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WHAT CAUSED THE POPULATION DECLINE OF THE BRIDLED WHITE-EYE ON ROTA, MARIANA ISLANDS?

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Abstract. The Bridled White-eye (*Zosterops conspicillatus rotensis*) was once thought to be common and widespread on Rota, Commonwealth of the Northern Mariana Islands, but is now restricted to several patches of native limestone forest in and adjacent to the Sabana region. Surveys conducted in 1990 indicated that the population had declined by 87% between 1982 and 1990 for unknown reasons. The low density and restricted habitat association of the Bridled White-eye on Rota contrasts with the situation on Saipan, Tinian, Agiguan, and formerly on Guam, where the Bridled White-eye is the most common forest bird and occurs at all elevations and in all habitat types. We surveyed the entire range of the Rota Bridled White-eye in 1996 to estimate its current numbers and distribution. We also reviewed existing information on the white-eye and evaluated potential causes of its decline, including predation by Black Drongos (*Dicrurus macrocercus*), rats (*Rattus* spp.), and the brown tree snake (*Boiga irregularis*); pesticides; avian disease; and habitat loss and alteration. We found that 94% of the extant population of 1,165 white-eyes on Rota was restricted to four patches of old-growth, native limestone forest covering only 259 ha. We believe that the population decline and current localized distribution is primarily a result of habitat changes due to agricultural development and typhoons, but the absence of white-eyes from several stands of native forest above 200 m remains unexplained. The Rota white-eye may be a different species from white-eyes found on Saipan, Tinian, Agiguan, and Guam, with different habitat preferences.

Key Words: Black Drongo; Bridled White-eye; brown tree snake; conservation; *Dicrurus macrocercus*; Mariana Islands; Rota; *Zosterops conspicillatus.*

Mosquito-borne avian diseases have had major effects on the distribution and population dynamics of Hawaiian forest birds, and yet the absence of certain native and nonnative species from apparently suitable habitat suggest that factors other than avian disease may be responsible for large-scale changes in bird distribution and numbers. Studies of declining bird populations on islands elsewhere in the Pacific where avian disease is not a confounding factor may help to explain some of the declines documented for Hawaiian species. The Bridled White-eye (*Zosterops conspicillatus*) is a small, flocking passerine species known only from Guam and the Commonwealth of the Northern Mariana Islands (CNMI) in Micronesia. Three subspecies are currently recognized: *Z. c. conspicillatus,* formerly on Guam but extinct since 1983; *Z. c. saypani* on Saipan, Tinian, and Agiguan; and *Z. c. rotensis* on Rota. On Saipan, Tinian, and Agiguan, the Bridled White-eye is by far the most abundant forest bird, with densities reaching 3,000 birds/km^2 on Tinian and 2,000 birds /km^2 on Saipan and Agiguan (Engbring et al. 1986). On Saipan, Craig (1996) found Bridled White-eyes at all elevations and in all habitats including limestone forest, secondary forest, beach strand, and disturbed habitats. On Guam, the white-eye was once found in coastal strand, grasslands, foothills, and mature forests (Jenkins 1983). Craig (1989, 1990; J. Craig, pers. comm.) found similar foraging behavior between the Rota subspecies and white-eyes on Saipan.

The status of the Bridled White-eye on Rota differs greatly from populations on Saipan, Tinian, and Agiguan, and the Rota subspecies is being considered for listing as endangered by the U.S. Fish and Wildlife Service. White-eyes were once found at lower elevations on Rota (Baker 1951, Craig and Taisacan 1994) but are currently found only above 170 m elevation in fragmented patches of forest on the upper plateau of the Sabana region and at the base of cliffs surrounding the Sabana (Fig. 1). All reports on the status and population trends of the Rota Bridled White-eye during the past 15 years agree that the population has been declining, but the reason for the decline has not been determined. Engbring et al. (1986) estimated the Rota Bridled White-eye population at 10,763 birds in 1982, with 93% of the birds in the Sabana. Surveys in 1990 using a combination of variable circular-plot (VCP; Reynolds et al. 1980) counts and area searches resulted in population estimates of < 300 birds by Greg Witteman and 1,500 birds by Stan Taisacan of the Division of Fish and Wildlife of the CNMI (CNMI-DFW), suggesting an 87% decrease in eight years (Craig and Taisacan 1994). Craig and Taisacan (1994) reported a linear decline based on monthly surveys in 1989–1990 and predicted that the white-eye population might be extinct by January 1997 if no action was taken. F. Ramsey and A. Harrod (unpubl. data) analyzed data from VCP surveys in 1994 that focused on the Bridled White-eye and reported a 53% decrease in densities between 1982 and 1994.

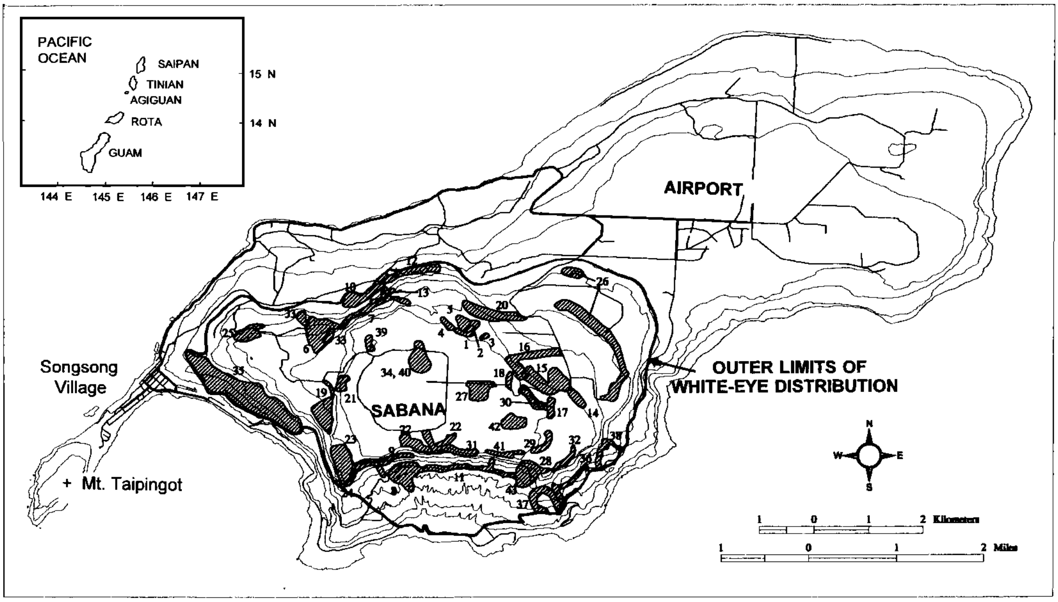

FIGURE 1. Areas searched (hatching) and distributional limits of the Rota Bridled White-eye.

At the request of the U.S. Fish and Wildlife Service, an interagency team of biologists surveyed Rota in September 1996 to determine the current status and trends of the Bridled White-eye population. We reviewed all published and unpublished reports on the white-eye and possible reasons for its decline, and we evaluated data from previous surveys after taking into account differences in survey coverage, weather conditions, and observer differences that might affect population estimates. Our primary objectives were to provide data for a habitat conservation plan being developed for Rota, and to recommend specific research and management actions to assist the recovery of the Rota Bridled White-eye.

METHODS

Based on previous surveys on Rota, we expected Bridled White-eyes to be patchily distributed in dense vegetation where detection distances are usually <50 m. Because of low numbers of white-eyes detected during past plot counts along transects, we stratified the species' distribution on Rota based on previous survey data and vegetation maps (Falanruw et al. 1989), and optimally allocated search effort to each stratum based on expected densities (Fig. 1). This approach allowed us to search a greater proportion of the known range and to follow flocks to get additional information on flock size and composition. Two-person teams of biologists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, CNMI-DFW, and Guam Division of Aquatic and Wildlife Resources conducted area searches between daybreak and late afternoon during 4–19 September 1996. Teams delineated the areas they searched on 1:10,000 scale aerial photos and 1:25,000 topographic maps that were later digitized. We calculated the density of white-eyes in each search area from the number of white-eyes detected (midpoint if a range was given); the total area searched; and the percentage of the area that the team was able to effectively search, taking into account the effects of vegetation and terrain on detection distances.

To extrapolate density estimates for each search area to the larger area they represented, we adjusted the original stratum boundaries based on numbers of white-eyes found in various areas, descriptions of the forest provided by participants, vegetation boundaries delineated by Falanruw et al. (1989), and our own photointerpretation of 1994 aerial photos and comparisons with 1987 photos. This approach resulted in 17 polygons that were assigned a density class of high, low, very low, or zero white-eyes (Fig. 2). Map boundaries were digitized and areas within each polygon were calculated with a geographic information system. Densities of all search areas within the four high-density and single low-density polygons were averaged, and the overall mean density and 95% confidence limits were calculated using equations 2.15–2.16 of Manly (1992: 29).

RESULTS

In all, 247–296 individual white-eyes were detected. Some flocks were heard but not seen, and ranges provided by some teams represented uncertainty about the number of birds in a flock or whether the team had already detected a particular bird. Based on location and timing of detections, 26–29 white-eyes may have been counted by more than one team. We estimate

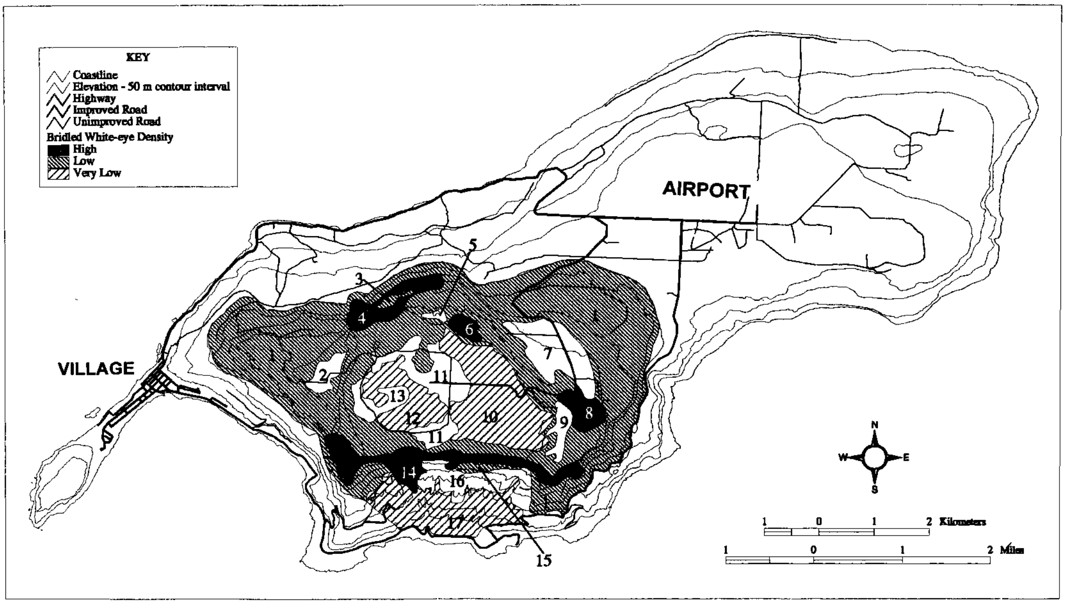

FIGURE 2. Polygons delineating areas of high, low, very low, and zero density of Bridled White-eyes on Rota.

that 221–267 different white-eyes were detected during these surveys.

Ninety-four percent of the resulting population estimate of 1,165 ± 390 (95% CI) Rota Bridled White-eyes occurred in four polygons totaling 259 ha (Table 1). We found the highest density of 6.51 birds/ha in Polygon 8 (Fig. 2) in relatively pristine limestone forest dominated by *Elaeocarpus*. Polygon 6, with a density of 5.47 birds/ha, also had several stands of relatively pristine forest dominated by *Elaeocarpus* and *Hernandia* with numerous epiphytes, although portions of this polygon were dominated by *Pandanus* with only scattered trees. Polygon 4, on the northern slopes of the Sabana, had a density of 4.94 birds/ha. Forests along the top and at the base of the southern cliffs of the Sabana (Polygon 14 of Fig. 2) had an estimated 398 white-eyes, including one flock that was observed foraging in an introduced stand of bamboo at 200 m elevation. The low-density Polygon 1 in Figure 2 included 747.7 ha, and we estimate that 71 white-eyes occurred there based on a mean density of 0.094 birds/ha (N = 25 search areas). Our total population estimate of 1,165 ± 390 (95% CI) white-eyes represents an 89% decline from the 1982 estimate of 10,763 white-eyes.

DISCUSSION

Several hypotheses for the population decline and range contraction of the Rota Bridled White-eye have been stated in the published and unpublished literature or in interviews with biologists familiar with Rota. The hypotheses evaluated here include declines caused by (1) Black Drongo (*Dicrurus macrocercus*) predation; (2) brown tree snake (*Boiga irregularis*) predation; (3) rat (*Rattus* spp.) predation; (4) pesticides; (5) avian disease; and (6) habitat

TABLE 1. NUMBER OF BRIDLED WHITE-EYES IN HIGH AND LOW DENSITY POLYGONS OF FIGURE 2

			Density		Population size	
Polygon	Areas sampled	Total area (ha)	Mean	SE	Mean	±95% CI
1–Low	25	747.72	0.0944	0.0313	70.6	46.7
4–High	3	65.21	4.9367	2.2191	321.9	289.4
6–High	5	19.31	5.4700	1.0086	105.6	39.0
8–High	1	41.15	6.5100	—	267.9	—
14–High	9	133.07	2.9944	0.9578	398.5	254.9
Total	43	1006.46	1.1570	0.1940	1164.5	390.4

change, including losses and modification of habitat because of agriculture, development, and damage from typhoons. We evaluated information supporting and refuting each hypothesis, and provide the following summary of our investigation.

BLACK DRONGO PREDATION HYPOTHESIS

Craig and Taisacan (1994) suggested that the Black Drongo, a medium-sized, flycatcher-like bird introduced from southeast Asia, was responsible for the distributional change and population decline of the Rota Bridled White-eye and several other native bird populations. Most biologists and Rota residents support this view. Craig and Taisacan (1994) noted that the Black Drongo became abundant on Rota in the 1960s, at the time when the decline in the Bridled White-eye population was first noted. Drongos are most abundant at lower elevations and in open habitats, whereas white-eyes are absent or rare in these places. Craig and Taisacan argued that white-eyes are particularly susceptible to predation by drongos because they are small and feed on the exposed upper branches of the forest canopy where they can be preyed upon by drongos. They also observed that bird species too large for drongo predation were abundant and widespread on Rota.

Occasional predation on small birds by Black Drongos is well documented (Vernon 1959, Beaty 1966, Ali and Futehally 1970, Drahos 1977, Maben 1982; G. Perez, unpubl. data), and drongos are known for their "belligerence in territorial defense" (Maben 1982:3) and their frequent chases of Rufous Fantails (*Ripidura rufifrons*), white-eyes, Eurasian Tree Sparrows (*Passer montanus*), and larger birds. However, it is very unlikely that the Black Drongo, which is primarily insectivorous (Thyagaraju 1934, Ali and Futehally 1970, Drahos 1977, Maben 1982) could have caused an island-wide range contraction and major population decline of the Bridled White-eye. On Guam, Drahos (1977) found only trace samples of bird bones in 82 drongo stomachs, and Maben (1982) found bird bones in only one of 113 drongo stomachs. Maben (1982: 73) wrote that "despite this well-documented ability to eat small birds, I did not observe drongos regularly attempting to capture and eat small birds even when seemingly available," and she concluded that predatory interactions between drongos and other birds were not a significant factor in the decline of Guam's forest bird populations.

The drongo hypothesis does not explain why white-eyes are absent from several blocks of seemingly pristine limestone forest at higher elevations where drongos do not occur, nor why populations of Micronesian Honeyeaters (*Myzomela rubratra*) and Rufous Fantails have not experienced similar population declines. However, considering the current low number of white-eyes on Rota and the greater amount of edges around remaining patches of intact limestone forest, the apparently low rate of predation by drongos on white-eyes and frequent harassment could have a measurable affect on the white-eye population if no action is taken.

BROWN TREE SNAKE PREDATION HYPOTHESIS

The accidental introduction of the brown tree snake to Guam in the late 1940s has led to the nearly complete extirpation of native bird species there (Savidge 1987a), as well as considerable economic losses because of frequent power outages and interference with cargo shipments (Fritts et al. 1987, 1990; Rodda et al. 1992, 1997). Rota receives much of its cargo from Guam, and two dead brown tree snakes were found in 1991 in construction equipment from Guam. The Bridled White-eye was the first forest bird species to go extinct on Guam as the brown tree snake expanded its distribution and population size (Savidge 1987a). It is possible that a small, undetected population of brown tree snakes occurs on Rota, but if the snake were widespread and numerous enough to have caused an island-wide range contraction and major population decline of the Bridled White-eye during the past 25 years, at least one live snake should have been detected on Rota by now. Rota has a high prey base of rats, geckos, small birds, and other prey, and we would expect brown tree snakes to multiply rapidly as they did on Guam. Heightened public awareness of the snake and extensive land clearing for housing developments and agriculture on Rota in recent years would increase the probability of detecting a snake if they occurred on Rota. Efforts to prevent the spread of the brown tree snake to Rota and other islands in Micronesia remain a top priority for conservation of Micronesian avifauna.

RAT PREDATION HYPOTHESIS

In Hawai'i, New Zealand, and other Pacific Islands, rats have been found to be important predators of native birds to the point where they cause population declines or the extinction of native birds (e.g., Atkinson 1977, 1985; Robertson et al. 1994, Innes et al. 1995, van Riper and Scott *this volume*). No detailed work on rats has been conducted on Rota, but opportunistic trapping (G. Beauprez, pers. comm.; S. Derrickson, pers. comm.) and the many observations of rats active during the daytime suggest that Rota has a very high density of rats. It has been assumed in the past that most rats trapped and seen on

Rota are either the roof rat *Rattus rattus* or the Polynesian rat *R. exulans,* because these species are found on most islands throughout the Pacific. However, Flannery (1995) indicates that *R. rattus* has never occurred in Micronesia because it is excluded by the Asian house rat, *R. tanezumi.* The two species are distinguishable only by chromosomal characteristics or by "morphological and biochemical traits" that have never been clearly outlined (Wilson and Reeder 1993:658, Flannery 1995).

The role of rats in the decline of forest birds on Rota is unknown. If rat densities are higher at low elevations on Rota, this could help explain changes in the white-eye distribution there. However, there is no evidence for a range contraction and major population decline of other species on Rota such as the Rufous Fantail and Micronesian Honeyeater, which would be expected if rats caused the population decline and range contraction of the Bridled White-eye. Nevertheless, rat predation may be an important mortality factor for the white-eye and other forest birds on Rota, and additional information is needed on rat populations and predation on Rota.

PESTICIDES HYPOTHESIS

Concern over pesticide use arose after Baker's (1946) report and other documents indicating that the U.S. military had liberally sprayed, dusted, and fogged DDT on Guam, Rota, and other islands in the Marianas during and after World War II (Jenkins 1983:52, Grue 1985). Grue (1985) found that DDT and DDE concentrations in bird carcasses and guano were not high enough to cause mortality in birds and concluded that there was no evidence for pesticides being responsible for bird declines on Guam. Organophosphates or carbamates have been used on Rota and other islands in recent years for agricultural and public health reasons (Engbring 1989, USDA 1989; CNMI-DFW, unpubl. data), but these pesticides break down rapidly and do not persist in the environment.

Small passerine populations are able to double or triple in size within a few years if adequate habitat is available and limiting factors are removed, and heavy use of pesticides would need to continue on an annual or biannual basis to keep bird populations depressed if pesticides were the primary cause of declines. Pesticide spraying also occurred on Saipan and Tinian, but the Bridled White-eye on those islands has not declined as it has on Rota. Even if pesticides caused mortality and distributional changes on Rota in the past, the pesticides hypothesis does not explain current patterns and trends seen on Rota with various forest bird species. We conclude that pesticide use cannot explain distributional changes and population declines in the Rota Bridled White-eye.

AVIAN DISEASE HYPOTHESIS

In Hawai'i, native forest birds are rare or absent from lower-elevation forests because of the presence of *Culex quinquefasciatus,* a cold-intolerant vector for avian malaria and avian pox that has a feeding preference for birds (Warner 1968, van Riper et al. 1986, Atkinson et al. 1995, Jarvi et al. *this volume,* Shehata et al. *this volume*). Avian malaria and avian pox have been documented for Mariana birds (Savidge 1986, Savidge et al. 1992), and several species of mosquitoes that might transmit avian diseases, including *C. quinquefasciatus,* also occur there (Savage et al. 1993).

We cannot rule out the possibility that avian disease restricts Bridled White-eyes to higher elevations, but we think that this is unlikely for several reasons. First, the elevational range on Rota is probably not great enough to restrict a disease vector to lower elevations. We found white-eyes as low as 170 m elevation, and most of the population occurs at elevations between 300 m and 496 m, the highest elevation on Rota. *Culex quinquefasciatus* in Hawai'i is common to elevations well above 1,500 m (Atkinson et al. 1995), and with even warmer temperatures in the Marianas we would expect it to be found at all elevations there. Second, if avian disease were an important factor, we would expect other species of native forest birds to be more abundant at higher elevations, but they are not. Third, if a disease vector restricts the white-eye to higher elevations on Rota, why is it found only in undisturbed native forest there and not in disturbed areas and second-growth forest as it is on Saipan and Tinian? Avian disease cannot be ruled out as a mortality factor on Rota without field sampling for vectors and parasites, but the avian disease hypothesis cannot adequately explain the population decline and range contraction of the Bridled White-eye.

HABITAT CHANGE HYPOTHESIS

We believe that historical changes in the distribution and population size of the Rota Bridled White-eye are primarily a result of habitat loss and modification, coupled with differences in habitat selection between the Rota white-eye and the white-eyes found on other islands in the Marianas. We found flocks of white-eyes in all areas where they have been recorded since the 1970s where the native limestone forest is relatively intact. We failed to find them in agricultural areas and most second-growth forests. Many of the areas mapped as tall limestone forest by Falanruw et al. (1989) based on 1987 aerial photos were damaged by super typhoon Roy in 1988 and are now poor habitat for white-eyes. White-eyes now have a patchy distribution among remnant stands of relatively pristine native forest separated by areas cleared for agriculture or supporting only scattered trees and *Pandanus* (Fig. 2).

Based on 1987 aerial photos, 58% of Rota was covered by native limestone forest (Falanruw et al. 1989), but much of this was second-growth or disturbed forest that may lack some attribute of old-growth forest important to the Rota Bridled White-eye. Between 1932 and 1935, more than a third of the island was cleared for sugar plantings (Bowers 1950), and additional clearing by the Japanese administration occurred until World War II. Areas that currently support relatively undisturbed tracts of native limestone forest were spared because the soil was too thin for agriculture or the terrain was too steep, as along the base of cliffs surrounding the Sabana (Fosberg 1960). Rota was one of the most heavily bombed islands in the Pacific, and by the end of World War II, few stands of undisturbed limestone forest remained.

Aerial photographs from 1946 and historical maps indicate that more than half of the Songsong Peninsula on and around Mt. Taipingot (elevation 143 m; Fig. 1) was forested just after the war, and many areas just above the village that have been cleared for small farms had more intact forest. The fact that white-eyes have not been seen in Songsong Village since the 1950s or in other lower-elevation areas as remembered by Rota elders may be a case of habitat degradation and fragmentation. As the village expanded and more of the forest around Mt. Taipingot and above the village was modified, the connectivity among habitat fragments for the white-eye was lost and flocks of white-eyes occupying those areas disappeared. It is possible that white-eyes observed at lower elevations were transients or dispersers from preferred habitats at higher elevation where white-eye density was much greater, and that as the population declined from habitat loss and modification during and following the war, white-eyes were no longer seen at low elevation. It is interesting that all of the reports of white-eyes at low elevation are for areas surrounding the Sabana, and no white-eyes have ever been reported for the eastern third of the island.

The habitat hypothesis assumes that Rota Bridled White-eyes require native limestone forest and does not explain why the species is absent from several areas currently supporting good stands of native forest at lower elevation. Also, Bridled White-eyes on Saipan and Tinian, and formerly on Guam, are found at all elevations and in all vegetation types, including nonnative and highly disturbed native forests. We believe that these discrepancies occur because the Bridled White-eye on Rota is a different species, with different habitat preferences, than the white-eyes on other islands in the Marianas. Preliminary findings from DNA analyses support this belief (R. Fleischer, pers. comm.). Every taxonomist that has studied the Bridled White-eye has commented on the differences between the birds on Rota and those on other islands (Oustalet 1895, Pratt et al. 1987). Pratt et al. (1987) stated that differences in plumage and song among subspecies of Bridled White-eye in the Marianas are as great as among many sympatric species of *Zosterops* elsewhere (e.g., *Z. lateralis* and *Z. explorator* in Fiji). They wrote that the Rota form resembles Caroline Islands birds (*Z. semperi*) in plumage but behaviorally is more like other Mariana Islands white-eyes. Pratt et al. (1987:283) suggest that "*Z. conspicillatus*" in Micronesia may have originated from two directions (a Melanesian ancestor and continental forms to the north) and may be more than one species.

Two puzzling aspects of our argument are that most white-eyes in Micronesia are habitat and foraging generalists, and that we found no white-eyes in several stands of seemingly high-quality native forest above 170 m elevation where we would have expected them. Forests in the Marianas have been referred to as "typhoon forests" because disturbance is a characteristic feature of them. Most Micronesian forest birds are versatile in their use of foraging sites, as would be expected on islands that are periodically defoliated by typhoons (R. Craig, pers. comm.). White-eyes on other islands in the Marianas occur at high density and forage in all habitat types, and only on Rota do they appear to be habitat specialists. The Rota Bridled White-eye does occasionally forage in introduced stands of bamboo and in second-growth forest (R. Craig, pers. comm.; this study), but the great majority of observations are in old-growth limestone forest. Two additional exceptions to the rule that white-eyes in Micronesia are generalists are the Samoan White-eye, *Z. samoensis,* that is restricted to mountaintops above 900 m on Savaii in Western Samoa, and the Great Truk White-eye, *Rukia ruki,* that is common only at the summit of Tol Island (Pratt et al. 1987).

Several stands of forest that we searched for white-eyes appeared to be suitable old-growth limestone forest and were at elevations above 170 m (the lowest elevation where we found white-eyes), and yet no white-eyes were found there. All of these areas, such as the hillside below Polygon 4 or below the easternmost portion of Polygon 14 (Fig. 2), are immediately adjacent to areas where white-eyes occur at high density, although white-eyes have never been documented there. This distributional pattern is inconsistent with the notion of habitat limitation, and yet predation and avian disease cannot easily explain this result either. In addition to the need for further work on the taxonomic status of the Rota Bridled White-eye, research on microhabitat selection and nesting ecology, and removal experiments involving Black Drongos and rats, are needed to understand distributional anomalies and determine appropriate management actions for conservation of this species.

IMPLICATIONS FOR CONSERVATION OF HAWAIIAN FOREST BIRDS

In Hawai'i, it is now widely accepted that mosquito-borne avian diseases, primarily avian malaria, are responsible for the absence of native forest birds from forests at lower elevations where the mosquito *C. quinquefasciatus* is common throughout the year. This has resulted in a conservation strategy in Hawai'i of protecting and restoring native forests at higher elevations where disease transmission is reduced, and has recently prompted research to develop tools for identifying disease-resistant individuals that might be used as founders for starting new populations at lower elevations (e.g., Shehata et al. *this volume*). In both Hawai'i and Rota, however, we still cannot explain why certain bird species are absent from areas of seemingly suitable habitat. On Rota, for example, the Bridled White-eye has never been found in several patches of forest that seem to have the same forest structure and plant composition as nearby stands where the white-eye occurs. In Hawai'i, several introduced species that are presumably resistant to avian malaria, such as the Japanese White-eye (*Zosterops japonicus*) and the Red-billed Leiothrix (*Leiothrix lutea*), are missing from some lower-elevation forests, and there are "distributional anomalies" for native species as well (e.g., Scott et al. 1986, Ralph et al. 1998). The Red-billed Leiothrix may now be extinct on Kaua'i (Male and Snetsinger 1998) and its numbers have declined in lower-elevation forests on the island of Hawai'i in the past 40 years for unknown reasons (Ralph et al. 1998). These findings from Rota and the Hawaiian Islands suggest that factors other than avian disease may be responsible for large-scale changes in bird distribution and numbers, and they highlight the need for additional work in both high- and low-elevation forests to identify or rule out factors so that appropriate management actions can be taken.

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