

The Aguiguan Expedition

Robert J. Craig

Editor

Proceedings : Marianas Research Symposium
A publication of Northern Marianas College

THE AGUIGUAN EXPEDITION

**Proceedings of a Symposium held at
Northern Marianas College**

January 15, 1993

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Expedition contributors: Boy Scouts of America, Carmen Safeway Meitetsu, CNMI Emergency Operations Center, Joeten Enterprises, Mobil Oil Corporation, Pacific Islands Aviation, Payless Supermarket, Radio Com Corporation, Saipan Ice Company, Shell Marianas, Townhouse Corporation

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Cover: *Premna obtusifolia* by Barbara A. Lussier. Text line drawings: *Premna obtusifolia*, goat skull by Barbara A. Lussier

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HISTORIOGRAPHY IN THE LOCAL CONTEXT: PROGRESS OF A REAL SORT

Keynote Address

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Investigating and interpreting the cultures, societies, and histories of the various island groups of the Pacific world has been, up until recently, largely a western-oriented and directed affair. Happily, this orientation is now changing fundamentally as well as instrumentally, and what we see here today—the start of the natural historical interdisciplinary investigation of Aguiguan Island by the Northern Marianas College—is a true manifestation of this change.

Other than for the fact that the final battle of the Chamorro–Spanish wars was fought there under the leadership of the Spanish governor Don Jose Quiroga in 1695, not much is known about Aguiguan. During World War II, the Japanese used it as a prisoners' compound, and since then, I believe that the Navy has, on occasion, practiced bombing and strafing runs there with aircraft.

That the College of the Northern Marianas is beginning a study about this island, and the concurrent establishment of the Institute for Marianas Studies, is a very significant undertaking. Of course, the fact of this study and its short-term gains are important and useful in themselves, but there is also a much wider importance, I believe, in the continuum of the stream of island history, and I would remind you all of this today in the hopes that it will promote the steadfastness of your resolve. Self-determination is a concept not confined to political affairs; it can and must also be applied to academia and historiography as well.

The written historiography of Micronesia began with the journals of Antonio Pigafetta, the gentleman-scholar who talked his way aboard Magellan's ships as chronicler of the first circumnavigation. Almost everything we know about that voyage comes from his recorded observations, including accounts of the

Marianas and the people. Micronesian history, considered comprehensively since Pigafetta, however, is not an esoteric discipline, isolated with a distinctive theoretical basis, jargon, and method; rather it is a specialization within the broader realm of historical study of the Pacific.

This broader realm belongs to the field of *modern history* as distinguished from *ancient history*, and it is within this context that the present discussion is placed. The modern study of Micronesian history has contributed significantly to our understanding of the region, especially since the arrival of the whalers, traders, scientific explorers, voyagers, and, finally, colonials during the 18th and 19th centuries. From this modern period there has been an enormous amount of historical literature emerge. A good number of western and Japanese scholars have written about various aspects of Marianas and Pacific history.

Today we have the appearance of many islanders themselves who are writing and publishing their own accounts and interpretations. An important work on Pohnpeian history by Luelen Bernart appeared in 1978. It is the first historical account of the island to be written by a native Pohnpeian, and was published by the University of Hawaii Press. All students in Micronesian history classes are familiar with *The Book of Luelen*.

The pattern I am indicating here is that the history of the Pacific and the Marianas has been written and interpreted, until recently, largely by outsiders. There is nothing particularly wrong with this, and there have been fundamental reasons for it. For one thing, the records of the earlier periods were kept by the colonial powers. For another, the outsiders were given to writing and keeping records, whereas island cultures were

"cultures of the word" rather than "cultures of the book." This oral tradition here in the Pacific has its particular charms to be sure, but the capacity for longitudinal study is not among them.

Some historians have labeled this accumulated written record of Pacific history as *imperial history*; that is, an interpretation of the record of outsiders and their activities in the islands. In some cases, these histories have been written from places far away from the islands by people who have never set foot on a Pacific island.

Some years ago, this reality was commented upon quite critically, by the venerable, and now deceased, Jim Davidson of the Australian National University. He said, 30 years ago, that Pacific history "lacked a basic direction." Another Australian historian, who is now retired but still with us, is Oskar Spate. He has pointed out that many outsider historians who have written and interpreted in the past, have been too narrow, and on occasion have been "unable to see the Ocean for the islands ... [and were] content to be marooned on ... their little atoll[s] of knowledge, regardless of the sweep of the currents which bring life to the islands." Professor, now emeritus, Greg Denning of New Zealand, has expressed an outright indictment of past historical practice in the Pacific:

If we applied the standards expected of social history in the United States, Britain, and the Continent, and the standards expected of cross-cultural history elsewhere in the world, then we would have to say the Pacific is an historically underdeveloped area.

Dr. Denning wrote these words over 15 years ago, and when I spoke with him last year, he reported happily that things were changing. The changes were largely due to the appearance of many local activities, programs, and people who were researching and interpreting their own past experience right here on their own turf. He was speaking, of course, about events such as the one we are celebrating today: the establishment of the Institute for Marianas Studies, and the kickoff of your interdisciplinary research program on Aguiguan.

The undertaking of local historical and social studies can yield results which are sometimes very pleasantly unexpected and very useful as contributions to the overall stock of knowledge. We have had such an experience not long ago at Guam which I want to tell you about. It concerns the circumnavigational

voyage of Ferdinand Magellan.

Some six years ago, on a Friday afternoon, my colleague Bob Rogers dropped by my office for coffee and a chat. He was just beginning then his large writing project of a book on history of Guam. "Did you know," he asked, "that there is historical confusion as to the exact landing place of Magellan in the Marianas?" I replied that I did, of course, and that some views had it that Magellan landed here at Saipan, others contended it was at Rota. Of course, traditionally, others maintained Umatac, Guam, as the landing place, and in fact there is a monument standing there today commemorating the event. Dr. Rogers and I continued to discuss the matter over the course of a few weeks, and finally decided that we would undertake research with a view to determining with precision where Magellan actually landed.

We proceeded to amass all the available records and interpretations of the Marianas landing of Magellan in March, 1521. We enlisted the aid of our colleagues in other disciplines at the university. Mrs. Marjorie Driver of MARC got all the relevant Spanish period materials, Mr. G.G. Anderson, a MARC research associate and authority on Magellan's voyage joined in, Dr. Lloyd Keukhle of the math department helped us to analyze the sea level distances that islands could be seen from Magellan's approach to the Marianas, and from the mid-points between various islands.

There are two surviving eye-witness accounts of the landing of Magellan in the Marianas. One is the account of the chronicler Antonio Pigafetta, whose original account was written in his native Italian. The other was the sparse nautical account of Francisco Albo—sometimes said Alvo—a Greek from Rhodes who was the flag pilot of the voyage. These two accounts differed in essential details. Pigafetta said he sighted three islands, whereas Albo says he saw only two. They also differed slightly in latitude.

After lengthy and rigorous study, debate, and continuing investigation, we were able to shed new light on the confusion. For one thing, the maps of the time put the prevailing winds at the bottom of the page; this realization enabled us to see that in the sketch appearing in Pigafetta's account puts north at the bottom, rather than at the top of the page. We found also that the original accounts were translated several times into other languages, such as French, Spanish, and Portugese. We discovered also that Rota, viewed by Pigafetta from the deck of one of the three ships, appeared as two islands since from the

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mid-point between Guam and Rota, one cannot see the isthmus which connects the Sabana from Mt. Tapingot. On the other hand, in the crow's nest of the Trinidad, Albo could see the isthmus, and so reported seeing only Guam and Rota.

These revelations were altogether stimulating. But we did not stop there. Next, we set to reenacting Magellan's approach to the Marianas on the 468th anniversary of the event; 6 March 1988. Before dawn on that day, four of us set out in Bob's 20 ft canopied fishing boat, and headed for the Rota channel. We intended to see for ourselves and also—in the true island tradition—to mix a little business with pleasure. We had fishing gear and a couple of cases of beer. The weather conditions that day were remarkably similar to those experienced by Magellan: haze with large swells, and it was humid and heavy. As we passed Ritidan Point, the sun came up and lit the sky a bright hazy gray. As we got further and further from the midpoint of the channel, the swells increased to 20 ft and two of our companions became so seasick that they were unable to stand. Only Bob and I, for some reason unafflicted, remained at the helm peering into the haze. Then, gradually, like a Polaroid photo, Rota came into view on the dim horizon. And there it was; two islands just like Pigafetta had seen, one island larger and higher than the other; the Sabana and the Wedding Cake Mountain. We laughed and backslapped in congratulatory excitement as our two friends lay miserably on the deck moaning and groaning in their sea-sickness.

Turning about, we headed back for Guam, and again gained revelations. As we came toward the island we could see that it was natural to head down the western side of Guam rather than the eastern since the west was the protected lee, whereas the east was windy. Naturally, Magellan, experienced mariner that he was, would have taken the western course rather than risk wrecking his ships on the east coast. We saw the limestone cliffs in the same description that Pigafetta had made nearly 500 years before. As we again passed Ritidan and came into the lee of Guam, the rough seas calmed, the winds abated, and our two seasick comrades revived. All of us started to drink beer in celebration. And then, what do you know? We started catching mahi-mahi! All in all, we caught 17 before coming into the Agana boat basin. The fish were an added benefit to what for us was a spectacular day! We had validated our research with this demonstration.

But then, there was more work to do; the story does not end here, it only pauses. We next had to write up and get published what we found and accomplished (Rogers and Ballendorf 1989). This is a very important aspect of research and I do not want the point to be wasted here, because it has to be an important point of your program here with your research in Aguiguan and the establishment of the Institute of Marianas Studies. The research and field work are two aspects which go hand-in-hand, and is often the most fun part of any research undertaking. But once that part is completed, then the write-up must follow. Without the write-up, no one who is knowledgeable can challenge your findings. Without this essential and well-documented write-up to your research, you liken your efforts to speeches often made by politicians: mostly hot air with no comparative, critical basis!

Now, what is the point of my story about Magellan's landing place in the Marianas? Who cares where he landed anyway? I'll grant that this matter is clearly a footnote to history. It is the process of the accomplishment and the fact that it was our university—a local Marianas institution—whose faculty and support enabled the realization of the research and the results of that research. We did all of this without any outside help: 100% within the local context. Moreover, we wrote up and published our findings for the academic and professional world to see and, furthermore, I am happy to say we were invited last year to an international academic conference to orally report our research on Magellan's landing place. From now on, all scholars from any place in the world who are writing and researching the voyage of Magellan, must consult our work in order to be accurate. This is indeed an indication that our institutions are coming of age and are taking their places within the realm of the wider community of higher education.

What you are initiating here today with your Institute of Marianas Studies and the pursuit of multidisciplinary studies on Aguiguan Island has to do with this very same direction in academic and educational self-determination. You are creating the facility and encouraging the practice for research in the local context. Your administrators, faculty, and staff deserve the salute and gratitude of your entire community for this effort.

In this way, the old paradigm of *imperial history* gradually gives way to the complimentary work and accomplishment of the people who live and work here.

This is truly progress of a real sort.



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WILDLIFE SPECIES RECORDED DURING THE AGUIGUAN EXPEDITION: 20-25 MAY, 1992

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Abstract. Wildlife of 32 species were recorded during the expedition. Two species were located whose Aguiguan populations were thought to be extinct: the endemic Aguiguan Nightingale Reed-warbler and the tree snail *Partula gibba*. The occurrence of the endangered Mariana Fruit Bat and Sheath-tailed Bat also was noted. Observation of a Gray-tailed Tattler represented a new record for the island. A probable owl was heard. Notes on the identification, natural history, and populations of certain species are reported. Lantana, although a noxious introduced weed, formed thickets that provided cover and an enormous food resource for certain native species of wildlife.

Faunal occurrence on Aguiguan remains, with the exception of birds (Engbring et al. 1986, Reichel and Glass 1991), poorly documented. Limited data on reptiles and amphibians are provided by Rodda et al. (1991), data on bats are reported by Lemke (1986) and Wiles et al. (1989), and miscellaneous faunal records are in unpublished field trip reports of the Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands. We here list those species encountered by expedition members, and report observations on the identification, natural history and populations of certain species.

SPECIES ACCOUNTS

Invertebrates (other than insects).

Tree Snail (*Partula gibba*)— Known from several of the Mariana Islands, this snail was thought to have been extirpated on Aguiguan (D. Hopper pers. comm.) by parasites released to control the introduced African Land Snail (*Achatina fulica*) (Nafus and Schreiner 1989). Live snails were first encountered by B. Lussier on trees in native forest, and were later found to range patchily along the western slope of the island from about the island's center to near its southern tip (Fig. 1). They inhabited native and secondary forest.

Reptiles and amphibians. No amphibians were located during the expedition, nor were any introduced

reptiles other than Monitor Lizards.

Green Turtle (*Chelonia mydas*)— observed by several expedition members swimming in the ocean off the island.

Monitor Lizard (*Varanus indicus*)— present commonly, particularly in forested areas.

Snake-eyed Skink (*Cryptoblepharus poecilopleurus*)— a lizard probably of this species was observed by R. Craig on rocks near the ocean at the southern tip of the island. Coppery flecks were noted on the sides of this small lizard.

Blue-tailed Skink (*Emoia caeruleocauda*)— present abundantly in forested areas, where the blue tails of females and juveniles were readily seen.

Island Gecko (*Gehyra oceana*)— an individual of this species was photographed by R. Craig at the southern end of the island. It was distinguished by its large size (ca. 10 cm), brown, mottled back with no chevrons, plain belly, and enlarged toe pads. The gecko was on the trunk of a sapling tree in native forest.

Birds.

White-tailed Tropicbird (*Phaethon lepturus*)— several seen when census routes for forest birds approached the ocean.

Red-tailed Tropicbird (*P. rubricauda*)— several observed during forest bird censuses.

Brown Booby (*Sula leucogaster*)— several seen over

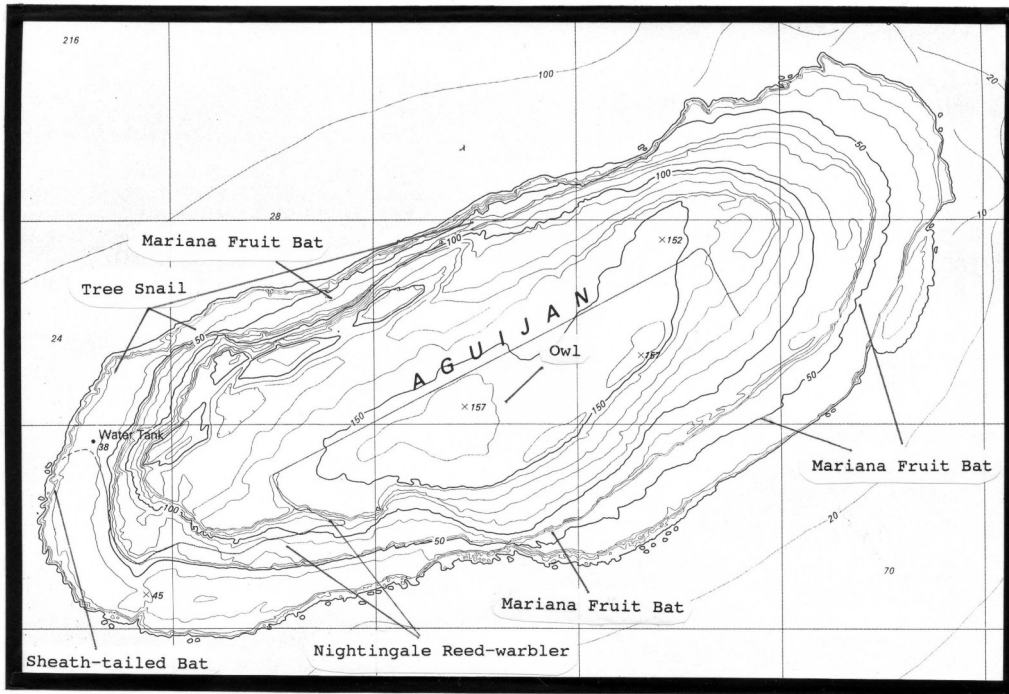


FIG. 1. Location of 1992 wildlife observations on Aguiguan.

the ocean.

Yellow Bittern (*Ixobrychus sinensis*)— As noted by Engbring et al. (1986) this species was uncommon. It inhabited herbaceous and thicket vegetation on the level plateau summit.

Micronesian Megapode (*Megapodius laparouse*)— present uncommonly in native forest. Pairs of birds were observed together and duetting was heard. A half grown juvenile was observed by R. Chandran.

Lesser Golden Plover (*Pluvialis dominica*)— several observed flying in a flock over the plateau.

Gray-tailed Tattler (*Heteroscelus brevipes*)— one seen by R. Craig on coastal rocks at the southern tip of the island. Its gray plumage and call notes distinguished it as this species. Although the Gray-tailed Tattler is a common migrant and winter resident in the Marianas, it has not been reported previously from Aguiguan (see Reichel and Glass 1991).

Brown Noddy (*Anous stolidus*)— common flying over the ocean and over the island. Some were observed perched in trees.

Black Noddy (*A. minutis*)— uncommonly seen flying over the ocean.

White Tern (*Gygis alba*)— commonly seen flying over the ocean and perching in trees.

Philippine Turtle Dove (*Streptopelia bitorquata*)— As

noted by Engbring et al (1986), this species was uncommon. It was largely restricted to forest edge and weedy thickets.

White-throated Ground Dove (*Gallicolumba xanthonura*)— fairly common, particularly in native forest. It often flew over the forest and over the open plateau summit, and it foraged in 1–2 m tall lantana (*Lantana camara*) thickets. It was observed foraging on the ground in native forest, where it probed leaf litter and flipped dead leaves with its bill to located food items (apparently seeds).

Mariana Fruit Dove (*Ptilinopus roseicapilla*)— common in native forest, where it generally inhabited the upper canopy. It also occurred in the extensive lantana thickets of the plateau summit, where it perched in taller trees and may have fed on lantana fruits.

Owl, unknown species— At about 24:00, 21 May, owl-like hooting was heard in the vicinity of a coral tree (*Erythrina variegata*)—sosome (*Acacia confusa*) grove 50–75 m from the campsite (site of the former Japanese village). The hooting occurred in two long series punctuated by periods of silence, with the entire calling sequence lasting at least 1 min. No hooting was heard on subsequent nights, although calls of Brown Noddies flying overhead were commonly heard other nights. Many members of the expedition heard the hooting.

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Island Swiftlet (*Aerodramus vanikorensis*)– observed commonly, particularly at dusk, over the open plateau summit and over native forest. A nest cave was located by P. McArthur at the south end of the island near the former Japanese dock.

Collared Kingfisher (*Halcyon chloris*)– fairly common in all habitats. A bird was observed with a gecko at least 10 cm in length in its bill. Another was mist-netted when it attacked and killed a Micronesian Honeyeater which was present in the mist net. Hence, Collared Kingfishers prey not only upon invertebrates and lizards, but also on birds. In native forest, an apparent nest or roost was located where birds entered and exited a hole in a dead tree.

Nightingale Reed-warbler (*Acrocephalus luscinioides nijoi*)– While performing forest bird censuses, R. Chandran encountered two singing males of this species on the southeastern slope of the island (Fig. 1). Chandran immediately recognized the song, and L. Klawunder clearly observed a bird with binoculars. Other expedition members familiar with this species, including R. Craig and B. Lussier, were later shown one bird, and concurred with the identification. Reed-warblers on Aguiguan are presently recognized as a distinct, endemic subspecies, but have been unreported since 1985 and were presumed extinct (Reichel et al. 1992).

Previous observations of reed-warblers on Aguiguan include those by Engbring et al. (1986), who reported hearing mostly brief segments of song. They suggested that this vocalization pattern might differ from that typical of Saipan birds. Glass (1987) believed that the song of the Nightingale Reed-warbler could be confused with that of the Golden White-eye, particularly on Aguiguan (P. Glass pers. comm). These authors and Reichel et al. (1992) also reported that Aguiguan Nightingale Reed-warblers were restricted to native forest, unlike birds from Saipan which are virtually absent from this habitat (Craig 1992a).

In contrast to these observations, both male reed-warblers we heard had songs indistinguishable from those of Saipan birds. These songs were entirely unlike those of the Golden White-eye, which vocalized similarly to Golden White-eyes from Saipan. Nightingale Reed-warblers on Saipan typically have a wide vocal repertoire, and the complexity of song appears to vary depending on the social and reproductive context in which the song is uttered. Rather than being related to inter-island differences in vocalizations, the brief songs reported by Engbring et al. (1986) (heard at the same time of year as our visit) were likely representative of

the particular behavioral state of the individuals observed.

Discrepancies also arose in our observation of habitat choice. Both male reed-warblers inhabited formerly disturbed areas vegetated by groves of casuarina (*Casuarina equisetifolia*) trees and 1–2 m tall lantana thickets. Such habitats resemble many chosen on Saipan. Reports of birds occurring solely in native forest may stem from misidentifications of birds heard but not seen. Difficulties reported by Glass (1987) in recognizing the songs of Nightingale Reed-warblers may indicate that some earlier observers were insufficiently familiar with the species to identify reliably vocalizing individuals. Inexperienced observers might have attributed calls of such species as the vocally variable Micronesian Starling, which is common in native forest, to the Nightingale Reed-warbler.

The similarity in vocalizations and habitat use of the birds we observed on Aguiguan with those on Saipan raises questions concerning the validity of the subspecies *nijoi*. The subspecies, based on five specimens, was distinguished by its shorter bill and slightly different coloration compared to Saipan birds (Yamashina 1942, Engbring et al. 1986, Reichel et al. 1992). However, R. Craig has observed that the bill length of post-fledging Nightingale Reed-warblers is substantially shorter than that of attending adults. The small series on which the subspecies is based, combined with age-related differences in such characteristics as bill length, suggest that further investigation into the validity of the subspecies *nijoi* is warranted.

Rufous Fantail (*Rhipidura rufifrons*)– common in forest and thicket habitats. As on Saipan, it appeared to defend territories and to occur in family groups of 3–4. Both Golden White-eyes and Micronesian Honeyeaters were observed to chase Rufous Fantails, and Rufous Fantails followed Golden and Bridled White-eyes while foraging.

Micronesian Starling (*Aplonis opaca*)– common in forest and thicket habitats, where it often occurred in flocks of 5–10 adults and juveniles (based on plumage differences). It appeared to feed in lantana thickets, probably on lantana fruit.

Micronesian Honeyeater (*Myzomela rubrata*)– common in forest and thicket habitats. It was aggressively territorial, and was observed chasing Rufous Fantails and Golden White-eyes. It fed on nectar from lantana flowers. A male and female (based on wing color) were observed engaging in courtship, which involved following each other back and forth on a heavy limb of a for-

est tree. During following, one bird led, then both turned around and the other led. Both birds kept their heads and bills tilted upward during following.

Golden White-eye (*Cleptornis marchei*)– common in forest and thicket habitats. It appeared to be territorial, and commonly occurred in family groups of 3–4. It was observed chasing Rufous Fantails and supplanting them at perches. Birds often occurred in lantana, where they appeared to feed on fruits. In one instance a bird was clearly observed eating lantana flowers. When mist netted in lantana, some Golden White-eyes had black, watery droppings, indicating that they had been feeding on lantana fruits.

Bridled White-eye (*Zosterops conspicillatus*)– abundant in forest and thicket habitats, where it occurred in flocks. Like the Golden White-eye, it frequently fed in lantana, and mist-netted birds had black, watery droppings indicative of feeding upon lantana fruits. Individuals were also observed taking nectar from lantana flowers.

Mammals.

Mariana Fruit Bat (*Pteropus mariannus*)– Surveys through native forest yielded four widely separated and, therefore, probably distinct roost sites (Fig. 1). These contained, respectively, 14, 6, 5, and ca. 5 bats, yielding a minimum population estimate of ca. 30. Dusk censuses of bats leaving roosts were attempted from the plateau summit, but these were unsuccessful in locating any bats. Assuming that some roosts were undetected, a total island population of 50 bats may be realistic. Previous population estimates for Aguiguan have ranged from 40–60 bats (Glass and Taisacan 1987).

Sheath-tailed Bat (*Emballonura semicaudata*)– On 23 May, P. McArthur investigated a cave at the south end of the island near the former Japanese dock (Fig. 1). In addition to Island Swiftlets, he reported two small bats, presumably Sheath-tailed Bats, exiting the cave. These were observed at close range, and possessed wide wings contrasting with the narrow wings of the swiftlets. Sheath-tailed Bats previously have been reported from this location (Glass and Taisacan 1987).

Goat (*Capra hircus*)– expedition members reported hearing one goat at the south end of the island, one at the north end, and a third from the east side of the island. Goats have been largely eliminated from Aguiguan through hunting by the CNMI Division of Fish and Wildlife (Rice 1990).

Rat, unknown species (*Rattus* sp.)– rats were abundant in the vicinity of the campsite, but no attempt was made to ascertain their specific identity.

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BIRD POPULATIONS ON AGUIGUAN: A TEN YEAR UPDATE

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Abstract. Four bird census transects (66 total census points) established on Aguiguan by the U.S. Fish and Wildlife Service in spring, 1982 were resurveyed during the May, 1992 Aguiguan expedition. Two observers surveyed two transects each, and employed the same variable circular plot methodology used by USFWS. Raw counts from 1982 and 1992 suggested that most populations were stable, although several may have declined. In contrast, 1992 estimates of population densities were ten times greater than many reported by the 1982 survey. Compared to 1982, the present study found the average distance to bird detection less for most species. Our density estimates corresponded favorably to the actual frequency with which birds were encountered. In comparison to concurrent censuses performed on Saipan, most species exhibited similar densities. However, the Mariana Fruit Dove and Micronesian Honeyeater averaged more abundant on Aguiguan than on Saipan. These trends, also reported by the 1982 survey, may be related to the presence of extensive areas of lantana on Aguiguan but not on Saipan. Both these species fed upon this heavily flowering, fruiting weed. The enormous densities estimated here for small passerines (>20/ha) are far greater than those typically reported for temperate forest birds, but are similar to those found for certain Hawaiian forest species. Such high counts may indicate that populations exist at equilibrium densities.

Comprehensive, quantitative population surveys of birds in the Mariana Islands were undertaken for the first time in 1982 (Engbring et al. 1986). These surveys, conducted by the U.S. Fish and Wildlife Service, employed the variable circular plot technique (Reynolds et al. 1980). This method involves counting birds at points along census transects and estimating the distance from the observer to each bird encountered. It has proven useful for characterizing the avifauna of rugged tropical terrain (e.g. Scott et al. 1986), such as that found in the Marianas.

Periodic resurveys of Marianas birds provide crucial management data on these populations, which in many instances are highly vulnerable to human encroachment into natural habitats. Presently, for example, five species of Marianas upland birds are categorized by the U.S. Fish and Wildlife Service as endangered, and one endemic population is a candidate endangered species. Three endangered species, the Micronesian Megapode (*Megapodius laparouse*), Island Swiftlet (*Aerodramus vanikorensis*), and Nighthingale

Reed-warbler (*Acrocephalus luscini*a), are historically known from Aguiguan, and one of two populations of the Marianas endemic Golden White-eye (*Cleptornis marchei*) resides on the island. Because the forest birds of Aguiguan have been virtually unstudied since the initial 1982 survey, we undertook a comprehensive resurvey in order to assess the present status and population trends of all forest bird species.

STUDY AREAS AND METHODS

Aguiguan is a raised coral island which is capped by a plateau. From its summit, a series of terraces descend to the ocean. The plateau has been largely cleared of native vegetation, and is presently covered by grasslands and weedy thickets dominated by the spiny, introduced shrub lantana (*Lantana camara*). In contrast, most of the relatively narrow terraces and steep escarpments that separate them are still vegetated by native forest. The forest is dominated by such species as *Pisonia grandis*, *Cynometra ramiflora*, and *Guamia*

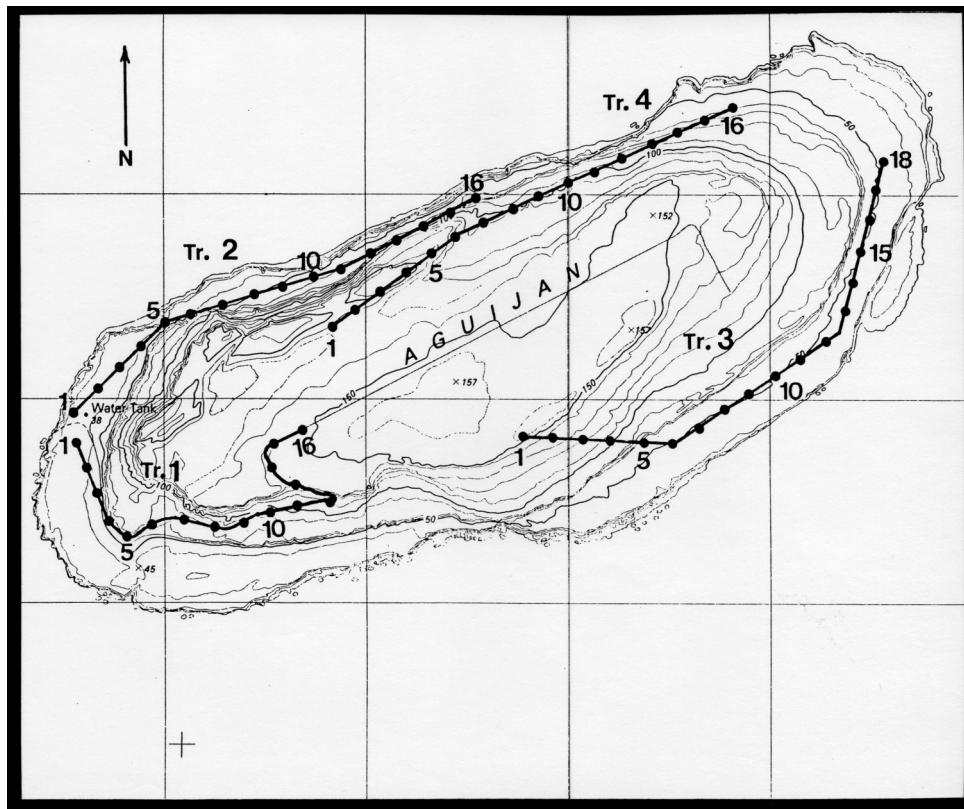


FIG. 1. Location of bird census transects on Aguiguan (from Engbring et al. 1986).

mariannae. The forest canopy is low (ca. 10–15 m high) as a consequence of frequent typhoon damage (Fosberg 1960). Moreover, the understory is open due to intensive browsing by feral goats (*Capra hircus*) (Engbring et al. 1986) which, however, have been nearly eliminated for three years.

Four census transects laid out in 1982 primarily traversed native forest on terraces (Fig. 1). Transects had points 150 m apart, and 66 total points were censused. Using the same methodology as Engbring et al. (1986), we censused these transects for birds beginning at sunrise. At each point, all birds encountered were recorded for eight minutes, and the distance from the point to each bird was estimated. Distance estimates were calibrated by placing plastic colored flagging at 10, 15, and 20 m intervals from selected points. Transects 1 and 3 were censused by R. Chandran, and transects 2 and 4 were censused by R. Craig. All counts were conducted under highly favorable weather conditions of light winds and partly cloudy skies. Counts were made on 1–4 June during the 1982 survey, whereas we censused on 21–22 May 1992.

In addition to the Aguiguan censuses, April, 1992 censuses were made by R. Craig on Saipan using similar methodology. Habitats chosen for the Saipan censuses were native forest like those on Aguiguan except that understory density was greater. Two 15 point transects were established, with points 100 m apart. R. Craig has performed these censuses on Saipan quarterly since Jan. 1991.

In censuses made on Aguiguan, all species encountered were recorded, including seabirds observed incidentally. However, we report raw counts primarily for forest-dwelling species. Exceptions are counts of the Philippine Turtle Dove (*Streptopelia bitorquata*) and Nightingale Reed-warbler, which inhabit forest edge, the Island Swiftlet, an aerial forager, and the White (Fairy) Tern (*Gygis alba*), a seabird that often nests in forest. Population densities were computed only for appropriate data, i.e. for forest species. In instances where species were encountered infrequently, Craig's average detection distances were used for computing population densities of Aguiguan birds. Accounts of incidentally recorded species are listed in Craig and

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TABLE 1. Count totals for censuses of Aguiguan forest birds, compared to 1982 data (Engbring et al. 1986). Total = birds/ 66 census stations, 1982 = mean birds/ 66 census stations.

Species	Transect:	Count				Total	1982
		Chandran		Craig			
		1	3	2	4		
Micronesian Megapode (<i>Megapodius lamarouse</i>)		1	2	2	6	11	7
White Tern (<i>Gygis alba</i>)		14	72	15	12	113	113.5
Philippine Turtle Dove (<i>Streptopelia bitorquata</i>)		0	0	3	8	11	7.5
White-throated Ground Dove (<i>Gallicolumba xanthonura</i>)	5	0	1	2	8	9.5	
Mariana Fruit Dove (<i>Ptilinopus roseacapilla</i>)		35	32	32	39	138	381
Island Swiftlet (<i>Aerodramus vanikorensis</i>)		3	8	9	0	20	84.5
Collared Kingfisher (<i>Halcyon chloris</i>)		15	39	16	13	83	79
Nightingale Reed-warbler (<i>Acrocephalus luscini</i>)		1	0	0	0	1	0
Rufous Fantail (<i>Rhipidura rufifrons</i>)		63	124	41	45	273	227.5
Micronesian Starling (<i>Aplonis opaca</i>)		42	60	10	15	127	104
Micronesian Honeyeater (<i>Myzomela rubrata</i>)		29	92	33	48	202	373
Golden White-eye (<i>Cleptornis marchei</i>)	70	74	54	47	245	223.5	
Bridled White-eye (<i>Zosterops conspicillatus</i>)		93	155	174	92	514	411

Chandran (present volume).

RESULTS

The four 1992 censuses yielded raw counts that for many species were similar to those obtained in 1982 (Table 1). Notable exceptions were that only 36% as many Mariana Fruit Doves (*Ptilinopus roseacapilla*) were found on the present censuses. Moreover, 24% as many Island Swiftlets and 54% as many Micronesian Honeyeaters (*Myzomela rubrata*) were found in 1992.

Although many of the raw counts of 1982 and 1992 were similar, estimates of population density based on these counts differed widely. For certain species, the 1992 estimates were ten times greater than

those computed in 1982 (Table 2). During the present census, the two observers also differed in population estimates, particularly for the abundant, flocking Bridled White-eye (*Zosterops conspicillatus*). Moreover, they diverged in raw counts, with Chandran estimating larger numbers of individuals than Craig for some species (Table 1).

The disparity in population densities computed in 1982 and 1992 can be traced to differences in estimates of detection distance (Table 3). Estimates of distance by Engbring et al. (1986) were far greater than those determined during the present survey. Limited differences also emerged between observers in 1992, but distance estimates by Craig on Aguiguan and Saipan were relatively consistent.

TABLE 2. Population estimates of Aguiguan forest birds, compared to 1982 data (Engbring et al. 1986) from Aguiguan and April, 1992 data from Saipan.

Species	Birds/ha				
	Chandran (mean 1-3) ¹	Craig (mean 2-4)	Mean 1-4 (±SD)	1982	Saipan
Micronesian Megapode	0.01	0.06	0.04(0.04)	0.03	0.02
White-throated Ground Dove	0.65	0.18	0.42(0.53)	0.09	1.54
Mariana Fruit Dove	4.70	0.66	2.68(2.04)	0.76	0.45
Collared Kingfisher	0.65	0.60	0.62(0.16)	0.11	0.81
Rufous Fantail	67.29	38.32	52.81(17.80)	3.82	36.38
Micronesian Starling	6.61	3.24	4.92(1.79)	1.11	5.94
Micronesian Honeyeater	11.44	36.34	23.88(13.48)	5.70	1.31
Golden White-eye	55.56	43.85	49.70(6.29)	6.15	38.37
Bridled White-eye	341.88	96.73	219.31(128.93)	19.30	120.00

¹ Numbers refer to transect numbers.

Although estimates of population density differed between 1982 and 1992, the relative abundance of species showed similarities between data sets. The Bridled White-eye was by far the most abundant forest species in both censuses, and the other small passerines (Rufous Fantail (*Rhipidura rufifrons*), Micronesian Honeyeater, and Golden White-eye) were relatively abundant. The Collared Kingfisher (*Halcyon chloris*) and Micronesian Starling (*Aplonia opaca*) were less common, and the Micronesian Megapode was rare. However, the Mariana Fruit Dove showed a major decline in relative abundance. Other species had populations inadequately characterized because they were poorly censused by the techniques employed. The White Tern, Philippine Turtle Dove (*Gallicolumba xanthonura*), and Nightingale Reed-warbler are not forest birds, the Island Swiftlet is principally crepuscular, and the White-throated Ground Dove vocalizes infrequently.

Comparison of Craig's Saipan and Aguiguan data suggested that most species attained similar densities on both islands (Table 2). However, the Micronesian Honeyeater was abundant in the native forest of Aguiguan, whereas it was uncommon in similar habitat on Saipan. Moreover, although its population densities were only modestly higher (detection distance greater on Aguiguan), the Mariana Fruit Dove appeared to be most abundant on Aguiguan. Raw counts (mean = 35.5/

16 stations) were three times higher than on Saipan (mean = 10.0/ 15 stations), and Chandran's counts (mean = 34.0/ 16 stations) also far exceeded those for Saipan.

DISCUSSION

Raw counts from 1982 and 1992 suggest that populations of most species have changed little on Aguiguan over ten years. Of those species with divergent counts, the Mariana Fruit Dove shows wide seasonal and annual variation in calling frequency (Glass 1987, Craig unpubl. data). Hence, lower 1992 counts may be due to infrequent calling during censuses rather than to a population decline. Similarly, Island Swiftlets widely vary in diurnal activity (Craig unpubl. data), so lower 1992 counts may only indicate a period of reduced activity. The recorded decline in the Bridled White-eye also may be artifactual, because large observer variation occurs (this study) in estimating flock sizes. The decline in Micronesian Honeyeater numbers is not easily explained, however, and may represent an actual population decline. Only periodic resurveys of these populations can confirm the trends suggested by our data.

The divergent population densities computed by the 1982 and 1992 surveys point out the limited utility of the variable circular plot technique in estimating bird

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TABLE 3. Average detection distances of Aguiguan forest birds estimated during May, 1992. Data from 1982 (Engbring et al. 1986) and 1990–1992 data from Saipan are compared.

Species	Distance (m)			
	Chandran	Craig	1982	Saipan
Micronesian Megapode	-	-	105	80
White-throated Ground Dove	-	-	80	20
Mariana Fruit Dove	25	70	159	50
Collared Kingfisher	60	50	193	50
Rufous Fantail	10	10	58	10
Micronesian Starling	25	20	66	15
Micronesian Honeyeater	20	10	58	15
Golden White-eye	10	10	42	10
Bridled White-eye	5	10	33	10

numbers. Relative densities based on raw counts suggest relative population stability or even declines for many species, whereas absolute density estimates suggest great population increases for most species. Variation among observers appeared great, especially in estimating detection distances, which led to conflicting density estimates. Because of these conflicts, we recommend comparing our raw counts with future censuses.

Despite this limitation in variable circular plot methodology, we believe that the population densities we computed for small passerines are consistent with other field observations, and closer to actual densities than those reported by Engbring et al. (1986). For example, an average detection distance of ten m for the Golden White-eye corresponds to encountering a bird every 20 m. This agrees with our field observations that family groups of ca. 4 birds were directly on the transect line at least once/100 m in native forest. However, as Engbring et al. (1986) believed, population estimates for the Bridled White-eye are likely inflated. Difficulties were encountered in estimating flock sizes of this abundant, actively moving species, and overcounting seemed likely.

The high densities we computed for small passerines were similar to densities reported (maximum = 32 birds/ha) for abundant Hawaiian forest birds like the Apapane (*Himatione sanguinea*), Common Amakihi (*Hemignathus virens*), and Iwi (*Vestiaria coccinea*)

(Scott et al. 1986). Indeed, R. Craig (pers. obs.) found when visiting Hawaii that the densities of these Hawaiian species and small passerines in the Marianas appeared similar. Moreover, such densities are far beyond those reported for temperate systems. When Craig (1987) reviewed population estimates for New England forest birds, the highest density reported was 2.6 birds/ha for the Red-eyed Vireo (*Vireo olivaceus*). High densities in these tropical island systems may indicate that populations exist at the carrying capacity of their habitat (i.e. populations are in equilibrium with available resources).

Comparative Saipan and Aguiguan data provide insights into inter-island population differences in which variation due to observer perception are eliminated. The greater abundance of the Mariana Fruit Dove and Micronesian Honeyeater on Aguiguan compared to Saipan is striking considering the general similarity of forest habitats on the two islands. The prevalence of these species on Aguiguan also was detected by Engbring et al. (1986). The most notable difference between the islands is that the native forest of Aguiguan is bordered by extensive stands of heavily flowering lantana. Few such stands occur on Saipan. Nectivorous Micronesian Honeyeaters vigorously defend territories (R. Craig pers. obs.), but birds also may leave their territories to feed upon this abundant nectar source. Similarly, the frugivorous Mariana Fruit Dove may travel to stands of lantana to feed on the abundant fruits. Doing so may dramatically increase the carrying capacity of forest habitat for these species.

In summary, bird populations on Aguiguan appear to have changed little in most instances in which data permitted valid comparisons. However, declines may have occurred in several species. Because of variation in observer perception, comparisons are best limited to raw census data. Most bird species had similar population densities on Aguiguan and Saipan, although the Mariana Fruit Dove and Micronesian Honeyeater appeared most abundant on Aguiguan. Population densities particularly for small passerines appeared great, and may indicate that populations exist at equilibrium densities.

Proceedings: Marianas Research Symposium 1: 17-21

FORAGING DIFFERENCES BETWEEN SMALL PASSERINES ON AGUIGUAN AND SAIPAN

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Abstract. May, 1992 data from Aguiguan on foraging by small passerines were compared with extensive 1991 dry season data from Saipan. The Bridled White-eye, Golden White-eye and Micronesian Honeyeater exhibited general similarities between islands in choice of forest zone, foraging method, foraging surface, and perch size. Differences noted included the tendency for Aguiguan Golden White-eyes to feed less from dead leaves, more from branches, and more from larger perches than Saipan birds. Aguiguan Bridled White-eyes also fed more from larger perches than Saipan birds. Comparison of Aguiguan results with 1988-1989 data from Saipan yielded alternate patterns of difference, and comparison of both sets of Saipan data produced additional foraging divergence within species. Because the differences uncovered between data sets were inconsistent, fundamental shifts between island populations in foraging ecology probably did not exist. The several inter-island differences uncovered were likely related to resource-generated temporal shifts in foraging patterns, and perhaps to alterations in methodology. Although these island populations appear genetically isolated, the similar forest habitat encountered by birds on the two islands provides similar foraging opportunities. Little pressure appears to exist for the populations to diverge ecologically.

When exposed to differing environments, populations of the same species often diverge ecologically. Such divergence has been shown to be related to behavioral plasticity or, particularly when gene flow is reduced, to genetic alteration (Morse 1980, Grant 1986). For example, in the genetically isolated *Dendroica* wood-warblers on Caribbean islands (Emlen 1981), distinct, stereotyped foraging behaviors have evolved. Among Hawaiian honeycreepers (Drepanidinae), populations artificially transplanted to new habitats have quickly undergone behavioral alterations (i.e. due to their behavioral plasticity), and the differing selective regimes in the new habitats are predicted to lead ultimately to genetic divergence (Conant 1988).

In the Mariana Islands, there is no recorded movement by the endemic small passerines between islands. Although the islands of Tinian and Saipan are separated by only 5 km, the Tinian Monarch (*Monarcha takatsukasa*) has never been reported from Saipan. Similarly, the Golden White-eye (*Cleptornis marchei*) and Night-

ingale Reed-warbler (*Acrocephalus luscini*), both common on Saipan, have never been reported from Tinian. Further evidence of genetic isolation is provided by the Rufous Fantail (*Rhipidura rufifrons*), which has songs that differ on the two islands (R. Craig pers. obs.). Hence, opportunities exist for genetic divergence between populations exposed to differing habitats.

In order to determine if ecological differences exist between the small passerines of Aguiguan and Saipan, we investigated foraging by three species that occur on both islands, the Bridled White-eye (*Zosterops conspicillatus*), Golden White-eye (*Cleptornis marchei*), and Micronesian Honeyeater (*Myzomela rubrata*). We relate findings to comparisons of the habitats encountered on the two islands.

STUDY AREAS AND METHODS

Aguiguan and Saipan are primarily raised coral islands. They are separated by ca. 30 km, and the island

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of Tinian lies between them. Areas chosen for study were steep limestone escarpments which, unlike level areas, are still vegetated by native forest. The forest is dominated by such species as *Pisonia grandis*, *Cynometra ramiflora*, and *Guamia mariannae*, and the canopy on both islands is low (ca. 10–15 m high) as a consequence of frequent typhoon damage (Fosberg 1960). On Saipan, the forest understory is dense, and characterized by the presence of abundant saplings and vines. In contrast, the understory on Aguiguan is open due to intensive browsing by feral animals (Engbring et al. 1986).

Data on both species of white-eyes from Saipan were gathered during the 1990–1991 dry season (December–May). Additional data were gathered on Bridled White-eyes in Jan.–Feb. 1988 (Craig 1989), and on Golden White-eyes in Jan.–Feb. 1989 (Craig 1990). Because Micronesian Honeyeaters were rare in the native forests of Saipan, data from the dry seasons of 1988, 1989, and 1991 were pooled in order to make comparisons. All Saipan observations were made by R. Craig. Aguiguan data were gathered from 20–25 May 1992. Because time on Aguiguan was limited, R. Craig, R. Kaipat, B. Lussier, and H. Sabino all observed after receiving training from R. Craig.

To study the methods which birds employed to exploit these forest habitats, we recorded the position and activity of individuals at the moment of a feeding attempt. For each attempt, we recorded the following: (1) forest zone—top, middle, lower; (2) foraging method—glean (removing an item from a surface while perched), probe (thrusting the bill into a crevice, fruit, or flower), aerial (removing an item from a surface while hovering, or darting from a perch to capture flying prey); (3) foraging surface—live leaf, dead leaf, branch, trunk, fruit, flower; (4) perch size—<0.25 cm, 0.25–<0.5 cm, 0.5–<1.0 cm, 1.0–<2.0 cm, 2.0–4.0 cm, >4.0 cm.

To make data statistically independent, each bird encountered was watched only once. The forests had a relatively low canopy (10–15 m) and were often on a steep slope, which made canopy and understory vegetation about equally visible. This minimized observational biases related to foraging height. We generally followed foraging individuals for >15 sec before observing a feeding attempt, which minimized potential biases associated with initial observations (Hejl et al. 1990). Initial observations are recommended over subsequent observations for characterizing such parameters as foraging microhabitats and methods, how-

ever (Bell et al. 1990).

RESULTS

Over six days on Aguiguan, we recorded 106 foraging attempts by the three species. We also made several incidental observations on other species, including the Rufous Fantail, Collared Kingfisher (*Halcyon chloris*), and White-throated Ground Dove (*Gallicolumba xanthonura*). These latter observations are reported by Craig and Chandran (present volume).

Golden White-eyes most frequently used the top and middle forest zones (Fig. 1a), and foraged mostly by gleaning (Fig. 1b). They often fed from live leaves and branches (Fig. 2a), and from 0.25–0.5 cm perches (Fig. 2b). These findings were generally similar to those for Saipan birds (Fig. 1,2; Craig 1990). Aguiguan data significantly differed from those from 1991 Saipan data in use of foraging surfaces ($\chi^2 = 13.4$, 5 df, $P < 0.025$) and perches ($\chi^2 = 12.1$, 5 df, $P < 0.05$). Aguiguan birds fed more from branches, less from dead leaves, and more from larger perches than did Saipan birds.

Bridled White-eyes most frequently used the forest canopy (Fig. 1a), and foraged mostly by gleaning (Fig. 1b) from live leaves (Fig. 2a) on 0.25–0.5 cm perches (Fig. 2b). Again, these findings were similar to those of Saipan birds (Fig. 1,2; Craig 1989). Aguiguan data differed significantly from 1991 Saipan data only in use of perches ($\chi^2 = 14.8$, 5 df, $P < 0.025$), with Aguiguan birds feeding more from larger perches. Also as on Saipan (Craig 1990), Bridled White-eyes significantly differed from Golden White-eyes in use of forest zones ($\chi^2 = 6.9$, 2 df, $P < 0.05$). Bridled White-eyes foraged more in the forest canopy. Moreover, Aguiguan Bridled White-eyes tended to feed more from live leaves and small perches than Golden White-eyes (differences non-significant, however), which also mirrored findings for Saipan (Craig 1990).

Like Micronesian Honeyeaters from Saipan, those from Aguiguan fed predominantly in the forest canopy where they probed flowers for nectar (Fig. 1,2). As with white-eyes on Aguiguan, they foraged mostly from 0.25–0.5 cm perches. No significant differences in foraging emerged between Micronesian Honeyeaters on Aguiguan and Saipan.

Comparison of the more limited Jan.–Feb. 1988–1989 Saipan foraging data with those from Aguiguan showed differences for Golden White-eyes in use of foraging surface ($\chi^2 = 19.0$, 5 df, $P < 0.005$)

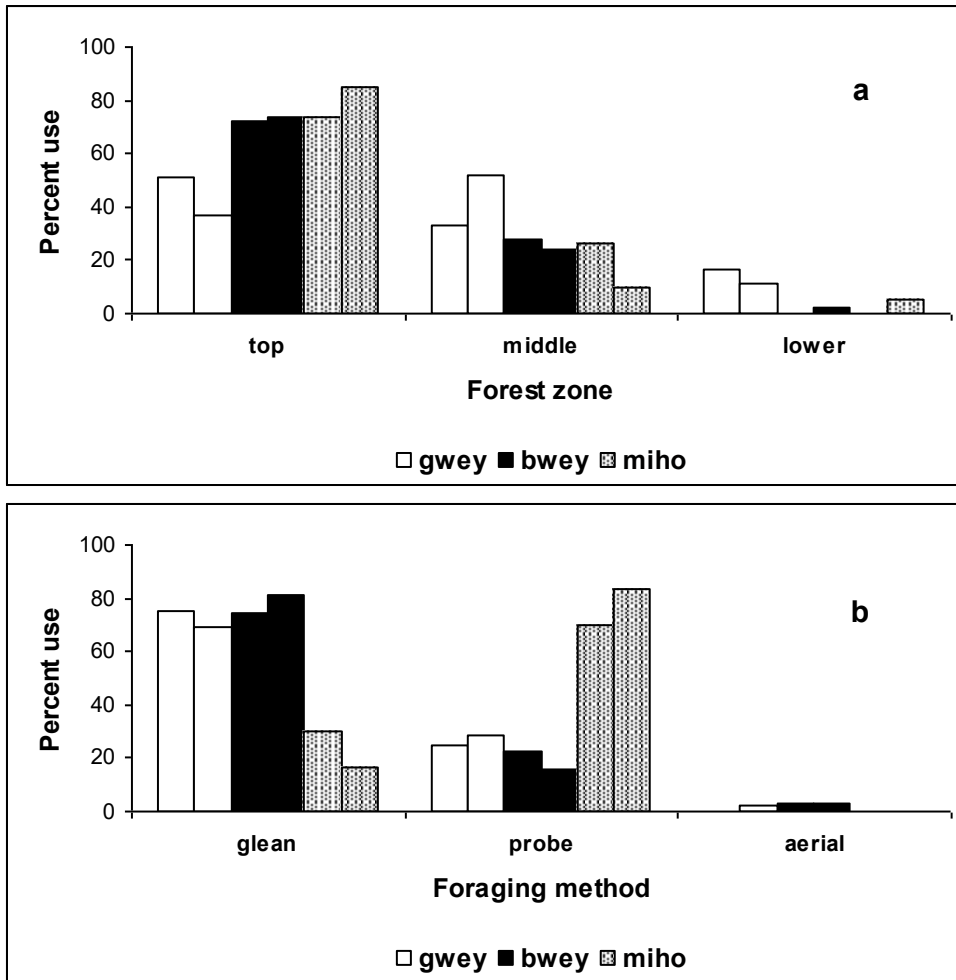


FIG. 1. The relationship between percent use of a) forest zones and b) foraging methods by three species of small passerines. For each species, Aguiguan data are displayed in the left bar, and 1991 Saipan data are displayed in the right bar. gwey = Golden White-eye, bwey = Bridled White-eye, miho = Micronesian Honeyeater.

and perches ($\chi^2 = 19.0, 5 \text{ df}, P < 0.005$). However, Bridled White-eyes showed significant differences in foraging methods ($\chi^2 = 8.4, 2 \text{ df}, P < 0.025$) rather than in use of perches. Bridled White-eyes on Aguiguan probed more than did 1988 Saipan birds.

When the two sets of Saipan data were compared, Golden White-eyes in 1989 differed from those in 1991 in use of forest zones ($\chi^2 = 7.7, 2 \text{ df}, P < 0.025$) and foraging surfaces ($\chi^2 = 11.1, 5 \text{ df}, P < 0.05$). Bridled White-eyes in 1988 differed from those in 1991 in use of foraging methods ($\chi^2 = 7.9, 2 \text{ df}, P < 0.025$), foraging surfaces ($\chi^2 = 19.8, 5 \text{ df}, P < 0.005$), and perches ($\chi^2 = 15.2, 5 \text{ df}, P < 0.01$).

DISCUSSION

Within species of birds, broad similarities emerged between islands in choice of forest zones, foraging methods, foraging surfaces, and perch sizes. Moreover, the two species of white-eyes showed differences in their foraging that were fairly consistent between islands. Several differences were noted, however, and may have been due to a) inter-island differences in foraging ecology, b) differences in methodology (e.g. multiple observers on Aguiguan, the brief period of observation on Aguiguan compared to Saipan), or c) temporal variation in foraging strategies employed by the

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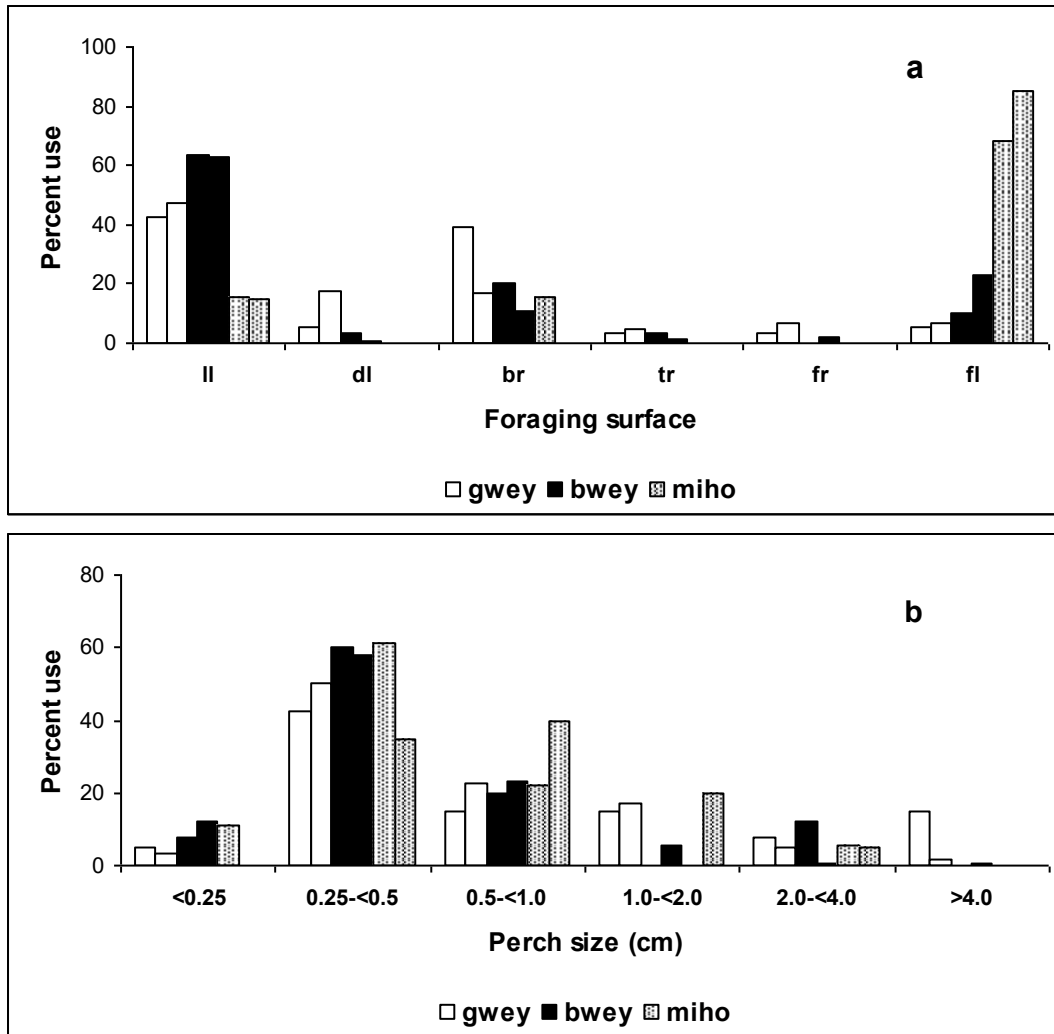


FIG. 2. The relationship between percent use of a) foraging surface (ll = live leaf, dl = dead leaf, br = branch, tr = trunk, fr = fruit, fl = flower) and b) perch size (1 = <0.25 cm, 0.25-<0.5 cm, 0.5-<1.0 cm, 1.0-<2.0 cm, 2.0-4.0 cm, > 4.0 cm.) by three species of small passerines. For each species, Aguiguan data are displayed in the left bar, and 1991 Saipan data are displayed in the right bar. gwey = Golden White-eye, bwey = Bridled White-eye, miho = Micronesian Honeyeater.

bird species.

Although we cannot quantify their effects, employing differing methodologies likely had some impact on results. In particular, observations on Aguiguan were made over six days, whereas the 1991 Saipan data were gathered over six months. Over these months, different foods became available (e.g. because of the particular flowering and fruiting periods of individual tree species). Therefore, the 1991 Saipan observations presented a general view of dry season foraging, whereas the Aguiguan data reflected foraging during a specific por-

tion of the dry season. Inconsistencies in foraging patterns uncovered through inter- and intra-island comparisons may mean, therefore, that temporal changes occur in foraging. Shifts by species in foraging, such as in use of specific foraging surfaces, could be due to differences in food availability between data sets.

The major difference between forest habitats on Aguiguan and Saipan was the absence of a dense forest understory on Aguiguan. However, the foraging shift likely to attend this habitat difference, greater reliance on foraging in the forest canopy, was not observed

(although a non-significant trend toward greater canopy foraging on Aguiguan occurred for the Golden White-eye). Other differences noted, including shifts in use of foraging surfaces and perch sizes, were not easily related to this difference in habitat. Differences were probably not the result of inter-population divergence, but rather seemed related to resource-generated temporal shifts in foraging patterns. Although these island populations appear genetically isolated, the similar forest habitat encountered by birds on the two islands provides similar foraging opportunities for birds. Little pressure appears to exist for the populations to diverge ecologically.

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Proceedings: Marianas Research Symposium 1: 22–25

GENETIC ISOLATION AND THE COMPARATIVE MORPHOLOGY OF SMALL PASSERINES ON AGUIGUAN AND SAIPAN

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Abstract. Five morphological measures from small passerines on Aguiguan were compared with similar data from Saipan. Univariate F tests showed that Bridled White-eyes from Aguiguan were significantly smaller than those from Saipan in mass, wing chord, bill length, bill depth, and tarsus length. Moreover, Aguiguan Golden White-eyes had lower mass, and Aguiguan Micronesian Honeyeaters had longer bills than those from Saipan. Discriminant function analysis showed that populations of the three species significantly differed in linear combinations of the five morphological variables. Few individuals were misclassified by the discriminant procedure as to their island of origin. Differences between the populations seem unlikely to have resulted from differing selective regimes, because similar physical environments and vegetation occur on the two islands. Founder effect and genetic drift may have played roles in shaping the present morphology of these island populations.

As noted by Craig et al. (present volume), in the Marianas there are no recorded inter-island movements by the small, native passerines. For these species little or no gene flow appears to occur between islands. Under such conditions, natural selection may operate to produce genetic divergence between isolated populations exposed to differing habitats or community relationships. Any differences between the populations also might arise from genetic differences present in initial colonists (founder effect). Furthermore, stochastic events such as typhoons might act to alter gene frequencies between island populations (genetic drift).

In order to determine if morphological differences exist between the small passerines of Aguiguan and Saipan, we captured and measured three species that occur on both islands, the Bridled White-eye (*Zosterops conspicillatus*), Golden White-eye (*Cleptornis marchei*), and Micronesian Honeyeater (*Myzomela rubrata*). We relate findings to comparisons of the habitats encountered on the two islands, as well as to other potential difference occurring between the islands.

STUDY AREAS AND METHODS

Aguiguan and Saipan are primarily raised coral

islands. They are separated by ca. 30 km, and the island of Tinian lies between them. Natural habitats consist of native forest, which is dominated by such tree species as *Pisonia grandis*, *Cynometra ramiflora*, and *Guamia mariannae*. The canopy on both islands is low (ca. 10–15 m high) because typhoon damage is frequent (Fosberg 1960). On Saipan, the forest understory is dense and characterized by the presence of abundant saplings and vines. In contrast, the understory on Aguiguan is open due to intensive browsing by feral goats (*Capra hircus*) (Engbring et al. 1986). Details of forest structure are reported by Chandran et al. (present volume) for Aguiguan and Craig (1992b) for Saipan. Thickets dominated by lantana (*Lantana camara*) are the second principal habitat of importance to birds on Aguiguan. On Saipan, thickets are dominated by tangantangan (*Leucaena leucocephala*). These two alien habitats became widespread after World War II (Engbring et al. 1986).

To measure birds, we captured individuals with a 12.8 m, 2.5 cm mesh mist net. Birds were netted on Aguiguan between 20–25 May 1992, and on Saipan during 1990 and 1992. Measurements taken on birds were mass, wing chord, bill length (from distal end of the nostril to bill tip), bill depth (taken at distal tip of the

TABLE 1. Morphological characteristics of three species of Marianas passerines. *n* = sample size, SD = standard deviation, *F* = *F* test, *P* = probability of accepting null hypothesis.

Species	Measure				
	Mass (g)	Wing (cm)	Bill length(cm)	Bill depth(cm)	Tarsus (cm)
Bridled White-eye					
Aguiguan (<i>n</i> = 14):					
Mean	7.4	50.4	7.7	2.8	17.5
SD	0.5	0.9	0.4	0.2	0.7
Saipan (<i>n</i> = 51):					
Mean	8.0	49.4	6.9	2.6	17.1
SD	0.6	1.2	0.3	0.2	0.6
<i>F</i>	15.0	7.4	56.8	17.4	4.3
<i>P</i>	<0.001	0.009	<0.000	<0.001	0.04
Golden White-eye					
Aguiguan (<i>n</i> = 9):					
Mean	15.7	69.4	9.6	3.8	24.3
SD	0.8	2.2	0.4	0.2	2.0
Saipan (<i>n</i> = 9):					
Mean	20.1	71.5	10.2	3.9	25.2
SD	2.5	3.7	0.8	0.2	0.9
<i>F</i>	25.3	2.2	4.0	0.7	1.5
<i>P</i>	<0.001	0.16	0.06	0.41	0.24
Micronesian Honeyeater					
Aguiguan (<i>n</i> = 7):					
Mean	12.7	67.9	12.5	3.3	20.9
SD	2.1	5.9	0.7	0.3	1.5
Saipan (<i>n</i> = 9):					
Mean	12.4	67.9	11.4	3.2	19.9
SD	2.5	4.2	0.8	0.2	1.4
<i>F</i>	0.5	<0.001	7.7	0.9	1.7
<i>P</i>	0.82	0.99	0.02	0.36	0.21

nostrils), and tarsus length. Mass was recorded to the nearest 0.1 g with a 50 g spring scale, and lengths were recorded to the nearest 0.1 mm with a dial caliper.

RESULTS AND DISCUSSION

All three species showed differences between islands in morphology. Univariate *F* tests (Table 1) demonstrated that the Bridled White-eye had significant-

ly lower mass but significantly larger wing, bill, and tarsus measurements on Aguiguan compared to Saipan. In contrast, Golden White-eyes on Aguiguan significantly differed from those on Saipan only in mass (smaller), although they averaged smaller in all measures. Micronesian Honeyeaters weakly differed between islands in most traits, but bill length was significantly greater on Aguiguan. Discriminant function analysis on the five morphological variables yielded clear distinctions be-

THE AGUIGUAN EXPEDITION

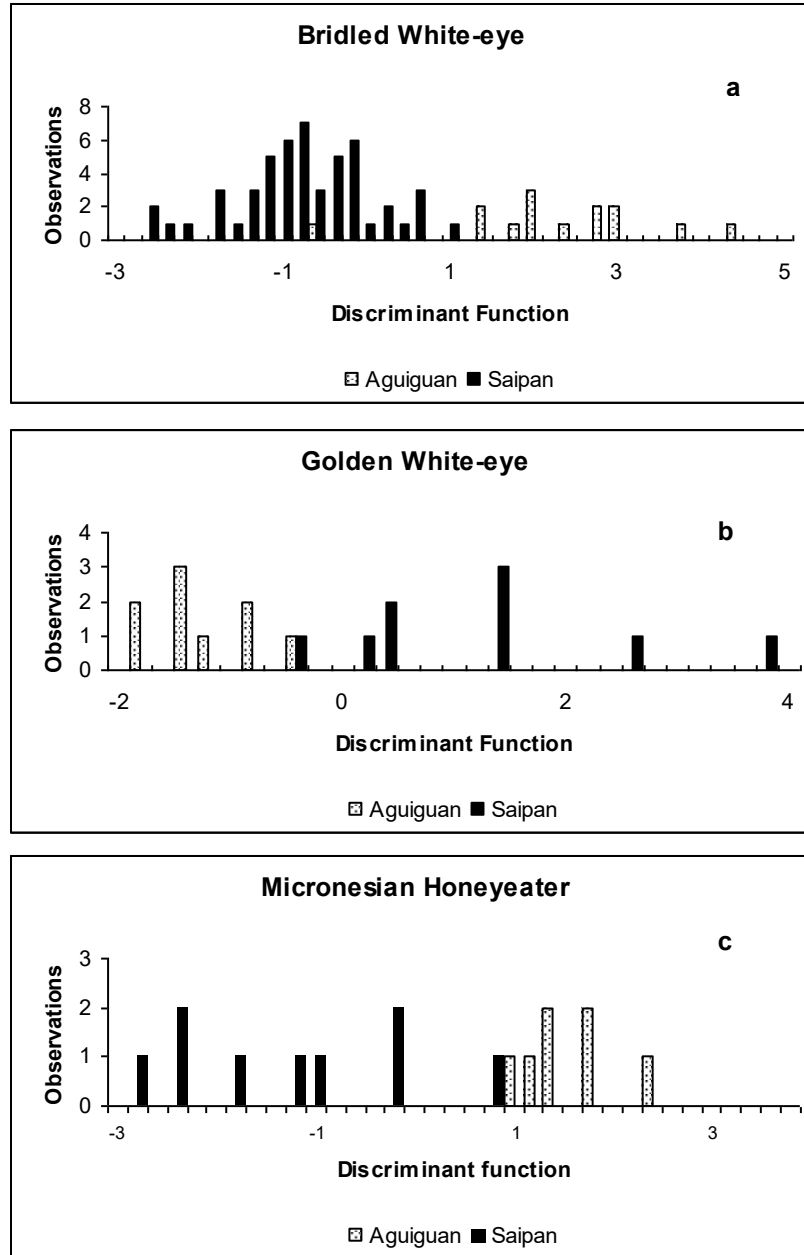


FIG. 1. Discriminant function analysis on five morphological variables for the a) Bridled White-eye, b) Golden White-eye, c) Micronesian Honeyeater.

tween island populations of all three species (Fig. 1a, b, c). Chi square approximations were significant for the Bridled White-eye ($\chi^2 = 60.8$, 5 df, $P < 0.001$), Golden White-eye ($\chi^2 = 14.9$, 5 df, $P < 0.02$), and Micronesian Honeyeater ($\chi^2 = 14.6$, 5 df, $P < 0.02$).

Differences noted between these populations are potentially attributable to 1) alteration in methods used

on the two islands, 2) morphological shifts occurring as a consequence of inhabiting differing environments, and 3) morphological divergence due to stochastic events. Data gathered on Aguiguan differed from those taken on Saipan in that Aguiguan birds were measured over six days, whereas Saipan birds were measured over two years. Because mass and wing length can change seasonally

(Nisbet and Medway 1972), observed inter-island divergence in these traits might have been due to differences between data sets in factors such as the breeding condition or plumage state of individual birds. However, measures of the bill and tarsus should show relatively little seasonal variation, especially among mature birds.

Because the Bridled White-eye differed significantly between islands in all measures, its divergence did not appear to be a methodological artifact. Moreover, even though Golden White-eye populations contrasted only in mass, all other measures showed the same trend of Saipan birds being the largest. Hence, this species also was likely divergent between islands. Evidence for a morphological shift was weakest in the Micronesian Honeyeater, which showed no consistent trend in measures, and which significantly differed between islands only in bill length.

Habitat dissimilarities potentially driving morphological divergence between island bird populations include differences in climate, soil, and vegetation. Aguiguan may average slightly drier than Saipan because it has lower relief (Young 1989, Butler 1992, Klawunder present volume), but much of lowland Saipan appears climatically similar to Aguiguan. Moreover, both islands have soils derived primarily from coral, though Saipan has limited exposures of volcanic soil (Young 1989). Species composition and structure of native forest is also similar between islands, although the details of tree relative abundance differ (Chandran et al. this volume, Craig 1992b). Finally, much of the forest understory on Aguiguan is presently damaged by goats, but feral animal damage formerly occurred on Saipan as well (Craig 1992b).

Based on these observations, subtle dissimilarities may exist between the habitats of Aguiguan and Saipan. The potential effects of such differences on bird morphology are uncertain, but likely small. Because there are no historically known differences in the bird species composition of Aguiguan and Saipan (although more species probably once inhabited both islands) (see Steadman 1992), there are also no obvious avian community differences between the islands that might result in morphological divergence. In the absence of other obvious explanations, founder effect and genetic drift seem by default to be potentially important agents in shaping the present morphology of these island populations.

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Proceedings: Marianas Research Symposium 1: 26–29

A CURSORY LOOK AT THE GEOLOGY OF AGUIGUAN ISLAND

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Abstract. Aguiguan is located at 14°51' north latitude and 145°34' east longitude. It is 9 km (5.4 mi.) south of the island of Tinian. It is the smallest of the five islands making up the southern portion of the Mariana Islands. Guam, Rota, Tinian, and Saipan all exceed Aguiguan's 718 ha (7.2 km²) by ten fold. The island is approximately 4.5 km long and 1.5 km at its widest. The maximum elevation is 168 m. The geology of Aguiguan is remarkable in its lack of complexity. It is entirely coralline limestone forming step-like terraces delineated by slopes ranging from gentle rock outcroppings to vertical cliffs. A sheer cliff rises from the sea on all sides, as a result of rapid uplift. Faulting has occurred and faults can be traced running parallel to and oblique to the islands long axis making for a complex pattern. It is also difficult to distinguish lesser faulting from the fracturing so characteristic of limestones on these islands. No evidence of volcanic activity is observed. The soils are fairly thin except for the central plateau and exhibit characteristics of the soils found on Tinian and Saipan.

The Mariana Island arc is located west of the Marianas Trench, delineating the Philippine Sea from the Pacific Ocean. These islands are generally separated into a northern component of active volcanic islands and a southern component of upraised coral islands without active volcanos.

Aguiguan Island and its small companion, Naftan Island, are part of the southern component of the southern Marianas, along with Guam, Rota, Tinian and Saipan. Aguiguan and Naftan have had very little attention from the scientific community. Two Japanese geologists, Risaburo Tayama and Yasushi Ota (Butler 1992) worked on the island during parts of 1936 and 1937. The U.S. Department of Agriculture, Soil Conservation Service surveyed and classified the soils of Aguiguan, Rota, Saipan, and Tinian in 1985–1986 (Young 1989). In 1990 a team from Southern Illinois University conducted an archaeological survey (Butler 1992) of Aguiguan. References are made about the phosphate deposits on the Island (Rodgers 1947), the vegetation (Fosberg 1960), and the birds have been surveyed (Engbring et al. 1986).

Aguiguan alone, of the southern Marianas, is uninhabited. It has been so since 1945. Aguiguan is local-

ly called Goat Island because a large population of feral goats (*Capra hircus*) that once occupied the island (Engbring et al. 1986). It is officially designated as a wildlife reserve and permission is required to visit it. Native limestone forest still may be observed on the island. The climate of these islands is best described as a two season climate, uniformly warm and humid throughout the year. Off the southern end of Aguiguan, the rocky pinnacles of Naftan Island are separated by water less than 10 fathoms deep, whereas the depths elsewhere around Aguiguan quickly reach 100 fathoms.

Although there are several variations to the spelling of Aguiguan, I have chosen the spelling used by the Municipality of Tinian to which Aguiguan belongs.

AGUIGUAN GEOLOGY

Tectonics. The Mariana Islands consist of two distinct volcanic island arcs. The frontal arc volcanos were active in Eocene–Oligocene time and again in Miocene time (Banks 1984). These make up the islands of Guam, Rota, Saipan, and Tinian. One can presume Aguiguan belongs with this group, although any volcanic eruptions must have been subaerial. This arc of

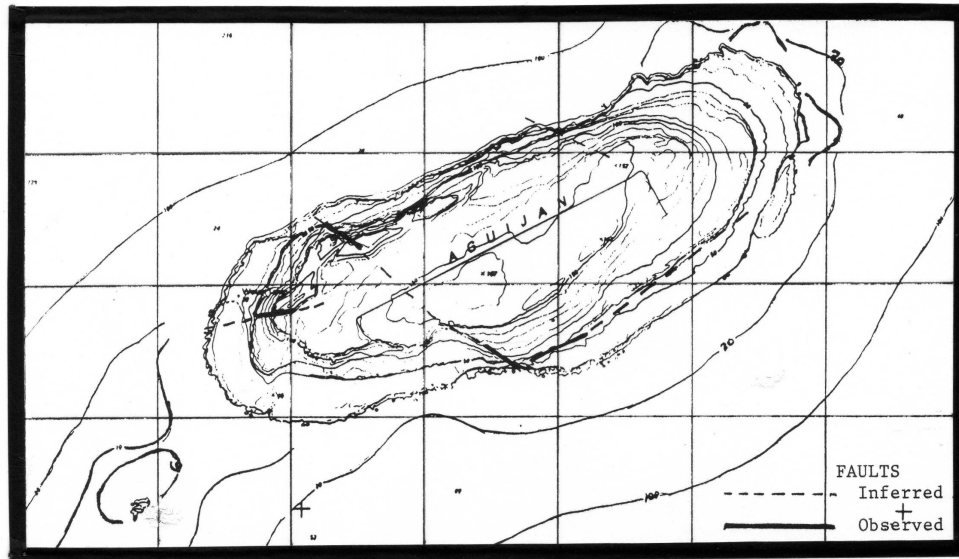


FIG. 1. Aguijuan and Naftan Islands, with principal faults depicted.

islands mark the boundary of the Marianas Trench where the Pacific plate is subducting beneath the Philippine Sea plate without causing large underthrusting earthquakes at the quake interface. (Yoshida et al. 1992). In this region, the Pacific plate is subducting with a west northwest translation. In studying the seismicity in this region, and particularly a large 7.5 earthquake that occurred beneath the trench in 1990, Yoshida et al. (1992) conclude that the slab is subducting vertically. They further interpret that event as due to gravitational pull of the slab rather than lithospheric flexure.

To the extent that this area is so active, past volcanic evidence would seem likely on Aguijuan. However, no evidence of volcanic activity was observed on Aguijuan. None has ever been reported although it may be assumed that a volcanic core exists as is evident on the other islands of this arc. As part of the Mariana Ridge, Saipan, Tinian and Aguijuan are related, further supporting the possibility of a volcanic core. The islands of the northern part of this arc are considered to be active. The subduction zone passes about 125 km beneath the island chain, with earthquake foci at depths of 50 to 250 km (Banks 1984).

Faulting. The faults observed during our expedition show trends similar to the faulting on Saipan as reported by Cloud et al. (1956). Several faults trending northeast to southwest and relatively parallel to the long axis of the island were observed. Although showing some westward dipping, more work is needed to verify

the presence of a pattern. Those faults that are generally perpendicular to the long axis offset the island. A few are readily identified on a map of the island (Fig. 1). Many of the faults show some lateral displacement, but additional data are needed before any mapping or interpretation can be attempted. These findings conform with the findings of Karig (1971). He reports surface deformation of the Mariana arc crest as restricted to block faulting along normal faults. The trends are both parallel and perpendicular to the arc axis. Much of the fracturing observed in the limestones appeared to be zonal and may indicate the presence of additional faulting.

Uplift events. That Aguijuan has been rapidly uplifted in its formation is not in question. The question instead is how rapidly and often have uplift occurred. Rapid uplift is indicated in the limestone terraces of the island (Fig. 2, 3). Tayama and Ota identify eight levels (Butler 1992), but from the profiles only four major levels are evident. These levels are delineated by very steep slopes or by sheer cliffs. Aguijuan has, therefore, experienced a minimum of four periods of rapid uplift.

Butler (1992) discussed the attention the Japanese paid to the sea level notches on the island. In particular, the 2 m notch is absent on Aguijuan but present on the other four islands of the southern Marianas. On Aguijuan, above the current sea level notch is a notch at 8 m. Butler (1992) suggests that rapid uplift, four times as much as the other islands, has occurred since the mid

THE AGUIGUAN EXPEDITION



FIG. 2. Long axis of Aguiguan (vertical exaggeration = 21x).

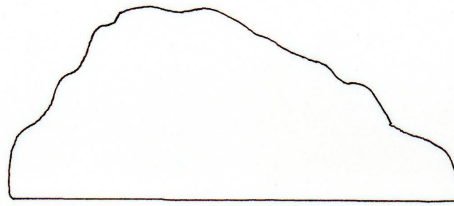


FIG. 3. Width of Aguiguan as seen from Tinian vertical exaggeration = 21x).

-to-late Holocene equilibrium with sea level.

The tectonic development of the Mariana arc system can be traced reliably from the early Miocene to the present (Karig 1971). Tectonic activity in the island arc system appears to be discontinuous. In a typical pulse of island arc activity, trench formation and volcanism was accompanied by several hundred meters of uplift along the frontal arc (Karig 1971). Initial observations of Aguiguan would seem to conform to this model.

Limestones. The limestones observed are similar to the limestones on Saipan. Those on Aguiguan should probably be classified as bioclastic limestones or constructional limestones. Cloud et al. (1956) further divides each group. Bioclastic limestones are made of the whole or parts of foraminifera, fragments of coral or other fossils, rather than pieces of other rocks. Bioclastics are subdivided on the basis of the dominant rock building organism present (Cloud et al. 1956). These are foraminiferal limestones, algal-foraminiferal limestones, coral-algal limestones, and algal limestones. Constructional limestones represent corals and calcareous algae masses that form reefs and indicate origin through growth position and location.

Several rock walls were observed on the ridges along the southeast side of the island. These are considered to be constructional limestones as fossil reef building organism can be seen in the rock along the escarpment. The same situation was observed in a channel-like ravine at the south end of the island. These channels seem likely to have been flow channels through the

reef formations rather than extremely wide fracture zones or terrestrial erosional remnants. Such channels can be seen today in areas of active reef formation. No rock was found that can be termed detrital or interclastic limestone. Detrital refers to rock composed of reworked and appreciably rounded material from a previous deposit or older limestones. This lack of detrital limestones may be the result of rather rapid uplift of the island. It suggests little time was available for the reworking of older limestones.

Soils. The soils of Aguiguan were surveyed and classified in 1985–1986 by a team from the U.S. Department of Agriculture, Soil Conservation Service. Of the 718 ha of soil surveyed on Aguiguan, fully 55% are classified as Takpochao–Rock outcrop complex with slopes ranging from 3% to 99% (Young 1989). These soils form over coralline limestone from reef formations. The limestone is very porous and water percolates downward rapidly. These soils, where we collected, appeared thin overall, dark brown to reddish, and as a cobbly clay-loam.

On the broader benches and on the central plateau, the soils were thicker, darker and generally showed a profile. These soils with more gentle slope are classified as Chinen clay loam (29%), Chinen–Rock outcrop complex (4%), Saipan–Rock outcrop complex (4%), and Dandan–Chinen complex (3%). These were the agricultural areas used by the Japanese. Rock outcrops were frequent over much of the island. The outcrop complex used in the classification of the soils indicates

that soils and rock outcrops are so intermixed that they cannot reasonably be separated. These outcrops ranged from exposed limestone on gentle slopes to vertical cliffs. Often these marked the boundaries of the terraces that are so discernable from a distance (Fig. 2, 3).

The economic usefulness of these soils is severely limited by the lack of water and their high permeability. During our week on the island, no rain fell, the soil was very dry, we dug no more than 30 cm, and shallow rooted plants were drying in the sun. No wells are confirmed on the island. However, one is reported near the boat landing area (S end), although it is apparently little more than a catchment basin. The Japanese used concrete catchments collecting from metal roofs in order to maintain a water supply for the inhabitants and for agriculture.

Naftan Island. Naftan Island is closely associated with Aguiguan. It stands about .9 km off the southern tip of Aguiguan with an altitude of just over 20 m. It has very little vegetation, which appears to be composed mostly of shrubs. Water depths between the two islands is less than 10 fathoms, and a submerged ridge extends for another km at the same depth south of Naftan. Naftan is an important seabird colony (Engbring et al. 1986). It was observed but not visited.

Economics. The Japanese reportedly located deposits of phosphates on Aguiguan (Butler 1992). It is doubtful if the quantities of phosphate are presently of any value. The following is paraphrased from Rodgers (1947): Bird droppings were the original source of the phosphorus in these deposits. Rain water carries the phosphoric acid down to the underlying limestone where it attacks the limestone, producing calcium phosphate. The phosphoric acid is concentrated enough to attack the limestone only above the water table. The phosphates exist as hard, shot-like grains in clay residual from the decomposition of the limestone.

Rodgers (1947) also made several generalizations about phosphate deposits. All occur in residual clay overlying or between pinnacles of limestone on uplifted coral islands. Many of the deposits occur on the highest parts of the island (not true of Saipan or Tinian, Rogers 1947), or lie in the northwest parts of the islands. Presently, there are too few seabirds on these islands, including Aguiguan, for droppings to accumulate. Moreover, the quantity of rainfall is unfavorable to the accumulation a guano to the extent that phosphoric acid will be of the concentration needed to attack the limestone. During the 1930s and 1940s, Japan used phosphate rock as a source of fertilizer, a resource absent from most of

their islands.

Water. Potable water is the single vital resource in very short supply on Aguiguan. There are concrete catchments constructed by the Japanese that still exist and contain a supply of water. However, the water is not very appealing. Vegetation, insects, and occasionally birds, lizards, and other small animals can be found floating in water. An examination of the water with a hand lens shows a substantial population of microorganisms. We found no other source of fresh water, even in caves. Estimates of fresh water resources have been made by U.S. Soil Conservation Service. They assume that a freshwater lens with heads <1 m (2-3 ft) above sea level could exist near the center of the island. No attempt has yet been made to check this assumption. These predictions are made assuming aquifer conditions similar to those on Tinian (C. Freer pers. comm.).

In summary, Aguiguan Island formed as a result of the Pacific plate subducting under the Phillipine plate. The frontal arc islands of Guam, Rota, Tinian, and Saipan have volcanic cores that were active as late as Miocene time. Aguiguan belongs with this group, but has no observable volcanics. Evidence strongly suggests a series of rapid uplift events in the past. Marine terraces are delineated by sheer cliffs, no interclastic (detrital) limestones are found, faulting is representative of island arc systems, and an equilibrium sea notch is absent. No attempt has been made to determine the age of the limestones or to correlate the limestone formations on Aguiguan to formations on Saipan or Tinian. Physical observations of these three islands indicate some similarities. Should wells be drilled on the island, valuable information of the subsurface geology would be available, along with information on water and phosphates. Another look at the absence of the 2 m sea notch and correlation of other sea level equilibrium notches with other islands of the southern Marianas may answer some questions. Aguiguan remains somewhat of an enigma.

ACKNOWLEDGEMENTS

My thanks to Rick Kaipat, who hacked trails through lantana with few scratches while the right forearm of the "instructor" looked like it had barely survived some mystical initiation into manhood. Perhaps I had. Also, my appreciation to Robert Latham for sweating through the hours in the rugged terrain, being part goat, and finding some interesting trails in our search of the island.

THE AGUIGUAN EXPEDITION

Proceedings: Marianas Research Symposium 1: 30–35

AGUIGUAN: A FIELD TRIP

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Abstract. Aguiguan is located at 14°51' north latitude and 145°34' east longitude. It is 9 km (5.4 mi) south of the island of Tinian. It is the smallest of the five islands making up the southern portion of the Mariana Islands. Guam, Rota, Tinian, and Saipan all exceed Aguiguan's 718 ha (7.2 km²) by ten fold. The island is approximately 4.5 km long and 1.5 km at its widest. The maximum elevation is 168 m. The geology of Aguiguan is very simple. It is entirely coralline limestone forming step-like terraces delineated by slopes ranging from gentle rock outcroppings to vertical cliffs. A sheer cliff rises from the sea on all sides. No evidence of volcanic activity is observed. The soils are fairly thin except for the central plateau and have not been disturbed for fifty years. Off the southern end of Aguiguan several rocky pinnacles called Naftan Island rise from the sea. The water depth between Aguiguan and Naftan does not exceed 10 fathoms, whereas the depths elsewhere around Aguiguan reach 100 fathoms in a very short distance. The weather is hot and humid with minimum rainfall between December and July. Fresh potable water is at a premium. Native limestone forests, so characteristic of these islands, still exist along with growing populations of noxious weeds. Monitor lizards abound, some feral goats still exist, and several populations of fruit bats can be observed. Large populations of native birds exist, some endemic and others rare. So, why go to Aguiguan on a field trip?

The Mariana Island arc is located west of the Marianas Trench, delineating the Philippine Sea from the Pacific Ocean. These islands are generally separated into a northern component of active volcanic islands and a southern component of upraised coral islands without active volcanos. Aguiguan Island and its small companion, Naftan Island, are part of the southern component along with Guam, Rota, Tinian and Saipan.

Aguiguan and Naftan have had very little attention from the scientific community. Two Japanese geologists, Risaburo Tayama and Yasushi Ota (Butler 1992) worked on the island during parts of 1936 and 1937. The U.S. Department of Agriculture, Soil Conservation Service surveyed and classified the soils of Aguiguan, Rota, Saipan, and Tinian in 1985–1986 (Young 1989). In 1990 a team from Southern Illinois University conducted an archaeological survey (Butler 1992) of Aguiguan. References are made about the phosphate deposits on the Island (Rodgers 1947), the vegetation (Fosberg 1960), and the birds have been surveyed (Engbring et al. 1986). This lack of attention pro-

vides an excellent vehicle to involve students in field work. It gives the work a sense of excitement akin to that of exploration. It is, in a very big sense, an exploration into the work of science and scientists.

On 20 May 1992, 16 students and instructors from Northern Marianas College, Saipan, visited Aguiguan Island. This trip was an effort to involve students in field work. Although six days were scheduled for the trip, only four of those days could be totally devoted to observations in the field. Transportation was by helicopter, which required five trips for the team, the gear and, most importantly, the water supply.

Due to time constraints and because of the rugged, rocky terrain, no more than one half of the island was traversed by this writer. This situation was not enhanced by the thickets of lantana (*Lantana camara*), an abundance of wasps (apparently two different species) (Butler 1992) nesting near the forest cliffs and in the leaf litter adjacent to open areas, and the very hot weather during that last part of May. Only a cursory look at Aguiguan was accomplished; nonetheless, it was

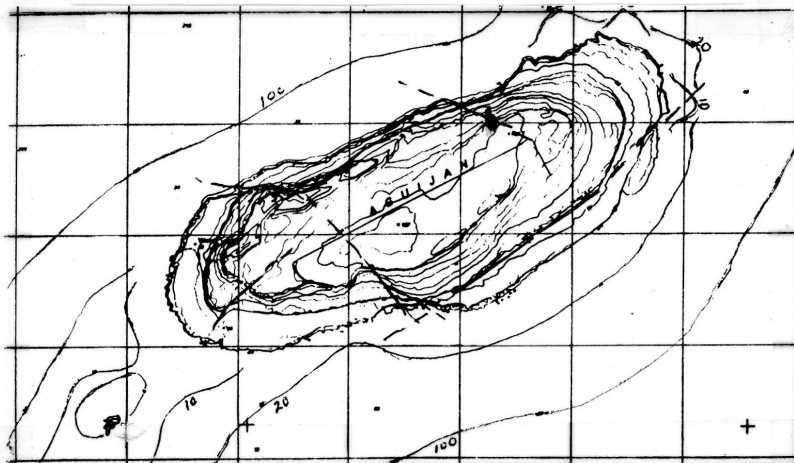
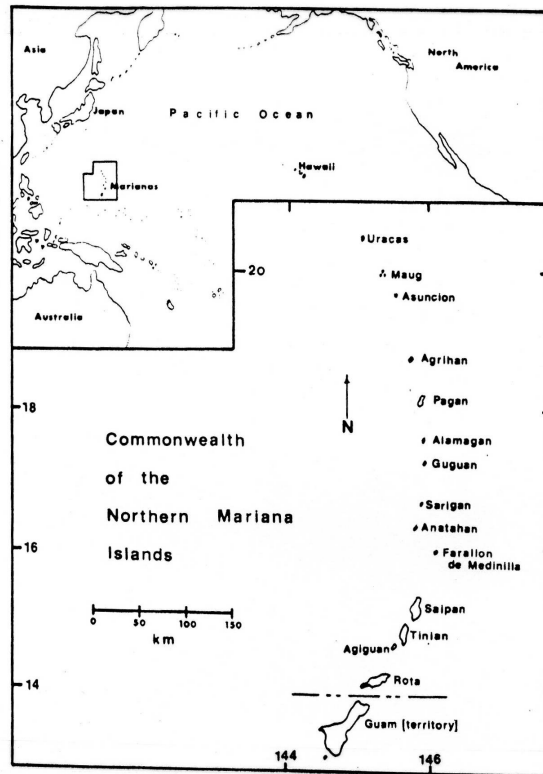


FIG. 1. The Mariana Island archipelago. Agiguan is south of Tinian in the southern Marianas.

a learning experience.

REGIONAL SETTING

Fauna. Agiguan alone, of the southern Mariana islands, is uninhabited. It has been so since 1945. Agiguan is locally called Goat Island because a large population of feral goats (*Capra hircus*) (Engbring et al.

1986) had occupied the island. These goats were brought to the island by Tinian settlers in the early 1800's, and their existence noted in publications by 1863 (Butler 1992). Most of the goats have been removed from the island by the Commonwealth Division of Fish and Wildlife people at the discretion of the Mayor of Tinian. Agiguan is officially designated as a wildlife reserve and is uninhabited by law. Permission

THE AGUIGUAN EXPEDITION

Meteorological Data - Precipitation (Rainfall) in inches													
Division of Plant Industry & Extension Services													
Department Of Natural Resources													
Kagman Agriculture Station													
10 YEAR AVERAGE RAINFALL- KAGMAN, SAIPAN													
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Total
Averages	3.37	2.72	3.04	1.87	3.69	4.11	9.06	19.5	12.8	10.3	8.94	4.51	83.9

FIG. 2. Average monthly precipitation at Kagman Station, Saipan.

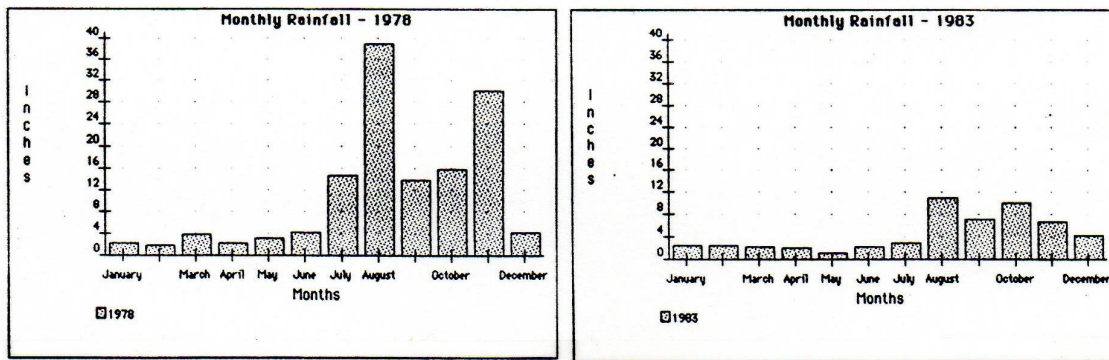


FIG. 3. Comparison of a rainfall amounts during a wet and dry year on Saipan (from Cabrera 1985).

is required to visit the island. However, people still visit the island for fishing, hunting coconut crabs (*Birgus latro*) and, unfortunately, poaching the rare Mariana Fruit Bat (*Pteropus marianas*). A large number of monitor lizards (*Varanus indicus*) were observed by our group. They were of interest as they were considerably larger than those occasionally observed on Saipan. We observed birds and of special interest was the Micronesian Megapode (*Megapodius laperouse*) and the Agui-guan Nightingale Reed-warbler (*Acrocephalus luscini-nijoi*). The megapode is rare and the reed-warbler is extremely rare. The team studied the Bridled White Eyes (*Zosterops conspicillatus*), the Golden White Eyes (*Cleptornis marchei*), and the Micronesian Honeyeater (*Myzomela rubrata*). The data gathered by the students was compiled and compared against similar data from Saipan. Some notable results were obtained. What effect will the introduction of game animals, or birds, have on the native populations on Agui-guan?

Flora. Characteristic native limestone forest still may be observed on the island. These forests are domi-

nated by *Pisonia grandis*, *Cynometria ramiflora*, and *Guamia mariannae*. Some of the canopy trees are large, but most are apparently kept trimmed by storms. One mature coconut tree survives on the south end of the island at the old boat landing. Several coconut trees have been planted at a camp location on the north central plateau near two cisterns and a small enclosed shelter.

Some of the larger trees on the island are not indigen-ous to Agui-guan. The flame trees (*Delonix regia*) and ironwoods (*Casuarina equisetifolia*) were planted by the Japanese (Raulerson and Rinehart 1991) and seem to be surviving despite the lack of cultivation. The Japanese cleared part of the island to cultivated sugar cane for export. These cleared areas are now overgrown with grasses, lantana, and ground-covering vines. A 1992 quarterly report of the Soil and Water Conservation District states that lantana covers 95% of the open fields, with the remaining vegetation made up of species like masigsig (*Wedelia biflora*), blue morning glory (*Ipomoea indica*), spiny mimosa (*Mimosa invisa*),

and grasses. It seems unusual that in 55 years the native vegetation hasn't reclaimed all these open areas. However, the Department of Natural Resources has tried controlled burning as an effort to control some of the weeds and may have contributed to checking the expansion of the native vegetation.

Students surveyed the forest canopy and understory. The compiled data were used to compare with similar data from Saipan, where most of the natural vegetation has been destroyed and only pockets of native forest remain. What changes will occur in the forest without the goats?

CLIMATE

The climate of these islands is comprised of two seasons. Uniformly warm, some say hot, and humid weather occur throughout the year. Saipan has the world's most equitable annual temperatures, lowest monthly variation (Stanley 1989). The wet season lasts from July through November and the dry season is from December through June (Fig. 2). Although the ten year averages shown in Fig. 2 indicate ample rain each month, the year to year variations can be extreme. For example, 1978 was a wet year, whereas 1983 was very dry (Fig. 3).

There are no rainfall records for Aguiguan as there are for Saipan. Fishermen who frequent the area around Aguiguan claim that the rainfall on the island is less than that of Tinian, which receives less than Saipan. A personal observation is that the rainfall on Aguiguan was less than on Saipan. I maintain a rain gauge at my house on Saipan and recorded approximately .1 inch of rain on Saipan while we were on Aguiguan. All of our party on the trip will attest to no rain falling on us. May was decidedly hot this micro-climate have on the flora and fauna of the island?

GEOLOGY

Aguiguan exists in a geologically active area. To the east is the Marianas Trench, an active subduction zone. The island arc of the Mariana Islands is divided into a southern portion, that includes Aguiguan and a northern portion of active volcanos. Aguiguan alone of the southern islands shows no sign of past volcanic activity. It's an uplifted coralline limestone island showing rapid uplift causing step-like terraces. Bioclastic and constructional limestones predominate. Faults can be found and traced to a certain extent. The soils of

Aguiguan were surveyed and classified in 1985-1986 by a team from the U.S. Soil Conservation Service. Although fairly shallow, they have been relatively undisturbed for the past fifty years. Profiles are observed in the flat areas where the deepest soils exist. We had too little time to do much more than identify a few faults and wonder about the geologic history of the island. Some rocks and soil samples were collected for classroom use. Should the faults be mapped? Is there a correlation with the terraces on Tinian?

Naftan Island. Naftan Island is closely associated with Aguiguan. It stands about .9 km off the southern tip of Aguiguan with an altitude of just over 20 m. It has very little vegetation, which appears to be composed mostly of shrubs. Water depths between the two islands is less than 10 fathoms and a submerged ridge extends for another km at the same depth south of Naftan. Naftan is an important seabird colony (Engbring et al. 1986). The island was observed but not visited. The marine environment poses special problems for study. There are no beaches, no sheltered coves for boats, in short, no safe access to the sea.

Resources. The Japanese reportedly located deposits of phosphates on Aguiguan (Butler 1992). It is doubtful if the quantities of phosphate are presently of any value. It remains for future explorations to determine this, as we did not investigate the area from which deposits are known.

Water. Potable water is the single vital resource most in short supply on Aguiguan. As previously noted, there are concrete catchments constructed by the Japanese that still exist and contain a supply of water. However, the water isn't very appealing. Vegetation, insects, and occasionally birds, lizards, and other small animals can be found floating in water. An examination of the water with a hand lens showed a substantial population of microorganisms. We found no other source of fresh water, even in the caves.

Archeology. Even though the island has been surveyed for archeological sites (Butler 1992) we did find a few sites that were not found earlier. In addition, Butler (1992) stated that their team did not cover the entire island. It remains for future teams of young scientists to discover and catalog the history of past cultures on the island.

In summary, Aguiguan is a small coral island with limited economic potential. It has holds remnants of the natural fauna and flora of the Mariana Islands. It contains evidence of past cultures and their history on these islands. The geology of the island is not complex. The

THE AGUIGUAN EXPEDITION

single most important aspect of this island is its lack of potable water. Life on the island is adjusted to this boom and bust climatic situation. It is a very suitable laboratory for new scientists. What the future holds for the island of Aguiguan is uncertain. Rumors abound concerning a hunting preserve, gambling or vacation resort, or nature preserve, but no definitive plan yet exists. Whatever the future of Aguiguan, it remains an enigma and it deserves more study. So, why go to Aguiguan? Because it is there?

(Note: Although there are several variations to the spelling of Aguiguan, I have chosen the spelling use by the Municipality of Tinian to which Aguiguan is a part.)

ACKNOWLEDGEMENTS

My first afternoon was a learning situation. On an outing with several students to scout the old Japanese road to the boat landing, I learned how to use effectively a machete. My thanks to Rick Kaipat who hacked trails through lantana with few scratches while the right forearm of the "instructor" looked like it had barely survived some mystical initiation into manhood. Perhaps I had. Also, my appreciation to Robert Latham for sweating through the hours in the rugged terrain, being part goat, and finding some interesting trails in our search of the island. Thanks to Sid Cabrera for the precipitation data and to NMC for seeing the value of our field trip and providing much needed support.

APPENDIX 1

Meteorological Data - Precipitation (Rainfall) in inches													
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Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Total
Averages	3.37	2.72	3.04	1.87	3.69	4.11	9.06	19.5	12.8	10.3	8.94	4.51	83.9

METEOROLOGICAL DATA - PRECIPITATION (RAINFALL) IN INCHES
 DIVISION OF PLANT INDUSTRY & EXTENSION SERVICES
 DEPARTMENT OF NATURAL RESOURCES
 KAGMAN AGRICULTURE STATION

MONTH	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
JANUARY	2.12	2.28	1.90	1.90	1.10	3.57	9.59	2.17	0.65	8.40	1.59
FEBRUARY	1.92	2.38	1.59	1.59	7.40	2.03	1.90	2.14	3.66	2.54	4.53
MARCH	1.30	4.39	3.63	3.63	1.34	2.45	8.18	1.90	1.60	1.93	1.66
APRIL	1.92	1.11	1.90	1.90	1.57	4.23	1.28	1.85	2.03	.95	5.45
MAY	4.66	0.72	2.96	2.96	4.34	2.25	2.85	.87	1.96	13.37	N/A
JUNE	2.39	1.39	4.07	4.07	4.37	2.84	6.77	2.01	8.41	4.79	N/A
JULY	10.12	3.45	14.46	8.69	6.26	15.57	11.27	2.57	9.92	8.27	N/A
AUGUST	14.87	N/A	38.60	10.90	11.91	29.70	10.32	10.76	18.36	12.10	N/A
SEPTEMBER	17.33	19.29	13.60	12.28	27.27	6.82	6.70	6.94	13.55	3.83	N/A
OCTOBER	2.45	14.85	15.58	11.75	8.99	9.20	17.45	9.79	7.77	5.06	N/A
NOVEMBER	4.82	8.78	29.83	3.01	11.78	12.02	2.60	6.46	6.30	3.79	N/A
DECEMBER	2.05	1.29	3.93	4.95	7.00	7.06	5.74	4.03	1.60	7.45	N/A

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MEGAPODES ON AGUIGUAN: SMASHING THE GLASS HYPOTHESIS?

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Abstract. The discovery of two possible megapode nest mounds on Aguiguan in 1989 prompted a re-evaluation of the hypothesis that *M. l. laperouse* requires geothermal heat or solar heated cinder fields for reproduction. The closely related *M. l. senex* builds mounds of sand and grass or forest litter on the coral islands of Palau. Historical reports of mounds in the Marianas, recent records of juvenile megapodes on Aguiguan and Sarigan, and burrow descriptions from Pagan suggest that *M. l. laperouse* is able to reproduce using all incubation strategies reported for megapodes, but that success is low where heat from litter decomposition is used. The known distribution and reproductive ecology of the species indicate that it is relatively secure on uninhabited islands, but strict protection and active management is required to maintain populations on inhabited islands.

The Micronesian Megapode (*Megapodius laperouse*), perhaps the smallest megapode species (ca. 350 g), is endemic to the Mariana and Palau Islands in the western Pacific. *M. l. laperouse* of the Marianas is the most northerly distributed megapode. It is now largely restricted to the remote volcanic islands north of Saipan, except for a small population on Aguiguan and reestablished populations on Saipan and possibly Tinian.

Megapodes are gallinaceous birds found only in the Australian region where pheasants are absent. The family Megapodiidae includes six genera that use external heat sources to incubate eggs. Dekker (1990) identified four incubation strategies used by megapodes: mound building (heat source is microbial decomposition of vegetative matter), burrow nesting at geothermal sites, burrow nesting at sun-exposed beaches, and burrow nesting between the roots of trees (decomposition).

While investigating the nesting biology and distribution of megapodes in the Marianas, Glass (Glass and Aldan 1987) developed a hypothesis, though not explicitly stated, that *M. l. laperouse* had lost the ability to use the heat of decomposition to incubate its eggs and, therefore, was incapable of reproducing on coral islands. Glass investigated a large communal nesting ground on Guguan, where solar radiation on the dark cinder soil provided heat for incubation. In

addition, megapodes on Pagan formerly nested near hot springs, though this site has since been deeply buried by cinders (D. Aldan pers. comm.). Glass determined from interviewing residents that the rediscovered Saipan population (Pratt and Bruner 1978) had its origin in birds and eggs transported to Saipan from northern islands in the 1960s and 1970s. He was unable to find evidence of nesting on Saipan, despite a relatively intensive study. Moreover, his investigations of megapode distribution in the Marianas indicated that megapodes were much more abundant on recently active volcanic islands. This led him to conclude that the small populations on Saipan and Aguiguan, and rare reports from the coral islands of Rota and Tinian all were related to megapode transports from the northern islands. Hence, Glass believed that *M. l. laperouse* could not reproduce on coral islands.

Recent observations on Aguiguan prompted a re-evaluation of the "Glass hypothesis" and development of an alternative hypothesis based on recent observations and a re-analysis of historical information. I summarize here the significance of recent findings on Aguiguan as they relate to current knowledge of the breeding biology of *M. laperouse*. Moreover, I comment on the conservation of the species in the Marianas.

STUDY AREA AND METHODS

Aguiguan is described in Craig et al. (present volume). Pagan, Sarigan, and Guguan are volcanic islands north of Saipan of 48, 5, and 4.2 km², respectively. Observations were made on Aguiguan during field trips for feral goat control in 1989. Observations on the status of megapodes on Saipan, Sarigan, Guguan, Pagan, and other northern islands were made over the past several years. This information is on file at the Division of Fish and Wildlife (DFW), and summarized in Glass and Aldan (1987) and Stinson (1993).

RESULTS AND DISCUSSION

I discovered what I believed to be a megapode nest mound during a trip to Aguiguan in May, 1989. The possible nest mound was approximately 2 m in diameter, 0.2 m high, and located at the base of a large fallen tree. The log was hollowed out and much of the rotten wood from inside seemed to be mixed into the soil of the mound. The mound had several depressions in its surface, presumably where birds had been digging. I did not investigate the mound further because I was uncertain that it was a nest, and I was unaware that there were no definite records of nest mounds from Aguiguan. Though small, this mound fit the description of mounds constructed by *M. l. senex* in Palau (J. Engbring, corresp. in DFW files).

On Aguiguan, a similar mound was reported in 1989, and a juvenile bird was seen (C. Rice pers. comm.). Moreover, Owen reported finding a nest mound on Aguiguan in 1955 (Glass and Aldan 1987). The observation of juvenile birds in 1983, 1985, and 1989 (DFW trip reports) suggest that megapodes are at least occasionally reproducing successfully on Aguiguan.

Aguiguan is the only southern island where megapodes have been found consistently in this century. There are also, however, enigmatic records of an adult on Tinian (Wiles et al. 1987) and immature megapodes from Saipan (Glass and Villagomez 1986) and Rota (Schmitt 1985). Such records may be related to continued transport of eggs from the northern islands or to misidentifications.

In historic times, megapodes were found on the larger coral islands of Guam, Rota, Tinian, and Saipan, but were common only on Saipan. With the exception of Saipan, they became extinct on these islands in the 19th century. They persisted on Saipan

into the 1930's, though they were hunted and trapped incessantly (Baker 1951). Moreover, much of the forest habitat of megapodes on Saipan, Tinian, and Aguiguan was lost to extensive clearing for sugar cane cultivation during the Japanese mandate (1914–1944).

Taka-Tsukasa (1932) described the nest mound in the Marianas (island not stated) as a large mound of sand and grass (ca. 10 m in diameter) a few meters in height. No large mounds have been reported from Saipan in recent years, but Taka-Tsukasa's description is similar to mounds seen on coral islands of Palau (Wiles and Conry 1990). Perhaps development and domestic animals now prevent megapodes from establishing nest mounds near Saipan beaches.

In June 1992, a megapode on Pagan was observed digging a burrow among the roots of a coconut palm (*Cocos nucifera*) (C. Rice pers. comm.), suggesting that decompositional heat was used for incubation. This is the first report of such an incubation strategy for *M. laperouse*. Furthermore, Sarigan (ca. 5 km²) supports a megapode population of about 200–300, yet does not appear to have geothermal or black cinder fields for nesting (Stinson 1993). Megapodes on this island may use inconspicuous mounds or tree root burrows for nesting. Finally, Ludwig (1979) reported that megapodes on Agrihan scraped volcanic soil together into a mound 3–4 m in diameter and 2/3 m in height. Egg burrows were then dug into this mound. The heat source for this mound was unknown, but the closed canopy of coconut palms seemed to prevent the sun from supplying the needed heat.

The apparent at least occasionally successful reproduction of megapodes on Sarigan, Aguiguan, and (historically and perhaps recently) Saipan, along with reports of mounds on Aguiguan, suggests that *M. l. laperouse* is indeed able to reproduce using the heat of decomposition. Use of decompositional heat is also supported by the observation of a tree root burrow on Pagan, accounts of mounds in the Marianas (Taka-Tsukasa 1932), and the use of mounds on coral islands by *M. l. senex* in Palau. I therefore hypothesize that *M. laperouse* uses all the reported incubation strategies: mounds (*M. l. senex* in Palau; *M. l. laperouse*, Taka-Tsukasa 1932, this paper), burrows at geothermal sites (on Pagan; D. Aldan, pers. comm.), burrows at sun-exposed beaches (Guguan—in this case dark cinder field; Glass and Aldan 1987), and burrows between tree roots (Pagan; C. Rice, pers. comm.; also perhaps on Aguiguan, Sarigan). Other *Megapodius* species (*M. cumingii*, *M. eremita*) are known to use

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more than one incubation strategy (Dekker 1990). Whether individual birds or island populations are behaviorally capable of all the strategies is unknown. *M. laperouse* may be capable of reproducing using all three external heat sources (solar, geothermal, and microbial) because it has remained plastic in behavior, and will attempt to reproduce opportunistically wherever warm, friable soil is found. On coral islands, this may include the use of rotting wood from a large tree-fall.

Conservation. The rarity of immature megapode sightings on coral islands and on volcanic islands without dark cinder fields or geothermal sites suggest that reproductive success on such islands is low. On such islands, incubation temperatures may remain sufficiently high only rarely. *M. laperouse* may, therefore, be rare or extinct on inhabited islands because it can not sustain added mortality resulting from domestic animals and hunting. The southern island populations of megapodes could become doomed by low recruitment, poaching, introduced predators (e.g. snakes, as occurred on Guam; Fritts 1988, Savidge 1987), and loss of habitat to development. However, suitable nesting grounds might be created using cinder soil brought to the southern coral islands (Glass pers.comm). When more is understood about the basic nesting biology of the species, and if the snake threat is reduced, then research should determine if developing an artificial nesting ground might be feasible.

Most of the uninhabited Mariana islands are rather remote and do not have safe anchorage, providing relatively secure refuges for wildlife. Guguan, Asuncion, Maug, and Farallon de Pajaros are designated Wildlife Sanctuaries in the Constitution of the Commonwealth. The future of the Micronesian Megapode on islands that remain uninhabited is relatively secure, but protection of habitat, predator control, and strict law enforcement will be essential on inhabited islands.

Proceedings: Marianas Research Symposium 1: 39

GOAT ERADICATION ON AGUIGUAN

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Abstract. Feral goats (*Capra hircus*) have extensively damaged forest vegetation on several Mariana Islands, including Aguiguan. Preliminary surveys on Aguiguan (7.2 km²) estimated a population of 100–300 goats. Goats were removed from Aguiguan in 1989 by capture and shooting. Initially, 22 hunters captured goats over three days by driving them into a net corral. Eight of 31 goats captured were fitted with radio collars and released to assist with hunting efforts. The remainder were removed. Subsequently, eight different hunters shot 158 goats during six hunts of about six days each, totalling 86 man-days. An estimated 40 goats (20% of the population) remained. Hunters had been instructed to shoot selectively for adult females before subadults, and adult males being lowest priority. Comparison of numbers shot with numbers sighted showed selection was not statistically significant. Analysis of covariance indicated that individual hunters had a significant effect on the number of goats shot/day. Hunting assisted by radio telemetry was not significantly different from unaided hunting for this phase of eradication. Previous efforts in New Zealand suggested that if the population is reduced by 80%, a total effort of 215 man-days would be needed to eradicate the Aguiguan goats. Data on change in vegetation was obtained using three point intercept transects in forest and open field sampled in 1989 and 1992. The forest transect showed marginal increases in shoots and seedlings of *Cynometra ramiflora* and *Ochrosia marianensis*. The percent of 0.33 x 0.33 panels obscured by vegetation increased by 24% at level 1 (0–0.33 m above ground) and 13% at all levels (0–2 m). Transects in open field showed a decrease in the common weeds *Tridax procumbens*, and *Mikania scadens*, but an increase in *Lantana camara* and grasses. Several grass species had colonized the site since 1989.

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Proceedings: Marianas Research Symposium 1: 40-41

STATUS OF FRUIT FLY POPULATIONS ON AGUIGUAN

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Abstract. Populations of two fruit flies, *Dacus cucurbitae* and *Dacus ochrosiae*, were sampled in March, 1992 and May, 1992 on Aguiguan, an uninhabited island in the Mariana Island chain. Cue-lure baited Steiner traps were used to capture flies. Although moderate numbers of *D. cucurbitae* were trapped in March, none were caught in May. This reduction was probably due to low numbers of wild bittermelon (*Momordica charantia*) fruit, which resulted from dry weather and their consumption by vertebrates. No infested fruits were found. The significance of these results is discussed with respect to the proposed eradication program for melon flies in the Marianas.

Presence of the melon fruit fly (*Dacus cucurbitae*) in the Mariana Islands has resulted in quarantine regulations which ban the shipment of fresh fruits and vegetables to potentially lucrative export markets. An eradication program is being planned to eliminate this impediment to the development of agriculture by releasing massive numbers of sterilized melon flies. Wild, fertile flies which mate with these sterile flies produce no offspring. If sufficient numbers of sterile flies are released for several generations, local populations will be eradicated. The sterile insect technique (SIT) is environmentally acceptable as only the target species is directly affected. A necessary step in planning an SIT program is to determine population levels and spacial distribution. The melon fly population on Aguiguan was studied by catching adult flies in specially designed traps and by examining host fruits for larvae. A closely related fruit fly, *D. ochrosiae*, was also caught. The ochrosia fly is endemic to the Marianas Islands and is not considered a pest species.

STUDY AREAS AND METHODS

Melon fly populations are routinely monitored by catching sexually mature adult males in traps baited with a non toxic olfactory attractant called cue-lure. Cue-lure also attracts males of several other related species including *D. ochrosiae*. Aguiguan island populations were monitored using traps designed by Stei-

ner. These traps consist of a plastic cylinder with baffled entrances at either end. Attractant was applied to a short length of dental wick suspended from a wire at the center of the trap. A small amount of fast acting insecticide (Naled) was also applied to the wick to prevent flies from leaving the trap. Traps were hung from foliage at about 2 m above the ground.

Steiner traps were placed on Aguiguan during two periods in 1992. C. Rice (Fish & Wildlife Division, CNMI Department of Natural Resources) operated five traps from 1-4 March. I operated five traps during the Aguiguan expedition from 20-25 May. During both sample periods traps were placed along a north-south transect across the central plateau in the vicinity of the Japanese town site.

From 22-24 May, all bittermelon (*Momordica charantia*) fruits, a host plant of the melon fly, were collected from within 2 m of each side of a path which lead across a field on the central plateau just north of the Japanese town site. This transect was 223 m in length.

RESULTS

During the first sample period, all traps caught at least one melon fly and many ochrosia flies. In contrast, no melon flies were caught during the second sample period and a reduced number of ochrosia flies were trapped (Table 1).

TABLE 1. Steiner trap catch on Aguiguan.

Sample period	Flies/ trap day	
	<i>D. cucurbitae</i>	<i>D. ochrosiae</i>
1-4 March	1.7	52.4
20-25 May	0.0	4.9

Bittermelon accounted for about 25% of the ground cover in this area, but there was very little fruit production. The 33 fruits collected had a total mass of only 5.0 g. Twenty-seven (82%) of these showed signs of vertebrate feeding damage. None of the fruits contained melon fly larvae.

DISCUSSION

The results of the trapping on Aguiguan are of significance to the proposed melon fly eradication program. The reduction of the melon fly catch from 1.7 to 0.0 flies/trap-day in less than three months between the two sample periods indicates that fly-free status for an island cannot be concluded from short term trapping. There is also some indication that trapping near the end of the rainy season (typically July through October) may be the best time of year for detecting melon flies due to the abundance of wild bittermelon fruits at this time.

In order to prepare adequate plans for eradicating the melon fly from the Mariana Island chain it is necessary to determine which islands are infested. Melon flies have never been detected on the islands north of Saipan. However, data is scant as travel to the Northern Islands is expensive and difficult. During May and June 1992 Shinya Miyano set up Steiner traps on Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Uracas. No melon flies were caught, but ochrosia flies were trapped on all islands except the three most northern ones: Asuncion, Maug, and Uracas.

The present study clearly shows that further sampling is required before it is concluded that the Northern Islands are not infested with melon fly.

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Proceedings: Marianas Research Symposium 1: 42-46

THE STRUCTURE AND TREE SPECIES COMPOSITION OF AGUIGUAN FORESTS

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Abstract. Native limestone forest on Aguiguan was studied to characterize its species composition, relative species importance, basal area, and density. Based on point-quarter samples on the east ($N = 200$ trees) and west slope ($N = 100$ trees) of the island, we found that, respectively, canopy basal areas were 262.0 and 427.6 m²/ha, and understory basal areas were 106.7 and 10.2 m²/ha. Tree densities in the canopy were 756.4 (E) and 323.6 (W) trees/ha, and those in the understory were 857.9 (E) and 1033.8 (W) trees/ha. *Pisonia grandis*, *Cynometra ramiflora*, *Guamia mariannae*, and *Drypetes dolichocarpa* were among the most dominant canopy trees, whereas *C. ramiflora* and *G. mariannae* greatly predominated in the understory. These forests were generally like similarly studied limestone forests on Saipan in species composition, except that on Aguiguan *D. dolichocarpa* was comparatively abundant. Moreover, the mature forests studied on western Aguiguan were similar in basal area but had lower tree density than mature Saipan forests. The apparently younger forests of eastern Aguiguan had lower canopy basal area, higher understory basal area, and lower understory density than on Saipan. Lower tree density on Aguiguan compared to Saipan is likely related to decades of browsing on Aguiguan forests by feral goats.

Most botanical studies of the Mariana Islands have concerned plant systematics and floristics (e.g. Stone 1970), although Fosberg (1960) also gave descriptions of the principal plant associations of Micronesia. One of these associations, limestone forest, presumably once covered most upland limestone areas in the southern Marianas. Past agricultural uses and wartime activities converted substantial portions of limestone forest from level areas. Today, such native forest is now largely restricted to steep limestone escarpments too difficult to clear.

Recently, Craig (1992b) studied a mature remnant forest on Saipan, and provided quantitative data on its species composition, relative species importance, basal area, and tree density. We report here on similar data gathered for limestone forest on Aguiguan. Because Aguiguan forests have been browsed for decades by a dense population of feral goats (*Capra hircus*) (Rice and Stinson present volume), we expected that our data would reflect this influence. Comparison of

Aguiguan and Saipan data should provide insights into the extent of goat-related forest damage on Aguiguan.

STUDY AREAS AND METHODS

To obtain data on the structure and species composition of Aguiguan forests, Chandran established five transects in forests along the eastern slope, and Craig established 2.5 transects along the western slope of the island. On each full transect, we placed 10 sample points paced about 12 m apart (108 m total), which was sufficient to make each point independent (i.e. no overlap in trees between points).

The plotless point-quarter sampling technique (Cottam and Curtis 1956) was used to measure four canopy and four understory trees/point. Canopy trees were defined as those first intercepting sunlight, and understory trees were those growing below the canopy but taller than 2 m. For each tree, we measured the distance from the sample point to the center of the tree

TABLE 1. Occurrence of canopy trees on Aguiguan, based on the following sample sizes: east:200 trees, west: 100 trees.

Species	Basal area (m ² /ha)		Trees/ha		Importance value	
	East	West	East	West	East	West
<i>Pisonia grandis</i>	94.58	11832.7	71.9	58.2	57.6	67.2
<i>Cynometra ramiflora</i>	54.54	1033.0	162.6	87.4	58.9	49.4
<i>Guamia mariannae</i>	22.69	27.2	162.6	19.4	49.7	10.7
<i>Drypetes dolichocarpa</i>	18.14	176.0	83.2	29.1	30.7	21.7
<i>Erythrina variegata</i>	2.95	1300.1	15.1	68.0	4.6	37.9
<i>Premna obtusifolia</i>	12.54	0	60.5	0	21.8	0
<i>Ochrosia mariannensis</i>	2.74	13.3	41.6	3.2	13.3	2.6
<i>Psychotria mariana</i>	12.58	13.9	41.6	6.5	17.1	5.1
<i>Ficus</i> spp.	23.40	27995.8	7.6	16.2	11.4	78.2
<i>Hernandia</i> spp.	6.33	0	53.0	0	13.2	0
<i>Eugenia</i> spp.	8.52	0	30.3	0	13.3	0
<i>Pouteria obovata</i>	0	233.1	0	12.9	0	9.2
<i>Aglaiia mariannensis</i>	0.03	3.0	3.8	3.2	1.3	2.5
<i>Morinda citrifolia</i>	0	9.8	0	6.5	0	5.1
<i>Artocarpus altilis</i>	0	78.0	0	2.7	0	3.2
<i>Acacia confusa</i>	2.58	0	11.3	0	3.2	0
<i>Pithecellobium dulce</i>	0.20	0	3.8	0	1.3	0
<i>Carica papaya</i>	0	8.1	0	3.2	0	2.6
<i>Neisosperma oppositifolia</i>	0	5.4	0	3.2	0	2.6
<i>Terminalia catappa</i>	0	31.7	0	3.2	0	2.6
<i>Cerbera dilatata</i>	0.03	0	3.8	0	1.3	0
<i>Polyscias grandiflora</i>	0.33	0	3.8	0	1.4	0

and the diameter at breast height (dbh). For the variety of tree growth forms encountered in the limestone forest, dbh proved the most equitable measure of diameter.

Point-quarter analysis yields data on the horizontal area covered by tree stems (basal area), no. stems/unit area (density), and dispersion of trees in the forest (frequency). From these three measures, we computed a relative importance index for each species known as the importance value (reviewed by Mueller-Dombois and Ellenberg 1974). Tree density, basal area, and frequency were also examined separately, with the former two measures serving as absolute indices of overall tree occurrence.

RESULTS AND DISCUSSION

We found that, respectively, canopy basal areas of the east ($n = 200$ trees) and west slope ($n = 100$ trees) of the island were 262.0 and 427.6 m²/ha, and understory basal areas were 106.7 and 10.2 m²/ha. Tree densities in the canopy were 756.4 (E) and 323.6 (W) trees/ha, and those in the understory were 857.9 (E) and 1033.8 (W) trees/ha. Hence, on the west slope canopy trees were large (mean = 1.32 vs. 0.35 m²/ha) and widely spaced (indicative of comparatively mature forest), and understory trees were small (mean = 0.01 vs. 0.12 m²/ha) and densely spaced compared to the east slope. As is typical for forests, all our data showed that canopy trees dominated in basal area, but

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TABLE 2. Occurrence of understory tree on Aguiguan, based on the following sample sizes: east- 200 trees, west- 100 trees.

Species	Basal area (m ² /ha)		Trees/ha		Importance value	
	East	West	East	West	East	West
<i>Pisonia grandis</i>	0.68	0	8.6	0	3.3	0
<i>Cynometra ramiflora</i>	34.30	524.6	283.1	434.2	92.9	123.9
<i>Guamia mariannae</i>	52.34	254.9	381.8	392.9	128.8	98.0
<i>Drypetes dolichocarpa</i>	6.76	0	42.9	0	19.7	0
<i>Erythrina variegata</i>	0.14	42.0	4.3	20.7	1.5	8.5
<i>Premna obtusifolia</i>	3.04	27.3	17.2	20.7	8.2	7.0
<i>Ochrosia mariannensis</i>	0.18	0	12.9	0	3.4	0
<i>Psychotria mariana</i>	3.42	23.5	17.2	20.7	8.6	9.0
<i>Maytenus thompsonii</i>	0.17	6.0	34.3	10.3	10.9	3.9
<i>Ficus</i> spp.	0.18	32.7	4.3	10.3	1.5	6.5
<i>Eugenia</i> spp.	4.26	0	21.4	0	10.7	0
<i>Aglaia mariannensis</i>	0.13	73.1	8.6	82.7	2.8	29.2
<i>Acacia confusa</i>	0.32	0	4.3	0	1.6	0
<i>Pandanus tectorius</i>	0	7.9	0	10.3	0	4.1
<i>Cerbera dilatata</i>	0.34	0	4.3	0	1.7	0
<i>Polyscias grandiflora</i>	0.45	0	8.6	0	3.1	0
<i>Lantana camara</i>	0.003	0	4.3	0	1.3	0

understory trees had the greatest density.

Pisonia grandis, *Cynometra ramiflora*, and *Ficus* spp. consistently predominated in canopy basal area on the east and west slopes (Table 1). Moreover, *Guamia mariannae* and *Drypetes dolichocarpa* also predominated in the east, and *Erythrina variegata* had high basal area in the west. In the understory (Table 2), *C. ramiflora* and *G. mariannae* dominated, although *D. dolichocarpa*, *Premna obtusifolia*, *Psychotria mariana*, and *Eugenia* spp. had high basal areas in the east.

Canopy tree densities (Table 1) exhibited a pattern similar to that for basal areas. *P. grandis* and *C. ramiflora* occurred densely throughout, *G. mariannae* and *D. dolichocarpa* were common in the east, and *E. variegata* was common in the west. In the understory, *C. ramiflora* and *G. mariannae* were by far the most densely occurring species (Table 2).

The relative measure of forest prevalence, the importance value, showed that *P. grandis* and *C. ramiflora* were the principal canopy species, although in

the east *G. mariannae* joined these as a principal species (Table 1). *C. ramiflora* and *G. mariannae* were the major understory species (Table 2).

A total of 15 canopy and 10 understory tree species were recorded from the western slope transects. On the eastern side, 16 canopy and 15 understory species were recorded (Fig. 1). Of these, *Lantana camara* is an introduced, weedy shrub, and *Pithecellobium dulce* and *Carica papaya* are introduced trees. On Aguiguan, *L. camara* is abundant on the plateau and level areas on the lower terraces. *P. dulce* and *C. papaya* are relatively uncommon.

In addition to trees located during sampling, the following native tree species were reported in field notes by R. Craig: *Dendrocnide latifolia* (several canopy trees) *Casuarina equisetifolia* (common on the plateau), *Excoecaria agallocha* v. *orthostichalis* (common in coastal forest), *Barringtonia asiatica* (uncommon), *Hibiscus tiliaceus* (present in scattered pure thickets), *Guettarda speciosa* (fairly common near the coast), *Callicarpa candicans* (seedlings at the

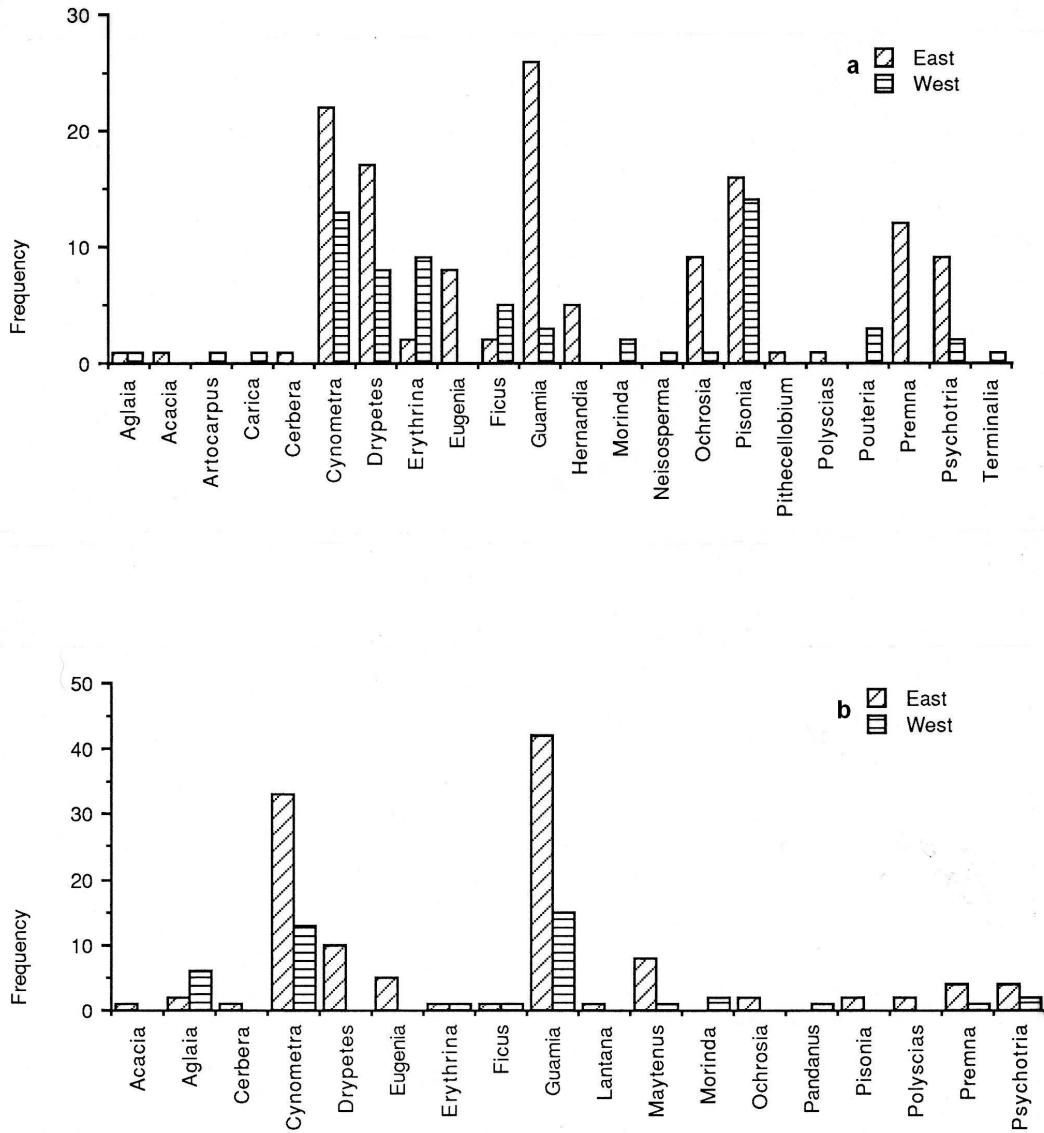


FIG. 1. Frequency of occurrence of (a) canopy and (b) understory trees on Aguiguan.

forest edge), *Cordia subcordata* (one tree), *Intsia bijuga* (largely logged off, but still common in north-western slope forests), *Melanolepis multiglandulosa* (mostly seedlings and saplings at the forest edge), *Thespesia populnea* (common near the coast), *Ficus prolixa* (fairly common), *F. tinctoria* (several), *Eugenia palumbis* (uncommon), and *Hernandia sonora* (uncommon). Furthermore, R. Chandran reported *Hernandia labyrinthica*, *Eugenia reinwardtiana*, *Pisonia umbellifera*, and *Streblus pendulinus* from east slope forests.

Comparison of limestone forests on Aguiguan with those studied on Saipan (Craig 1992b) indicated general similarity in structure and species composition between the islands. The forests were generally alike in species proportions, except that on Aguiguan *D. dolichocarpa* was comparatively abundant. Moreover, the mature forests studied on western Aguiguan were similar in basal area but had lower tree density than mature Saipan forests. The apparently younger forests of eastern (windward) Aguiguan had lower canopy basal area, higher understory basal area, and lower

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understory density than those on Saipan. Features such as these may indicate greater typhoon damage to windward slope forests. Lower tree density on Agui-guan compared to Saipan is likely related to decades of browsing on Agui-guan forests by feral goats (*Capra hircus*).



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AGUIGUAN SYMPOSIUM

January 15, 1993
Northern Marianas College

12:15 The Comparative Morphology of Small Passerines on Aguiguan and Saipan. Dr. Robert Craig and Mr. Aaron Ellis, NMC

12:30 Closing

SCHEDULE:

08:00 Welcome

08:30 Welcoming address: President Agnes McPhetres, NMC

09:00 Keynote address: Aguiguan, the World, and History. Dr. Dirk Ballendorf, University of Guam

09:30 Paper session I

09:30 Aguiguan: a Field Trip. Mr. Larry Klawunder, NMC

09:45 The Geology of Aguiguan. Mr. Larry Klawunder, NMC

10:00 Wildlife Species Recorded During the Aguiguan Expedition. Mr. Ravi Chandran, NMC

10:15 Tree Species Composition of Aguiguan Forests. Mr. Ravi Chandran and Ms. Zara Keys, NMC

10:30 Bird Populations of Aguiguan: a Ten Year Update. Dr. Robert Craig, NMC

10:45 Foraging Differences Between Small Passerines on Aguiguan and Saipan. Dr. Robert Craig, NMC

11:00 Artistic/Interpretive Exhibit and Reception. Mr. Jimmie Ellis and Ms. Barbara Lussier, NMC

11:30 Paper Session II

11:30 Aguiguan Entomology. Dr. Aubrey Moore, CNMI Cooperative Extension Service

11:45 Goat Eradication on Aguiguan. Dr. Clifford Rice, CNMI Division of Fish and Wildlife.

12:00 Megapode Populations on Aguiguan. Mr. Derek Stinson, CNMI Division of Fish and Wildlife.