The Condor 91:187–192

OBSERVATIONS ON THE FORAGING ECOLOGY AND SOCIAL BEHAVIOR OF THE BRIDLED WHITE-EYE[1]

ROBERT J. CRAIG
Department of Natural Resource Management and Engineering, University of Connecticut, Storrs, CT 06268

Abstract. I studied the foraging ecology and social behavior of the Bridled White-eye (*Zosterops conspicillatus*) on Saipan and Tinian, Mariana Islands. On Saipan, birds foraged in flocks of 10–40, and dominance relationships existed within flocks. The white-eye appeared socially subordinate to the other insectivorous passerines. Bridled White-eyes foraged principally on the outer crown of trees and shrubs, where they perched on relatively slender branches to glean invertebrates from leaf surfaces. They foraged similarly in two habitats, but they used a wider range of perch sizes in limestone forest than in tangantangan (*Leucaena leucocephala*) thickets. Hence, absolute vegetation height was of little importance to this species. Bridled White-eyes were versatile in their foraging, which included every microenvironment from the ground to treetops. They used gleaning, probing, hovering, and sallying to feed on invertebrates, nectar, fruits, and seeds.

Key words: Mariana Islands; Saipan; Tinian; Bridled White-eye; foraging; social behavior; limestone forest; tangantangan thickets.

INTRODUCTION

The Bridled White-eye (*Zosterops conspicillatus*; Zosteropidae) was apparently once the most common forest bird throughout the southern Mariana Islands. The Guam subspecies, *Z. c. conspicillatus,* although now probably extinct (Engbring and Ramsey 1984), was once abundant (Seale 1901), but was already reported as occurring locally by Baker (1951). On Rota, north of Guam, *Z. c. rotensis* was apparently also once common, but is now uncommon and restricted in range (Engbring et al. 1982). North of Rota, on Agiguan, Tinian, and Saipan, the subspecies *Z. c. saypani* remains abundant, with Saipan populations estimated at 229,138 (Engbring et al. 1982). The suggestion that Saipan and Tinian populations may be subspecifically distinct (Marshall 1949, Baker 1951), has not been adequately studied, and no taxonomic distinction is presently recognized.

Aside from population surveys (Engbring et al. 1982, Engbring and Ramsey 1984) and general observations of natural history (Seale 1901, Marshall 1949, Baker 1951, Jenkins 1983), the ecology of the Bridled White-eye is essentially unknown. I here describe my observations of *Z. c. saypani,* which were conducted to provide data useful in understanding its habitat needs and community relationships. Such studies are particularly important in light of recent population declines of *Z. c. conspicillatus* and *Z. c. rotensis* (Savidge 1984, 1987; Engbring and Pratt 1985).

STUDY AREAS AND METHODS

I gathered data on Saipan and made additional qualitative observations on Tinian between 6 January and 24 February 1988 (total 334 hr). My studies on Saipan were made mainly in the Marpi Cliffs region at the north end of Saipan, but I also made observations at Mt. Tapotchau, Talufofo, and Kagman Peninsula on that island and in the Hagoi region at the north end of Tinian.

I studied the birds in two principal habitats, limestone forest and tangantangan (*Leucaena leucocephala*) thickets. Limestone forest is limited to steep slopes and cliffs and, in the Marpi region, is dominated by such native canopy trees as *Guamia mariannae, Neisosperma oppositifolia, Ochrosia mariannensis, Melanolepsis multiglandulosa, Cynometra ramifolia, Ficus prolixa, Pisonia grandis, Psycotria mariana, Randia cochinchinensis, Premna obtusifolia, Morinda citrifolia, Guettarda speciosa, Pandanus* spp., and *Erythrina variegata.* In the Talufofo and Mt. Tapotchau regions such native trees as *Artocarpus mariannensis, Cerbera dilatata, Hernandia nymphaeifolia, Hibiscus tiliaceus, Mammea odorata,* and *Barringtonia asiatica* are also common. Canopy height is generally restricted to less than 15 m because of frequent typhoons, and understory vegetation is dense.

[1] Received 15 June 1988. Final acceptance 25 August 1988.

Tangantangan thickets are largely a monoculture of the introduced *Leucaena leucocephala*. The thickets generally grow to 6 m, and are often covered with vines. Native swordgrass (*Miscanthus floridulus*) meadows frequently break up the thickets. Tangantangan, aerially seeded following World War II to prevent erosion, occupies flat areas formerly cultivated for sugarcane (Engbring et al. 1982). Large numbers of unexploded shells still present throughout study sites serve as reminders that much of the habitat was obliterated during the war.

I observed foraging at all hours between dawn and dusk (approximately 06:45 to 18:30). I traversed the interior of forests and thickets or walked dirt roads through these habitats. I analyzed data collected by these two ways to assess observational bias and differential use of interior and edge environments.

I divided habitat space into vertical and horizontal zones (see Robinson and Holmes 1982). In limestone forest, I recognized three vertical zones: the upper, middle, and lower thirds of the canopy trees, and two horizontal zones: the outer and inner. I divided the lower stature tangantangan thickets into two vertical zones: the top and lower halves, but recognized the same two horizontal zones. In both habitats the spindly form of most trees yielded an inner horizontal zone of only the trunk and major limbs and an outer zone of the branched, foliated portion of the tree. Furthermore, I noted whether birds used canopy or understory trees.

To gather data on foraging surfaces, I recorded use of the following: leaf upper or lower surface, dead leaf, rolled leaf (lepidopteran cocoon), bud, flower, fruit, branch, trunk; and foraging 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, and >4.0 cm. For analyzing perch data using a general linear model (Freund and Littell 1981) I used the following mean values for the first five categories: 0.20, 0.38, 0.75, 1.50, 3.00 cm. For branches >4.0 cm I used my field estimates of perch size. I periodically checked my visual estimates of branch diameter by measuring branches with dial calipers. I concurrently recorded foraging movements: removing prey from a surface while perched (glean); thrusting the bill into a crevice, fruit, or flower (probe); removing prey from a surface while hovering (hover); and capturing flying prey by darting from a perch (sally). A foraging observation consisted of the position and activity of a bird at the moment of a feeding motion.

To insure that my sample was representative, I did not knowingly gather more than five observations on any one individual. For chi square tests on data, I did not use categories where zeros (no observations) occurred; hence, test results are conservative. Additional data were gathered from mist-netted and weighed birds. Taxonomy follows that of Pratt et al. (1987).

RESULTS

SOCIAL BEHAVIOR

Bridled White-eyes foraged in flocks, with flock size on Saipan usually 10–40 individuals (maximum: 50). I also saw male-female pairs feeding away from flocks, even though they appeared nonterritorial (see also Marshall 1949, Jenkins 1983). Individuals frequently chased and supplanted each other on perches, suggesting that dominance relationships exist in foraging flocks. Further evidence of the social nature of Bridled White-eyes is provided by my observation of one bird preening another individual, probably its mate.

While foraging in flocks, individuals communicated via a series of *chit-chit* notes (taped calls on file at the Library of Natural Sounds, Cornell Laboratory of Ornithology), although a second group of whining vocalizations were also commonly given. On several occasions I observed perched birds communicate with flock members by tilting the head at 45°, moving the head from side to side, and flicking the wings while giving whining calls. These whining notes also were used in agonistic interactions, such as those involving chases between a pair of birds and a third individual, and when birds mobbed Collared Kingfishers (*Halcyon chloris*). As suggested by Marshall (1949), Collared Kingfishers are likely regular predators on Bridled White-eyes. I observed a Collared Kingfisher take a probable fledgling from a branch while being vigorously scolded by a pair of white-eyes.

Bridled White-eyes appeared to be socially subordinate to other small forest passerines. I observed them being chased or supplanted on perches four times by the Golden White-eye (*Cleptornis marchei*), and once each by the Rufous Fantail (*Rhipidura rufifrons*) and the Micronesian Honeyeater (*Myzomela rubrata*). I

TABLE 1. Percent use of tree zones, with sample size in parentheses.

Habitat	Top		Middle		Lower	
	Outer	Inner	Outer	Inner	Outer	Inner
Limestone forest						
Edge	65.8 (48)	1.4 (1)	27.4 (20)	2.7 (2)	2.7 (2)	0
Interior	71.4 (50)	5.7 (4)	17.1 (12)	4.3 (3)	1.4 (1)	0
Total	68.5 (98)	3.5 (5)	22.4 (32)	3.5 (5)	2.1 (3)	0
Tangantangan thicket						
Edge	79.2 (103)	6.2 (8)			12.3 (16)	2.3 (3)
Interior	65.4 (51)	10.3 (8)			21.8 (17)	2.6 (2)
Total	74.0 (154)	7.7 (16)			15.9 (33)	2.4 (5)

never saw Bridled White-eyes chasing or supplanting other passerines. Preliminary foraging data on the Golden White-eye (74 observations) indicate substantial similarity to the Bridled White-eye in all aspects of foraging behavior. The Rufous Fantail and Tinian Monarch (*Monarcha takatsukasae*), both foliage gleaners, also resemble the Bridled White-eye in foraging behavior.

FORAGING ECOLOGY

Based on 360 foraging observations I found that on Saipan, Bridled White-eyes are versatile foragers and feed on foliage invertebrates, flying insects, nectar, fruits, and seeds. In limestone forest they foraged mostly in the top outer portions of trees (Table 1), where the foliage is most dense. The only other tree zone used extensively was the middle outer zone. Results for edge and interior forest observations did not significantly differ ($\chi^2 = 4.3$, df = 4, $P > 0.05$). This same pattern of outer canopy preference also held for tangantangan thickets; results also did not significantly differ for edge and interior data ($\chi^2 = 5.1$, df = 3, $P > 0.05$). Only eight of 146 (5.5%) observations in limestone forest and 24 of 214 (11.2%) observations in tangantangan thickets came from understory trees. Birds fed at the top outer portion of understory trees in 29 of 32 (90.6%) total observations. In addition to foraging in trees, birds fed on seeds of herbaceous weeds and gleaned from swordgrass leaves while perched on their stems. On occasion I also flushed foraging birds from roadsides and lawns.

In both limestone forest and tangantangan thickets foraging birds appeared to prefer sunlit areas. In the morning on the west-facing Marpi Cliffs most foraging birds were at the top of the cliffs, the area first illuminated by sun. By contrast, in the early morning birds fed actively in the sunlit tangantangan thickets at the base of these cliffs. However, few birds used tangantangan by late morning, when daytime temperatures neared their peak. Numerous thicket-foraging birds were again present in the afternoon, but when thickets became shaded toward evening I found few birds. On the Marpi Cliffs, illuminated by late afternoon sun, birds foraged to nearly sunset.

In limestone forest and tangantangan thickets Bridled White-eyes foraged mostly among leaves (Table 2). They searched buds, fruits, trunks, dead leaves, and rolled leaves only infrequently. Birds fed often from either upper or lower surfaces of leaves. While foraging among leaves, Bridled White-eyes reached above and below and also dangled beneath perches. When foraging in trees with large leaves, they sometimes stood on leaf surfaces. This latter behavior was possible because the birds average only 8.2 g (SD = 2.9, $n = 6$). I found no significant differences in use of foraging surfaces between edge and interior observations (limestone forest: $\chi^2 = 4.3$, df = 3, $P > 0.05$; thicket: $\chi^2 = 5.4$, df = 4, $P > 0.05$) or habitats ($\chi^2 = 5.4$, df = 6, $P > 0.05$).

Although it was more difficult to observe birds in large-leaved trees, thereby making tree species preference difficult to assess, I saw birds foraging in the following limestone forest taxa: *Guamia, Pisonia, Cynometra, Ficus, Premna, Melanolepsis, Ochrosia, Erythrina, Randia, Morinda, Hernandia, Barringtonia, Neisosperma, Hibiscus,* and *Artocarpus.* I also observed birds in native and introduced tree species more characteristic of other habitats, such as beach strand and formerly cultivated areas, including: soshuge (*Acacia con-*

TABLE 2. Percent use of foraging surfaces, with sample size in parentheses.

Habitat	Leaf				Bud	Flower	Fruit	Branch	Trunk
	Upper	Lower	Dead	Rolled					
Limestone forest									
Edge	45.8 (33)	34.7 (25)	2.8 (2)	0	2.8 (2)	2.8 (2)	2.8 (2)	5.5 (4)	2.8 (2)
Interior	54.3 (38)	25.7 (18)	0	1.4 (1)	0	10.0 (7)	0	7.1 (5)	0
Total	50.0 (71)	30.3 (43)	1.4 (2)	0.7 (1)	1.4 (2)	6.3 (9)	1.4 (2)	6.3 (9)	1.4 (2)
Tangantangan thicket									
Edge	47.7 (63)	34.8 (46)	1.5 (2)	0	0	8.3 (11)	1.5 (2)	3.8 (5)	2.3 (3)
Interior	38.5 (30)	52.6 (41)	0	0	0	0	3.8 (3)	3.8 (3)	1.3 (1)
Total	44.3 (93)	41.4 (87)	1.0 (2)	0	0	5.2 (11)	2.4 (5)	3.8 (8)	1.9 (4)

fusa), monkeypod (*Samanea saman*), kapok (*Ceiba pentandra*), coconut (*Cocos nucifera*), avocado (*Persea americana*), and mangrove (*Bruguiera gymnorrhiza*).

The principal foraging method used by Bridled White-eyes in both limestone forest and tangantangan thickets was gleaning (Table 3), with invertebrates (approximately 2–22 mm in length, based on comparisons to bill size) being the most frequently taken food. Birds hovered and sallied only when chasing invertebrates. In 18 observations, birds probed: flowers, apparently for nectar (8); bark (1); dead leaves (3); rolled leaf (1); and passionfruits (*Passiflora foetida*) (5). In one instance I saw a bird extract the fleshy red seed from a passionfruit. When foraging, the birds searched methodically, inspecting numerous surfaces before seizing prey. I found no significant difference in use of methods between edge and interior observations (limestone forest: $\chi^2 = 0.8$, df = 2, $P > 0.05$; thicket: $\chi^2 = 0.1$, df = 2, $P > 0.05$) or habitats ($\chi^2 = 3.2$, df = 2, $P > 0.05$).

Perches 0.25–<0.5 cm in diameter were preferred in both limestone forest and tangantangan thickets, with <0.25 and 0.5–<1.0 cm perches used secondarily (Table 4). Although birds could use larger perches, they did so infrequently. I found no significant difference in perch use between edge and interior observations ($F = 0.2$, $P > 0.05$) or an interaction between habitat and edge and interior observations ($F = 2.1$, $P > 0.05$), but a significant difference between habitats in perch use ($F = 11.9$, $P < 0.01$), with birds more frequently choosing larger perches in limestone forest.

TABLE 3. Percent use of foraging methods, with sample size in parentheses.

Habitat	Glean	Probe	Hover	Sally
Limestone forest				
Edge	89.0 (65)	5.5 (4)	5.5 (4)	0.0
Interior	89.0 (65)	6.8 (5)	2.7 (2)	1.4 (1)
Total	89.0 (130)	6.2 (9)	4.1 (6)	0.7 (1)
Tangantangan thicket				
Edge	93.8 (122)	4.6 (6)	1.5 (2)	0.0
Interior	94.9 (74)	3.8 (3)	1.3 (1)	0.0
Total	94.2 (196)	4.3 (9)	1.4 (3)	0.0

DISCUSSION AND CONCLUSIONS

The size of Bridled White-eye flocks that I observed on Saipan was greater than the average flock size of six to 12 reported by Engbring et al. (1982) for the Northern Marianas. Similarly, Downs (1946), who observed immediately after World War II, found the species common but in flocks of only two to seven on Tinian, whereas P. Glass (pers. comm.) has recently found up to 100 individuals foraging in single flocks on Tinian. Currently on Rota, where populations are now low, flock size is typically below 10 (J. Reichel, pers. comm.). When the species was abundant on Guam, Seale (1901) found flocks of 10–20 birds, but during the years of rapid population decline, Pratt et al. (1979) found flocks of up to 15, Jenkins (1983) reported flocks of three to eight, and Engbring and Ramsey (1984) reported flocks of three to six. These data suggest that flock size is related to population density.

The Bridled White-eye may be characterized as a forager of the outer forest canopy, where it perches on relatively slender branches to glean invertebrates from leaf surfaces. When tree height drops, as it does from limestone forest to tangantangan thickets, foraging still occurs in the uppermost structural zone. Hence, absolute vegetation height seems of little importance in

TABLE 4. Percent use of perch sizes, with sample size in parentheses.

Habitat	Perch size (cm)					
	<0.25	0.25–<0.5	0.5–<1.0	1.0–<2.0	2.0–<4.0	>4.0
Limestone forest						
Edge	31.8 (7)	36.4 (8)	9.1 (2)	9.1 (2)	13.6 (3)	0
Interior	14.3 (6)	38.1 (16)	31.0 (13)	9.5 (4)	0	7.1 (3)
Total	20.3 (13)	37.5 (24)	23.4 (15)	9.4 (6)	4.7 (3)	4.7 (3)
Tangantangan thicket						
Edge	31.8 (28)	39.8 (35)	22.7 (20)	3.4 (3)	1.1 (1)	1.1 (1)
Interior	16.5 (13)	57.0 (45)	24.1 (19)	2.5 (2)	0	0
Total	24.6 (41)	47.9 (80)	23.4 (39)	3.0 (5)	0.6 (1)	0.6 (1)

the foraging ecology of this species. Similar foraging surfaces and foraging methods are also used in both habitats. However, the relatively slender tangantangan trees restrict the perch sizes available to the birds, i.e., a wider range of perch sizes is used in limestone forest, and therefore birds in thickets use a smaller range of perch sizes.

As did Engbring et al. (1982), I found that Northern Mariana populations of the Bridled White-eye fed on a wide range of foods. However, the extent to which patterns of foraging that I observed shift seasonally is unknown. On Guam, Seale (1901) and Jenkins (1983) reported only insectivory. The difference may only reflect their more limited observations rather than restricted foraging by Guam birds. Because feeding on foliage invertebrates greatly predominates, only very detailed observations would reveal use of other foods. Marshall's (1949) report of fruits as a principal island *Zosterops* food, based on analyses of stomach contents (although invertebrates and seeds were also present in stomachs), was perhaps the consequence of a shift due to the temporary abundance of a food source. Coultas (in Baker 1951) described Tinian white-eyes as feeding on seeds, although the extent of such feeding is not clear from the report. Catterall (1985) found preference for insectivory, with secondary dependence on fruit by another tropical island white-eye, the Heron Island Silvereye (*Zosterops lateralis chlorocephalus*), although a major part of the birds' energy intake was provided by energy rich fruits.

The behavioral flexibility of this species is illustrated by its ability to forage in other tree zones, use other foraging surfaces, use alternate foraging methods, and feed in herbaceous vegetation and on the ground. Such flexibility may be an adaptation for persisting on a periodically typhoon-devastated island. However, the extent to which flexibility is limited by other bird species is unknown. Preliminary observations on the Golden White-eye indicate that probing dead and rolled leaves, as well as mid-canopy foraging are more prevalent in this species. Because the Golden White-eye is apparently socially dominant over the Bridled White-eye, the Golden White-eye's preferred foods and feeding sites may be restricted from Bridled White-eyes. As a probable example of restriction, in one instance I observed a Bridled White-eye wait for a Golden White-eye to finish feeding at a cluster of *Melanolepsis* fruits before it flew to investigate them.

ACKNOWLEDGMENTS

I thank A. Palacios, Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands, for approving my studies in the Commonwealth. P. Glass and J. Reichel extended their hospitality and field companionship, and provided essential field equipment while I was on Saipan. G. Clark, Jr., H. Pratt, and D. Tomback provided thoughtful reviews of the manuscript, J. Engbring and J. Savidge encouraged me to pursue this project, and U. Koehn provided statistical advice. I also thank my wife Barbara for her enthusiastic support and encouragement. Financial support was provided in part by the University of Connecticut Research Foundation. Scientific contribution No. 1266 of the Storrs Agricultural Experiment Station.

LITERATURE CITED

BAKER, R. H. 1951. The avifauna of Micronesia, its origin, evolution, and distribution. Univ. Kans. Publ. Mus. Nat. Hist. 3:1–359.

CATTERALL, C. P. 1985. Winter energy deficits and the importance of fruit versus insects in a tropical island bird population. Aust. J. Ecol. 10:265–279.

DOWNS, T. 1946. Birds of Tinian in the Marianas. Trans. Kans. Acad. Sci. 49:87–106.

ENGBRING, J., AND H. D. PRATT. 1985. Endangered birds in Micronesia: their history, status, and fu-

ture prospects, p. 71–106. *In* S. A. Temple [ed.], Bird conservation II. Univ. Wisconsin Press, Madison.

ENGBRING, J., AND F. L. RAMSEY. 1984. Distribution and abundance of the forest birds of Guam: results of a 1981 survey. FWS/OBS-84/20.

ENGBRING, J., F. L. RAMSEY, AND V. J. WILDMAN. 1982. Micronesian forest bird survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish Wildl. Serv. Report.

FREUND, R. J., AND R. C. LITTELL. 1981. SAS for linear models. SAS Institute, Cary, NC.

JENKINS, J. M. 1983. The native forest birds of Guam. Ornithol. Monogr. No. 31. American Ornithologists' Union, Washington, DC.

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

PRATT, H. D., P. L. BRUNER, AND D. G. BERRETT. 1979. America's unknown avifauna: the birds of the Mariana Islands. Am. Birds 33:227–235.

PRATT, H. D., P. L. BRUNER, AND D. G. BERRETT. 1987. A field guide to the birds of Hawaii and the tropical Pacific. Princeton Univ. Press, Princeton, NJ.

ROBINSON, S. K., AND R. T. HOLMES. 1982. Foraging behavior of forest birds: the relationships among search tactics, diet, and habitat structure. Ecology 63:1918–1931.

SAVIDGE, J. 1984. Guam: paradise lost for wildlife. Biol. Conserv. 30:305–317.

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

SEALE, A. 1901. Report of a mission to Guam. Bernice P. Bishop Mus. Occas. Papers 1:17–60.