Population Assessment of the Mariana Fruit Bat (*Pteropus mariannus mariannus*) on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug;
15 June – 10 July 2010

Administrative Report

Pteropus mariannus mariannus at a roost on Pagan, Photograph by E. W. Valdez

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EXECUTIVE SUMMARY

The Mariana fruit bat (*Pteropus mariannus mariannus*) occurs on the 15-island archipelago of the Commonwealth of the Northern Mariana Islands (CNMI) and Guam (Wiles and Glass, 1990). Because of direct impacts from over-harvesting for human consumption and introduction of the brown tree snake on Guam, as well as indirect impacts and habitat loss from agriculture, typhoons, and feral ungulates, populations of *P. m. mariannus* have declined, leading to its current listing as Threatened under the Endangered Species Act (U.S. Fish and Wildlife Service (USFWS) 2005, Utzurrum and others 2003, Wiles and Glass 1990, Wiles 1987). Populations of the Mariana fruit bat on some southern islands of the CNMI and Guam continue to decline, with much of the decline related to illegal hunting and brown tree snake on Guam (USFWS 2005, 2009). At present, most known populations of the Mariana fruit bat inhabit the northern islands (USFWS 2005, 2009). Given the remote locations of these northern islands, many have not been surveyed as frequently as the southern islands (USFWS 2005, 2009) or surveys have been limited to only a single or few islands at a time (e.g., Wiles and Johnson 2004, Cruz and others 2003, Worthington and others 2001, Cruz and others 2000a-f, Wiles 1987).

Thus, current information on population status of the Mariana fruit bat throughout the northern islands of the Mariana Archipelago is limited (USFWS 2005). As part of a multiple-taxa assessment of the "northern Mariana Islands" (NMI), funded by the Department of Defense (DOD) and subcontracted from USFWS, the U.S. Geological Survey (USGS) formed a Mariana Fruit Bat Team (MFB) and conducted an assessment of the Mariana fruit bat (*P. m. mariannus*). The main objective of this study was to locate and conduct counts of *P. m. mariannus* on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracas of the NMI using a newly-developed protocol (Mildenstein and Boland 2010) and compare our counts to previous studies. Initial efforts were directed to areas where roosts had been previously documented, followed by searches for new locations by conducting ground searches, as well as aerial and boat surveys. Secondary objectives included the collection of natural history information, such as habitat preference and information on reproduction.

On 28 May 2010, J. Boland and T. Mildenstein instructed the MFB team on how to conduct counts of the Mariana fruit bat (*Pteropus mariannus mariannus*) at roosts during the day and departure counts in the evenings. A submarine volcanic eruption between Sarigan and Anatahan on 30 May 2010 resulted in the evacuation of people from the neighboring islands, thus causing a delay in initiating assessments of *P. m. mariannus* and an extension of the training until 3 June 2010. As a result, the amount of time spent on each island was reduced with efforts on the NMI conducted between 15 June and 10 July 2010. Furthermore, because of limited time and resources, some islands included in the original proposal were not visited (i.e., Uracas) or only assessed briefly from a helicopter (i.e., Anatahan).

We used the Mildenstein and Boland (2010) protocols to assess populations on eight islands. However, because of limitations of time, resources, personnel, or other logistical issues, aspects of the protocol could not be implemented (e.g., replication of counts), thus no summary statistics were calculated. Information on the number of bats observed on each island is presented as the maximum number of bats counted by method used. Maximum number of bats counted were not adjusted with a correction factor, as used in earlier studies (e.g., Johnson 2001, Worthington and others 2001, Cruz and others 2000a-f, Wiles and others 1989).

The overall maximum number of bats counted on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug combined, totaled 3,078 bats. The greatest number of individuals documented in 2010 for any island was for Pagan (1,017), followed by Agrihan (858), Asuncion (573) Guguan (226), Sarigan (157), Anatahan (150), Alamagan (86), and Maug (11). Each of these maximum counts are based on direct counts or counts from photographs, with the exception of Guguan and Anatahan. On Guguan, 226 bats were counted during an exit count of a roost that was positioned in a ravine on a northeast-facing cliff. A single roost on the west side of Anatahan was located by flying over the island via helicopter and estimated visually from the air to have about 150 bats.

Because earlier studies (e.g., Johnson 2001, Cruz and others 2000a-f, Wiles and others 1989) used different methods of counting and often included correction factors, it is difficult to make statistical comparisons between their minimum population estimates with maximum number of bats counted in this study. For example, Cruz and others (2000e) reported a minimum population estimate of 1,500 bats occurring on Pagan as based on a sum of estimates arrived from departure counts, station counts, and individual sightings. Of these, 1,200 individuals were represented by the sum of adjusted departure counts, 75, 125, and 381 bats, recorded from three different colonies. The tallies of 75 and 125 bats were doubled to produce estimates of 150 and 250 bats occurring at the two roosts, respectively. This adjustment was based on the assumption that bats counted during departure counts represented only half of the total number of bats at the colony, whereas the remainder did not leave the roost until after dark and could not be seen. The departure count of 381 bats at the third colony was adjusted to an estimate of 800 individuals. This adjustment was based on “high levels of activity” that included at least 10-20 bats circling above the colony site during counts and continued until dark. According to Cruz and others (2000e), all three departure counts were taken from a boat on choppy seas that “made it difficult to observe roosting bats and their tree species of choice.”

Although there are discrepancies between methods used across studies and it is difficult to make statistical comparisons across islands, a gross comparison of the values for Anatahan, as noted by Wiles and other (1989), Cruz and others (2000), Johnson (2001) and this study, show a notable decline in population size. However, it likely can be best explained by the eruption in 2003 that devastated much of the habitat and possibly the bats occurring on the island. Prior to the eruption Johnson (2001) noted that there was a population decline on Anatahan that resulted from feral ungulates destroying habitat. From our observations on other islands, feral ungulates appeared to have an effect on habitat degradation and likely provided opportunities for invasive plants to replace native vegetation used by *P. m. mariannus*. The effects of super typhoon Choi-wan that hit several islands in 2009 may have had an impact on the population size of *P. m. mariannus* on some islands, especially Alamagan; although this was one episodic event. Although I did not find any supportive evidence, hunting pressures likely continue to have an impact on the populations of *P. m. mariannus* across the NMI as noted by Wiles and others (1989).

Despite the intense efforts by the MFB team, it is likely that some colonies remain unknown. This paucity of information is mostly related to the limited amount of time and lack of resources available for each island. Furthermore, this study was conducted during a short time-period in June and July and it is possible that some colonies may move frequently and occupy different parts of the landscape throughout the year. Thus, the results from this study only represent a snapshot of time and space.

Overall, lack of information on *P. m. mariannus* between assessments, especially between 2001 and this study, underscores the need for repeated surveys in the future to provide better insight on population trends and allow for further refinement of techniques and methodologies.

INTRODUCTION

The Mariana fruit bat (*Pteropus mariannus mariannus*) is a relatively large bat that occurs on the 15-island archipelago of the Commonwealth of the Northern Mariana Islands (CNMI) and Guam (Wiles and Glass, 1990). Because of direct impacts from over-harvesting for human consumption and introduction of the brown tree snake on Guam, as well as indirect impacts from and habitat loss from agriculture, typhoon, and feral ungulates, populations of *P. m. mariannus* have declined drastically leading to its listing as Threatened under the Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS 2005, Utzurrum and others 2003, Wiles and Glass 1990, Wiles 1987). Despite its Threatened status, populations of the Mariana fruit bat on some southern islands of the CNMI and Guam continue to decline, with much of the decline related to illegal hunting (USFWS 2005, 2009). At present, most populations of the Mariana fruit bat inhabit the northern islands (USFWS 2005, 2009). However, given the remote locations of these islands, many have not been surveyed as frequently as the southern islands (USFWS 2005, 2009). Furthermore, surveys of these northern islands have been limited to only a single or few islands at a time (e.g., Wiles and Johnson 2004, Cruz and others 2003, Worthington and others 2001, Cruz and others 2000a-f, Wiles 1987).

In 1983, Wiles and others (1989) provided an archipelago-wide assessment of the Mariana fruit bat. From their surveys on the islands north of Saipan (i.e., Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug), they calculated the overall population of these eight islands to be about 7,450 bats. In subsequent surveys of the Mariana fruit bat on Guguan, Alamagan, Sarigan, Anatahan, Pagan, and Agrihan conducted by Cruz and others (2000a-f), the overall population estimate was reported to be 4,250 individuals, whereas Wiles and others (1989) estimated 7,025 bats for the same islands. In a conservative interpretation of these estimates, USFWS (2009) stated that there was “roughly a 40% decline in fruit bat numbers between 1983 and 2000.” A more recent study by Johnson (2001) was conducted across the archipelago, and results were notably different compared to previous studies. However, USFWS (2005, 2009) noted that methods used by Johnson (2001) were significantly different from those by Wiles and others (1989) and Cruz and others (2000a-f), and therefore did not use Johnson’s (2001) estimates in their comparisons of population trends over time.

Aside from recent aerial surveys of some single islands (e.g., flights over Anatahan by C. Kessler), current information on population status of the Mariana fruit bat throughout the northern islands of the Mariana Archipelago is limited (USFWS 2005). As part of a multiple-taxa assessment on the northern islands of the CNMI, funded by the Department of Defense (DOD) and subcontracted from USFWS, the United States Geological Survey (USGS) formed a Mariana Fruit Bat Team (MFB) and conducted a census of the Mariana fruit bat (*P. m. mariannus*). The main objective of this study was to locate and conduct counts of *P. m. mariannus* on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracas of the "northern Mariana Islands" (NMI) using newly-developed protocols (Mildenstein and Boland 2010) and compare these counts to previous studies. Initial efforts were directed to areas where roosts had been previously documented, followed by searches for new locations by conducting ground searches, as well as aerial and boat surveys. Secondary objectives included the collection of natural history information, such as habitat preference, sexes of bats, and information on reproduction. These efforts were in collaboration with the Department of Land and Natural Resources-Division of Fish and Wildlife (DLNR-DFW) and the Northern Island Mayor's Office (NIMO). Herein I report findings and chronicle the events used to obtain these data during the censuses of *P. m. mariannus* on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug conducted from 15 June to 10 July, 2010.

METHODS AND MATERIALS

Terminology---Herein the use of "census, colony, count, day roost, location, observation, and population," follow definitions by Ellison and others (2003). Definitions of terms are located in Appendix 1.

Training---Before conducting censuses of *P. m. mariannus*, members of the MFB team were instructed by J. Boland and T. Mildenstein on how to implement the newly developed protocols (Mildenstein and Boland 2010) in the field (summarized below). Training was initiated on Rota on 28 May and was to be completed by 30 May 2010. However, during the training, a submarine volcanic eruption occurred and all field activities in the NMI were suspended. This allowed for additional training on Rota until 3 June.

Counts of bats in photographs taken during direct counts---At vantage points where direct counts were conducted, digital photographs were taken prior to direct observation counts (Mildenstein and Boland 2010). This included taking the series of photographs, with the first frame at the top left area of a roost, and while keeping the vertical plane fixed, the camera was panned horizontally by one frame after each photograph. Edges of the following photograph were matched with the leading edge of the previous photograph to ensure that there was minimum overlap and to eliminate double counting. Once a row was completed, the camera was lowered by one frame length below the last photograph and the process was repeated, but in the opposite direction. Photographs were later viewed in a photograph-editing program (e.g., MS Paint). While using the photograph-editing program, bats viewed in the photographs were marked with colored dots, usually red, and then tallied for a total count of bats viewed from a vantage point. This process was repeated for all photographs taken at different vantage points and times.

Direct counts of roosts---As performed on Rota, direct counts in the NMI involved locating fruit bat colonies by viewing suitable habitat and activity of bats flying nearby, using binoculars or naked eye. Once a roost was located, a vantage point was selected to provide the best viewing area. After photographs were taken, a high-powered spotting scope was attached to the tripod and bats were counted using the same horizontal and vertical movements as done for the camera. However, because the circular view from the spotting scope did not provide straight edges like the photographs, the MFB team modified this technique by scanning and counting bats by row, instead of by frame. Counting bats by row allowed the observer to slowly pan from left to right and vice versa, along the horizontal plane, until the spotting scope needed to be lowered to the next view and row.

Equipment used for direct counts and photographs from direct-count vantage points include: 190XB, 128RC Manfrotto tripods; STM-80 Swarovski spotting scopes with 30x eyepieces; and Canon EOS Rebel XSi digital cameras with Canon EF 300 mm, image stabilizing lenses. When vantage points were close enough or there was a need for a less-detailed view of an area an EF-S 18-55 mm lens was used. When vantage points were very close, binoculars were used to conduct counts.

Exit counts from roosts---This method is a standard technique (Kunz and others 2009) modified by Mildenstein and Boland (2010). This method is similar to departure counts used by earlier studies (e.g., Wiles and others 1989). Once a roost was located, the view was divided visually between two observers, with each half dedicated to the corresponding observer. Arrival and setup at the site was approximately 30-45 min prior to evening departure of the bats (1830h on Rota). Flight activity and directions of bats were recorded, in addition to the number of bats passing a designated visual boundary that were counted as either exiting or returning. Counts were then tallied and combined for a total number of bats leaving the roost. These counts are not the same as evening flight activity counts (see definition below), which did not involve the direct observation of bats leaving a roost.

Evening flight activity counts---This technique is similar to the station counts used by earlier studies (e.g., Cruz and others 2000e) and involved observations from a fixed vantage point, usually between two compass bearings. The area between compass bearings varied, depending on location of observer and any apparent obstruction that hindered direct observation. When possible, at each bearing endpoint, a rangefinder was used to determine the distance viewed. These observations were used primarily to locate general areas where bats were flying from (i.e., roost) and to (i.e., feeding areas). However, depending on the location of observer and flight direction of bats, the number of individuals recorded was used as an estimate for the amount of activity for an area (e.g., “passage rates”). Recorded evening flight activity counts should not be confused with exit counts.

Counts of bats in photographs taken from helicopters---Despite efforts to count or locate a roost by land or boat, at times it was not possible and a helicopter was used (e.g., Agrihan). Counts from helicopters included searching for roosts using either a Bell 206 “Jet Ranger” or a Messerschmitt-Bölkow-Blohm Bo 105 (“Bolkow Bo 105”). Once a roost was detected, coordinates were taken with a GPS unit and a rough visual estimate of number of bats in the roost was made. Depending on the size of the roost(s) and number of trees used by bats, a series of photographs was taken in a sequential pattern and merged to form a collage of the landscape. The same method of counting bats from direct photograph counts was implemented for photographs taken from the helicopter. Because it was difficult to hover with the helicopter near these roosts, exact edges of neighboring photographs were difficult to match.

Observation and counts using thermal imaging camera---A FLIR-RECON III thermal imaging system, provided by USFWS, was used to detect and count bats on some occasions. This system was set to grey scale for best viewing and was best used during early morning hours when the surrounding vegetation temperatures were cool compared to bats. Like the digital camera and spotting scope, the FLIR-RECON III was mounted to a tripod for best viewing of a located roost. However, it was also attached to the rappelling hooks of the Jet Ranger for use during early morning reconnaissance flights. Bats could be viewed through the eyepieces, and images and video could be recorded when it was interfaced with the Panasonic digital video camera (Model PV-GS200). The FLIR-RECON III also was used at times for assessing evening flight activity on some islands (e.g., Guguan, Maug), as well as for searching for roosts (e.g., Alamagan).

Location data---The MFB team collected roost location data, including GPS waypoints of vantage points or roosts and compass bearings from vantage point to center of mass where most of a colony was concentrated. Corresponding distance to compass bearings were recorded using Nikon range finders, from the vantage point to the center of mass. From a vantage point, the team also recorded compass bearings of the left- and right-most edges of the colony, especially if the colony was spread out across multiple trees, with corresponding distances. In addition, angles from the vantage point to the topmost and bottommost edges of a colony were recorded with inclinometers, along with corresponding distances. When possible, habitat data and other natural history information (e.g., colony composition, presence of pups) of a roost were recorded. Many of the trees and plants were identified by local members of the MFB team, however scientific names and some identifications were aided by the use of Vogt and Williams (2004). Waypoints are presented as UTM coordinates using WGS 84 Datum.

Maximum number of bats counted---Because there was limited time in the field to allow for a replication of counts at one vantage point, as suggested in the protocol by Mildenstein and Boland (2010), no summary statistics were calculated or presented. However, I present in tables for future comparisons all counts recorded by each observer from a vantage point, using direct counts of roosts, exit counts from roosts, or counts of bats from photographs.

The overall number of bats documented on an island, as determined by the method (i.e., exit counts, direct counts, counts from photographs) that produced the largest count, was presented as the overall maximum number of bats counted. These counts were obtained from distinct vantage points that included distinct individuals. If more than one observer counted from the same vantage point, at the same time, and counts were different, the largest count was used to represent the maximum number of individuals. If more than one vantage point was used, a sum of the largest counts across vantage points was presented as the maximum number of individuals counted for an island. However, counts were summed only if tallies represented distinct individuals that were not counted at another vantage point.

Evening flight activity counts were not included as a maximum number of bats for an island. At no point were counts from different methods combined to produce a maximum number of individuals counted. At no point were maximum counts adjusted with a correction factor, as used in earlier studies (e.g., Cruz and others 2000e).

RESULTS

Assessments of *P. m. mariannus* occurring on the NMI began on 15 June 2010, with Sarigan visited first, followed by Guguan, Alamagan, Asuncion, Maug, Agrihan, Pagan, and Anatahan, and were completed 10 July 2010. During this time, teams of at least two USGS biologists and a minimum of one local member from Department of Land and Natural Resources-Division of Fish and Wildlife (DFW) and/or Northern Island Mayor's Office (NIMO) searched for bats by hiking or attempting to locate roosts from boat or helicopter. Once a roost was located, data were collected following the methods described by Mildenstein and Boland (2010). Results and findings are presented by each island and in the order they were surveyed.

SARIGAN (15–16 June 2010)

We started surveys on Sarigan from 15 June to 16 June 2010. Upon arrival, two members of the MFB team searched for roosts using a Jet Ranger helicopter. Flight coverage of the island was extensive during searches for *P. m. mariannus,* and efforts confirmed the finding of a moderate-sized colony at SA Col. 1 that had been previously reported by the USFWS-led Micronesian megapode team from surveys earlier in the summer (Fig. 1). A second but smaller colony of fruit bats comprised of only a few individuals, also previously located by the Micronesian megapode team, was confirmed from the helicopter search of SA Col. 2 (Fig. 1). Aside from scattered singletons, no new colonies were located using the helicopter.

After searching for colonies via helicopter, the entire MFB team was transported to the top of the island where a spike camp was established. From there, the MFB team hiked to the main colony, then split into two groups and initiated the bat counting protocol from two vantage points (Fig. 1). From vantage point SA1, two observers used binoculars and a spotting scope to conduct direct counts of colony 1. Counts from this vantage point ranged from 109 to 154 individuals (Table 1). At vantage point SA2 of the same roost, two different team members used a spotting scope and counted 126 and 128 individuals (Table 1). Twelve photographs taken on 15 June of the roost from each vantage point were examined and counted, with 78 and 63 bats counted in photographs from respective vantage points SA1 and SA2 (Table 2).

At the second and smaller roost, located on the eastern side of the island, the team split into two groups and counted bats from two different vantage points. At vantage point SA3 three bats were counted in the roost tree (i.e., tropical almond, *Terminalia catappa*), whereas at SA4 no bats could be observed, mostly because of surrounding vegetation. However at least 2-3 bats were observed flying and landing in other neighboring trees. Overall maximum number of bats counted on Sarigan based on the sum of the largest direct counts from two colonies was 157 bats (Table 1).

GUGUAN (17–18 June 2010)

On 17 June, the MFB team, comprised of six individuals, was transported to Guguan. This island was divided into two areas with the southeastern half having more vegetation, including trees and more suitable roosting and foraging habitat for *P. m. mariannus*. The northwestern half of the island was not as densely vegetated and contained more exposed ground. Upon arrival, two members conducted an aerial survey of the island using the Jet Ranger helicopter (Fig. 2). Although a few singletons were located in the forest on the southeastern side of the island, no major colonies were observed from the air. Afterwards, we located a colony on a cliff-side by hiking along the northeast side of the island. From vantage point GU1 at 203 m away and compass bearing 102°, two members of the MFB team conducted an exit count and observed 27 bats leaving the trees from 1725h to 1825h (Table 3).

On 18 June, vantage point GU1 was revisited by three individuals, where they conducted a direct count using a digital camera, spotting scope, and FLIR thermal imaging system. Their direct counts started at 0700h and were completed by 0725h. At the same time, the remaining 3 members moved to vantage point GU2, where they conducted a direct count of the same roost. From this second vantage point direct counts only involved the use of a digital camera and spotting scope. From vantage point GU1, 16 bats were counted by each observer using spotting scopes, whereas 19 and 21 bats were counted with the FLIR thermal imaging system (Table 4). At vantage point GU2, the team counted 43 and 48 individuals each with the spotting scope (Table 4).

On 18 June, because exit flights of bats from the roosts on Sarigan and Guguan appeared to be occurring at an earlier time compared to the exit times observed on Rota (i.e., 1830h), exit counts were initiated at 1600h at vantage point GU2 for Colony 1. Two team members visually divided the area and conducted an exit count that ended at 1802h. A total of 225 bats was counted leaving the roost (Table 3). Many bats were positioned in trees behind taller trees and other vegetation that likely obscured direct viewing of the colony during counts on 17 June.

Despite earlier aerial survey efforts on 17 June that involved multiple passes by the helicopter over the island in search of the roost location where 300 *P. m. mariannus* had been reported by Johnson (2001), no colony was found. Therefore, in an effort to locate this colony, a ground search of this area was conducted on 18 June by a single team member. Although the large colony was not found, from vantage point GU3 and near the hiking route reported in Johnson (2001), 6 bats were observed roosting in a tropical almond tree (*Terminalia catappa*) 185 m away, at compass bearing 152°. At approximately 1600h, two team members revisited vantage point GU3 but only observed a single bat roosting in the general area. From vantage point GU3, the MFB team conducted an evening flight activity count from 1700h to1930h. During this time the MFB team counted 20 bats flying and feeding on pandanus fruit (*Pandanus tectorius*) in the area, but only observed a single bat exit the original roost that had six bats. Therefore, based on the 225 distinct individuals observed exiting from GU2, combined with the single bat observed exiting a roost from GU3, the overall maximum number of bats counted on Guguan is 226 bats (Table 3).

ALAMAGAN (19–21 June 2010; 10 July 2010)

On 19 June a team of seven individuals, including a former resident, arrived on the island of Alamagan. A team of two individuals searched for roosts across the island using a Jet Ranger helicopter. After approximately three hours (1245h to 1553h) of flying over the entire island, with a stop for refueling, only a few singletons were located (Fig. 3).

On 20 June, two team members conducted another aerial search that started shortly after dawn, around 0600h. During this search one of the team members used the FLIR thermal imaging system to locate bats. The aerial searches ended at 0730h, and although several nesting birds and scattered livestock were found with the FLIR equipment, no major colonies were found. Concurrent with aerial searches, the remaining MFB team members searched for bats while on foot. Ground searches ended around 1200h with no major colonies observed.

At 1600h, two teams of three individuals each positioned themselves at vantage points AL1, located on a ridgeline, and AL2 located at approximately 118 m east and below the ridgeline, to conduct an evening flight activity count (Fig 3). Although there were multiple bats observed from both vantage points, with total counts ranging from 27 to 41, many bats appeared to be circling the area and were likely counted more than once. Therefore, no accurate assessments could be made from these counts. However, during their observations from the ridgeline, the team at AL1 noted several bats landing in a ravine approximately 350 m east of their location.

On 21 June, the MFB team hiked north along the ridgeline from the vantage point AL1 and searched for bats in the ravine to the west and northwest. At vantage point AL3, a single bat was found roosting in a tree that was in the ravine, approximately 200 m away at compass bearing 246^{o} (Fig. 3). Later that day, at approximately 1600h, the MFB team split into two groups. In an effort to achieve a better vantage point of the west and northwestern habitat needed for a better evening flight activity count, one group returned to the ridge-top above AL1, and were positioned at vantage point AL4 (Fig. 3). From this site, the team members started their evening flight activity count at 1609h and ended at 1900h. During this time, two team members counted 37 and 45 bats, respectively.

As the team at AL4 conducted their evening flight activity count, the other team members searched in the ravine east of vantage points AL1 and AL2, where bats were observed landing on 20 June. After about 30 minutes of searching, they discovered an area where several bats were landing and feeding on the fruits of a fig tree (*Ficus tinctoria*) in the ravine. From vantage point AL5, a member of the MFB team noted that most of the bats in the area were concentrated in a fig tree that was 28 m away and at compass bearing 252^{o} (Fig. 3). However, the observer also noted that bats were feeding in another fig tree 11 m away, at compass bearing 232^{o}. Three tiger claw trees (*Erythrina variegata*) at distances of 33 m, 16 m, and 6 m, with respective compass bearings 248^{o}, 194^{o}, and 154^{o}, as well as one breadfruit tree (*Artocarpus mariannensis*) at 34 m and compass bearing 240^{o} periodically had bats, although these trees appeared to be used as temporary roosts. This foraging area was monitored from 1650h to 1900h and multiple bats arrived and left at different times. It was difficult to determine if individuals had been counted, therefore the minimum and maximum counts of bats documented, represent the total number of bats observed. The minimum number of bats counted from vantage point AL5 was 6 individuals, whereas the maximum number counted was 15. Peak activity with 12 or more bats in the area was from 1721h to 1753h.

During this same time, at vantage point AL6, approximately 26 m northwest of vantage point AL5, another MFB team member monitored 2 bats roosting in a breadfruit tree at 36 m and compass bearing 344^{o} (Fig. 3). From this vantage point at 36 m and compass bearing 318^{o}, the team members also observed 8 bats feeding in a fig tree. The sum of these 10 bats at AL6 combined with the maximum number (15) counted at AL5 provides a total of 25 bats as the maximum number of bats counted using this foraging area.

On 10 July, two members of the MFB team, C. Kessler (USFWS), and pilot of the Bolkow Bo 105 helicopter returned to Alamagan on their flight back to Saipan. After several passes over the island and in the caldera while searching for *P. m. mariannus*, a single colony was observed near the top of the cone on the eastern side of the island at AL Col. 1 (Fig. 3). This colony of 50 bats, visually estimated, was in a tree positioned behind a rock outcrop or "rock fin." It was this rock outcrop that made it difficult to locate the colony initially, but once the colony was found, the helicopter was able to hover briefly while a series of 5 photographs was taken. Of these photographs, a total of 86 bats were counted from two different views. Therefore, the overall maximum number of bats counted on Alamagan as based on counts from photographs taken from a helicopter is 86 (Table 5).

ASUNCION (24-30 June 2010)

On 24 June the MFB team arrived at Asuncion. Subsequently, two USGS biologists and 3 DFW and NMO employees were transported to Maug (see section on Maug for details). On Asuncion, six individuals made up the MFB team. Because no aerial reconnaissance was conducted prior to or upon arrival, efforts to locate fruit bats started with an evening flight activity count from shoreline, near camp. On 24 June, one observer was positioned on the western shoreline at vantage point AS1 (Fig. 4). Because it rained shortly after counts had began, the observer was only able to get a partial count of 312 bats flying over the ridgeline before they stopped counting. Most of the bats observed were flying north.

On 25 June the MFB team searched for bats along the southwestern side of Asuncion and located a large colony spread across several trees in a ravine. From vantage points AS2 and AS3, two observers conducted a direct count of the colony that was scattered across coconut (*Cocos nucifera*), tropical almond (*Terminalia catappa*), beach hibiscus (*Hisbiscus tiliaceus*), papaya (*Carica* sp.), and fig trees (*F. tinctoria*; Fig. 4). Counts were conducted from 0941h to 1020h. One observer counted 179 bats that included 12 pups and 1 male in the group, whereas the other observer counted 139 that included 6 pups and 1 male (Table 6). Although several photographs were taken before the direct counts were conducted, no bats could be viewed in them.

Afterwards, the MFB team positioned themselves at vantage point AS4 and at compass bearing 234^{o}, continued their count of bats that were not counted at vantage points AS2 and AS3 (Fig. 4). From AS4, most of the bats were observed roosting in camachile trees (*Pithecellobium dulce*). In an effort to locate more vantage points of this large colony, two team members continued searching after counting bats in a partial view of this area, whereas the remaining members were able to view the entire area and counted 98 and 81 individuals (Table 6). Of the 81 bats counted by one observer, 1 was noted as being a male and 3 were identified as pups (Table 6). Afterwards, the MFB team continued searching southward along the western side of Asuncion and located a second group of bats belonging to the same colony from vantage point AS5, but the team did not count them because of the limited time available (Fig. 4).

On 26 June, three members of the team returned in the morning to vantage point AS5 and conducted direct counts of bats that were roosting in a fig tree (*F. tinctoria*), with counts of 216, 296, and 295 bats recorded independently. Of the 295 bats counted by one observer, 6 were identified as being pups. Again, photographs were taken prior to direct counts but because of windy conditions, none of the images could be used for counting. During the counts at AS5, two other members of the MFB team searched for new roosts and observed approximately 42 bats at vantage point AS6, located about 252 m south-southeast of AS5. Although this was a new locality for bats, both observers believe that these individuals were flushed from the main colony observed from vantage points AS2-5. Afterwards, all team members returned to the main base camp, where later one member was positioned at vantage point AS1 and conducted evening flight activity counts. The remaining members continued searching the western coastline north of camp (Fig. 4). At vantage point AS1, the observer started evening flight activity counts at 1541h and ended at 1911h. During that time, the observer counted 775 bats flying north over the ridge and 11 flying south.

As counts were conducted at vantage point AS1, the MFB team located on Maug was transported to Asuncion, where some members positioned themselves at AS7 and conducted evening flight activity counts. Because of their late arrival from Maug, counts began at 1701h and ended at 1911h and during that time a total of 488 and 625 bats were recorded. A comparison could be made across the three counts during 1701h –1754h with observer from vantage point AS2 counting 258 bats, whereas the other observers at vantage point AS1 each counted 216 bats, indicating minimal differences in the number of individuals observed and counted. Another comparison could be made 1754h–1904h, with 213 bats counted from vantage point AS1, whereas observers at AS7 independently counted 389 and 264 bats.

On 27 June, 2 team members continued with searches on Asuncion and later conducted an evening flight activity count at AS7 and a new vantage point approximately 259 m north of camp at vantage point AS8 (Fig. 4). Both counts viewed the skyline, however because the view from vantage point AS8 was not as open compared to AS7, the observer counted bats crossing an imaginary boundary at compass bearing 95^{o}. At vantage point AS7, counts started at 1503h and ended at 1915h, whereas at vantage point AS8, counts started at 1500h and ended at 1840h. Counts from vantage point AS7 were dominated by flight activity of bats flying in one direction, with 1,126 individuals flying northward, and 42 flying south. Evening flight activity from vantage point AS7 showed 440 bats flying north and crossing the imaginary boundary line and 218 bats were flying south.

On 28 June, two members of the MFB team hiked to the same ravine where the large colony was located on 25 June. The team viewed the colony and conducted direct counts from 6 different vantage points, including AS2-5, 9 and 10 (Fig. 4). From vantage points AS2 and AS9 at respective compass bearings of 145^{o} and 90^{o}, with similar distances of 28.5 m from the roost, one observer counted 69 bats and the other counted 59 (Table 6). Many of the views of bats were covered or obscured by neighboring vegetation and counts often required waiting for bats to move in the tree. This is apparent in the 2-dimensional view of the roost as recorded by photographs, with 15 photographs taken and 27 bats counted in them. At vantage points AS3-5 and AS10, the MFB team viewed the colony at respective compass bearings 130^{o}, 220^{o}, 220^{o}, and 260^{o}.

From these vantage points, observer 1 counted 164 bats that included 2 males, whereas observer 2 counted 145 bats that included 3 males and 1 pup (Table 6). The combined counts for observer 1 from all 6 vantage points was 233 bats in the ravine, whereas the combined counts for observer 2 was 204 bats (Table 6).

On 29 June, two members of the team revisited vantage point AS8 to conduct an evening flight activity count. The evening flight activity count started at 1440h and ended at 1910h. During this time they counted 383 bats flying north and 218 flying south. On 30 June, the MFB team returned to AS8 to conduct their final evening flight activity count. The observers started the count at 1505h and ended at 1855h. During this time the MFB team counted 369 bats flying north and 222 flying south.

Because there was no aerial or boat support available during the time on the island and most of the suitable habitat used by *P. m. mariannus* was on the western half of the island, searches were conducted by hiking. However, on the exit flight to Pagan on 1 July, two members of the MFB team circled the island and searched for isolated roosts that could not be reached by foot (Fig. 4); no roosts were located. Although evening flight activity counts produced a higher number of individuals documented for Asuncion, it is difficult to determine whether some of these individuals had not circled around the ridgelines and were double counted. Therefore, the overall maximum number of bats documented on Asuncion as based on the sum of maximum counts of distinct individuals and roost trees, arrived from direct counts taken on 25 and 26 June from vantage points AS2-5 is 573 bats.

MAUG (24-26 June 2010)

On 24 June, a MFB team comprised of two USGS biologists and two local members from the CNMI arrived on the eastern islet of Maug. Because there was limited time and fuel for the helicopter, the remaining two islets were not assessed by air for the presence of *P. m. mariannus*. Furthermore, because of the late-afternoon arrival and need for establishing a base camp, there was no daytime available for ground searches after landing on the eastern islet. After camp had been established, the MFB team observed from vantage point MA1, the area west of camp for any bat activity, using binoculars (Fig. 5). During this time 5 bats were observed flying over the forest.

On 25 June, the MFB team initiated ground searches by using part of the established Micronesian megapode transects to get to the western edge and rim of the islet. At vantage point MA2 from the rim, there was limited viewing of the east- and south-facing areas of the other islets, but a second vantage point MA3 was found and scanning of the areas using tripod and spotting scope ensued (Fig. 5). The maximum area viewed was encompassed between bearings 178^{o} and 315^{o}. No bats were observed in this area. Ground searches continued across the island following the Micronesian megapode transects with no roosts located.

After searching for roosts by hiking, the MFB team conducted an evening flight activity count from vantage point MA1 and observed the area between compass bearings 347^{o} and 193^{o}. From this location the MFB team was able to see most of the east-facing side of the eastern islet of Maug and monitored the area starting at 1600h and ending at 1959h. Four bats were observed flying in this area.

On 26 June, the MFB team suspended surveys for *P. m. mariannus* until 1130h, after the Micronesian megapode team completed their transect surveys that started early in the morning. During the interim, the MFB team scanned and photographed the visible area between bearings 186° to 332° from MA1, with no bats observed. However, during their transect surveys, the Micronesian megapode team located a bat roosting in a coconut tree near vantage point MA4 near Micronesian megapode transect (MAU3-2; see Micronesian megapode report for transect station coordinates). Another member of the Micronesian megapode team noted that he heard, but did not see, multiple bats "chattering" from vantage point MA5 near the Micronesian megapode transect station MAU2-2 from 0749h to 0800h. Following this lead, two individuals from the MFB team started searching for the roost site. While en route, the MFB team observed a different roost comprised of three individuals. Of the three, one was a male roosting in an Indian Mulberry or Noni tree (*Morinda citrifolia*) and approximately 2 m away a female and pup were roosting in a fig tree (*Ficus tinctoria*, Table 7). Initially, from vantage point MA6 at compass bearing 172° and 15 m away, the MFB team could not see that a pup was attached to the female and originally recorded the total count of two bats (Table 7). However, when the team moved to vantage point MA7 at compass bearing 25° and 15 m away, the female opened her wings and exposed the attached pup that was about 2/3 the size of the adult female. Unlike some of the roosts observed on other islands, these bats were approximately 6 m below the canopy. Bats were not disturbed by our quiet presence.

After 45 minutes of observing and recording data from the second roost, the MFB team hiked northward along a Micronesian megapode transect for approximately 140 m until the discovery of a third roost. This roost was comprised of 7 bats, including 2 pups. From vantage point MA8 at compass bearing 37° and 11 m away, the team could see that the bulk of the colony (5 bats) were roosting in a fagot tree (*Neisosperma oppositifolia*), whereas the other two bats were in unidentified trees at bearings 21° and 317°, at distances of 16 m and 13 m, respectively. Of the five bats located in the fagot tree, two of them were identified as adult females, each with pups. Interestingly, the pups attached to the two females appeared smaller, at 1/3 the size of the adult females, compared to the pup recorded from the second roost on Maug (Fig. 5). Before additional data could be collected or searches for more roosts made, the MFB team was unexpectedly extracted from Maug on 26 June 2010 at 1430h, and transported to Asuncion. Overall, the maximum number of bats counted on Maug as based on direct counts at roosts was 11 individuals (Table 7).

AGRIHAN (27 June–3 July 2010)

On 27 June, a MFB team comprised of five individuals arrived on Agrihan and because of limited time and no helicopter support, the team hiked south along the south-southwestern coastline to conduct an evening flight activity count of bats that could be present in the area. At 1600h, the MFB team positioned themselves on the shoreline, south of camp at vantage point AG1, facing the island and scanned the horizon between compass bearings 52° and 131° (Fig. 6). From vantage point AG1, the habitat appeared to be dominated by sword grass (*Miscanthus* sp.). At approximately 1800h the MFB team ended the evening flight activity count with no bats documented for this area.

No boat was available, so on 28 June the MFB team comprised of three individuals hiked north from base camp along the coastline, then eastward over a ridge top, and ending at the coastline while searching for bats (Fig. 6). Because vegetation was dense, mostly with tangantangan or haole koa (*Leucaena leucocephala*), viewing colonies was difficult to do from any elevation, including at the top of ridgelines. After three hours of searching by foot, no bats were located. At approximately 1630h, three members of the MFB team hiked along the western shoreline from camp to vantage point AG2 and from this site they conducted an evening flight activity count with views between compass bearings 49^{o} and 148^{o} (Fig. 6). Because several nearby ridge tops blocked distant views of the area, only a handful of bats were noted flying southward towards the main base camp. It is likely that some of these bats were traveling to the main base camp and were feeding on ripe mango fruits, as observed earlier by the camp manager.

On 29 June, the MFB team was cleared to use the boat and from it searched along the western coastline to the southern tip of the island, south of camp (Fig. 6). As noted from the observations conducted on 27 June from vantage point AG1, most of the visible habitat appeared to be dominated by sword grass and scattered tangantangan. No bats were observed during these searches. Later, one team member revisited vantage point AG2 to conduct an evening flight activity count, whereas the remaining team members used the boat to scout and conduct concurrent evening flight activity count, offshore and north of AG2 at vantage point AG3 (Fig 6). The team member at vantage point AG2 noted the first presence of *P. m. mariannus* at 1710h and ended counts at 1843h, whereas the team at vantage point AG3 documented first activity at 1715h and ended at 1830h. At vantage point AG2, the observer counted 22 bats flying southward during the monitoring period, whereas at vantage point AG3 the team's combined count was 58 bats flying in different directions. Interestingly, one observer of the MFB team at vantage point AG3 counted 22 individuals flying towards vantage point AG2. Of the 22 recorded at vantage point AG2, 6 bats were observed landing in bread fruit trees (*Artocarpus altilis*) near the ridge that had been hiked on 28 June.

On 30 June, we searched the ridgeline where the observer at vantage point AG2 documented 6 *P. m. mariannus* landing. After hiking the area, the MFB team did not see evidence of a roost or feeding area. Later, we divided into three groups, with two members climbing to the top of the ridgeline and positioning themselves at vantage point AG4 on top of ridge to conduct an evening flight activity count. Another MFB team member was positioned at vantage point AG2 and the remaining members of the group were positioned at vantage point AG3. At vantage points AG2, 3, and 4, each team started their respective evening flight activity counts at 1700h, 1658, and 1715h. Nineteen bats were counted from vantage point AG2, 78 from AG3, and 19 bats from AG4.

From the previous evening flight activity counts, it appeared that counts from the northern part of the island and from a boat, were greater. Therefore, on 1 July some of the MFB team traveled by boat north of vantage point AG3 to scout for bats along the shoreline. Later, the MFB team positioned themselves offshore at vantage point AG5 and conducted an evening flight activity count (Fig. 6). Counts from this site started with first bat activity noticed at 1656h and ending at 1830h. During this time the MFB team counted 126 *P. m. mariannus* in the area, with most of the bats flying southward and between compass bearings 90^{o} and 119^{o}. Although there was a large number of bats counted and it appeared that most were flying from near the top of the island, local cloud cover blocked views of the exact location from which bats were originating.

On 2 July, helicopter support was provided and starting at 0630h, two members of the team searched for roosts across the entire island (Fig. 6). Their initial efforts were concentrated on historic roost sites documented by Johnson (2001), but after visiting those sites, no colonies were observed. After several passes along ravines on the northwest side of the island, the MFB team directed their efforts near the rim of the caldera, where bats had been observed from the evening flight activity counts conducted from the boat. At the top of the island and near the rim of the caldera, a few singletons were found and after the low lying cloud over the caldera had dissipated, the team entered the caldera over the historic outflow of lava on the north-northwest side of the island. Upon entering the caldera, the flight path was clockwise, with the helicopter flying near the walls (Fig. 6). After several passes within the caldera, we smelled the strong and unique odor produced by *P. m. mariannus* from the helicopter as we passed directly over the colony. Shortly after smelling the bats the colony was visually located on a ridge, near the southwest side of the caldera at AG Col. 1 (Fig. 6). This colony appeared to be fairly large and the MFB team visually estimated from the helicopter about 200 bats scattered up the ridgeline. After a second and third pass by the colony, another colony was observed on the neighboring ridge top at AG Col. 2, although it appeared to contain fewer bats (Fig. 6).

Several photographs were taken from the helicopter starting at the top of the ridgeline above the bats and were, as best as possible, matched to the next photograph taken below it, providing a linear series of photographs of the entire roost area, to be examined at a later date. Camera settings were adjusted to a fast shutter speed to accommodate for the movement of the helicopter and at times, the lens was focused manually. No other colonies were found in the caldera or other parts of the island.

On 3 July the colony was revisited via helicopter and another set of photographs was taken to provide additional support in calculating the number of bats that occur on Agrihan. Later, we conducted an evening flight activity count from a boat at vantage point AG5. From this location and knowing the position of the colonies in the caldera, we monitored activity between three landmarks on the horizon at compass bearings 93^{o}, 117^{o}, and 128^{o}. Activity of bats began at 1628h and ended at 1830h. During the monitoring period, 120 bats were observed flying south from the caldera rim, 9 flew north, and 13 flew east, with peak activity between 1628h and 1826h. It is likely that the 9 bats that flew north were individuals that had flown south, earlier in the evening. Although bat activity continued past 1830h, safety regulations required small boats to be returned to base camp by 1900h.

After field efforts on Agrihan were completed, a series of 31 photographs that was taken from the helicopter on 2 July were merged into one montage and used for counting bats. To avoid double counting the same bat in multiple photographs, landmarks were used to distinguish individuals. From this montage, the overall maximum number of bats counted on Agrihan was 858 bats (Table 8).

PAGAN (1–10 July 2010)

On 18 June 2010, a local resident of Pagan, while conducting reconnaissance with another party located a colony of approximately 200 bats on the north-northeastern part of the island. A few days after the colony was observed, the local resident revisited the site but the colony was no longer there. Because of this recent record of occurrence, early efforts by the MFB team were focused on locating this roost after their arrival from Asuncion on 1 July. The team initiated their reconnaissance by searching along the western coastline of the island, where approximately 5 bats were observed flying along the cliffs. Afterwards, they continued to the north end of the island where the colony had been reported and although a few singletons were observed flying over the tree tops, no major colonies were found from the boat.

On 2 July, after being transported via All Terrain Vehicle (ATV) from the main base camp to a spike camp on the north end of the island, the team hiked eastward towards the reported colony. They began at 1100h and ended at 1900h, with all three members hiking in parallel paths, approximately 10 m apart. Because only one GPS unit was available, only the center transect was recorded (Fig. 7). Most of the habitat consisted of ironwood forest (*Casuarina equisetifolia*), however there were small pockets of native vegetation where a few bats were located. No colonies were located on 2 July, thus a second effort was conducted on 3 July, starting at 0500h and ending at 1130h. Again, no colonies were located.

On 4 July, the team returned to the northern end of the island, using a boat to survey the coastline (Fig. 7). At the same time three individuals arrived from Agrihan, and two of them used a helicopter to conduct reconnaissance (Fig. 7). Both teams found only a few singletons on the north end of the island, but reconnaissance from the helicopter continued throughout the morning, covering most of the island, including all of the coastlines and areas where suitable habitat for bats occurred (Fig. 7).

At 1130h the team in the helicopter located a colony on the southeast side of Pagan at PA Col. 1 (Fig. 7). During the flight, the team visually estimated about 100 bats roosting in the area as they circled several times with the helicopter. In addition to the observations, several digital photographs were taken of the colony and area where bats were located. Afterwards, the surveillance continued northward along the southeastern coastline and at 1153h, a second and larger colony was found at PA Col. 2 (Fig. 7). The MFB team visually estimated the colony to be comprised of about 200-300 individuals, with many concentrated in a large tropical almond tree (*Terminalia catappa*). Photographs were taken of the second colony, as well as of the neighboring trees where some bats were also roosting.

After the two colonies had been located, the MFB teams conducted direct counts of each. However, because of limited boat and field support, as well as conflicting schedules with other concurrent projects, the amount of time set to conduct direct counts was limited to 2.5 days. On 5 July, two teams, one comprised of 3 individuals and the other of 4, went separately to the newly found colonies located on the southeastern side of Pagan. Because the southeastern coastline was difficult to operate boats, it was recommended that the teams access the colonies from different starting points. The first team (3 individuals) used a boat to access a natural port on the southwest coastline of the island, then hiked eastward across the island to PA Col. 1. The second team (4 individuals) traveled by ATVs almost directly east from the main base camp to an area where they could hike down to the coastline, then continued southward along the coast to PA Col. 2.

The first MFB team was guided to PA Col. 1 by a local resident of Pagan and once on the ground, all traveled in the direction of where a colony had been historically located, as noted by the guide. Upon reaching the historic location near PA Col. 1, only a single bat was found roosting in a tree observed from vantage point PA1 (Fig. 7). However, following the coordinates of the roost taken from the helicopter on 4 July, the team was able to reach within 200 m of the colony at vantage point PA2 (Fig. 7). Unfortunately, the team could not get closer to the colony because of a steep ravine and large cliff interrupting passage. Furthermore, the colony was positioned behind a ridgeline, obscuring any direct observation of bats or activity. Ultimately, a direct or exit count could not be conducted. Therefore, the team positioned themselves in an area where any activity could be monitored. However, because of the rugged and steep terrain of the coastline, the time used to conduct evening flight activity counts of bats was shortened on 6 July to allow for safer return to the distant spike camp.

At PA2, two observers recorded flight activity at 1615h on 5 July and 1628h on 6 July, with the respective end times of 1900h and 1800h. During their counts, the observers documented multiple individuals flying from the colony area and flying northward along the coast, but several returned a short time after leaving. Overall on 5 July 2010, a total of 48 and 47 bats were recorded by Observer 1 and 2, respectively. On 6 July, a total of 13 bats were recorded by both observers.

Because of inclement weather, failure of equipment, and other logistical issues, two of the four team members from the second MFB team returned to the main base camp. The remaining two members were able to access the cliffside where the second colony was located. Because PA Col. 2 was positioned on a steep incline, within tall trees, and spread across several trees, the main observer of the team had to count from vantage points PA3-5, but later found a better view at vantage point PA6 that replaced vantage point PA4 (Fig. 7). Ultimately, counts of bats from the best vantage points included PA3, 5, and 6. Because many of the views from these vantage points were obscured by dense vegetation, the single observer used binoculars in addition to a spotting scope and digital camera to observe and conduct direct counts. The largest number of bats recorded from a direct count at one vantage point on Pagan was at PA5 with a total of 353 bats on 7 July. Of the 353 bats, 12 were recorded as pups (Table 9). The number of bats counted on Pagan as based on the sum of largest direct counts of Colony 2 from vantage points (VP) PA3, 5, and 6, and conducted on the same day (7 July) was 563 bats (Table 9).

Only one exit count of PA Col. 2 was conducted on 6 July and was conducted from vantage point PA7, a site where the observer could see 3 roosts (Fig. 7). The count started at 1700h, while it was raining, with most of the bats circling over the roost, and not departing immediately. At 1800h, the rain stopped and there was an increase in the number of bats exiting the roosts. From 1800h to approximately 1830h, the observer documented 172 bats leaving the roosts, with 29 returning. Overall, a total of 143 individuals were confirmed leaving the roost for the evening. During their exodus, most of the bats flew south along the coastline and towards PA Col. 1, although a few individuals flew north.

On 7 July a MFB team, comprised of 4 individuals that also included a boat operator, revisited the general area of the western coastline where bats had been observed on 1 July. At the site, the MFB team and boat positioned themselves offshore at vantage point PA8, and conducted an evening flight activity count (Fig. 7). The MFB team started counts (1611h) at the first sign of bat activity and stopped (1905h) when bats were no longer observed in the area. The area monitored was located between compass bearings 116^{o} and 176^{o}, and included multiple ridges and ravines.

Peak flight activity of bats, with movement across the landscape, was between 1829h and 1903h. A total of 77 individuals was documented in the area with 30 flying north, 42 flying south, and the remainder with no direction recorded. Most of the individuals observed crossing the outermost bearings did not return, however those that remained in the area were observed landing periodically in trees. From the vantage point, the observers could not determine the point of origin of where most bats came from and no colony was located at this site.

On 8 July, a second evening flight activity count was conducted at the same site monitored on 7 July. The first evening flight activity of bats in this area was not observed until 1725h and ended by 1848h. During this time, only 8 bats were observed flying in the area. During this visit, the sky was cloudy and the wind was blowing in a southerly direction, at a speed strong enough to move the leaves and some branches of the coconut palms in the area.

On 10 July, a team of four individuals that included a USGS biologist, the local resident of Pagan, C. Kessler (USFWS), and pilot flew across the landscape of Pagan, revisiting the same routes used on 4 July, as well as covering new areas. Unlike the previous flight in the Jet Ranger, the Bolkow Bo 105, a much more powerful helicopter was used, making navigation along some of the cliff-sides easier. At one point, members of this team were guided by the resident of Pagan to the site of PA Col. 3 where he had documented a colony of about 200 bats on 18 June 2010 (Fig. 7). Although the vegetation appeared to be suitable habitat for a colony, no bats were found at this location, as noted from previous ground searches. Only two major colonies were documented during this trip, both of which were located on the southeast side of Pagan and had been previously located on 4 July 2010. Overall, a total of two hours, starting at 0630h and ending 0830h with time to refuel in between, was used to conduct a thorough surveillance of Pagan on 10 July 2010.

After field efforts were completed, the 244 photographs taken on 7 July during the direct counts of PA Col. 2 from vantage points PA3, 5, and 6 were examined and a total of 552 bats were counted (Table 10). In addition, the photographs of PA Col. 1 and 2 that were taken from the helicopter on 4 July were also analyzed. For PA Col. 1, a series of 24 photographs taken of the colony and neighboring area were merged into a montage, using unique landmarks (e.g., plants, rocks, branches of trees) in each photograph as a reference point. The merged photographs were examined closely to avoid any double counting individuals. A total of 347 bats were counted at Colony 1 from the montage (Table 11).

At PA Col. 2, a series of 22 photographs were taken and were also merged into one montage. Many frames had 10 or more bats, however the maximum number of bats counted in one frame was 317 individuals concentrated in one tree. The maximum number of bats counted at PA Col. 2, based on a combination of photographs taken from a helicopter was 670 individuals (Table 11). The overall maximum number of bats counted on Pagan as based on the combined counts of bats from photographs of PA Col. 1 and 2 that were taken from a helicopter on 4 July, is 1,017 individuals (Table 11).

ANATAHAN (10 July 2010)

During the flight on 10 July, two members of the MFB team, C. Kessler, and helicopter pilot circled over the known location of a colony on the western side of Anatahan. During this time the team and C. Kessler, visually estimated approximately 150 individuals located in a roost on the northwestern edge of the island at AN1 (Fig. 8). This location was at compass bearing 87^{o} and approximately 238 m east of the coastline (Fig. 8). Although no photographs were taken to confirm the habitat type and number of roosts, from the aerial observations bats appeared to be concentrated in one or two closely neighboring trees. The overall maximum number of bats documented on Anatahan, as based on a rough visual estimate from a helicopter was 150 individuals.

DISCUSSION

From 15 June to 10 July 2010, a population assessment of the Mariana fruit bat (*P. m. mariannus*) was conducted on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug. We computed that the maximum number of bats counted for all islands combined, as determined from various counting techniques, totaled 3,078 individuals (Table 12). The greatest number of individuals documented in 2010 for any island was for Pagan (1,017), followed by Agrihan (858), Asuncion (573) Guguan (226), Sarigan (157), Anatahan (150), Alamagan (86), and Maug (11). Each of these maximum counts are based on direct counts or counts from photographs, with the exception of Guguan and Anatahan. On Guguan, 226 bats were counted during an exit count of a roost that was positioned in a ravine on a northeast-facing cliff. A single roost on the west side of Anatahan was located by flying over the island via helicopter and estimated visually from the air to have about 150 bats.

Because earlier studies (e.g., Johnson 2001, Cruz and others 2000a-f, Wiles and others 1989) used different methods of counting and often included correction factors, it is difficult to make statistical comparisons between their minimum population estimates with the maximum number of bats counted in this study (Table 12). For example, Cruz and others (2000e) reported a minimum population estimate of 1500 bats occurring on Pagan as based on a sum of estimates arrived from departure counts, station counts, and individual sightings. Of these, 1,200 individuals were represented by the sum of adjusted departure counts, 75, 125, and 381 bats, recorded from three different colonies. The tallies of 75 and 125 bats were doubled to produce estimates of 150 and 250 bats occurring at the two roosts, respectively. This adjustment was based on the assumption that bats counted during departure counts represented only half of the total number of bats at the colony, whereas the remainder did not leave the roost until after dark and could not be seen. The departure count of 381 bats at the third colony was adjusted to an estimated 800 individuals. This adjustment was based on “high levels of activity” that included at least 10-20 bats circling above the colony site during counts and continued until dark. According to Cruz and others (2000e), all three departure counts were taken from a boat on choppy seas that “made it difficult to observe roosting bats and their tree species of choice.”

Although there may be discrepancies between methods used by earlier studies and it is difficult to make statistical comparisons, a gross comparison of the values for Anatahan, as noted by Wiles and other (1989), Cruz and others (2000), Johnson (2001) and this study, show a notable decline in population size (Table 12). It is likely that this decline can be best explained by the eruption in 2003 that devastated much of the island's habitat and possibly the bats inhabiting the island at that time. However, prior to the eruption of Anatahan, Johnson (2001) noted a major decline in population size from an estimated 3,000 individuals documented in 1983 by Wiles and others (1989) to the estimated 1,000 bats in his study, and suggested that poaching and ungulates were the major factors for this decrease. In 2010, the MFB team noticed several feral ungulates on some islands (e.g., Alamagan, Pagan, and Agrihan) and their negative effects on the native vegetation. I suspect that this degraded habitat by feral ungulates provides opportunities for invasive plants to replace native vegetation used by fruit bats. Another factor that may have had an effect on population sizes were the effects of super typhoon Choi-wan that hit several islands in 2009, especially Alamagan, although this was one episodic event. Although I did not find supportive evidence, I suspect that hunting pressures continue to have an impact on the populations of *P. m. mariannus* across the NMI, as noted by Wiles and others (1989).

SARIGAN

Sarigan is an island approximately 5 km^2 in size and was the first to be surveyed for *P. m. mariannus* during this study. Because this was a small island compared to some of other islands of NMI, the amount of time allowed to conduct counts was reduced. Using the Jet Ranger helicopter was helpful in locating the colony, as well as transporting personnel to the top of the island.

It appears that most of the bats on Sarigan were concentrated at one roost, but it is possible that there were smaller colonies that we missed during the two-day assessment. This current location was more centralized in the island and is approximately 600 m northwest of the roost site noted by Johnson (2001) and Cruz and others (2000c). This location may be an artifact of super typhoon Choi-wan. Given the proximity of Sarigan to Anatahan, it is also possible that some of the bats found on Anatahan came from Sarigan, as migration has been inferred by Cruz and others (2000c).

Because of its size, type of terrain, and location of the island in the archipelago, Sarigan served as a good starting point for conducting assessments. I recommend that future assessment efforts of the NMI start with Sarigan and continue northward. I also recommend that future efforts on Sarigan include more than 2 days for assessments.

GUGUAN

Guguan was unique in that the northern half of the island, where two volcanic cones were located, did not contain much vegetation or suitable habitat to support roosts or foraging areas for *P. m. mariannus*, whereas the southern half of the island did. Thus our efforts were focused on the southern half of the island. However, this side of the island also posed one of the more challenging aspects for surveying. This was mostly attributed to the number of birds of various species using the ground, trees and cliff-sides as nesting sites. Fortunately, the pilot was experienced and was able to avoid any problems. As for the other islands, I recommend that future projects include the use of a helicopter to locate roosts, and for Guguan specifically, a larger and more powerful helicopter like the Bolkow Bo 105 would be used to make it easier to locate roosts along cliff-sides.

Surprisingly, the location of the only large colony on the island was not located from helicopter, but instead by ground searches. However, it is likely that if the Bolkow Bo 105 helicopter was available to search for roosts, we might have had better success. Regardless, the location of the roost was unique in that it was situated along the northeastern cliff side of the island and was inaccessible by foot. Although it is possible that this location is an artifact of bats being forced to relocate because of typhoon conditions, I suspect that this precarious roost site is a result of human disturbance. However, during our assessment we did not see evidence of hunting or other human disturbance, but this roost location is similar to those observed on Rota where hunting pressures are prevalent. It is possible that individuals using this roost represent some bats that belonged to the colony of approximately 300 bats that was situated on the southwestern portion of the island as reported by Johnson (2001).

ALAMAGAN

It was difficult to conduct counts here because no roosts were located during our first visit in spite of multiple efforts. However, we did find a feeding area for the fruit bats which was particularly important, because Alamagan was in the direct path of the super typhoon Choi-wan.

Fortunately, on 10 July 2010, we were able to revisit the island and found a colony using the larger Bolkow Bo 105 that made maneuvering easier along the side of the island. We finally located the small colony in a tree behind a rock fin near the caldera. It is possible that this rock fin has sheltered the colony from typhoons and its location near the caldera rim may have given the illusion that bats were located in the caldera, as suggested by former residents. It is unknown if bats were directly affected by super typhoon Choi-wan, but it is possible that this island did not sustain a large colony as noted by Johnson (2001), Cruz and others (2000b), and Wiles and others (1989).

Alamagan was one of several islands where there was a noticeable presence of feral ungulates. The combined effects from super typhoon Choi-wan, as noted by former residents, and the presence of feral ungulates likely have major impacts to the native vegetation used by *P. m. mariannus*.

ASUNCION

Future studies on Asuncion should initiate efforts with reconnaissance using helicopter and/or boat prior to ground searches. One of the more difficult aspects of conducting counts of *P. m. mariannus* on Asuncion was locating a vantage point that did not have an obstructed view due to the dense vegetation. If more time was available for counting bats, instead of locating bats, it is likely that better vantage points could have been located and more than two counts from each vantage point could have been conducted. Because this large colony was spread across multiple trees in a ravine and required multiple vantage points to count, a minimum of four individuals, including local support from DFW or NIMO, should be considered for future counts.

MAUG

Maug comprises three islets and during the assessment of *P. m. mariannus*, only the eastern islet was visited. However in an effort to detect the presence of bats on the other islets, we scanned with a spotting scope the visible areas of these islets from a vantage point near the top of the eastern islet, but no bats or suitable habitat were located. Because of the unexpected extraction from the island and less than 2 days of field effort, I believe that the actual number of bats is greater than 11 bats. Like many of the other islands, additional time and different periods of the year should be considered to provide an accurate assessment of the number of *P. m. mariannus* that occur on Maug.

During the direct counts of bats, the MFB team noted that most of the bats in their roosts were located approximately 2 m below the canopy. There were openings in the canopy that bats could use to enter or leave the roost site from above. Future searches using helicopters and thermal imaging equipment from a helicopter may be difficult because of the bats' location in the tree and the vegetation blocking direct views. Evening flight activity counts were not effective, despite the wide view from the vantage point and use of the thermal imaging equipment. Ground searches appear to be the best method for documenting bats on Maug.

During the search for roosts of *P. m. mariannus*, an effort was made to ground-truth the rumor of Pacific sheath-tailed bats (*Emballonura semicaudata rotensis*) occurring on Maug. From the approximately 2 days spent on one islet of Maug, there was no evidence for the presence of *E. s. rotensis* or habitat suitable to support this bat. At present, *E. s. rotensis* appears to be restricted only to Aguiguan.

AGRIHAN

Agrihan proved to be one of the more difficult islands to conduct a census of *P. m. mariannus*. This was partially due to size of the island and rugged terrain, but also because of the absence of boat or helicopter support during our first two days. Despite the inability to access other parts of the island during this time, efforts to locate bats were made by hiking the western coastline, nearby ridges and ravines, followed by evening flight activity counts. After a boat became available, evening flight activity counts could be made from better vantage points away from the island. From these evening flight activity counts, the MFB team was able to pinpoint a general area on the north end of the island, where some bats were coming from.

Helicopter use for an island as big as Agrihan is critical for future studies. As documented in this study, the location of a colony could only have been done from a helicopter. Furthermore, had a helicopter been available, it is likely that the roost could have been found earlier. Nonetheless, using a boat did provide a general area of where to concentrate efforts while searching via helicopter.

We counted 858 bats from photographs of the roost (Table 12), whereas we counted 126 with evening flight activity counts. It is likely that many of the bats at the colony, as documented by photographs taken from the helicopter, either left the roost after 1830h when our evening flight activity counts had stopped because of safety regulations or most of the colony exited in another direction and could not be observed from a single vantage point. The lack of congruence between methods of counting bats reinforces the need for multiple techniques to be used, with an emphasis on helicopter use, especially in hard to reach locations.

The presence of a large colony inside the caldera, compared to previous locations noted by Johnson (2001), suggests that super typhoon Choi-wan may have had some influence in their movement to this new location. Inside the caldera, bats are sheltered from severe weather conditions, however this location may have some effects from gases venting from the center of the caldera. This may be particularly critical when cloud layers cover the top of the caldera, trapping possible toxic gases beneath the blanketed area. I suspect that the historic roost location near the western shore of Agrihan, as noted by Johnson (2001), was abandoned because it could be easily accessed by hunters and those bats make up the colony in caldera. It is the location of the roosts in the caldera and its inaccessibility by foot that has likely sheltered bats from major storms and people.

Given the specific location of the colony in the caldera, it would be difficult to conduct a direct count for future studies. Even if a team were to hike to the rim on the north end of the caldera, descent into the caldera would require individuals with experience in rappelling and rock-climbing and the descent is greater than 100 m from rim to the floor of the caldera. If possible, landing a helicopter on the caldera floor, followed by hiking to a vantage point might be best. However, the stability of the caldera floor should be investigated before landing and hiking. If landing by helicopter is possible, the amount of time spent in the caldera and air quality should be taken into account for reaching a vantage point to count bats.

PAGAN

During the 9-day period spent on Pagan, the MFB team covered most of the island by using boats, helicopters, and hiking. Despite the repeated searches for a colony of an estimated 200 bats, reported by a Pagan resident on 18 June 2010, none was found. Two major (i.e., greater than 50 individuals) colonies were found by helicopter and were positioned along the eastern cliff-side on the southern end of Pagan. This general location was also noted by other studies including Wiles and others (1989), Cruz and others (2000e), and Johnson (2001). These sites also share the same general locations of four main sites where *P. m. mariannus* have been known to occur, as reported by Pagan residents. These include habitat near Barankan Lanchu (near the colony reported on 18 June 2010) and Talage Beach on the north end of the island, and near Fuwaebasu and Piarama on the southern end of the island.

From the searches conducted in 2010, I suspect that most of the bats on Pagan were concentrated in the two colonies located on the southern end of Pagan. I also suspect that the colony observed on the northern end of the island on 18 June may have moved to one or both of the newly found colonies. Reasons for the movement of the colony from the northern end of Pagan are unknown, but the movement of such a large number of bats within a 12-day period of our surveys underscores the importance of timing and frequency of conducting future *P. m. mariannus* assessments.

Based on photographs, the southern-most colony was made up of 347 individuals, whereas Colony 2, located north of Colony 1, was comprised of 670 bats. Thus, the overall maximum number of bats counted on Pagan, as determined from the sum of these photographs was 1,017 bats. Because of inaccessibility of Colony 1 by foot, no direct counts were made, however the direct counts of Colony 2 were conducted from three vantage points. Of the two days (6 and 7 July 2010) surveyed, the second day provided the maximum count of 563 bats observed. A general comparison of this value with the number of individuals at the same roost and counted in the photographs taken from the helicopter show that there is a relatively small difference of 107 individuals.

It is possible that the population of *P. m. mariannus* on Pagan continues to be affected by habitat degradation or loss, illegal hunting, or a combination of both, as noted by Johnson (2001). In the study by Cruz and others (2000e), they noted that the "ecological integrity of Pagan has been compromised by the large number of feral animals." It is likely that negative effects by the feral animals on the vegetation are exacerbated by invasive plant species (e.g., ironwood, *C. equisetifolia*; swordgrass, *Miscanthus* sp.), especially when replacing native food resources (e.g., breadfruit, *A. mariannensis*) used by *P. m. mariannus*. During the flight over Pagan, the MFB team noticed that much of the native food resources were isolated in small patches on the northern end of the island and scattered along the ravines of the southern end of the island. It is likely that during the fruiting periods of these trees, bats can be concentrated in these areas, causing them to be susceptible to illegal hunting, especially in areas where there is easy access by boat on the northern end of the island.

In the management recommendation by Cruz and others (2000e), it was suggested that a fence be placed across the isthmus of Pagan to separate the northern and southern parts of the island, because "the southern peninsula seems to hold most of the remaining species of concern, such as megapodes, fruit bats, and Coconut crabs." Although I agree with the reasoning for placing a fence across the isthmus, I disagree that only the southern portion of the island should be exclusive to all native fauna. Because of limited food resources I believe that the entire island is critical for the local population of *P. m. mariannus*, perhaps at different times of the year, thus suggesting the need for additional surveys during different periods of the year.

ANATAHAN

The local population of *P. m. mariannus* on Anatahan has been monitored by C. Kessler over the past 10+ years and includes pre- and post-eruption information. According to C. Kessler, after the eruption in 2003, most of the habitat used by *P. m. mariannus* was destroyed by heavy deposits of ash. Since then, some vegetation has slowly returned and combined with vegetation that was not destroyed, has become large enough to sustain a small population.

From the visual estimation of 150 individuals and confirmation from C. Kessler who was also in the helicopter during the counts on 10 July, it is apparent that parts of Anatahan can support a small colony. It is difficult to determine if the 150 individuals counted on 10 July represent bats that survived the volcanic eruption or if they emigrated from neighboring islands such as Sarigan. From the brief flights over Anatahan at the start and end of the surveys, it appears that there is only a limited amount of suitable habitat for *P. m. mariannus*. Moreover, because of proximity of this colony to the shoreline and being restricted to only part of the island, it may be vulnerable to hunting or natural catastrophes in the future.

NATURAL HISTORY

SENSITIVITY TO DISTURBANCE

During this study, the MFB team observed noticeable differences in behavior, especially related to human presence. Because hunting pressures on *P. m. mariannus* are more intense on Rota, bats at their roosts on this island were extremely sensitive to the odors and presence of humans nearby (e.g., from distances of 150 m away). Often this resulted in bats quickly leaving and/or circling the roost. If the disturbance or scent was removed immediately, bats would generally return to the roost, as observed during our training on Rota. However, Boland (pers. comm.) noted that continued presence of the scent or disturbance would eventually cause bats to move to another location, as she had documented on Rota.

From our observations of bat behaviors on the NMI during this study, it appears that colonies *P. m. mariannus* were not as sensitive to the scent or quiet presence of people. Most of the time, the MFB team was able to conduct counts from distances less than 50 m. Reasons for this may be attributed to the lesser hunting pressures in the NMI compared to Rota. In some instances, bats were observed leaving during their evening departures from their roosts to forage and would land above observers and even by established base camps (e.g., at Agrihan) where food resources were available (e.g., ripe mango fruits). During these instances, many of the bats were aware of the presence of people, but did not fly away and/or continued to eat. When bats were inadvertently flushed, as a result of researchers cutting trails or hiking through forest habitat searching for roosts and making a fair amount of noise, they generally would return to their original roost.

It is likely that this reduced sensitivity has contributed to bats being harvested by hunters easier than on other islands like Rota. However on Guguan, Alamagan, Pagan, and Agrihan, the main colonies were located on steep cliff-sides, inside a caldera, or other areas that are inaccessible by foot or boat, which may be an indication of bats being sensitive to human disturbance. This may be particularly noteworthy for most of these islands where suitable roosting habitat is available on other parts of the island but can be accessed easily by people.

EVENING ACTIVITY TIME

One of the more interesting behavioral differences observed on the northern islands that also had an effect on this study and use of the Mildenstein and Boland (2010) protocol was the time when bats departed from their roosts in the evening. On Rota, the training of the MFB team by J. Boland for exit counts usually involved starting counts at 1830h. On the northern islands, the MFB team found that bats were exiting their roosts at an earlier time by at least 2 hours, with counts on some islands (e.g., Asuncion) starting as early as 1500h. This behavior was observed first at Sarigan and Guguan, and as a result the time needed to set up and conduct exit or evening flight activity counts was adjusted. For most of the islands, any departure or evening flight activity counts started around 1600h, and depending on the size of the colony would continue until dusk and evening during the evening hours. Although this early flight activity of bats and need to start counts earlier was reported for the northern islands by some studies (e.g., Cruz and others 2000a-f), few studies (e.g., Worthington and others 2001) compared directly this behavior with the evening activity times of bats on Rota, especially within the same study. Moreover, other studies (e.g., Wiles and others 1989) that worked on multiple islands, including Rota and the northern islands, only provided a range of start and end times for the counts of bat activity on the islands as a group.

I am uncertain why the behavior between the northern islands and Rota are so different, but I suspect that the later flights on Rota may be related to hunting pressures.

It is likely that leaving the roost on Rota at a later time may prevent detection of where bats go to feed or prevent the detection of the day roost. Future studies should take this observed behavior of bats in the NMI into account to avoid missing most of the bats leaving the roost while conducting exit or evening flight activity counts.

REPRODUCTION

Evidence of reproduction was observed on most of the islands, including the presence of pups and even observations of mating behaviors. On Maug, two sizes of pups were observed at two different colonies. One of the pups observed at Colony 2 on Maug was approximately 1/3 the size of the adult female that it was attached to. The other pups at Colony 3 on Maug were much larger at about 2/3 size of the adult females that they were attached to. Thus, there may be some slight differences in the timing of birth. Pups on other islands, such as Asuncion, appeared much larger and closer to adult size when compared to pups from Maug. It is possible that the timing of birth may vary across the archipelago and possibly reflects the availability of food resources on each island.

FEEDING BEHAVIOR

During evening flight activity counts on Guguan, *P. m. mariannus* was observed eating pandanus fruits. At times, multiple bats (3 to 5) would land in one pandanus tree to feed on ripened fruit. Often these bats would fly away with fruits in their mouths to feed elsewhere, however some were observed feeding while roosting in the tree. During this study there were observations of other animals using the same food resource. For example, on Guguan the MFB team observed coconut crabs climbing up to the top part of the plant and feeding on the ripened fruit. Also, there were several pandanus fruits on Guguan that had been partially eaten by rats, leaving this food resource unusable by bats. Because some food resources may be limited on some islands (e.g., Guguan) competition with non-native species such as rats may have an impact on populations of *P. m. mariannus*.

On other islands, the MFB team observed *P. m. mariannus* feeding on fig and pandanus fruits. However, I suspect that some of the major food resources may have been destroyed by the super typhoon Choi-wan that hit some of the islands in late 2009. According to former residents on some of the islands (e.g., Alamagan), after super typhoon Choi-wan hit many bats were observed landing on fallen trees where the only food resource was available. This loss of food resource may have had an overall impact on population sizes. Although *P. m. mariannus* has evolved with seasonal typhoons, it is the presence of feral ungulates found on many islands (e.g., Pagan, Alamagan) that may have an even greater impact to the remaining food resources and vegetation.

MIGRATION

During our stay on the islands in 2010, we found no evidence of bats migrating between islands, as noted by Johnson (2000). However, given the presence of a small colony on Anatahan after it erupted in 2003, and the lack of evidence to dispute inter-island movement of bats, migration remains a possibility.

FUTURE RECOMMENDATIONS

Given the long intervals between previous surveys and the generally lower estimates found in our study, I strongly recommend that there be continued surveys of colonies across all of the NMI, semi-annually or at least annually. More frequent surveys will not only allow estimates of bat numbers to be refined but also will allow further refinement of techniques and methodologies.

Some additional recommendations should be considered in future work on *P. m. mariannus* and are addressed under three general categories that include: 1) Timing and Logistics; 2) Protocol and Future Research; and 3) Helicopter Use.

TIMING AND LOGISTICS

Despite intense efforts by the USGS MFB team in 2010, the population assessments and respective natural history information is limited by our time spent on each island. Although multiple days originally were proposed for each island, the time available to conduct reconnaissance and counts was greatly reduced, mostly by the submarine volcanic eruption. Logistics to consider in trying to obtain accurate data, include reserving transportation in advance, time spent moving among islands, and splitting resources (e.g., boats) with other sympatric projects. I recommend that future assessments of *P. m. mariannus* be conducted independently of other projects to prevent any competition for resources. Alternatively, provide enough resources and personnel to accommodate overlapping projects with minimal impacts to each.

During this project, there was some difficulty in accessing sites or islands when transportation was not available. For example, given the size and rugged terrain of Agrihan, accessing the various habitat types and locations of this island required both boat and helicopter support, yet they were not available for several days. During the interim, efforts were restricted to hiking. Although hiking allowed us to find some bats, the overall size of this large island and limited amount of time available to conduct this study, made it difficult to cover the island efficiently.

When resources were available, they often were limited and there had to be in-the-field coordination of travel and transportation resources with other concurrent projects. This was evident on Agrihan where only one boat was available but it was needed by the Megapode and MFB teams on the same day. Even though both teams were able to work together in sharing this resource, it involved constant communication with scaled-back efforts by both parties.

PROTOCOL AND FUTURE RESEARCH

The protocols used to assess populations of fruit bats in the northern islands during the summer of 2010 was developed by Mildenstein and Boland (2010), both of whom have experience working with pteropodids in the Philippines and on Rota, respectively. In the protocol, the recommended techniques are direct observations and counts of bats during the day (i.e., typically early morning; 6am-10am) to be taken from distant vantage points (i.e., 150 m or greater), while using spotting scopes. In addition to direct counts conducted during the daytime, it also was recommended that photographic counts be conducted at the same location, using digital SLR cameras equipped with 300 mm stabilizing lenses. These daytime counts were then to be followed by evening departure counts of bats exiting roosts (See Mildenstein and Boland 2010 for specific protocol details).

Using these techniques served as a good basis for assessing bat populations. However, because this protocol was developed and tested on Rota, where the locations of known roosts had been monitored for more than 1 year, there was some difficulty in implementing such methodologies in the NMI where many of the roosts had moved from historic locations or were unknown. Moreover, because of local conditions (e.g., steep cliffs, dense vegetation, and lack of resources) and lack of "good" areas for needed vantage points, the application of some of these techniques was difficult. Nonetheless, the protocol developed by Mildenstein and Boland (2010) does provide a good foundation. Therefore, I recommend that future studies follow Mildenstein and Boland (2010) as a guide for conducting assessments of *P. m. mariannus* populations in the Mariana Islands.

Future projects should investigate landscape use by *P. m. mariannus* during different periods of the year to better understand habitat use, reproductive behaviors, and local migration relative to the phenology of trees that serve as food and roost resources. Pagan offers special opportunities in this regard given the unexplained movement of bats there. Inter-island movement of bats might also be considered for study although such a project might be expensive and difficult. Future projects also could include capturing the knowledge of local individuals with respect to their understanding of the bats and their movements.

HELICOPTER USE

At times the MFB team discovered that some islands (e.g., Agrihan) were too large to cover by hiking and the best way of finding fruit bats was by using helicopters. The type of helicopter used for these studies was a major factor in locating roosts. In general, the Jet Ranger was sufficient for most island work and transportation of personnel. However at times, it was critical to use the larger and more powerful Bolkow Bo 105 to fly over some of the steeper and larger islands. This was particularly noticeable when the Bolkow Bo 105 was used as part of the "mop-up" efforts during the last part of the surveys. For example, using this helicopter allowed for more maneuverability around Alamagan; this eventually led to finding the single colony on 10 July, after there had been repeated ground searches by hiking efforts and aerial surveys with the Jet Ranger during 19-21 June 2010. Overall, the use of helicopters for locating roosts was the most efficient way to cover land across all islands, but it was also the most expensive. These expenses should be factored into future projects.

ACKNOWLEDGMENTS

I thank K. Montoya, R. Rodriguez, M. Gorresen, T. Mildenstein, and L. Jenkins for their assistance in the field. I extend my deepest gratitude to P. Lisua, T. Castro, L. Stoll, P. Santos, G. Castro, S. Castro, J. Babauta, J. Camacho, J. Omar, G. Camacho, and the rest of the CNMI field crew for their help. I thank F. Amidon, C. Eggleston, and P. Radley of the Micronesian megapode crew for their assistance, willingness to share resources, and collaboration in the field. I thank C. Kessler, C. Clark, I. dela Cruz, S. Igisomar, L. Williams, the CNMI Department of Land and Natural Resource offices and

Northern Island Mayor's Office on Saipan, and camp managers on each island for their logistic support. I give special thanks to Americopters Inc., and pilots R. Crowe, N. Kogure, and J. Walker for their expertise in flying me and my crew safely to, from, and around islands during this project. I thank T. Mildenstein, J. Boland, A. Brooke, G. Wiles, and D. Worthington for their insights on fruit bats. I extend special thanks to T. Mildenstein for her assistance on the interpretation of these data. I thank M. Bogan, K. Geluso, and M. Gorresen for review of this administrative report. Primary funding came from the U.S. Navy through an interagency agreement with the U.S. Fish and Wildlife Service and U.S. Geological Survey. Any use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Table 1. Number of individuals counted using direct counts at roosts on Sarigan. Unidentified sexes or females are counted as "# of bats," with total equaling the sum of all categories for each observer. Maximum number of bats counted on Sarigan as based on the sum of largest counts from Colony 1 Vantage Point (VP) SA1 and Colony 2 VP SA3.

Direct Counts at Roosts	Date	Location and Observer	# of bats	# males	# pups	TOTAL
		Colony 1,VP SA1				
Binocular	15-Jun-10	Obs. 1	147			147
Binocular	15-Jun-10	Obs. 2	107		2	109
Spotting Scope	15-Jun-10	Obs. 1	154			154
Spotting Scope	15-Jun-10	Obs. 2	140	1	2	143
		Colony 1, VP SA2				
Spotting Scope	15-Jun-10	Obs. 3	124	1	1	126
Spotting Scope	15-Jun-10	Obs. 4	128			128
		Colony 2, VP SA3				
Binocular	16-Jun-10	Obs. 3	1			1
Binocular	16 Jun-10	Obs. 4	3			3
		Colony 2, VP SA4				
Binocular	16-Jun-10	Obs. 1	0			0
Binocular	16 Jun-10	Obs. 2	0			0
Maximum number of bats counted						**157**

Table 2. Number of individuals counted using counts from photos taken during direct counts at a roost on Sarigan. Unidentified sexes or females are counted as "# of bats." Because of the possible overlap in views from SA1 and 2, and the likelihood of bats being counted twice, counts from each vantage point were not added together to produce a maximum number of bats counted.

Counts from Photos during Direct Counts	Date	Location and # frames viewed	# of bats	# males	# pups	TOTAL
		Colony 1				
Photos from vantage point SA1	15-Jun-10	12	78			78
Photos from vantage point SA2	15-Jun-10	12	63			63

Table 3. Number of individuals counted using exit counts on Guguan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Guguan as based on the sum of largest exit counts from Colony 1 Vantage Point (VP) GU2, both observers combined, and Colony 2 VP GU3.

Exit Counts	Date	Location and Observer	# of bats	# males	# pups	TOTAL
		Colony 1, VP GU1				
Binocular/ Naked eye	17-Jun-10	Obs. 1	27			27
Binocular/ Naked eye	17-Jun-10	Obs. 2	27			27
		Colony 1, VP GU2				
Binocular/ Naked eye	18-Jun-10	Obs. 2	70			70
Binocular/ Naked eye	18-Jun-10	Obs. 3	155			155
		Colony 2, VP GU3				
Binocular/ Naked eye	18-Jul-10	Obs. 1	1			1
Maximum number of bats counted						**226**

Table 4. Number of individuals counted using direct counts at roosts on Guguan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Guguan as based on the sum of largest direct counts from Colony 1 Vantage Point (VP) GU2 and Colony 2 VP GU3. Asterisks denote count at a later time of the day and not simultaneous with other counts on 18 June 2010.

Direct Counts at Roosts	Date	Location and Observer	# of bats	# males	# pups	TOTAL
		Colony 1, VP GU1				
Spotting scope	18-Jun-10	Obs. 1	16			16
Spotting scope	18-Jun-10	Obs. 2	16			16
FLIR	18-Jun-10	Obs. 1	21			21
FLIR	18-Jun-10	Obs. 2	19			19
		Colony 1 VP GU2				
Spotting scope	18-Jun-10	Obs. 3	43			43
Spotting scope	18-Jun-10	Obs. 4	48			48
		Colony 2, VP GU3				
Binocular	18-Jun-10	Obs. 5	6			6
Spotting scope	18 Jun-10*	Obs. 1	1*			1*
Maximum number of bats counted						**54**

Table 5. Number of individuals counted using counts from photos taken from a helicopter, of a roost on Alamagan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Alamagan as based on largest number of bats counted in photos taken from a helicopter of Colony 1.

Counts from photos taken from Helicopter	Date	Location and # frames viewed	# of bats	# males	# pups	TOTAL
		Colony 1				
Photo from helicopter	10-Jul-10	5	86			86
Maximum number of bats counted						**86**

Table 6. Number of individuals counted using direct counts at roosts on Asuncion. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Asuncion as based on the sum of largest direct counts from Colony 1 Vantage Points (VP) AS2-5, collected on 25 and 26 June. Asterisks denote counts not taken of bats in other trees because observers were searching for new roosts.

Direct Counts at Roosts	Date	Location and Observer	# of bats	# males	# pups	TOTAL
		Colony 1, VP AS2, 3				
Spotting Scope	25-Jun-10	Obs. 1	166	1	12	179
Spotting Scope	25-Jun-10	Obs. 2	132	1	6	139
		Colony 1, VP AS4				
Spotting Scope	25-Jun-10	Obs. 1	25 + 52	1	3	81
Spotting scope	25-Jun-10	Obs. 2	24 + 74			98
Spotting scope	25-Jun-10	Obs. 3	22 + *		1	23
Spotting scope	25-Jun-10	Obs. 4	24 + *			24
		Colony 1, VP AS5				
Spotting Scope	26-Jun-10	Obs. 1	215		1	216
Spotting Scope	26-Jun-10	Obs. 2	295		1	296
Spotting Scope	26-Jun-10	Obs. 3	289		6	295
		Colony 1, VP AS2, 9				
Spotting Scope	28-Jun-10	Obs. 1	65	3	1	69
Spotting Scope	28 Jun-10	Obs. 2	59			59
		Colony 1, VP AS3, 4, 5 &10				
Spotting Scope	28-Jun-10	Obs. 1	162	2		164
Spotting Scope	28 Jun-10	Obs. 2	141	3	1	145
Maximum number of bats counted						**573**

Table 7. Number of individuals counted using direct counts at roosts on Maug. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Maug as based on the sum of largest direct counts from Colonies 1, 2 Vantage Point (VP) MA7, and 3.

Direct Counts at Roosts	**Date**	**Location and Observer**	**# of bats**	**# males**	**# pups**	**TOTAL**
		Colony 1, VP MA4				
Naked Eye	26-Jun-10	Obs. 1	1			1
		Colony 2, VP MA6				
Naked Eye	26-Jun-10	Obs. 1	1	1		2
Naked Eye	26-Jun-10	Obs. 2	1	1		2
		Colony 2, VP MA7				
Naked Eye	26-Jun-10	Obs. 1	1	1	1	3
Naked Eye	26 Jun-10	Obs. 2	1	1	1	3
		Colony 3, VP MA8				
Naked Eye	26-Jun-10	Obs. 1	5		2	7
Naked Eye	26 Jun-10	Obs. 2	5		2	7
Maximum number of bats counted						**11**

Table 8. Number of individuals counted using counts from photos taken from a helicopter, of a roost on Agrihan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Agrihan as based on largest number of bats counted in photos taken from a helicopter of Colony 1.

Counts from photos taken from Helicopter	**Date**	**Location and # frames viewed**	**# of bats**	**# males**	**# pups**	**TOTAL**
		Colony 1				
Photo from helicopter	2-Jul-10	31	858			858
Maximum number of bats counted						**858**

Table 9. Number of individuals counted using direct counts at roosts on Pagan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Pagan as based on the sum of largest direct counts from Colony 2 Vantage Points (VP) PA3, 5, and 6. Asterisks denote count from this vantage point includes individuals counted from VP PA4.

Direct Counts at Roosts	Date	Location and Observer	# of bats	# males	# pups	TOTAL
		Colony 2, VP PA3				
Spotting scope	6-Jul-10	Obs. 1	97	2		99
Binocular	6-Jul-10	Obs. 1	106			112
Spotting scope	7-Jul-10	Obs. 1	97	9		106
Binocular	7-Jul-10	Obs. 1	146			146
		Colony 2, VP PA4				
Spotting scope	6-Jul-10	Obs. 1	23			23
Binocular	6-Jul-10	Obs. 1	40			40
		Colony 2, VP PA5				
Spotting scope	6-Jul-10	Obs. 1	221		7	228
Binocular	6-Jul-10	Obs. 1	189			189
Spotting scope	7-Jul-10	Obs. 1	341		12	353
Binocular	7-Jul-10	Obs. 1	252			252
		Colony 2 VP PA6				
Spotting scope	7-Jul-10	Obs. 1	40			40*
Binocular	7-Jul-10	Obs. 1	64			64*
Maximum number of bats counted						**563**

Table 10. Number of individuals counted using counts from photos taken during direct counts at roosts on Pagan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Pagan as based on largest number of bats counted in photos taken during direct counts at Colony 2 Vantage Points (VP) PA3, 5, and 6.

Counts from Photos during Direct Counts	Date	Location and # frames viewed	# of bats	# males	# pups	TOTAL
		Colony 2				
Photos from vantage points PA3, 5, & 6	7-Jul-10	299	552			552
Maximum number of bats counted						**552**

Table 11. Number of individuals counted using counts from photos taken from a helicopter, of roosts on Pagan. Unidentified sexes or females are counted as "# of bats." Maximum number of bats counted on Pagan as based on largest number of bats counted in photos taken from a helicopter of Colony 1 and 2 combined.

Counts from photos taken from Helicopter	Date	Location and # frames viewed	# of bats	# males	# pups	TOTAL
		Colony 1				
Photo from helicopter	4-Jul-10	24	347			347
		Colony 2				
Photo from helicopter	4-Jul-10	22	670			670
Maximum number of bats counted						**1,017**

Table 12. Summary of the maximum number of bats counted at Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, and Maug from this study and minimum population estimates reported by Johnson (2001), Cruz and others (2000a-f), and the 1983 findings by Wiles and others (1989). Superscripts denote method(s) used to arrive at the maximum number of bats counted or minimum population estimate. Asterisks denote studies with some island estimates that were arrived from multiplying counts by a correction factor; adjusting counts based on size of island, amount of forest cover, plant diversity and abundance; or combination of these variables.

Island	2010	2001*	2000*	1983*
Anatahan	150[a]	1,000[g]	1,000[b,e,f]	3,000[c,f]
Sarigan	157[b]	400[a,b,d]	150-200[b,e,f]	125[e]
Guguan	226[c]	550[b]	350[b,c,e,f]	400[e]
Alamagan	86[d]	100[g]	200[e,f]	0[e]
Pagan	1,017[d]	1,500[a,b,c]	1,500[c,e,f]	2,500[c,f]
Agrihan	858[d]	1,000[a]	1,000[b,c,e,f]	1,000[c,e]
Asuncion	573[b]	800[a,e,f]	NA	400[e]
Maug	11[b]	50[g]	NA	<25[g]
TOTAL	**3,078**	**5,400**	**NA**	**7,450**

a. Visual estimate from helicopter.
b. Direct counts of bats at roosts.
c. Exit count of bats at roosts.
d. Counts of bats in photograph taken from helicopter.
e. Evening flight activity count (aka, station count).
f. Visual sightings from the ground.
g. Estimate not based on a count taken during that study.

Appendix 1. Definition of some terms used in the report as defined by Ellison and other (2003).

Census: A complete count of bats in a survey area, but usually made without estimating and correcting for sampling and observation probabilities.

Colony: A group of bats of a single species which occupy a definable boundary at a particular time interval where population parameters can be defined.

Count: A generic term for how many bats were found in a particular location on a unique date.

Day Roost: Any place a bat settles down to rest during the daylight hours, but sources do not specify roost function (e.g., roost could be used for a maternity, bachelor, or hibernating colony).

Location: A unique site where bats were observed.

Observation: A document of bat occurrence on a unique date at a unique location. An observation can be a count or any method of estimating colony size for a particular species of bat on a unique date at a unique location.

Population: A group of individuals of the same species living in a particular area. A population can consist of multiple colonies with spatial boundaries that vary within and among years.