375114	1947500	11	5	374916	1946108
1	9	376600	1944347	5	2	375251	1947429	11	6	375072	1946082
1	10	376750	1944347	5	3	375273	1947275	11	7	375176	1946066
2	1	375250	1944647	5	4	375156	1947173	12	1	375488	1944489
2	2	375400	1944647	5	5	375065	1947295	12	2	375644	1944493
2	3	375550	1944647	5	6	375023	1947441	12	3	375798	1944491
2	4	375700	1944647	5	7	374995	1947598	12	4	375948	1944499
2	5	375850	1944647	5	8	375242	1947582	12	5	376100	1944484
2	6	376000	1944647	6	1	375500	1947227	12	6	376247	1944498
2	7	376000	1944797	6	7	375416	1947345	20	1	375229	1947722
2	8	376000	1944947	6	8	375597	1947110	20	2	375378	1947695
2	9A	375691	1944877	6	11	375495	1947064	20	3	375530	1947692
2	9B	375805	1944976	6	13	375362	1947126	20	4	375647	1947592
2	9C	375990	1945089	10	1	374332	1946756	20	5	375761	1947495
2	10	376144	1945178	10	2	374464	1946682	20	6	375916	1947493
3	1	375543	1944797	10	3	374604	1946636	20	7	376070	1947486
3	2	375544	1944944	10	4	374748	1946584	20	8	376204	1947554

F – Pagan: All transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	369038	2003886	5	2	368738	2006736	9	9	364388	1998936
1	2	369188	2003736	5	3	368888	2006736	9	10	364388	1999086
1	3	369338	2003736	5	4	369038	2006736	10	1	364020	1997750
1	4	369488	2003586	5	5	369188	2006736	10	2	363942	1997620
1	5	369638	2003586	5	6	369338	2006736	10	3	363904	1997479
1	6	369788	2003436	5	7	369488	2006736	10	4	363873	1997336
1	7	369968	2003356	5	8	369638	2006736	10	5	363840	1997152
1	8	370388	2003436	5	9	369788	2006736	10	6	363823	1997008
1	9	370538	2003407	5	10	369913	2006644	10	7	363803	1996856
1	10	370688	2003286	6	1	368745	2008235	10	8	363754	1996719
1	11	370838	2003286	6	2	368895	2008230	10	9	363927	1996773
1	12	370988	2003286	6	3	369038	2008236	10	10	363941	1996918
2	1	371588	2003348	6	4	369188	2008236	10	11	363968	1997075
2	2	371738	2003394	6	5	369333	2008229	11	1	364977	1997249
2	3	371892	2003462	6	6	369483	2008246	11	2	364830	1997265
2	4	372034	2003529	6	7	369633	2008235	11	3	364689	1997333
2	5	372180	2003639	6	8	369764	2008246	11	4	364536	1997373
2	6	372341	2003705	6	9	369924	2008217	11	5	364388	1997436
2	7	372650	2003720	6	10	370085	2008227	11	6	364567	1997723
2	8	372552	2003586	6	11	370232	2008234	11	7	364405	1997707
2	9	372450	2003443	7	1	370838	2008836	11	8	364251	1997733
2	10	372338	2003286	7	2	370988	2008836	11	9	364318	1997874
2	11	372282	2003142	7	3	371138	2008836	11	10	364431	1998003
2	12	372279	2002986	7	4	371288	2008836	11	11	364414	1998145
3	1	368831	2003282	7	5	371438	2008836	11	12	364358	1998292
3	2	368831	2003432	7	6	371588	2008836	11	13	364480	1998371
3	3	368681	2003432	7	7	371738	2008836	11	14	364632	1998393
3	4	368647	2003290	7	8	371888	2008836	11	15	364781	1998392
3	5	368675	2003130	7	9	372038	2008836	11	A	365127	1997225
3	6	368696	2002968	7	A	370818	2009028	11	B	365307	1997189
3	7	368699	2002814	8	1	372788	2008086	11	C	365463	1997166
3	8	368705	2002661	8	2	372788	2007936	11	D	365605	1997240
3	9	368857	2002643	8	3	372938	2007936	14	1	370538	2002686
3	10	369005	2002744	8	4	372948	2007775	14	2	370688	2002686
3	A	368783	2003728	8	5	373088	2007786	14	3	370838	2002686
3	B	368841	2003583	8	6	373238	2007486	14	4	370838	2002836
4	1	369188	2004486	8	7	373388	2007336	14	5	370988	2002836
4	2	369188	2004636	8	8	373538	2007336	14	6	371138	2002836
4	3	369338	2004636	8	9	373538	2007186	14	7	371288	2002836
4	4	369338	2004786	8	10	373538	2007036	14	8	371438	2002836
4	5	369488	2004786	9	1	364088	1997886	14	9	371588	2002836
4	6	369488	2004936	9	2	364088	1998036	14	10	371738	2002836
4	7	369638	2004936	9	3	364088	1998186	14	11	371738	2002686
4	8	369638	2005086	9	4	364088	1998336	14	12	371888	2002686
4	9	369788	2005086	9	5	364088	1998486	15	1	363655	1996273
4	10	369661	2005168	9	6	364214	1998649	15	2	363772	1996171
4	11	369589	2005292	9	7	364397	1998649	15	3	363885	1996065
5	1	368588	2006736	9	8	364389	1998799	15	4	364011	1995985

G – Agrihan: All transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	362506	2076324	4	8	361823	2073632	7	10	357848	2079316
1	2	362504	2076189	4	9	361898	2073782	8	1	358879	2080352
1	3	362578	2076037	4	10	362047	2073816	8	2	358729	2080343
1	4	362450	2075965	5	1	358673	2071832	8	3	358675	2080218
1	5	362569	2075914	5	2	358598	2071982	8	4	358598	2080082
1	6	362713	2075968	5	3	358448	2071982	8	5	358545	2079938
2	1	362505	2076494	5	4	358298	2071982	8	6	358474	2079789
2	2	362504	2076653	5	5	358223	2072132	8	7	358518	2079643
2	3	362482	2076814	5	6	358073	2072132	8	8	358598	2079482
2	4	362480	2076981	5	7	358178	2072286	8	9	358705	2079371
2	5	362632	2076913	5	8	358223	2072432	9	1	358493	2079203
2	6	362676	2077063	5	9	358368	2072464	9	2	358295	2079451
2	7	362542	2077146	5	10	358448	2072582	9	3	357959	2079675
2	8	362501	2077294	6	1	357442	2073315	9	4	357622	2079340
2	9	362518	2077448	6	2	357356	2073444	9	5	357596	2079240
2	10	362429	2077583	6	3	357345	2073604	9	6	357099	2078827
3	1	361295	2072617	6	4	357324	2073762	9	7	357216	2078718
3	2	361217	2072770	6	5	357206	2073868	9	8	356539	2077297
3	3	361116	2072888	6	6	357176	2074024	9	9	356688	2077299
3	4	360986	2072984	6	7	357081	2074155	9	10	356730	2077278
3	5	360850	2073073	6	8	357017	2074294	9	11	356340	2076733
3	6	360853	2072907	6	9	357032	2074458	9	12	356506	2076780
3	7	360813	2072746	6	10	356856	2074365	9	13	356666	2076815
3	8	360721	2072612	7	1	358448	2080382	9	14	356807	2076798
3	9	360588	2072508	7	2	358403	2080201	9	15	356466	2076519
3	10	360480	2072383	7	3	358286	2080098	9	16	356507	2076329
4	1	361448	2072582	7	4	358197	2079971	9	17	356659	2076359
4	2	361523	2072732	7	5	358039	2079936	9	18	356803	2076396
4	3	361598	2072882	7	6	357886	2079903	9	19	356625	2075197
4	4	361673	2073032	7	7	357815	2079767	9	20	357159	2074234
4	5	361748	2073182	7	8	357772	2079607	9	21	357490	2073680
4	6	361823	2073332	7	9	357737	2079444	9	22	357625	2073766
4	7	361898	2073482								

H – Asuncion: All transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	2	331250	2178266	2	5	331483	2177384	3	9	331727	2179051
1	3	331402	2178269	2	6	331639	2177376	3	10	331872	2179047
1	4	331550	2178287	2	7	331790	2177341	4	1	331401	2177260
1	5	331696	2178318	2	8	331934	2177363	4	2	331556	2177243
1	6	331690	2178143	2	9	332085	2177323	4	3	331688	2177177
1	7	331738	2178001	3	1	331360	2178366	4	4	331703	2177032
1	8	331603	2177928	3	3	331479	2178492	4	5	331835	2176945
1	9	331450	2177934	3	4	331625	2178495	4	6	331971	2176878
1	10	331309	2177996	3	5	331767	2178465	4	7	332055	2176757
2	1	331329	2177849	3	6	331747	2178612	4	8	332204	2176782
2	2	331321	2177698	3	7	331731	2178759	4	9	332350	2176768
2	3	331304	2177551	3	8	331730	2178902	4	10	332502	2176773
2	4	331330	2177402								

I – Maug: All transects and stations were established in 2010.

Transect	Station	X	Y	Transect	Station	X	Y	Transect	Station	X	Y
1	1	315194	2215061	1	6	315056	2214326	2	4	315344	2214611
1	2	315194	2214911	1	7	314915	2214234	2	5	315344	2214461
1	3	315194	2214761	2	1	315344	2215061	2	6	315194	2214311
1	4	315194	2214611	2	2	315344	2214911	2	7	315473	2214699
1	5	315194	2214461	2	3	315344	2214761				

Appendix 6. Model selection statistics for A) 16 models of megapode abundance on islands without ungulates, B) 4 models of megapode abundance on islands with ungulates, and C) histograms of the best-fit models

A)

Model	*k*	*L*	AIC_c	ΔAIC_c	w_i
H-rate Key DectType	3	-1254.60	2515.26	0.00	1.000
H-rate Island	5	-1323.94	2658.05	142.79	<0.0001
H-rate Key	2	-1332.89	2669.80	154.54	<0.0001
H-norm Cos	2	-1333.67	2671.38	156.12	<0.0001
H-rate Habitat	3	-1333.61	2673.28	158.02	<0.0001
H-rate Gust	5	-1334.08	2674.45	159.19	<0.0001
H-rate Clutter	3	-1334.91	2674.45	159.19	<0.0001
H-rate CanHgt	3	-1334.20	2674.48	159.22	<0.0001
H-rate Cloud	3	-1334.31	2674.69	159.43	<0.0001
H-rate Wind	4	-1334.06	2676.24	160.98	<0.0001
H-norm Key	1	-1337.13	2676.28	161.02	<0.0001
H-rate CanCov	5	-1333.32	2676.82	161.56	<0.0001
H-rate Obs	9	-1332.42	2683.36	168.10	<0.0001
H-norm H-poly[1]					
H-rate Cos[2]					
H-rate S-poly[1]					

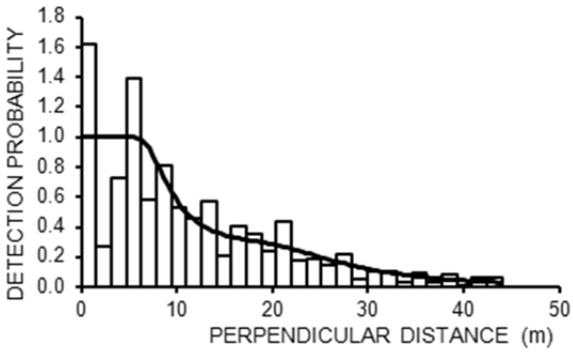
[1] Key model was chosen.
[2] Model failed to converge.

B)

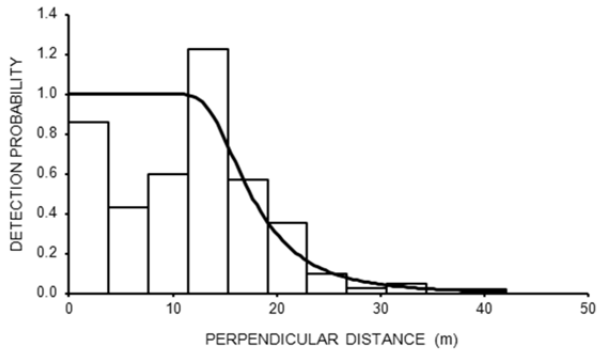
Model	*k*	*L*	AIC_c	ΔAIC_c	w_i
H-rate Key DectType	3	-439.87	885.94	0.00	0.999
H-rate Island	4	-445.94	900.20	14.26	0.001
H-rate Key	2	-456.67	917.44	31.50	<0.0001
H-norm Key	1	-460.36	922.75	36.81	<0.0001

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.

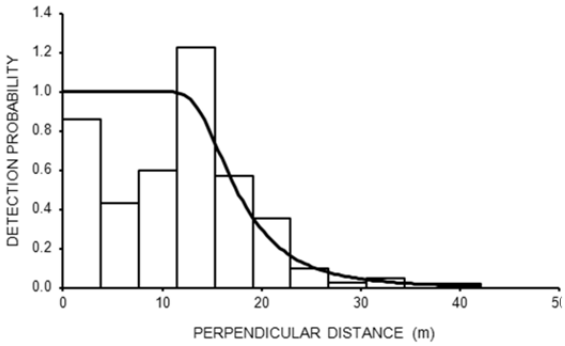
C)



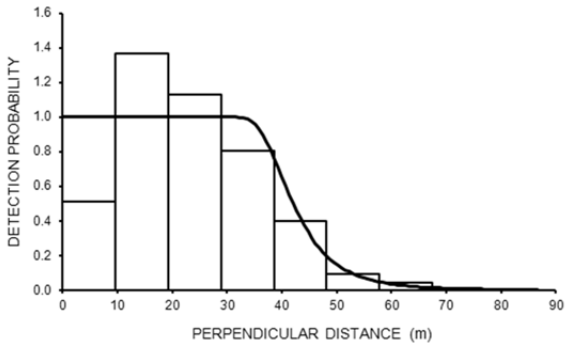
i. Histogram of the hazard-rate detection function with covariate detection type fitted to megapode detections from islands without ungulates.



ii. Histogram of the hazard-rate detection function with covariate detection type fitted to megapode detections from Saipan.



iii. Histogram of the hazard-rate detection function with covariate detection type fitted to megapode detections from Alamagan.



iv. Histogram of the hazard-rate detection function with covariate detection type fitted to megapode detections from Pagan.

Appendix 7. SAS code to model unobserved movement from a training dataset of paired observed and "unobserved" distances, and to predict unobserved movement for a larger dataset of megapodes detections.

```
/*** develop model relating to unobserved movement various covariates ***/
/*** adjust count data equal to zero ***/
data UNOBS2;
set UNOBS1;
   adjunobs = unobs + 0.5;
   if adjunobs <= 0 then adjunobs = 0.5;
   log_dist = log(dist);
   log_adjunobs = log(adjunobs);
run;

/*** run unobserved distance model ***/
proc genmod data = UNOBS2;
   title1 "Simulated Distances";
   model log_adjunobs = log_dist dettype island;
   class dettype island;
run;
/*** extract relevant parameter coefficient values from genmod output for next section ***/


/*** apply unobserved movement model to new dataset of detections ***/
/*** generate specified number of simulated values for unobserved distance movements ***/
data SIMUL2;
set SIMUL1;
   do sim = 1 to 1000;                                  /*** specify number of simulations ***/
   mu = -7.7710+2.4703*log(dist)-1.1189*dettype+0.7041*island;  /*** input relevant parameter coefficients ***/
                                                        /*** values from genmod output   ***/
   SimDistMoved = exp(rand("NORMAL", mu, 1.0832)); /*** input scale parameter value from genmod output ***/
   output;                                              /*** NOTE: if observed distances include zeros, then ***/
   end;                                                 /*** add 0.5 prior to log transformation and subtract ***/
run;                                                    /*** 0.5 from resulting SimDistMoved output ***/
```