

The Mammals of Tinian, Mariana Islands

GARY J. WILES

Division of Aquatic and Wildlife Resources, P.O. Box 2950, Agana, Guam 96910

A. BINION AMERSON, JR.

4020 Brookhaven Club Drive #1520, Dallas, Texas 75244

ROBERT E. BECK, JR.

Division of Aquatic and Wildlife Resources, P.O. Box 2950, Agana, Guam 96910

Abstract—Twelve species of mammals are reported from the island of Tinian. The island's native mammal fauna included the Marianas fruit bat (*Pteropus mariannus*) and possibly the Pacific sheath-tailed bat (*Emballonura semicaudata*). With the arrival of human settlers, a number of other mammals eventually reached Tinian. Polynesian rats (*Rattus exulans*) probably accompanied early Chamorros, while Europeans introduced several species of ungulates, carnivores, and other rodents. Some of these animals established wild populations. Numbers of feral cattle (*Bos taurus*) and pigs (*Sus scrofa*) increased greatly by the 1700s, probably resulting in severe and long-lasting impacts on the island's vegetation. The two most recent mammal introductions to Tinian were the Philippine deer (*Cervus mariannus*) and musk shrew (*Suncus murinus*) in the 1960s or early 1970s.

Introduction

Island ecosystems are susceptible to biological invasions (Stone & Scott 1985, Vitousek 1988, Schofield 1989). In the Mariana Islands, the effects of introduced animals and plants on the native biota have been poorly documented, but nonetheless have likely been severe. The island of Tinian has experienced drastic ecological changes since the arrival of humans, perhaps more so than any other island in the archipelago. Fosberg (1960) believed that much of the island's vegetation was originally modified by a large indigenous Chamorro population prior to European contact. Other major impacts on plant communities and wildlife have come from extensive grazing by introduced ungulates during the last 300–400 years, the clearing of most of the island for sugar cane cultivation in 1929 and the 1930s by the Japanese (Fosberg 1960, Peattie 1988), and military construction during World War II. Bowers (1950) estimated that only 2% of the island remained forested after the war. Tinian's vegetation is now largely characterized by secondary growth and numerous alien plants. In this paper, historic information on the mammals of Tinian, comprised primarily of introduced species, is reviewed. We also document the status of mammals on the island through 1985.

Study Area

Tinian (15°N, 145°38'E) is 102 km² in size, being approximately 20 km long and 9 km wide. The nearest islands are Saipan, which is 4.5 km northeast, and Aguijan, which

is 9 km southwest. Tinian is a relatively low and level island composed almost entirely of limestone terraces. The highest elevations are 178 m at Kastiyu and 166 m at Mt. Lasu (Mt. Lasso). The island's climate is tropical and temperatures remain warm and fairly uniform during the year, ranging from 20-32°C. Annual rainfall averages about 200 cm with the wettest months being July to October. A dry season occurs from January to April.

Descriptions of Tinian's plant communities are given by Fosberg (1960), Engbring *et al.* (1986), and Hawaiian Agronomics, Inc. (1985). Tangantangan (*Leucaena leucocephala*) forest and open fields are the most predominant habitats, covering 38.3% and 30.9% of the island, respectively (Engbring *et al.* 1986). Other vegetation types include secondary forest (19.2%), native forest (4.9%), strand vegetation (3.6%), cultivated fields (1.9%), urban areas (0.8%), and marshland (0.1%) (Engbring *et al.* 1986).

Large tracts of tangantangan, a small exotic tree, grow in northern and central Tinian. In many areas, this habitat is composed almost exclusively of this species. Canopy height is usually 4-5 m. Tangantangan forests occur primarily on abandoned sugar cane fields.

Open fields are characterized by grasses or low herbaceous growth and many are actively maintained as cattle pastures. Common grasses are *Pennisetum purpureum*, *Panicum* spp., and *Paspalum* spp., while weedy species include *Chromolaena odorata*, *Mikania scandens*, *Mimosa invisa*, *Lantana camara*, and *Operculina ventricosa*.

Secondary vegetation is dominated by a number of introduced trees and shrubs, which grow to heights of 2-20 m. Typical trees include *L. leucocephala*, *Acacia confusa*, *Cocos nucifera*, *Pithecellobium dulce*, *Casuarina litorea*, and *Delonix regia*. A dense understory is usually present.

Native forest generally remains on steep slopes or rugged limestone substrates where agricultural clearing did not occur. Two types of native forest can be distinguished with both having canopy heights of 6-15 m. Inland forest often contains *Cynometra ramiflora*, *Guamia mariannae*, *Premna obtusifolia*, *Pisonia grandis*, and *Ficus* spp. Coastal forest occurs along shorelines and contains *Pandanus tectorius*, *Ochrosia mariannensis*, *G. mariannae*, *C. ramiflora*, *Mammea odorata*, *Heritiera longipetiolata*, *Cerbera dilatata*, and *Barringtonia asiatica*. The only large tract of native forest remaining on Tinian is at Kastiyu on the island's southeastern corner, and it consists of mainly of coastal forest.

Strand vegetation occurs along shorelines and consists of shrubby plants that are 1-4 m tall. *Pemphis acidula*, *Scaevola taccada*, *Tournefortia argentea*, *Thespesia populnea*, and *Ipomea pes-caprae* characterize this habitat.

Cultivated fields contain bananas (*Mus sapientum*), sorghum (*Sorghum* spp.), papayas (*Carica papaya*), watermelon (*Citrullus lanatus*), and a number of other vegetable crops. The only significant marsh on the island is at Hagoi, with *Phragmites karka*, *Scirpus littoralis*, and *Acrostichum aureum* present. A slightly smaller wetland at Makpo is heavily overgrown by woody vegetation, primarily *Hibiscus tiliaceus* (Engbring *et al.* 1986).

Tinian's human population numbers about 1,000 residents, most of whom live in the town of San Jose on the southwestern side of the island. The northern two-thirds of the island, which is known as the Military Retention Area (MRA) (Figure 1), has no permanent residents but is regularly visited by farmers and ranch workers. Tinian's only harbor is adjacent to San Jose.



Figure 1. Map of Tinian, Mariana Islands, with names of locations used in the text. The Military Retention Area lies north of the dashed line. Count stations for Marianas fruit bats are designated by closed circles.

Methods

Visits to Tinian were made on 21–25 November 1984, 5–12 January 1985, 10–14 May 1985, and 11–15 October 1985. Most field work for this study was conducted in the MRA, with some data also recorded from the southern portion of the island.

Surveys for fruit bats were made at nine observation points in the MRA (Figure 1). Observers used 7X or 10X binoculars to scan the forest for flying or roosting bats. Counts lasted 30 minutes and were made at dusk (total of 15.5 hr) or in the morning after sufficient light became available (total of 1.5 hr), when fruit bats are most visible to observers. Observation locations provided ample viewing of stands of native and secondary forests growing primarily along cliffclines.

Trapping for small mammals took place in January and May in a variety of different habitats. A trap line of 10-60 snap traps, spaced 10 m apart, was set each afternoon from 1600-1800 hours at one or more sites. Traps were retrieved the following morning between 0600-0800 hours. Traps, which measured 8×14 cm or 9×18 cm in size, were baited with peanut butter, toasted coconut, or dampened oatmeal. Standard morphological measurements were taken from captured animals and compared with those given in Johnson's (1962) key for Micronesian rodents to determine species identity. Skulls of rats were examined to verify identities (Marshall 1977). Trapping success for each species of small mammal in a habitat type was calculated by dividing the number of individuals of a species caught by the total number of trap nights in a habitat. Trapping success was low, with hermit crabs (*Coenobita* sp.) suspected of setting off 60-90% of all traps.

In addition, searches for Norway rats were made by placing 10-25 traps at each of three locations. These included a grove of tangantangan forest next to the harbor, a roadside near several homes on the outskirts of San Jose, and the municipal dump located on 8th Avenue 1.8 km northwest of San Jose.

Interviews with local residents, searches for tracks, droppings and feeding evidence, and direct observations provided information on the large mammals. All caves encountered during the survey were searched for sheath-tailed bats.

Species Accounts

Musk Shrew, *Suncus murinus*

Previous Records: Musk shrews were apparently introduced to Guam in the early 1950s, possibly arriving in ship-borne cargo from the Philippines (Peterson 1956). Shrews were first discovered on Saipan in 1962 and on Rota in 1966 (Barbehenn 1974) and probably arrived on Tinian about this time. However, their occurrence on the island was not reported until Owen (1974) saw an animal in the village of San Jose in 1974.

Present Survey: Musk shrews were observed islandwide on Tinian and were common in most habitats (Table 1). Trapping success was highest in secondary vegetation (success=3.0% of trap nights) and tangantangan forest (success=2.5%) (Table 2). Shrews were frequently seen along roadsides at dusk and at night, and their characteristic squeaking was often heard in pastures and in San Jose. As an indication of their high abundance, seven shrews were seen crossing a kilometer-long stretch of highway bordered by tangantangan forest in Malatu during a 2-minute period at dusk one night. Strand vegetation was the only habitat in which shrews were not recorded, however, their presence in this plant community was probably overlooked.

Marianas Fruit Bat, *Pteropus mariannus*

Previous Records: Fritz (1901) remarked about the large number of fruit bats on Tinian in 1900 and noted that they were a choice food of the native islanders. In the late 1920s and 1930s, loss of habitat caused by extensive land clearing by the Japanese probably greatly reduced the abundance of bats on the island. In 1945, J. T. Marshall, Jr. (unpubl. field notes) observed single colonies of about 500 fruit bats at Makpo and 50-100 bats at Mt. Lasu. However, Downs (1948), who was on Tinian at the same time as Marshall, did not mention the presence of *Pteropus*, a general indication that bats were neither common nor widespread at the time.

Table 1. Current known (+) and suspected (s) occurrences of mammals in different habitats on Tinian, Mariana Islands

Species	Tangantangan forest	Open fields	Secondary vegetation	Strand vegetation	Native forest	Cultivated land	Urban
Musk shrew	+	+	+	s	+	+	+
Marianas fruit bat	s	s	s		+		
House mouse		+					
Roof rat	+	+	+	+	s	+	+
Dog	+	+				+	+
Cat	+	+				+	+
Horse		+					
Pig						+	+
Cow	+	+	+	+	+	+	+
Goat	s	s			+	+	+

Table 2. Numbers of small mammals captured in six habitats in northern and central Tinian in January and May 1985

Habitat	No. traps nights	No. of animals captured			Capture rate of all species (%)
		Musk shrew	Roof rat	House mouse	
Tangantangan forest	198	5	8	0	6.6
Open fields	123	1	3	1	4.1
Secondary vegetation	67	2	2	0	6.0
Strand vegetation	47	0	8	0	17.0
Native forest	25	0 ^a	0 ^b	0	0.0
Municipal dump	25	0 ^a	1	0	4.0
Total	485	8	22	1	6.4

^a Individuals were seen but not captured in a habitat.^b Individuals believed to be of this species were seen in this habitat.

Fruit bats were heavily hunted for commercial purposes in the 1970s, causing numbers to decline greatly. Bats were exported to Guam and Saipan for use as a delicacy by Chamorro residents (Owen 1974, Wheeler 1980, Wiles & Payne 1986). Between 1975 and 1981, an average of 210 bats (range=60-430 bats) was shipped annually to Guam from Tinian (Wiles & Payne 1986), although these figures probably include some bats taken on Aguijan as well.

Owen (1974) failed to observe bats during his survey but received reports that they still occurred on the island. Wheeler (1980) believed that only 25-100 fruit bats survived on Tinian by 1979, and Wiles *et al.* (1989) estimated the population to contain fewer than 25 animals in 1984. All of the bat sightings made during these two studies occurred at Kastiya.

Present Survey: Marianas fruit bats were not seen during 17 hours of observations in

the MRA. Our findings were corroborated by the reports of residents who stated that fruit bats are rarely seen on the island. A few recent reports from the MRA included several sightings of single bats flying over Bateha during the summer of 1984 (W. Menzies, pers. comm.) and at Mahalang during 1983 and 1984 (A. Borja, pers. comm.). A group of five bats was seen at Kastiyu about 10 days prior to our visit in November 1984. (A. Borja, pers. comm.). These data support the conclusion of Wiles *et al.* (1989) that Tinian's current population of fruit bats is very small.

The occasional sightings of fruit bats at Kastiyu indicate that remote native forests are the preferred habitats of this species on Tinian. Residents stated that bats occasionally enter secondary and tangantangan forests, farms, and coconut groves in search of fruiting and flowering trees.

Overhunting has caused the dramatic decline in fruit bats on Tinian and other islands in the southern Marianas (Wiles 1987, Wiles *et al.* 1989). Although bats are afforded legal protection in the Commonwealth of the Northern Mariana Islands (CNMI) by a series of hunting moratoriums that have existed since 1977, bats are still killed by hunters when the opportunity arises (Wiles *et al.* 1989). Tinian appears to have sufficient food resources to sustain a much larger fruit bat population. The island's native forests possess a number of tree species that are used as food sources by bats; these sources include *Pandanus tectorius*, *Neisosperma oppositifolia*, *Erythrina variegata*, *Mammea odorata*, *Premna obtusifolia*, and *Ficus* spp. Secondary and tangantangan forests, open fields, and farms contain additional food trees such as *Carica papaya*, *Cocos nucifera*, *Ceiba pentandra*, and *Mangifera indica*.

Pacific Sheath-tailed Bat, *Emballonura semicaudata*

Previous Records: The status and distribution of sheath-tailed bats in the Mariana Islands was summarized by Lemke (1986). Historically, the bat is known from Guam, Rota, and Aguijan, with unverified sightings on Saipan, Anatahan, and Maug. At present, the only known extant population occurs on Aguijan, where a small number of bats was recently rediscovered (Lemke 1986). Although never reported from Tinian, sheath-tailed bats probably once inhabited this island as well. Reasons for the decline of this species in the Marianas are not known, but human disturbance and destruction of caves during World War II, and post-war spraying of insecticides (Baker 1946a) may have been factors.

Present survey: Sheath-tailed bats were not found in any of 10 small natural caves located along hillsides at Laderan Lasu and Maga. Bats were also absent from a small natural cave situated along the ocean south of Puntan Lamanibot Sanhilo (D. R. Moore, pers. comm.). None of these caves contained guano. Because little is known about the roosting requirements of *E. semicaudata*, it is uncertain whether these caves, each of which was less than 12 m in length, were large enough to support this species. Additional searches for sheath-tailed bats should be conducted in Kastiyu, where the rugged limestone terrain may hold more caves.

House Mouse, *Mus musculus*

Previous Records: The origin of house mice in the Mariana Islands is unknown. Marshall (1962a) reported *M. musculus* from Tinian, Saipan, and Guam, and mice have been observed on Rota and Cocos Island (Wiles, pers. observ.). Marshall's record for

Tinian is based on specimens collected at the end of World War II (R. D. Fisher, pers. comm.). Downs (1948) observed unidentified mice on the island during this same period.

Present Survey: Only one house mouse was captured during trapping efforts in the study (Table 2). This animal was a male in breeding condition and was taken along a fence row in pastureland at Unai Dangkolo on 8 January. Based on skull characteristics, it was subsequently identified as belonging to the subspecies *M. m. castanea* (R. D. Fisher and J. T. Marshall, pers. comm.). House mice seem to be uncommon on Tinian; however, the use of large snap traps in this study may have resulted in the low capture rate of this small rodent. Additional trapping in pastures and the village may reveal that mice are more common than indicated here. Elsewhere in Micronesia, *M. musculus* is found primarily near buildings and homes but also inhabits a variety of plant communities except for undisturbed forest (Baker 1946b, Enders 1949, Marshall 1962b).

Roof Rat, *Rattus rattus*

Previous Records: Roof rats likely reached Tinian aboard European shipping traffic sometime between the 1600s and 1800s. Unidentified rats were numerous on the island in 1742 (Thomas 1971). Kuroda (1938) and Marshall (1962a) are the only writers that have identified *R. rattus* from Tinian, with Marshall's record based on a number of animals that were caught in 1944 and 1945 (R. D. Fisher, pers. comm.). Downs (1948) and Owen (1974) mentioned the occurrence of rats on the island but did not identify the species present.

Present Survey: Roof rats were collected at a number of sites in the MRA and appear to be distributed throughout the island. They were taken in all types of habitats except native forest, where several unidentified rats, probably *R. rattus*, were visually recorded (Table 1). This species was captured most frequently in strand vegetation (trapping success=17.0%) and tangantangan forest (success=4.0%) (Table 2). Roof rats are capable climbers and were frequently observed 3-6 m high in tangantangan and *Casuarina* trees at night.

Polynesian Rat, *Rattus exulans*

Previous Records: Polynesian rats are generally thought to have dispersed throughout the Pacific in association with early human travelers (Johnson 1962, Williams 1973). Presumably, these rats were introduced to the Mariana Islands by the Chamorros, who have inhabited the archipelago for at least 3,500 years (Spoehr 1957). Marshall (1962a) is the only author to identify *R. exulans* from Tinian, having captured several animals in 1945 (R. D. Fisher, pers. comm.).

Present Survey: No Polynesian rats were captured during 485 trap nights in six habitats. These data suggest that this species is rare or has been extirpated from the island, however, further trapping should be conducted to confirm this.

The rarity or possible absence of *R. exulans* in the MRA may be related to the abundance of *R. rattus*. Williams (1973) noted that there is great variation in the ability of Polynesian rats to associate with other species of *Rattus*. In some locations, close associations between *R. exulans* and other *Rattus* occur, while elsewhere, Polynesian rats appear to be displaced by congeneric taxa, possibly because of interspecific competition. On Saipan, Enders (1949) found *R. exulans* was the least common of three rat species and

believed that they had been forced from "the best habitats" through competition with other *Rattus*. He reported that Polynesian rats were confined to cliffsides, forests, abandoned plantations, and dumps where *R. rattus* and *R. norvegicus* were rare or absent. In contrast, Baker (1946b) reported that *R. exulans* and *R. rattus* occurred sympatrically in grasslands, brushy uplands, and coconut groves on Guam, but believed that competition for food and den sites probably existed between the two species.

Norway Rat, *Rattus norvegicus*

Previous Records: Von Prowazek (1913) reported Norway rats, using the synonym of *Mus decumanus*, from Tinian and saw them climbing in guava (*Psidium guajava*) shrubs. It is not known whether von Prowazek (1913) confirmed the identities of these rats by collections; however, their climbing behavior suggests that he observed *R. rattus* or *R. exulans* rather than *R. norvegicus*. There have been no subsequent records of Norway rats from the island. The species has occurred on Saipan since the late 1800s (Kuroda 1938, Barbehenn 1974) and on Guam since 1962 (Barbehenn 1974).

Present Survey: Norway rats were not captured during this study. This species is primarily commensal with man, thus further trapping around San Jose and the harbor may reveal its presence.

Dog, *Canis familiaris*

Previous Records: The presence of feral and domestic dogs on Tinian was noted by many authors between the mid-1700s and early 1900s (Fritz 1901, 1904, Schnee 1911a, 1911b, von Prowazek 1913, Anon. 1927, Thomas 1971, Walter & Robins 1974, Driver 1984). During this period, dogs were commonly used for hunting feral pigs (Fritz 1901, 1904, Schnee 1911a, Anon. 1927). Schnee (1911a) reported that the leaseholder of the island kept about 150 dogs for this purpose, of which about 50 were killed during hunts each year. Colonial administrators regarded feral dogs as a serious problem because they preyed on feral livestock. Bounties were implemented to control the dogs, and twice resulted in more than 100 animals being killed (Fritz 1901, Driver 1984). A tax on pet female dogs was also tried in an effort to limit numbers (Fritz 1904).

Owen (1974) saw domestic dogs but never observed or heard reports of feral animals. Lemke (1984) implicated predation by dogs in the disappearance of Philippine deer from Tinian.

Present Survey: Two free-ranging dogs, which may have been feral or stray pets, were recorded during this survey. One animal was sighted along Broadway Avenue between two open fields near Laderan Lasu. A second dog was seen in tangantangan forest approximately 100 m from the island's municipal dump. We found no other indications of a truly feral population of dogs on Tinian. Domestic dogs were common in San Jose.

Cat, *Felis catus*

Previous Records: De la Corte mentioned the presence of cats on Tinian in the mid-1800s (Anon. 1927). Small numbers of domestic and free-ranging cats occurred on the island in 1900 (Fritz 1901, 1904). Owen (1974) also observed domestic and feral cats.

Present Survey: Domestic cats were present in San Jose. Outside the village, cats

were observed 13 times along roadsides during evening surveys. The locations of sightings were widespread and often far from human habitations, indicating that a feral population still occurs on the island.

Pig, *Sus scrofa*

Previous Records: Tinian held a large population of feral pigs between the 1700s and early 1900s (Marche 1889, Fritz 1901, 1904, Schnee 1911a, 1911b, Hornbostel 1921–1924, Hawksworth 1929, Gilbert 1968, Thomas 1971, Walter & Robins 1974, Driver 1984). Rooting by pigs may have contributed greatly to the disturbed condition of the island's vegetation as reported in 1742 (Walter & Robins 1974). Feral pigs were an important source of meat for the crews of visiting ships and residents of other islands during the Spanish and German governments. Animals were frequently captured with hunting dogs or snares and sold to buyers on Saipan, Rota, and Guam (Marche 1889, Fritz 1901, 1904, Schnee 1911a, Seidel 1914, Anon. 1927, Hawksworth 1929, Thomas 1971, Walter & Robins 1974). During the early 1900s, about 600 pigs were killed annually from an estimated population of several thousand animals (Schnee 1911a). Feral dogs often harassed and preyed on feral pigs (Anon. 1927, Driver 1984). Schnee (1911a) remarked that domestic pigs were raised on the island. In 1974, Owen (1974) saw domesticated swine on the island, but did not find evidence of a feral population.

The approximate date that feral pigs were extirpated from the island is unknown. It is likely that their abundance was greatly reduced during the Japanese era, when most of the island was cleared for agriculture. Extensive clearing probably forced pigs into small pockets of remaining habitat, making for easier hunting and eradication efforts.

Present Survey: Penned domestic pigs were seen at homes and small farms in San Jose and Banaderon Nunu. However, no indications of feral pigs, such as tracks, wallows, rubs, scats or rooting signs, were found during this study. Personnel from the CNMI Division of Fish and Wildlife also told us that feral pigs were no longer known to occur on Tinian (T. O. Lemke and A. Borja, pers. comm.).

Philippine Deer, *Cervus mariannus*

We follow recent taxonomic studies (Grubb & Groves 1982, Groves & Grubb 1987) and refer to deer in the Mariana Islands as being *Cervus mariannus*. Other authors (Whitehead 1972, Wheeler 1979, Lemke 1984) have considered these deer as being *C. unicolor mariannus*, a subspecies of sambar deer.

Previous Records: Philippine deer were brought to Guam from the Philippines between 1771 and 1774 by the Spanish (Safford 1905) and were later taken to Rota and Saipan (Marche 1889, Fritz 1904, von Prowazek 1913). Owen (1974) wrote that six deer from Saipan and Rota were released on Tinian in the early 1960s. Despite some hunting, their numbers increased to about 100–200 animals by 1974. Owen (1974) warned that deer could become a serious pest to agriculture and the island's native flora if they became too abundant. The presence of deer on Tinian was brief. They were extirpated in the 1970s or early 1980s, apparently through heavy hunting pressure and predation by dogs (Lemke 1984).

Present Survey: No evidence of Philippine deer was found during the survey. Residents were unable to provide any information on recent sightings of deer on the island.

Cow, Bos taurus

Previous Records: Cattle were introduced to Tinian early in the period of Spanish colonial rule, and were left to roam the island freely in a feral state. Their effect on Tinian's vegetation was probably severe (Fosberg 1960). In 1742, Anson attributed the island's park-like scenery to overgrazing by cattle (Walter & Robins 1974), and chroniclers of his voyage estimated several thousand to at least 10,000 animals were present at the time (Thomas 1971, Walter & Robins 1974). However, reports from 1765 to 1788 indicate that feral cattle numbers probably decreased substantially within a few decades (Hawksworth 1929, Gilbert 1968). Subsequent population estimates were placed at about 800 animals in the mid-1800s (Anon. 1927), 200 animals in the 1880s (Driver 1984), 600–800 animals in 1900 (Fritz 1901, 1904), and 300–400 animals in 1912 (von Pro-wazek 1913). In contrast, Schnee (1911a, 1911b) and Hornbostel (1921–1924) reported 2,000–3,000 head were present.

Tinian served as an important cattle harvesting station for colonial governments and temporary settlements of islanders from the 1700s to early 1900s. Meat and animals were regularly transported from the island to be sold on Saipan, Guam, and Rota (Marche 1889, Fritz 1901, Schnee 1911a, Seidel 1914, Anon. 1927, Thomas 1971, Walter & Robins 1974), although at times, concern about overharvesting and poor levels of production caused government administrators to restrict the amount and gender of animals that could be captured (Fritz 1901, Anon. 1927, Driver 1984). Other sources of mortality to feral cattle included losses to feral dogs (Fritz 1901, 1904), starvation during droughts (Driver 1984), and miring on the edge of the wetland at Hagoi, where large numbers of animals went to drink (Fritz 1901, Anon. 1927, Driver 1984). Hundreds of cattle skulls littered the lake's shore in the 1920s (Hornbostel 1921–1924).

Within a few years after the Japanese began intensive cultivation of sugar cane, Uchida (1935) warned that the feral cattle population was very low and could become extinct. The last feral cow on Tinian was apparently killed in about 1952 (R. Owen, pers. comm. to L. Eldredge).

In the early 1960s, the Micronesian Development Corporation leased about 4,000 ha of the island for use as a ranch and brought in beef and dairy cattle to stock it. Owen (1974) estimated that several thousand head were present in 1974. He also noted that local residents had obtained cattle to raise for their private use.

Present Survey: Domestic cattle were common throughout Tinian and probably number about 4,000–5,000 animals. The largest herd has 3,500 head of beef cattle (J. Mason, pers. comm.) and is owned by the Bar-K Ranch. The ranch continues to hold about 4,000 ha of land with about 40% of this inside the MRA. It maintains a series of pastures and tangantangan groves ranging from Masalok southward to Kastiyu and Carolinas. Smaller herds of cattle were present on many of the small farms located on the western side of the island.

Cattle were routinely pastured in a variety of habitats (Table 1), particularly open fields, tangantangan forest, and secondary vegetation. They also fed and rested in native forest and strand vegetation. They were noted to drink from several small ponds at Sabanetan Mangpang and stock ponds in Kastiyu and Carolinas. Cattle appeared to avoid only extremely rocky hillsides with native forest, such as those at Kastiyu and Laderan Lasu, and the marsh at Hagoi.

Heavy grazing, browsing, and trampling by cattle have probably eliminated or lowered the abundance of some species of indigenous plants, reduced understory vegetation, lowered plant diversity in native forests, and increased soil erosion and compaction. As an example of possible changes in plant diversity, coastal forest along the cliffline at Kastiyu has a greater variety of indigenous trees than does a stand of inland forest at Laderan Lasu. The topography is much more rugged at Kastiyu, however, and may function to keep cattle out of that site. Cattle have probably also enhanced the spread of certain introduced plants around the island. Examples of these species include *Bidens alba*, *Lantana camara*, *Mimosa invisa*, *Achyranthes aspera*, *Chromolaena odorata*, and *Jatropha gossypifolia*.

The impacts of widespread cattle grazing on Tinian's native wildlife is speculative, but habitat degradation has probably resulted in population declines of fruit bats and frugivorous birds, such as Mariana fruit-doves (*Ptilinopus roseicapilla*), and white-throated ground-doves (*Gallicolumba xanthonura*). The reproductive success of Micronesian megapodes (*Megapodius laperouse*) may have declined in areas where nesting sites were trampled and soils were compacted by cattle (Wiles *et al.* 1987). Destruction of wetland vegetation at Hagoi in the 1800s likely impacted common moorhens (*Gallinula chloropus*) using the marsh. During the 1800s, de la Corte noted that cattle drank from the wetland at Hagoi, which was then approximately 800 m \times 300 m in size, converting the edges of the marsh into "quagmires" (Anon. 1927).

Goat, *Capra hircus*

Previous Records: Feral goats inhabited the slopes and cliffs along the southeastern coast of Tinian in the early 1900s, with the population estimated at a few hundred to 500 animals (Fritz 1901, 1904, Schnee 1911a, Hornbostel 1921–1924). The goats typically lived in herds of about 20 individuals (Schnee 1911a). Animals were killed or captured alive for sale on Saipan (Fritz 1901, Schnee 1911a, Seidel 1914). Owen (1974) observed domestic goats at farms but remarked that at least one herd of feral goats continued to exist at an unspecified location. He feared that unless controlled, goat numbers would increase and eventually damage the vegetation in some parts of Tinian in a manner similar to that which has occurred on Aguijan, where a large feral goat population resides.

Present Survey: A few domestic goats are raised at homes and farms near San Jose, but we found no evidence of a feral population of goats in the MRA. Personnel from the CNMI Division of Fish and Wildlife provided similar information, but reported that a feral herd of unknown size still occurs in the extensive tract of coastal forest at Kastiyu (T. O. Lemke, A. Borja, and D. Aldan, pers. comm.).

Other Species

Horses were absent from Tinian and the other German-controlled Mariana Islands in the early 1900s (Fritz 1904). Their occurrence on Tinian was first reported by Owen (1974). Feral horses have not been reported from the island. We observed one group of 20 domestic horses in a fenced pasture near the Bar-K Ranch headquarters at Chalan Famalaoan.

Fosberg (1960) reported that two other ungulates, the guanaco (*Lama guanicoe*) and water buffalo (*Bubalus bubalis*), may have formerly occurred on Tinian. The guanaco

record may refer mistakenly to Byron's report of the species on Saipan in the 1700s (Hawksworth 1929). The hypothetical record of water buffalo was not verified in any of the historical reports examined.

Acknowledgments

Funding for this study was provided by the U.S. Navy through a contract to Hawaiian Agronomics (International), Inc. Special thanks go to L. G. Eldredge for directing this study and to H. Muna for assisting with field work. We also thank A. Borja, T. O. Lemke, D. Aldan, R. D. Fisher of the U.S. National Museum of Natural History, L. Raulerson, D. R. Moore, G. Noori, J. D. Reichel, C. F. Aguon, C. P. Stone, and C. G. Rice for contributing information or reviewing the manuscript.

References

- Anon. 1927. Memoirs of Don Felipe de la Corte's eleven years as Governor of Guam, 1855–1866. *Guam Recorder* 3:270–271, 282–283.
- Baker, R. H. 1946a. Some effects of the war on the wildlife of Micronesia. *Trans. N. Am. Wildl. Conf.* 11:207–213.
- Baker, R. H. 1946b. A study of rodent populations on Guam, Mariana Islands. *Ecol. Monogr.* 16:393–408.
- Barbehenn, K. R. 1974. Recent invasions of Micronesia by small mammals. *Micronesica* 10:41–50.
- Bowers, N. M. 1950. Problems of resettlement on Saipan, Tinian and Rota, Mariana Islands. Ph.D. Thesis, Univ. Michigan, Ann Arbor. 480 pp.
- Downs, T. 1948. Amphibians and reptiles of Tinian Island. *Trans. Kansas Acad. Sci.* 51:112–116.
- Driver, M. G. 1984. The Mariana Islands 1884–1887: random notes of Governor Francisco Olive y Garcia. *Micronesian Area Res. Center*, Mangilao, Guam.
- Enders, R. K. 1949. A field study of the rats in the Marianas and Palaus. *Scientific Investigations in Micronesia*, Pacific Science Board. Unpublished report.
- Engbring, J., F. L. Ramsey & V. J. Wildman. 1986. Micronesian forest bird surveys, 1982: Saipan, Tinian, Aguiguan, and Rota. U.S. Fish Wildl. Serv., Honolulu. Unpublished report.
- Fosberg, F. R. 1960. The vegetation of Micronesia. *Bull. Am. Mus. Nat. Hist.* 119:1–75.
- Fritz, G. 1901. Die Insel Tinian (Marianen). *Deutsches Kolonialblatt* 12:150–154.
- Fritz, G. 1904. Die Chamorro. Eine geschichte und ethnographie der Marianen. *Ethnologisches Notizblatt* 3(3):25–110.
- Gilbert, T. 1968. Voyage from New South Wales to Canton, in the year 1788. De Capo Press, New York. 85 pp.
- Groves, C. P. & P. Grubb. 1987. Relationships of living deer. In C. Wemmer (ed.). *Biology and Management of the Cervidae*, pp. 21–59. Smithsonian Institution Press, Washington, D.C.

- Grubb, P. & C. P. Groves. 1982. Notes on the taxonomy of the deer (Mammalia, Cervidae) of the Philippines. *Zoologischer Anzeiger* 210:119–144.
- Hawaiian Agronomics, Inc. 1985. Final report for flora and fauna survey on Tinian, Northern Mariana Islands. Honolulu, Hawaii. Unpublished report.
- Hawksworth, J. 1929. An account of the voyages undertaken by the order of his present majesty. *Guam Recorder* 6:66–67, 76–79.
- Hornbostel, H. G. 1921–1924. Unpublished field notes: Guam, Rota, Saipan, and Tinian. B. P. Bishop Mus., Honolulu. Unpublished report.
- Kuroda, N. 1938. A List of the Japanese Mammals. Published by the author, Tokyo.
- Johnson, D. H. 1962. Rodents and other Micronesian mammals collected. *In* T. I. Storer (ed.), *Pacific Island Rat Ecology*. pp. 21–38. *Bull. B. P. Bishop Mus.* 225.
- Lemke, T. O. 1984. Sambar deer surveys and inventories. *In* Pittman-Robertson federal aid in wildlife restoration annual report, FY 1984. pp. 27–37. Commonwealth of the Northern Mariana Islands Div. Fish Wildl., Saipan.
- Lemke, T. O. 1986. Distribution and status of the sheath-tailed bat (*Emballonura semicaudata*) in the Mariana Islands. *J. Mammal.* 67:743–746.
- Marche, A. A. 1889. Rapport general sur une mission aux Iles Mariannes. *Nouvelles Archives des Missions Scientifiques et Litteraires (Nouvelles Serie)*. 1:241–280. (1982 English translation by S. E. Chang, Micronesian Area Res. Center, Univ. Guam, Mangilao, Guam)
- Marshall, J. T., Jr. 1962a. Geographic distribution and color phases of Micronesian rodents. *In* T. I. Storer (ed.), *Pacific Island Rat Ecology*, pp. 39–44. *Bull. B. P. Bishop Mus.* 225.
- Marshall, J. T., Jr. 1962b. House mouse. *In* T. I. Storer (ed.), *Pacific Island Rat Ecology*, pp. 241–246. *Bull. B. P. Bishop Mus.* 225.
- Marshall, J. T., Jr. 1977. Family Muridae. *In* B. Lekagul & J. A. McNeely, *Mammals of Thailand*, pp. 397–487. Kurasupa Press, Bangkok. 758 p.
- Owen, R. P. 1974. Environmental impact study on the terrestrial fauna and flora of Tinian with respect to the proposed establishment of a U.S. military base on that island. Trust Territory of the Pacific Islands, Biol. Lab., Koror, Palau. Unpublished report.
- Peattie, M. R. 1988. Nan'yo: the Rise and Fall of the Japanese in Micronesia, 1885–1945. Univ. Hawaii Press, Honolulu. 382 pp.
- Peterson, G. D. 1956. *Suncus murinus*, a recent introduction to Guam. *J. Mammal.* 37:278–279.
- Prowazek, S. von. 1913. Die Deutschen Marianen. Ihre natur und geschichte. Johann Ambrosius Barth, Leipzig. 125 p.
- Safford, W. E. 1905. The Useful Plants of the Island of Guam. *Contrib. U.S. Natl. Herb.* 9:1–416.
- Schnee, P. 1911a. Die verwilderten Haustiere auf Tinian. *Z. Kolonialpolitik* 13: 350–362.
- Schnee, P. 1911b. Einiges uber die hohere Tierwelt der Marianen. *Z. Naturwissenschaften* 82:458–470.
- Schofield, E. K. 1989. Effects of introduced plants and animals on island vegetation: examples from the Galapagos archipelago. *Conserv. Biol.* 3:227–238.

- Seidel, H. 1914. Die Insel Tinian und ihre Stellung im Marianen-Bogen. *Geographische Z.* 20:558–567.
- Stone, C. P. & J. M. Scott (eds). 1985. *Hawaii's Terrestrial Ecosystems: Preservation and Management*. Coop. Natl. Park Resources Studies Unit, Univ. Hawaii, Honolulu. 584 p.
- Spoehr, A. 1957. Marianas prehistory: archaeological survey and excavations on Saipan, Tinian and Rota. *Fieldiana: Anthropology* 48:1–185.
- Thomas, P. 1971. *Journal of a Voyage to the South-seas*. De Capo Press, New York.
- Uchida, T. 1935. On the wild cattle of Tinian. *Bot. Zool. Sci. Appl.* 3:639–640. (in Japanese).
- Vitousek, P. M. 1988. Diversity and biological invasions of oceanic islands. In E. O. Wilson (ed.), *Biodiversity*, pp. 181–189. National Academy Press, Washington, D.C.
- Walter, R. & B. Robins. 1974. *A Voyage Round the World in the Years MDCCXL, I, II, III, IV* by George Anson. Oxford Univ. Press, London. 402 pp.
- Wheeler, M. E. 1979. The Biology of the Guam Deer. Div. Aquatic Wildl. Resources Tech. Rept. No. 3. 53 p.
- Wheeler, M. E. 1980. The status of the Marianas fruit bat on Saipan, Tinian, and Rota. *'Elepaio* 40:109–113.
- Whitehead, G. K. 1972. *Deer of the World*. Viking Press, New York. 194 p.
- Wiles, G. J. 1987. The status of fruit bats on Guam. *Pac. Sci.* 41:148–157.
- Wiles, G. J., R. E. Beck & A. B. Amerson. 1987. The Micronesian megapode on Tinian, Mariana Islands. *'Elepaio* 47:1–3.
- Wiles, G. J., T. O. Lemke & N. H. Payne. 1989. Population estimates of fruit bats (*Pteropus mariannus*) in the Mariana Islands. *Conserv. Biol.* 3:66–76.
- Wiles, G. J. & N. H. Payne. 1986. The trade in fruit bats *Pteropus* spp. on Guam and other Pacific islands. *Biol. Conserv.* 38:143–161.
- Williams, J. M. 1973. The ecology of *Rattus exulans* (Peale) reviewed. *Pac. Sci.* 27:120–127.