HOWE, F. P. AND L. D. FLAKE. 1988. Mourning Dove movements during the reproductive season in southeastern Idaho. J. Wildl. Manage. 52:477–480.

KLETT, A. T., H. F. DUEBBERT, C. A. FAANES, AND K. F. HIGGINS. 1986. Techniques for studying nest success of ducks in upland habitats in the prairie pothole region. U.S. Dep. Inter., Fish and Wildl. Serv., Resour. Publ. 158.

MAYFIELD, H. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456–466.

MCBRIDE, R., N. R. FRENCH, A. H. DAHL, AND J. E. DETMER. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. U.S. Dep. Energy Tech. Rep. IDO-12084. Nat. Tech. Inf. Ser., Springfield, Virginia.

MCCLURE, H. E. 1950. An eleven-year summary of Mourning Dove observations in the west. Trans. North Am. Wildl. Conf. 15:335–346.

MILLER, H. W. AND D. H. JOHNSON. 1978. Interpreting the results of nesting studies. J. Wildl. Manage. 42:471–476.

MULLER, L. I., T. T. BUERGER, AND R. E. MIRARCHI. 1984. Guide for age determination of Mourning Dove embryos. Alabama Agric. Exp. Stn. Circ. 272.

NUDDS, T. D. 1977. Quantifying vegetative structure of wildlife cover. Wildl. Soc. Bull. 5:113–117.

REYNOLDS, T. D. AND C. H. TROST. 1981. Grazing, crested wheat, and bird populations in southeastern Idaho. Northwest Sci. 55:225–234.

STODDART, L. A., A. D. SMITH, AND T. W. BOX. 1975. Range management. 3rd ed. McGraw-Hill Book Co. New York, New York.

SWANK, W. G. 1952. Trapping and marking of adult nesting doves. J. Wildl. Manage. 16: 87–90.

———. 1955. Feather molt as an aging technique for Mourning Doves. J. Wildl. Manage. 19:412–414.

WESTMORELAND, D. AND L. B. BEST. 1985. The effect of disturbance on Mourning Dove nesting success. Auk 102:774–780.

FRANK P. HOWE AND LESTER D. FLAKE, *Dept. Wildlife and Fisheries Sciences, South Dakota State Univ., Brookings, South Dakota, 57007.* *Received 27 June 1988, accepted 22 Nov. 1988.*

Wilson Bull., 101(3), 1989, pp. 472–477

Nest sites of the Micronesian Kingfisher on Guam.—The Guam subspecies of the Micronesian Kingfisher (*Halcyon cinnamomina cinnamomina*) is one of the casualties of the recent extinction of Guam's avifauna. Predation by the introduced brown tree snake (*Boiga irregularis*) is thought to be the prime factor (Savidge 1986, 1987). The Micronesian Kingfisher was formerly widespread and common throughout the forested regions of Guam (Marshall 1949, Baker 1951) and was one of the last bird species, along with the Mariana Crow (*Corvus kubaryi*) and Guam Rail (*Rallus owstoni*), to decline to critical population levels (Savidge 1987).

The present study, conducted from March to July 1985, was part of a joint effort by the Guam Division of Aquatic and Wildlife Resources, Wildlife Conservation International, and the American Association of Zoological Parks and Aquariums. I censused the remaining kingfishers and studied nest sites in order to assess habitat requirements for conservation and captive breeding.

TABLE 1

RELATIVE FREQUENCY AND RELATIVE DOMINANCE OF TREE SPECIES FOUND AT 16 MICRONESIAN KINGFISHER NEST SITES ON GUAM[a]

Tree species	Relative frequency[b]	Relative dominance[b]
Premna obtusifolia	21.3 ± 13.8	18.0 ± 13.6
Pandanus fragrans	15.9 ± 12.2	11.6 ± 7.9
Cycas circinalis	15.7 ± 15.3	16.8 ± 16.3
Aglaia mariannensis	11.6 ± 10.2	6.0 ± 5.7
Neisosperma sp.	10.0 ± 6.2	11.8 ± 9.2
Tristiropsis acutangula	9.2 ± 14.5	16.0 ± 16.7
Guamia mariannae	5.7 ± 5.4	3.2 ± 3.6
Hibiscus tiliaceus	3.6 ± 8.4	1.3 ± 2.1

[a] Only tree species with 1.0% relative frequency or more are included in the table.
[b] Mean ± SD per 0.04 ha plot.

Study area and methods.—Guam is the southernmost of the Marianas Island group in the western Pacific. The study area lay within Andersen Air Force Base on the elevated limestone plateau at the northern end of the island. The Conventional Weapons Storage Area and Northwest Field (hereafter referred to as CWSA and NWF) are two adjoining areas comprising approximately 1860 ha at the northwest corner of the Air Base. The area is covered with second-growth typhoon forest (Fosberg 1960, Stone 1970). The CWSA is characterized by a network of intersecting service roads and regularly spaced mowed areas for munitions storage which very effectively break the forest up into a series of islands. Human disturbance is frequent in the maintained areas but rare in the forest. There is extensive disruption of the forest floor by foraging feral pigs (*Sus scrofa*) which are common in the area. NWF was not heavily used by the Air Force at the time of the study. The forest there is broken into larger islands, being divided by unused runways, stands of *Casuarina equisetifolia,* and early succession areas. The kingfishers were censused by playback of tapes of territorial Guam Micronesian Kingfisher calls. An area-wide census was first conducted on perimeter roads and internal transect roads. More intensive efforts subsequently were made in areas in which kingfishers were heard or sighted. Due to the variability of the response and movement of the birds, censusing was repeated regularly throughout the entire area. Pairs were considered to be on a territory if observed engaging in excavation behavior or entering a nest cavity. The kingfisher is the only nest hole excavator on Guam, therefore all nest cavities were assumed to be Micronesian Kingfisher nest sites. Incomplete nest excavations (those which did not terminate in a nest chamber) were also assumed to be the work of kingfishers. No Guam bird species are recorded as making foraging excavations in dead trees, and in the course of this study, no kingfishers were observed foraging in dead trees. However, during bouts of excavation, pairs were observed to work on as many as five excavation sites on a given tree. Only at a later stage of excavation did the pairs focus on one hole. Macrohabitat variables were recorded for 16 nest sites, as outlined by James and Shugart for 0.1-acre circles (1970). These 0.04-ha circles were centered on the nest tree. Only live nest trees were included in the tree count. Canopy height was determined with a forester's sextant. Four characteristics of nest cavities were measured: entrance width (one horizontal measurement across the circular entrance mouth), entrance depth (entrance mouth to nest chamber entrance), cavity depth (entrance mouth to back of nest chamber), and height from ground. In the case of multiple excavations, height from ground was measured

TABLE 2

RELATIVE FREQUENCY OF SHRUB SPECIES FOUND AT 16 MICRONESIAN KINGFISHER NEST SITES ON GUAM[a]

Species	Frequency[b]
Guamia mariannae	32.9 ± 16.5
Aglaia mariannensis	20.7 ± 13.7
Triphasia trifolia	10.3 ± 14.0
Neisosperma sp.	5.9 ± 6.7
Piper guahamense	4.0 ± 7.7
Cycas circinalis	3.6 ± 4.4
Maytenus thompsonii	3.4 ± 4.7
Mammea odorata	3.3 ± 9.4
Morinda citrifolia	2.1 ± 2.7
Eugenia sp.	2.0 ± 6.0
Pandanus fragrans	1.9 ± 3.9
Melanolepsis multiglandulosa	1.6 ± 4.0
Premna obtusifolia	1.5 ± 2.6

[a] Only shrubs and small trees with a diameter breast height <7.5 cm, and with 1.0% relative frequency or more are included in the table.

[b] Mean ± SD per 0.04-ha plot.

for the highest and lowest excavations only. An assessment of density of the nest-cavity substratum was made by taking the mean of 10 manual penetrations with a 12.5-cm long ice pick into the nest tree in the vicinity of the existing excavations. To standardize as much as possible the same posture was used throughout, and the ice pick was pushed only as far as it would go in a single thrust. Sites for testing penetrability were chosen by randomly stabbing the substrata. This was also done with live trees for comparison with dead trees. Arboreal termitaria were not included in the statistical analysis of penetrability. Two of the active nest sites were snake-proofed by pruning back the surrounding canopy vegetation and installing a 1.2-m wide sheet-metal collar approximately 2 m from the ground.

Results.—A total of eight pairs and 10 solitary male Micronesian Kingfishers were found on the northern half of the CWSA. Only two pairs were on NWF. Solitary males were most variable in their site tenacity, sometimes being found in the vicinity of nest sites and sometimes in other areas. However, as none of the birds were marked, the extent of local migration is unknown. Three pairs were observed with eggs, but only one succeeded in rearing young (at one of the two snake-proofed nest sites). The nest-site vegetation species in the CWSA and NWF areas of AAFB are those typical of the typhoon forest found on the limestone plateau of northern Guam (Fosberg 1960, Stone 1970) (Tables 1 and 2). Despite the pattern of past deforestation, the vegetation species are mainly native. This history of past deforestation and the current maintenance of open areas (particularly in the CWSA) has rendered a major portion of the study area fragmented second growth vegetation. The nest-site macrohabitat characters were variable, but indicate that the Micronesian Kingfisher is a forest-nesting species with nest sites characterized by a high degree of canopy cover and vegetation density (Table 3). Nest excavations were always located in decaying standing wood, arboreal termitaria (the nests of *Nasutitermes* sp. termites), or arboreal fern root masses. No termitaria or decaying standing trees in the study area were ever encountered that lacked some evidence of kingfisher nesting activity. The mean penetrability of nest trees

TABLE 3
MACROHABITAT VARIABLES FOR 16 MICRONESIAN KINGFISHER NEST SITES ON GUAM

Variable	Mean ± SD[2]
Trees (7.5–15.0 cm DBH[1])	19.6 ± 7.7
Trees (15.0–22.5 cm DBH)	9.3 ± 5.5
Trees (22.5–37.5 cm DBH)	2.0 ± 1.0
Trees (>37.5 cm DBH)	1.0 ± 1.0
Total tree frequency	32.9 ± 10.9
Total basal area cm^2	3378.8 ± 1378.3
Shrubs	195.0 ± 66.9
% Ground cover	43.0 ± 24.9
% Canopy cover	83.5 ± 14.1
Canopy height (m)	9.5 ± 2.5

[1] DBH = diameter breast height.
[2] On each 0.04-ha plot.

($\bar{x}$ = 7.4 ± 1.8 cm [SD], N = 5) was significantly greater than that of live trees ($\bar{x}$ = 1.0 ± 0.41 cm, N = 4; df = 7, t = 6.84, P = 0.0002). In five termitaria tested, the ice pick always entered the full 12.5 cm. Nest cavity dimensions did not differ significantly between tree (N = 13) and termitaria (N = 6) nests for the dimensions of entrance width (t = 0.10, df = 17, P = 0.92) or entrance depth (t = −0.12, df = 17, P = 0.90). The difference was slightly significant for cavity depth (t = −2.18, df = 17, P = 0.04). Nest trees always had multiple excavations, the majority of which (80.1% of all examined) were incomplete. Termitaria had far fewer excavations than trees (Table 4). Nest trees fell well into the largest tree size class (see Table 3), with a mean diameter breast height of 42.7 ± 12.7 cm. During the present study, tree cavity nests were found in *Tristiropsis acutangula, Pisonia grandis,* and *Artocarpus* sp.

Discussion.—The decline of the Micronesian Kingfisher follows a general pattern of extinction seen in other Pacific island birds (Greenway 1967). The Guam extinction differed from others in that an introduced reptile, the brown tree snake, was the final agent of extinction. The kingfisher is a cavity nester and this behavior is known to confer some protection from nest predators. However, it is also known to incur a cost in that the availability of suitable nest sites may limit the number of suitable breeding territories (von Haartman 1957, Collias and Collias 1984). Due to the protection it offers the eggs and young, cavity nesting may in part account for the Micronesian Kingfisher's outlasting open-nest native bird species of similar size and smaller. The remaining population was found in disturbed habitat and, while apparently tolerant of human interference, the kingfisher has specific nest-site requirements. Known nest tree species are *Pisonia grandis,* coconut palms (*Cocos nucifera*), banyan trees (*Ficus* sp.), and breadfruit trees (*Artocarpus* sp.) (Baker 1951, Jenkins 1983, R. Beck, Jr. and G. Wiles pers. comm.). In addition, *Tristiropsis acutangula* was found being used as a nest tree during the present study. The repeated use of nest sites, as evidenced by multiple excavations, indicates their importance. The kingfishers require a soft substratum for nest cavity excavation. It is unlikely that suitable trees remain standing for long due to their advanced state of decay. Nest-site trees are softer than live trees and termitaria are softer still.

One of the last populations of the kingfisher was found just north of the study area below the limestone plateau in the vicinity of Ritidian Point (R. Beck, Jr. pers. comm.). This area

TABLE 4

MICROHABITAT VARIABLES FOR MICRONESIAN KINGFISHER NEST SITES ON GUAM

Variable		Mean ± SD
Number excavations per site		
Trees (N = 6)		19.3 ± 17.7
Termitaria (N = 6)		2.7 ± 1.9
Nest excavation status (N = 166)		
Complete		12.7%
Not complete		80.1%
Undetermined		7.2%
Height of excavations		
Trees (N = 6)		4.9 ± 1.5 m
Termitaria and arboreal fern root masses (N = 5)		5.2 ± 2.1 m
Nest cavity dimensions		
	Trees (N = 13)	Termitaria (N = 6)
Entrance width	5.29 ± 0.58 cm	5.26 ± 0.46 cm
Entrance depth	7.21 ± 1.46 cm	7.29 ± 0.47 cm
Cavity depth	17.07 ± 3.14 cm	20.21 ± 1.68 cm

is largely undisturbed native forest. The Ritidian Point population was extinct at the time the present study was begun and the finding of a more southerly population in the CWSA and NWF was contrary to the northward pattern of extinction noted by previous researchers (Ralph and Sakai 1979, Jenkins 1983, Savidge 1984). The area around Ritidian Point differs from the study area in both the degree of habitat modification and human use. The forest there is contiguous and relatively untouched. A large number of former kingfisher nest sites were observed there in *Pisonia grandis*. I saw no brown tree snakes at the one successful nest site at the CWSA, and attempts to trap snakes there failed. However, at the edge of the plateau which defined the north edge of the study area less than 1 km away, nine snakes were captured by hand in 90 min by walking the forest edge and spotlighting them after dark. Thus, the persistence of the kingfisher at the CWSA and NWF may have indirectly been enhanced by forest fragmentation limiting local migration of the arboreal brown tree snake coupled with the abundance of feral pigs which are known to eat snakes.

The Micronesian Kingfisher of Guam will soon be extant only in captivity. The captive population is breeding and it is hoped to reintroduce them to Guam at a time when the snake population may be controlled. The brown tree snake is not likely to be eradicated completely from the island, however its numbers may be controlled. The situation in the CWSA may be a model for future management of the species. The best hope may lie in creating snake-controlled refugia using traps and drift fences. The kingfishers' dependence on suitable nest sites may be exploited by the supplying of artificial nest sites, such as by relocating termitaria and selectively killing suitable trees in snake-controlled areas. Extensive habitat still lies on military reservations as well as on private land. Secure nest sites might be created using criteria established in the present study.

Acknowledgments.—I thank C. Sheppard of the New York Zoological Society for the opportunity to perform this research; R. Beck, Jr. for his invaluable guidance while on Guam; the entire staff of the Guam Division of Aquatic and Wildlife Resources, especially G. Wiles for his help in plant identification and H. Muna and C. Kerns for assistance in the field. Field work on Andersen Air Force Base was facilitated by B. Sachse, V. Tobey, and the Air Force. Funding was provided by Wildlife Conservation International and the Friends of the National Zoo. I would additionally like to thank R. Beck, Jr., M. Hodge, J. Savidge, G. Uetz, and G. Wiles for helpful comments on an earlier draft of the manuscript.

LITERATURE CITED

BAKER, R. H. 1951. The avifauna of Micronesia, its origin, evolution and distribution. Univ. Kansas Pub. 3:13–59.

COLLIAS, N. E. AND E. C. COLLIAS. 1984. Nest building and bird behavior. Princeton Univ. Press, Princeton, New Jersey.

FOSBERG, F. R. 1960. The vegetation of Micronesia. Bull. Amer. Mus. Nat. Hist. 119: 4–75.

GREENWAY, J. C. 1967. Extinct and vanishing birds of the world. Dover Pub., Inc., New York, New York.

JAMES, F. C. AND H. H. SHUGART JR. 1970. A quantitative method of habitat description. Aud. Field Notes 24:727–736.

JENKINS, J. M. 1983. The native forest birds of Guam. Ornith. Monogr. 31.

MARSHALL, J. T. 1949. The endemic avifauna of Saipan, Tinian, Guam and Palau. Condor 51:200–221.

RALPH, C. J. AND H. F. SAKAI. 1979. Forest bird and fruit bat populations and their conservation in Micronesia: notes on a survey. 'Elepaio 40:20–26.

SAVIDGE, J. A. 1984. Guam: paradise lost for wildlife. Biological Conservation 30:305–317.

———. 1986. The role of disease and predation in the decline of Guam's avifauna. Ph.D. diss., Univ. Illinois, Urbana-Champaign, Illinois.

———. 1987. Extinction of an island forest avifauna by an introduced snake. Ecology 68: 660–668.

STONE, B. C. 1970. The flora of Guam. Micronesica 6:1–659.

VON HAARTMAN, L. 1957. Adaptation in hole-nesting birds. Evolution 11:339–347.

SAMUEL D. MARSHALL, *Wildlife Conservation International, New York Zoological Society, 185th St. and Southern Blvd., Bronx, New York 10460.* (Present address: *Dept. Zoology, Graduate Program in Ethology, Univ. Tennessee, Knoxville, TN 39776.*) *Received 10 June 1988, accepted 22 Nov. 1988.*

Wilson Bull., 101(3), 1989, pp. 477–481

Release of gaping in hummingbirds (Trochilidae).—Gaping is an instinctive behavior of many altricial birds in which the nestling displays a widely opened bill and, in most cases, produces loud begging calls to stimulate feeding by the parents (Stresemann 1927–1934). Gaping may be elicited by non-specific or specific stimuli (Skutch 1976, Bischof and Lassek 1985). At one time, gaping was considered to be restricted to passerines, but it has also been documented in certain non-passerines, e.g., woodpeckers (Picidae), cuckoos (Cuculidae), and mousebirds (Coliidae) (Stresemann 1927–1934).