Impact of Post-typhoon Hunting on Mariana Fruit Bats (*Pteropus mariannus*)[1]

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Abstract: We examined the abundance of Mariana fruit bats (*Pteropus mariannus* Desmarest) on the Pacific islands of Rota and Guam before and after a severe typhoon in December 2002. After the typhoon, bat abundance declined by 70% on Rota. On Guam, bat abundance initially increased by ca. 100 individuals (103%), perhaps due to immigration from Rota, but then declined an average of 32% from pretyphoon levels for the remainder of 2003. An increase in post-typhoon hunting pressure represents at least a partial cause for the decline observed on Rota. Interviews with 29 suspected poachers on the island revealed a 34% increase in bat harvest from 2002 to 2003. Hunting of bats is rare on Guam because access to their remaining habitat is restricted by the U.S. military. However, juvenile bats are preyed on by introduced brown tree snakes (*Boiga irregularis* Bechstein) on Guam to such an extent that little to no within-island recruitment occurs. We therefore suggest that the brief increase and subsequent decrease in bat abundance on Guam was due to interisland movements, a reduction in the source population (Rota), and/or changes in roosting patterns on Guam. Rota is vital to recovery prospects for *P. mariannus* in the southern Mariana Islands because it holds the only viable population in this part of the archipelago. If the species is not conserved, forest ecosystems may suffer because *P. mariannus* is almost certainly an important seed disperser and pollinator on these depauparate islands. We recommend that agencies responsible for managing hunted fruit bat populations make special efforts to prevent illegal hunting after severe typhoons.

The Mariana fruit bat (*Pteropus mariannus* Desmarest), like many pteropodids, almost certainly plays an important role in pollination and seed dispersal (Wiles and Fujita 1992) and may be a keystone species on the depauparate, oceanic islands where it occurs (Cox et al. 1991, Rainey et al. 1995). Despite a long-standing moratorium on bat hunting in the Commonwealth of the Northern Mariana Islands (CNMI), the species is heavily hunted on these islands (Wiles and Payne 1986, Sheeline 1991, Lemke 1992, Stinson et al. 1992; this study). On Guam, the southernmost Mariana island and not part of the CNMI (Figure 1), *P. mariannus* receives greater protection because the only colony resides within a U.S. Air Force base, where law enforcement is substantial and public access is restricted. However, the introduced brown tree snake (*Boiga irregularis* Bechstein) preys on juvenile fruit bats on Guam to such an extent that little to no within-island recruitment has occurred for many years (Wiles 1987). Guam thus represents a sink for bat

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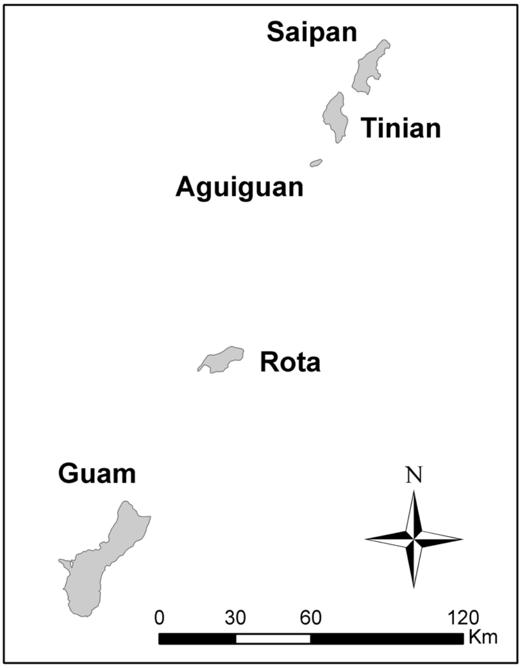

Figure 1. The southern Mariana Islands: Guam is a U.S. Territory; Rota and the islands north of it are part of the Commonwealth of the Northern Mariana Islands.

populations, with immigrants coming from neighboring Rota (Wiles 1987, Wiles and Glass 1990). Brown tree snakes are not known to be established on Rota. Recently, *P. mariannus* was listed as Threatened under the U.S. Endangered Species Act, largely because of continued hunting in the CNMI (U.S. Fish and Wildlife Service 2005).

Within the southern Mariana archipelago, only Rota has maintained sizable numbers of fruit bats, with estimated populations of ca. 600–2,600 individuals between 1984 and 2003 (Wiles et al. 1989, Stinson et al. 1992; this study). Bat numbers on the other southern islands (Guam, Aguiguan, Tinian, and Saipan) have generally remained less than 200 each over the same period, primarily due to hunting and snake predation (Wiles 1987, Wiles et al. 1989, Stinson et al. 1992; this study).

Bat hunting intensity sometimes increases after typhoons because hunters take advantage of relatively clear lines of sight in defoliated forests, and some fruit bat species become increasingly diurnal and forage in areas more accessible to hunters, such as agricultural and urban areas, when food sources are depleted in forests (Stinson et al. 1992, Craig et al. 1994, Pierson et al. 1996). Craig et al. (1994) documented 80–90% declines in *P. tonganus* (Quoy & Gaimard) and *P. samoensis* (Peale) in Samoa following two severe typhoons. They, and Pierson et al. (1996), attributed the declines to starvation, predation by domestic animals, and hunting. McConkey et al. (2004) reported a post-typhoon decline of 70–96% in *P. tonganus* in the Vava'u Islands and suggested that bats probably starved after the storm. Stinson et al. (1992) noted a 57% decline in *P. mariannus* on Rota after a typhoon in 1988; they attributed the loss to hunting and interisland movements.

Typhoons are a common occurrence on many tropical and subtropical islands. Three super-typhoons (defined as sustained winds >241 km/hr), and many less powerful storms, hit Rota from 1988 to 2003. The impact of typhoons on forests can be dramatic—high winds uproot entire trees and strip standing vegetation of limbs, leaves, fruits, and flowers (Elmqvist et al. 1994, Franklin et al. 2004). This damage affects the behavior of fruit bats, presumably by reducing food supplies and cover (Cheke and Dahl 1981, Richards 1990*a*, Pierson et al. 1996, Grant et al. 1997).

On 8 December 2002, Typhoon Pongsona severely damaged vegetation on Rota and Guam. Sustained winds and gusts were estimated at 204 km/hr and 249 km/hr on Rota and >185 km/hr and >232 km/hr on Guam, respectively (Guard et al. 2003). On Rota, most trees were entirely defoliated and forest-canopy cover was greatly reduced over broad areas (J.A.E., pers. obs.). Vegetation on Guam was similarly affected, but some topographically sheltered areas received less damage (D.J., pers. obs.). J.A.E. and D.J. were present on Rota and Guam, respectively, before, during, and after the typhoon.

Herein, we assess the impact of Typhoon Pongsona on fruit bat populations on Rota and Guam by comparing numbers of *P. mariannus* before and after the typhoon, and relate the observed changes in abundance to three potential causes: hunting, starvation, and interisland movements.

MATERIALS AND METHODS

Study Area

Rota (14° 10′ N, 145° 12′ E) is a limestone island that lies 60 km north of Guam and measures 85 km^2 (Figure 1). Maximum elevation is 491 m. Topography is dominated by a western plateau that averages 450 m elevation. Much of the island's forest has been fragmented; the most intact forests persist on precipitous, rocky, and inaccessible terrain. Total forest cover was estimated at 4,916 ha (58%) in 1984 (Falunruw et al. 1989).

Guam (13° 27′ N, 144° 43′ E) is the largest (540 km^2) and southernmost island in the Mariana archipelago. It is composed of both raised limestone and volcanic material. Maximum elevation is 407 m. Guam's forest cover was estimated at 48% by Donnegan et al. (2004). Vegetation on the island has been drastically altered by development, war, and introduced plants and animals (Fosberg 1960, McConnell and Muniappan 1991, Schreiner 1997).

Bat Surveys on Rota

We monitored *P. mariannus* on Rota by conducting evening departure counts monthly at seven colony sites (Liyo, Saguapakpak, As Pupuenge, Lupok, As Akodo, Uyulan Hulo, and Palii) from January 2002 through April 2004, with the exception of September 2003. During most months, colonies (groups $\geq$100 individuals) occurred at only one to two of these sites, with relatively few bats using the other five to six sites. Colonies occasionally formed in areas outside these seven sites, but their presence in those areas was generally brief. Length of evening departure counts was variable ($\bar{X} = 81 \pm 16.5$ min [$\pm$1 SD]), but all counts started before sunset ($\bar{X} = 46 \pm 16.4$ min before sunset) and continued until darkness precluded further observation ($\bar{X} = 35 \pm 10.1$ min after sunset). We generally conducted evening departure counts during clear weather, but we occasionally experienced mild showers with diminished visibility for a few minutes. Evening departure counts were conducted on consecutive evenings as much as possible, given weather conditions. We established landmarks on either side of each colony; bats that flew past the landmark and away from the colony were counted as having departed, whereas those entering the area were subtracted from the total. Bats flying within the survey region but not departing were included in the total, but observers made a conscious effort to avoid double-counting. We consider double-counting a trivial problem because most bats departed the colony sites in the same direction, and very few bats were observed returning or circling over the colony site. Evening departure counts provide conservative estimates of colony size because some bats depart after dark or in directions not visible to the observer (Utzurrum et al. 2003). We used the sum of the seven evening departure counts taken each month as an index of bat abundance on the island. After Typhoon Pongsona, we noted any unusual bat behavior thought to be related to the typhoon.

Due to the low numbers documented with evening departure counts after Typhoon Pongsona, we began making extensive searches for other bat colonies. During February 2004, we searched all suitable habitats on Rota, primarily by scanning forested areas during the day with 10 by 50 binoculars and 20–60× spotting scope. For a few inaccessible areas, we positioned ourselves along potential flyways adjacent to the inaccessible areas, and watched for departing bats from ca. 1730 hours until dark. On 22 April 2004, we again searched all suitable habitats on the island for bat colonies, this time by helicopter. We deliberately flew at a low altitude to encourage bats to fly from their roosts, making them clearly visible.

Bat Surveys on Guam

The only bat colony on Guam was surveyed monthly (except August 2003) with direct counts. Roosting bats were counted during the day using a 20–60× spotting scope from an elevated observation post, approximately 150 m distant.

Islands North of Rota

Because fruit bats occasionally move among islands in the Marianas (Wiles and Glass 1990), the possibility existed that many bats left Rota for neighboring islands after the storm. We therefore asked conservation officers and biologists who lived on Tinian and Saipan for the duration of this study if they had observed, or heard reports of, large numbers of bats at any time during 2003. As part of another study (Esselstyn et al. 2004), we visited Aguiguan for 10 days in September 2003 and walked over most of this small (7 km^2), uninhabited island, noting any fruit bats.

Poacher Interviews

A sample of suspected poachers that lived on Rota for the duration of this study was interviewed during March 2004. A long-time, well-trusted resident of Rota conducted confidential interviews for us in the Chamorro language. Only individuals who were believed by the interviewer to hunt fruit bats were asked to participate. We asked the following questions:

1. How many bats did you capture during 2002?
2. How many bats did you capture during 2003?
3. If the number of bats you captured during those years changed, why?
4. Do you believe that Rota's bat population is (a) increasing, (b) decreasing, or (c) stable?
5. If you believe the population is either increasing or decreasing, what do you think is the primary cause?

We used the calendar year to compare harvest levels before and after Typhoon Pongsona to provide clarity and consistency in the interviews. This strategy biased the data against our hypothesis that hunting had increased after Pongsona, because our estimated pretyphoon hunting rate included a period of 3 weeks after the storm, a time during which much hunting took place. We asked questions 4 and 5 not to test our hypothesis that bat abundance had declined, but because we wished to gauge hunters' awareness and concern, or lack thereof, that they may be directly causing the decline.

Data Analysis

To test for a post-typhoon decline in bat abundance on Rota, we compared monthly evening departure count sums from 2002 and 2003. We used a one-tailed t-test (unequal variances) on $\log_{10}$-transformed data in MINITAB, release 11. We performed the same analysis using data from monthly direct counts for the only colony on Guam.

RESULTS

Bat Surveys

The average monthly evening departure count total on Rota was 1,167 $\pm$ 174 ($\pm$1 SE, $n = 11$ months) in 2002 but only 345 $\pm$ 108 ($n = 11$ months) in 2003, suggesting a decline of 70% ($t = 3.94$, df = 15, $P < 0.001$) (Figure 2). The substantial variation in evening departure count sums during 2002 does not represent real fluctuations in abundance, but rather is an artifact of our methods. These fluctuations are largely due to changes in the numbers of bats observed departing a single colony (Liyo). For example, during 2002, counts at Liyo ranged from 169 to 1,815 bats. During the 4 months with the highest totals from 2002 (January, June, July, and October), 85–98% of the bats we counted were observed departing the Liyo colony. Each time we documented a large colony at Liyo using evening departure counts, we observed bats continuing to depart as darkness truncated our surveys, suggesting that even our highest counts were conservative.

Bat abundance on Guam peaked a few weeks after the storm (up ca. 100 individuals or 103% from the previous count), but quickly returned to numbers similar to those documented before the typhoon (Figure 2). Comparisons of direct counts on Guam between 2002 and 2003 revealed a marginally significant decline ($t = 1.75$, df = 15, $P = 0.05$). If the peak in numbers from January 2003 is

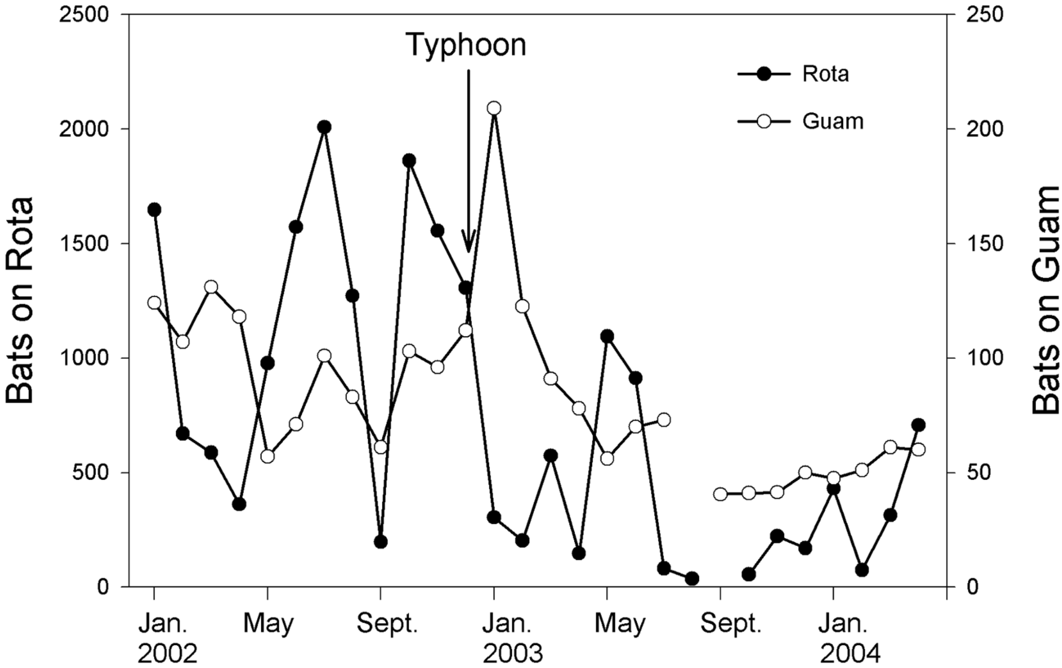

FIGURE 2. The impact of Typhoon Pongsona on Mariana fruit bat (*Pteropus mariannus*) abundance on Rota and Guam. Data from January 2002 to April 2004 are included. Rota data represent the sums of monthly evening departure counts taken at seven colony sites. Guam data are from direct counts taken at the only colony on the island.

removed, the mean number of bats dropped from 97.0 ± 7.0 in 2002 to 66.3 ± 8.3 in 2003, representing a decline of 32% ($t = 2.89$, df $= 16$, $P < 0.01$).

On Rota, we found no colonies outside the areas accounted for by evening departure counts during our extensive ground surveys in February 2004. Similarly, the search conducted by helicopter found only one small group of ca. 40 bats outside the areas covered by evening departure counts.

Very few bats were observed on Saipan and Aguiguan, and no groups of more than five individuals were noted from either island during 2003. No *P. mariannus* has been seen on Tinian for several years, including 2003.

Other Observations

For several weeks after Typhoon Pongsona, we perceived an increase in diurnal activity by bats on Rota and greater foraging activity in areas that were more accessible to hunters (e.g., abandoned coconut plantations). Although this suggests that food sources were reduced, the situation did not appear to be severe. That is, we did not observe, or receive reports of, bats foraging on the ground or in villages, as is known to happen when bats are severely food stressed (Craig et al. 1994, Pierson et al. 1996, McConkey et al. 2004). In addition, we observed two adult females carrying juveniles in flight: one was seen 2 weeks after the storm; the other, 3 months after the storm. Given the length of reproductive cycles of large pteropodids (Pierson and Rainey 1992), these bats must have been pregnant or lactating when the storm passed.

Poacher Interviews

Twenty-nine suspected bat hunters on Rota participated in the interviews, and three declined to answer our questions. Seventeen of 29 (59%) respondents indicated that they captured more bats during 2003 than during

2002, seven (24%) indicated fewer were captured during 2003, one (3%) said about the same number were captured, and four (14%) denied capturing bats during either year. Of the 17 respondents who captured more bats during 2003, nine (53%) linked their increase in harvest to the greater ease in shooting fruit bats after Typhoon Pongsona. Five of seven (71%) respondents who captured fewer bats during 2003 linked the change to extraneous personal matters. The mean number of bats captured by all interviewees who admitted hunting was 9.4 (range 0–60) in 2002 and 12.6 (0–70) in 2003, representing a 34% increase in harvest.

Seventeen of 25 (68%) admitted poachers believed that *P. mariannus* on Rota was declining, and 88% of these respondents implicated hunting as the primary cause. Nine (36%) respondents believed the population to be stable, and three (12%) said that they didn't know what the current population trend was. No respondents believed the population was increasing.

DISCUSSION

Our evening departure counts show that the abundance of *P. mariannus* on Rota declined dramatically after Typhoon Pongsona. Although there was substantial variation in evening departure count sums, especially during 2002, we consider even the highest monthly sums to represent conservative estimates of abundance. During the months when our counts were high, the sums were dominated by the Liyo colony. Because bat abundance at the other six sites was trivial relative to that of the Liyo colony during those months, we can eliminate intercolonial movements as a confounding factor (i.e., counting the same bats at different colony sites) that might have artificially inflated our estimates. In addition, the Liyo evening departure counts are probably conservative because bats were still departing when our counts ended. Thus, we are as concerned by the lack of high evening departure count sums during 2003 as we are by the very low counts taken regularly during that year.

Increased hunting appears to have been at least a partial cause of the decline on Rota. We perceived and documented an increase in bat harvest and were unable to identify any support for alternative explanations (starvation and direct mortality). Our observations of surviving juveniles suggest that at least some adult females were able to meet the metabolic demands of pregnancy and lactation in the immediate aftermath of the storm, and we did not observe, or hear reports of, bats foraging on the ground or in villages. Similarly, Stinson et al. (1992) noted that bats collected on Rota after Typhoon Roy were fat and healthy.

Direct storm mortality of large pteropodids is much more difficult to assess because of inherent challenges in making observations during and immediately after powerful storms. Although direct mortality has never been rigorously quantified, Stinson et al. (1992) suggested that it was negligible for a typhoon similar in strength to Pongsona. Their estimates of *P. mariannus* abundance on Rota immediately after the typhoon were comparable with those taken before the storm, but then declined over the subsequent year. In contrast, McConkey et al. (2004:558), citing S. Campbell (pers. comm.), reported "large numbers of flying foxes" floating in a sheltered lagoon immediately after a typhoon. Although one of us was present on each island during and immediately after Typhoon Pongsona, we did not see, or hear reports of, dead bats in the days following the storm. However, because we did not search colony sites specifically for dead bats, we are unable to address the possibility that mortality during the storm may have been substantial.

We did find evidence that ca. 100 *P. mariannus* may have migrated from Rota to Guam and perhaps back to Rota, but this figure is insufficient to explain the decline on Rota. Bats may have left colonies and roosted solitarily after the storm, driving down our evening departure counts, but it seems unlikely that this would continue for 16 post-storm months given the variation in extracolonial abundance documented on the island by a previous study (Stinson et al. 1992).

On Guam, we found no evidence that bats starved, nor did we note any unusual behavior after the storm. Thus, we believe that the slight reduction in abundance seen from 2002 to 2003 on the island was the result of interisland movements, a reduced source population (Rota), and/or increased extra-colonial roosting on Guam.

Although the bat population on Rota remained viable after Typhoon Pongsona, the potential for repeated occurrence of intensified hunting following severe weather is of great concern. If multiple storms strike an island, or group of islands, over a relatively short period, the effects of poststorm hunting could be especially detrimental (e.g., Craig et al. 1994, Pierson et al. 1996). The majority of hunters on Rota that we interviewed believed that fruit bats were in decline and implicated hunting as the primary cause. Despite this awareness, hunting remains common. Wildlife agencies responsible for protecting hunted populations of large pteropodids should make law enforcement a priority, particularly after severe storms. We believe that intensive law enforcement for several weeks after severe cyclonic storms will do much to conserve this and other intensively hunted fruit bat populations. The need for such action will be especially acute if the frequency and intensity of cyclonic storms are increasing, as some researchers suggest (Trenberth 2005, Webster et al. 2005).

Aside from Rota, very few *P. mariannus* remain in the southern Marianas, and prospects for recovery of these populations rely on the presence of a large and thriving bat population on Rota. Conservation of keystone species is especially important because their loss may have major implications for ecosystems. Specifically, there is evidence that large pteropodids may disperse seeds widely only when bat density is sufficient to promote competition for fruit; thus, when bat abundance is low, they may not perform some of the ecosystem functions that give them keystone status (Richards 1990*b*, Rainey et al. 1995, McConkey and Drake 2002). The abundances of fruit bats on Rota and many other Pacific islands are probably far lower than the islands' carrying capacities. Wiles et al. (1991) found that *P. mariannus* on Ulithi Atoll in the Carolines, where they are not intensively hunted, reached a density of 2.8 bats per hectare. This figure, extrapolated to 4,916 ha of forest on Rota (Falanruw et al. 1989), yields an estimated carrying capacity of nearly 14,000 bats—many more than have ever been reported from the island (e.g., Wheeler 1980, Wiles et al. 1989, Stinson et al. 1992).

The low density of bats on Rota and Guam may explain why neither we nor Stinson et al. (1992) observed any evidence of starvation after severe typhoons. Although food resources were certainly reduced after typhoons in 1988 and 2002, they apparently remained sufficient for the small number of bats on the island. However, 20 months after Pongsona, another powerful storm hit Rota; bats reportedly foraged on the ground shortly afterward and hunting was again common (U.S. Fish and Wildlife Service 2005). Given these events, we consider post-typhoon hunting an important threat to these populations of *P. mariannus* and perhaps other insular pteropodids.

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