Habitat Relationships and Life History of the Rota Bridled White-eye (*Zosterops rotensis*)

by

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HABITAT RELATIONSHIPS AND LIFE HISTORY OF
THE ROTA BRIDLED WHITE-EYE (*Zosterops rotensis*)

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(ABSTRACT)

The Rota bridled white-eye (*Zosterops rotensis*)(Aves, Passeriformes) has experienced a severe population decline and range restriction over the last four decades. Little is known about this species and factors involved in the decline and range restriction are unclear. This study examined the potential roles of habitat alteration, introduced black drongos (*Dicrurus macrocercus*), and introduced rats in the decline and gathered more information on the behavior and breeding biology of this species. New life history data were collected and Rota and Saipan bridled white-eyes were found to differ in nest site characteristics and some behaviors. The importance of habitat alteration was assessed by examining Rota bridled white-eye habitat relationships at the microhabitat, within-range, Sabana-wide, and island-wide levels. Rota bridled white-eyes show a preference for high elevation wet forest but what drives their distribution within their current range was unclear. However, the alteration of this forest type by supertyphoon Roy in 1988 was probably the major factor in the decline of Rota BWEs between 1982 and 1996. Black drongo and Rota bridled white-eye relationships were addressed using current and historical survey data. Black drongos were found to prey on Rota bridled white-eyes but they probably only played at most a partial role in the decline of the Rota bridled white-eye. Introduced rats densities were assessed in Rota bridled white-eye areas

and on other areas of the island and no evidence for rat numbers limiting Rota bridled white-eyes to their current range was found.

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TABLE OF CONTENTS

LIST OF TABLES...viii

LIST OF FIGURES...x

LIST OF APPENDICES...xiii

INTRODUCTION...1

METHODS AND STUDY AREA...9
- Data Collection...11
  - Rota Bridled White-eye Life History...11
    - Breeding Biology...11
    - Behavior...12
  - Seasonal Effects...13
  - White-eye Population Estimate...15
  - Habitat Alteration...15
    - Microhabitat Relationships...15
    - Within Range Relationships...17
    - Sabana-wide Relationships...18
    - Island-wide Relationships...21
    - Insect Relationships...21
  - Black Drongos...23
  - Rat Populations...25
- Statistical Analysis...26

RESULTS...30
- Rota Bridled White-eye Life History...30
  - Breeding Biology...30
  - Behavior...32
- Seasonal Effects...34
- White-eye Population Estimate...35
- Habitat Alteration...36
  - Microhabitat Relationships...36
  - Within Range Relationships...36
  - Sabana-wide Relationships...38
  - Island-wide Relationships...38
  - Insects Relationships...39
- Black Drongos...41
- Rat Populations...43

DISCUSSION... 44
Rota Bridled White-eye Life History.. 44
Seasonal Effects... 46
White-eye Population Estimate..46
Habitat Alteration...47
Black Drongos...54
Rat Populations.. 55
Management Recommendations...55

LITERATURE CITED...59

VITA..121

LIST OF TABLES

Table 1. Correlations between habitat variables and the first three principal components extracted from data recorded at 20 Rota bridled white-eye study sites on Rota, 1998 and 1999..........66

Table 2. Nest dimensions of Rota, Saipan, and Tinian bridled white-eye nests recorded in the Commonwealth of the Northern Mariana Islands, 1999. Wilcoxon rank-sum tests were used to determine the difference between Rota and Saipan bridled white-eye nests..........67

Table 3. Nest site characteristics of Rota and Saipan bridled white-eye nests recorded on the islands of Rota and Saipan, CNMI, 1998 and 1999..........67

Table 4. Method used to produce a crude estimate of the Rota bridled white-eye population size within five study regions on Rota, CNMI in 1998 and 1999..68

Table 5. Mean habitat characteristics for Rota bridled white-eye foraging habitat use (n = 32) and availability (n = 32). See text for descriptions of habitat measurements..........68

Table 6. Proportion of Rota bridled white-eye foraging substrate types and substrate species used and available in two Rota bridled white-eye study plots on Rota, CNMI 1998 and 1999..........69

Table 7. Mean density per hectare indices and frequency of birds detected over three survey periods in study plots designated high (≥ 2 white-eyes/ha) and low (< 2 white-eyes/ha) density Rota bridled white-eye areas by Fancy and Snetsinger (1996) on Rota, 1998 and 1999..........70

Table 8. Mean descriptive habitat characteristics for areas designated high (≥ 2 white-eyes/ha) and low (< 2 white-eyes/ha) density Rota bridled white-eye areas by Fancy and Snetsinger (1996) on Rota, 1998 and 1999. See text for descriptions of habitat measurements..........71

Table 9. Composition of woody flora (≥ 10 cm dbh) per hectare within ten study plots designated low (< white-eyes/ha) and ten study plots designated high (≥ 2 white-eyes/ha) density Rota bridled white-eye areas by Fancy and Snetsinger (1996)..........72

Table 10. Regression coefficients from stepwise multiple linear regression analyses for

three bird species occurring in Rota bridled white-eye study plots on Rota, 1998 and 1999. Sample size for all regressions was 18..................................74

Table 11. Regression coefficients from stepwise multiple linear regression analysis for Rota bridled white-eye abundance estimates on nine transects with 57 stations in the Sabana region of Rota, 1999. Model was significant ($P<0.001$) with an R^2 of 0.57..74

Table 12. Presence and absence of woody flora (≥ 10 cm dbh) within five Rota bridled white-eye study areas on the Sabana and six Mariana crow study sites at various locations around the island of Rota, CNMI...75

Table 13. The five woody species (≥ 10 cm dbh) in each of the twenty Rota bridled white-eye study plots with the highest basal areas and densities on Rota, CNMI, 1998 and 1999...77

Table 14. Pearson's correlation coefficients for abundance estimates of six bird species within 35-m radius sampling stations along transects on the Sabana region of Rota in 1982 (n = 66) and 1994 (n = 136)...78

Table 15. Mean black drongo detection per transect estimates for the Sinapalo, Sabana, and intermediate regions of Rota in 1982, 1995, and 1998..............................78

Table 16. Number of rats captured in 40 snaptraps in Rota bridled white-eye and four Mariana crow study areas in April 1999 on Rota, CNMI.................................79

Table 17. Approximate duration (days) of incubation period, nestling stage, and fledgling stage for four white-eye species (Zosteropidae)............................... 79

LIST OF FIGURES

Figure 1. Locations of the Sabana and the village of Songsong on the island of Rota, CNMI... 80

Figure 2. Locations of areas designated high and low density Rota bridled white-eye areas by Fancy and Snetsinger (1996)...81

Figure 3. Locations of Rota bridled white-eye study areas and study plots on the island of Rota, CNMI... 82

Figure 4. Locations of Mariana crow study sites on the island of Rota, CNMI.............83

Figure 5. Locations of the 25 transects surveyed using the variable circular plot method in 1982, 1997, 1994, 1995, and 1998 on Rota, CNMI. See Appendix E for information on how transect labels changed across years................................84

Figure 6. Locations of variable circular plot transects considered part of the Sabana, Sinapalo, and intermediate (areas not included in Sabana and Sinapalo regions) regions of Rota, CNMI...85

Figure 7. Monthly rainfall levels (inches) recorded at the Rota Airport on the island of Rota, CNMI in 1998 and 1999. Data from the NOAA webpage for the Rota Airport (see text for details)..86

Figure 8. Rota bridled white-eye foraging behaviors observed during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999...........87

Figure 9. Foraging substrate types used by Rota bridled white-eyes in the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.......... 87

Figure 10. Tree species used for foraging by Rota bridled white-eyes in the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.......... 88

Figure 11. Perch diameters used by foraging Rota bridled white-eyes during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999..88

Figure 12. Foraging locations of Rota bridled white-eyes observed during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999..89

Figure 13. Foraging heights used by Rota bridled white-eyes during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.......... 89

Figure 14. Foraging methods used by Rota bridled white-eyes on Rota in 1998 and 1999 and Saipan bridled white-eyes on Saipan (Craig 1989, 1990), CNMI.............90

Figure 15. Perch sizes used by foraging bridled white-eyes on Rota in 1998 and 1999 and Saipan bridled white-eyes on Saipan (Craig 1989, 1990), CNMI...................90

Figure 16. Foraging substrates used by Rota bridled white-eyes on Rota in 1998 and 1999 and Saipan bridled white-eyes on Saipan (Craig 1989, 1990), CNMI.............91

Figure 17. Rota bridled white-eye non-foraging behaviors recorded in the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999...........91

Figure 18. Mean (± SE) number of insects and snails per branch recorded during the wet (June - August) and dry (February - April) seasons in Rota bridled white-eye study areas on Rota, 1999...92

Figure 19. Mean (± SE) number of insects recorded per branch in the wet (June - August) and dry (February - April) seasons on four tree species sampled in Rota bridled white-eye study areas on Rota in 1999...92

Figure 20. Mean (± SE) number of snails recorded per branch in the wet (June - August) and dry (February - April) seasons on four tree species sampled in Rota bridled white-eye study areas on Rota in 1999...93

Figure 21. Differences in the percentage of trees flowering or fruiting between the wet (June - August) and dry (February - April) seasons in five Rota bridled white-eye study areas on Rota in 1999...93

Figure 22. Differences in percentage of tree species fruiting and flowering between the wet (June - August) and dry (February - April) seasons in five Rota bridled white-eye study areas on Rota in 1999..94

Figure 23. Mean (± SE) abundance per hectare indices of six bird species in Rota bridled white-eye study plots in three survey periods on Rota, 1998 and 1999...........94

Figure 24. Locations of transects surveyed on the Sabana in April 1999 on Rota, CNMI.. 95

Figure 25. Locations of upper and lower elevation insect biomass transects sampled in July 1999 on Rota, CNMI..96

Figure 26. Mean milligrams of eight insect orders per gram of plant mass between upper (380-450 m) and lower (150-250 m) elevations in mature *Elaeocarpus joga* trees along three transects on Rota in July 1999...97

Figure 27. Mean number of insects in six families sampled at upper (380-450 m) and lower (150-250 m) elevations in mature *Elaeocarpus joga* trees along three transects on Rota in July 1999... 97

Figure 28. Mean (± SE) number of snails and insects per branch sampled at three high (≥ 2.5 white-eyes) and three low (< 1.0 white-eye) abundance Rota bridled white-eye study plots on Rota in 1999...98

Figure 29. Mean (± SE) milligrams of insect per gram of plant mass and mean number of snails per gram of plant mass sampled at upper (380-450 m) and lower (150-250 m) elevations in mature *Elaeocarpus joga* trees along three transects on Rota in July 1999.. 98

Figure 30. Mean (± SE) abundance estimates of six bird species recorded along four transects on the Sabana in 1982 (Engbring et al. 1986) and 1994 (USFWS, unpubl. data) on Rota, CNMI. An asterisk by the species indicates a difference between years (T-test, P < 0.10).. 99

Figure 31. Mean (± SE) black drongo abundance indices in exterior (< 150 m from edge) and interior (≥ 150 m from edge) Rota bridled white-eye study plots in three survey periods on Rota in 1998 and 1999...99

Figure 32. Stomach contents of female and male rats (*Rattus tanezumi*) trapped on Rota bridled white-eye study sites in April 1999 on Rota, CNMI..........................100

LIST OF APPENDICES

Appendix A. GPS locations of Rota bridled white-eye study plots on Rota, CNMI, in 1998 and 1999....101

Appendix B. Locations of study plot point count stations on Rota, CNMI during 1998 and 1999. All point count stations marked with a square were not included in estimates of bird abundance....103

Appendix C. Program Distance (Laake et al. 1998) estimates of effective detection radii of 11 bird species recorded in Rota bridled white-eye study plots in 1998 and 1999....104

Appendix D. Program Distance (Laake et al. 1998) estimates of effective detection radius (EDR) for three point count stations in 20 Rota bridled white-eye study plots on Rota in 1998 and 1999....105

Appendix E. Number of stations and observers for each transect sampled using variable circular plot counts of birds in five survey periods on Rota, CNMI. See Figure 5 for locations of transects....106

Appendix F. Program Distance (Laake et al. 1998) estimates of effective detection radius (EDR) in meters for six bird species during 1982 and 1994 surveys on Rota, CNMI....108

Appendix G. Locations of Rota bridled white-eye nests found in 1997, 1998, and 1999 on Rota, CNMI....109

Appendix H. Nest discovery dates, fledging dates, and approximate durations of the incubation and nestling stages for all known Rota bridled white-eye nests discovered as active nests on Rota, CNMI....110

Appendix I. Banding and resighting information on nine Rota bridled white-eyes banded in 1998 and 1999 on Rota, CNMI....111

Appendix J. Photograph of a Rota bridled white-eye nest found in a *Merrilliodendron megacarpum* in 1999 on Rota, CNMI....112

Appendix K. Average number of insects and snails recorded per branch during six sampling periods in Rota bridled white-eye study plots on the island of Rota, CNMI in 1999....113

Appendix L. Percentage of five study areas containing fruiting (S) or flowering (F) members of 22 woody plant species over 12 two-week periods on Rota, CNMI in 1999 114

Appendix M. Breeding characteristics of 16 white-eye species (Zosteropidae) 118

Appendix N. Unsuccessful research methods used during this study on Rota bridled white-eyes on Rota in 1998 and 1999 120

INTRODUCTION

The Rota bridled white-eye (*Zosterops rotensis*) is a small bird (9-10 g) found only on the island of Rota, Commonwealth of the Northern Mariana Islands (CNMI). Rota is part of the Mariana Archipelago, a chain of 15 volcanic islands located in the western Pacific. The Rota bridled white-eye (Rota BWE) was originally classified *Zosterops conspicilliata rotensis*, a subspecies of *Zosterops conspicillata*, with Mariana Island subspecies found on both Saipan and Tinian (*Z. c. saipani*) and one, currently extinct, subspecies on Guam (*Z. c. conspicillata*) (Stresemann 1931). However, based on recent genetic work (Slikas et al. 2000) and observations of differences in plumage, vocalizations, and behavior by H. D. Pratt and colleagues (Pratt et al. 1987, Collar et. al. 1994), the Rota BWE is treated here as a full species.

Unlike the well studied silvereye (*Zosterops lateralis*) (Catterall et al. 1982, 1989; Kikkawa and Wilson 1983; Wilson and Kikkawa 1987; and others) and the recently studied Saipan bridled white-eye (Saipan BWE) (Craig 1989, 1990), the Rota BWE has not received much research attention. Before this study, work on the Rota BWE focused on population estimation (Engbring et al. 1986, Engbring 1987, Ramsey and Harrod 1995, Fancy and Snetsinger 1996) along with a few publications on nest descriptions (Yamashina 1932, Pratt 1985, Lusk and Taisacan 1997) and behavior (Craig and Taisacan 1994). Consequently, little is known about this species.

In 1991, the Rota BWE was listed as threatened or endangered by the CNMI government (the CNMI makes no distinction between the threatened and endangered categories) (Public Law 2-51). Presently, the Rota BWE is also a candidate species for protection under the U.S. endangered species act (61 FR 7596). The listing of this species by both governments was a result of concern over the apparent population decline and range restriction of the species over the last several decades.

Early descriptions of the Rota BWE by Baker (1948) describe this species as "numerous" and found at lower elevations. Residents of Rota during the post-war years (>1945) also remember seeing Rota BWEs at low elevations in Songsong village (Fig. 1) (Engbring et al. 1986). However, in 1975, Pratt et al. (1979) found no Rota BWEs in the lowland areas and only observed birds on the central plateau region (Sabana)(Fig. 1). In 1977, Ralph and Sakai (1979) estimated Rota BWE densities to be 22 birds/km^2, (17% of the density reported on Saipan, CNMI) although the majority of their work was done using roadside counts on the Sabana, which may have resulted in lower counts.

The first island-wide survey of forest birds on Rota was conducted in 1982. During this survey Rota BWEs were only found in forested areas above 300 m elevation (Engbring et al. 1986). The average BWE density on Rota was determined to be 296/km^2 (6% of the average density of BWEs on the island of Tinian, CNMI) with an island population estimate of 10,763 birds (95% CI = 8,270 to 13,256 birds). Other surveys following the 1982 survey showed little change in the Rota BWE distribution but did show a decline in white-eye numbers (Engbring 1987, 1989; Craig and Taisacan 1994). In 1994, the U.S. Fish and Wildlife Service (USFWS) did a survey focusing on the Rota BWE and found that densities had decreased by approximately 50% (to 155 birds/km^2)

from the 1982 estimate (Ramsey and Harrod 1995). In the fall of 1996, a survey by Fancy and Snetsinger (1996) estimated the population of Rota BWEs to be 1,167 birds, an 89% decline from the 1982 estimate.

The 1996 survey determined that the population was restricted primarily to four patches of forest covering an area of 259 ha above 200 m elevation (this elevation change from the 1982 estimate may reflect increased survey coverage and not a range expansion) (Fig. 2). These patches were located near the Uyulan Hulo (65 ha) and As Mundo areas, the southern cliffs of the Sabana (133 ha), and the northeast portion of the Sabana (41 ha) (Fancy and Snetsinger 1996). Ninety-four percent of the Rota BWEs were found to occur in these patches. The remaining 6% of the population was located in what were considered low density areas (748 ha) (Fig. 2).

Factors implicated as potential causes of the population decline and range restriction of the Rota BWE were: (1) habitat loss, (2) avian disease, (3) introduced predators, and (4) pesticides. A thorough review of the available information on each factor was given by Fancy and Snetsinger (1996). However, for completeness a brief description of each factor is given below.

Habitat loss is an important factor in the decline and range restriction of many white-eye species. Eleven of the 21 white-eye species listed in the IUCN's list of threatened birds are threatened by habitat loss (Collar et al. 1994). Loss of native habitat on Rota is primarily a result of land clearing for agriculture or development and storm damage from typhoons.

Rota can be divided into 10 main habitat types: native limestone forest (58% of island), secondary vegetation (13%), introduced forest (1%), introduced ironwood (*Casuarina equisetifolia*) thickets (2%), agroforest (5%), grassland (15%), strand (3%), urban (1%), cultivated (< 1%), and barren (< 1%) (Falanruw et al. 1989). A full description of each of these habitat types can be found in Fosberg (1960) and Falanruw et al. (1989). The Rota BWE is believed to be primarily a native limestone forest species (Fancy and Snetsinger 1996), though it has been recorded in secondary growth (Craig and Taisacan 1994, pers. obs.) and introduced forest (Fancy and Snetsinger 1996, pers. obs.). Native limestone forest on Rota can be divided into two categories based on elevation. The forests at low elevation tend to be drier forests because of low levels of rainfall during the dry season. Forests at high elevation tend to be predominantly wetter forests because of the high levels of rainfall these areas receive year round caused by accumulation of clouds over the Sabana (Fosberg 1960, Falanruw et al. 1989). The 1996 distribution of Rota BWEs shows that the highest densities are found in the wet limestone forests (Falanruw et al. 1989, Fancy and Snetsinger 1996).

Documentation of land clearing on Rota began during the Japanese administration (1914-1944) even though changes in vegetation communities have occurred since the island was first colonized by humans (Chamarros) (Fosberg 1960). Unfortunately, documentation on the changes in native forest did not distinguish between low elevation dry and high elevation wet native limestone forests. During the Japanese administration, much of the level land on Rota was cleared for sugar cane cultivation and areas on the Sabana were cleared for phosphate mining (Bowers 1950, Fosberg 1960, Engbring et al. 1986). To support the economic development of the island, the population increased to over 7,000 people (a 1,500 % increase from the population in 1913) and a narrow gauge train system was built to transport sugar cane and phosphate (Bowers 1950). Rota was spared invasion during World War II but was heavily bombed (Engbring et al. 1986). In 1946, approximately 25% of the total area of Rota was covered in well-developed forest divided into small parcels or located along the base of cliffs (Fosberg 1960). Engbring et al. (1986) reported that 60% of Rota was composed of native forest in 1982, with a large portion of this being in an altered condition. The best developed forests were found along the cliffs of the Sabana with the forests on level portions of the island being primarily secondary growth. Today, because of land clearing for the Rota Resort, < 60% of the island is covered with native limestone forest. However, the amount of native limestone forest remaining today is probably substantially more than was available during and immediately after the Japanese administration due to the reduction in land use after World War II (Bowers 1950).

The majority of the high elevation forests along the upper plateau have not been threatened by development and clearing because of their rugged topography. However, these high elevation areas have received extensive typhoon damage in the past 12 years which resulted in a decrease in wet native limestone forest at high elevation. In 1988, Typhoon Roy hit Rota with winds >150 mph and completely defoliated almost all forests (Fancy and Snetsinger 1996). In some areas 50% of trees were downed and 100%

suffered limb damage. The wet forests of the upper cliffline were drastically altered by this storm and did not recover quickly (Fancy and Snetsinger 1996). In December 1997, super typhoon Paka hit Rota and much of the upper plateau was defoliated again (J. M. Morton, USFWS, pers. comm.).

The spread of malaria (*Plasmodium relictum capistranoe*) and avian pox (*Poxvirus avium*) by the introduced mosquito, *Culex quinquefaciatus*, was implicated as the cause of the extinction of much of Hawaii's avifauna from 1920 to the present (Warner 1968, van Riper et al. 1986). However, no evidence of disease playing a role in native bird population declines in the Mariana Islands has been reported. Observations made by biologists and veterinarians working on Rota do not indicate the presence of pathogens or of an epidemic occurring there (Pratt and Sileo 1983, Fancy and Snetsinger 1996). However, no extensive sampling for pathogens in native forest birds has occurred on Rota, so it is not possible to completely rule out disease as a factor in the decline.

Introduced predators include the brown tree snake (*Boiga irregularis*), Asian house rat (*Rattus tanezumi*), Polynesian rat (*Rattus exulans*) and the black drongo (*Dicrurus macrocercus*). Black drongos were thought to have been introduced to Rota from Taiwan by the Japanese South Seas Development Company in 1935 to control destructive insects (Baker 1948). Black drongos are noted for their aggressiveness toward and occasional predation on small passerines (Ali and Ripley 1972, Maben 1982). On Guam, black drongos have been observed eating small birds such as Eurasian tree sparrows (*Passer montanus*) (Maben 1982), rufous fantails (*Rhipidura rufifrons*), and

Guam swiftlets (*Aerodramus vanikorensis*) (Perez 1968). Craig and Taisacan (1994) suggested that black drongos were responsible for the decline and range restriction of the Rota BWE based on correlations between the increasing abundance of drongos on the Sabana and the decline of Rota BWEs. They reported that survey data by Engbring et al. (1986) showed that the density of potential black drongo prey species, like the Rota BWE and rufous fantail, were lower in areas with high black drongo densities. They also reported, based on personal observations, that black drongos became more abundant in the 1960s when the decline of Rota BWEs was first noted. However, no data are available to confirm this and the reason for the apparent increase in black drongo numbers is unknown.

Two species of introduced rat, *Rattus tanezumi* and *Rattus exulans*, have been recorded on Rota (Johnson 1962, Flannery 1995). *Rattus tanezumi* was thought to have been introduced to Micronesia over 1,000 years ago, while *Rattus exulans* was believed to have been introduced during European colonization between 200-500 years ago (Flannery 1995). The impact of *Rattus tanezumi* on bird populations is unknown. However, Olson and James (1982) concluded that *R. exulans* was a contributing factor to the massive extinctions of Hawaiian bird species that took place during the Polynesian occupation.

Little research has been done on the effects of introduced rats on Rota's avifauna. In fact, there was some uncertainty as to which species of rat was commonly found on the island. However, morphometrics of trapped specimens indicate that *Rattus tanezumi* is probably the most common species (Morton et al. 1999). Recent work by

Morton et al. (1999) indicates high densities of rats may exist on Rota. Nest success data on the rufous fantail indicate that nest predation by rats may have important negative impacts on nesting success (S. Plentovich, USFWS, pers. comm.). However, no data are available on the effects of rats on Rota BWEs.

The brown tree snake was found to be the major factor in the decline of native forest birds on Guam with the smallest species, such as the Guam BWE, experiencing declines first (Savidge 1986, 1987). However, no observations of live brown tree snakes have ever been reported on Rota (G. Rodda, U.S. Geological Survey, pers. comm.) and no other bird species appear to be experiencing a severe decline. Because of this, Fancy and Snetsinger (1996) did not believe that the brown tree snake was a factor in the decline of the Rota BWE.

Pesticides were considered a factor in the decline of the Rota BWE due to the reports that the U.S. military liberally applied DDT on the Mariana Islands during and after WWII (Baker 1946, Grue 1985). Pesticide use on Guam was also implicated as a potential factor in the decline of Guam's avifauna (Diamond 1984, Jenkins 1983) but concentrations of DDT and DDE in swiftlet carcasses and guano were considered to be too low to cause mortality or reproductive failure (Grue 1985). The insecticide malathion was used on Rota to control the melon fly in 1988 and 1989 (Engbring 1989). A study to monitor the status of birds on Rota before and after the insecticide application did not report any adverse effects on Rota's bird populations (Engbring 1989). Based on this information, Fancy and Snetsinger (1996) determined that there was no evidence for pesticides being an important factor in the decline of the Rota BWE.

Based on a review of the available information and the recommendations of Fancy and Snetsinger (1996), we decided to focus our research on accomplishing two basic goals. The first goal was to gather more information on Rota BWE life history. The second goal was to reassess the role that habitat alteration, black drongos, and introduced rats played in the decline and range restriction of Rota BWE populations and provide relevant management and research recommendations. The objectives of this study were the following: (1) gather information on Rota BWE behavior and breeding biology for comparison with Saipan BWEs; (2) examine seasonal differences in bird abundance, insects, and fruiting and flowering tree species; (3) produce a crude estimate of the Rota BWE population during the study period; (4) examine Rota BWE habitat relationships at the microhabitat, within range, Sabana-wide, and island-wide levels; (5) examine the relationships between black drongo and Rota BWE numbers using current and historical survey data; and (6) determine if rat densities differ between the Rota BWE's current range and the rest of the island.

METHODS AND STUDY AREA

This study took place on the islands of Rota (14º 10' N, 145º 12' E), Saipan (15º 12' N, 145º 45' E), and Tinian (15º 10' N, 145º 38' E) during June-August 1998 and January-August 1999. This study encompassed two wet seasons (June - August 1998 and 1999) and one dry season (February - April 1999). Rota has the highest elevation (491 m) of the three islands followed by Saipan (436 m) and Tinian (178 m). Saipan is the largest

(122 km^2) of the three islands followed by Tinian (100 km^2) and Rota (86 km^2). The climate on all three islands is tropical, with mean temperatures of 24 to 32^o C, high humidity, and average annual rainfall of 200 to 260 cm (NOAA 1998). We focused our research on the island of Rota but did gather supplementary information from the Marpi region of Saipan and the entire island of Tinian.

On Rota, we conducted our study on the five regions of the 450 m high plateau known as the Sabana, which dominates the western half of the island. The regions of the Sabana we used as study areas were as follows: (1) northeastern Sabana (Area A); (2) As Mundo (Area B); (3) Uyulan Hulo (Area C); (4) southern cliffs of the Sabana (Area D); and (5) the southeastern cliffs of the Sabana (Area E)(Fig. 3). We selected these regions because they encompassed the areas designated high density Rota BWE areas by Fancy and Snetsinger (1996).

We set up 20 study plots and distributed them among the five study areas listed above (Fig. 3) (Appendices A and B). Each study plot consisted of four 50-m radius point count stations arranged in a square. The centers of the point count stations were 100 m apart and at 90^o angles to one another. We determined the location of one corner of each study plot by overlaying a grid on a map of Fancy and Snetsinger's (1996) high and low density Rota BWE areas and selecting a random location using a random numbers table. We then placed the remaining corners of the study plot so that the entire study plot was within the same habitat type and Rota BWE density. In addition, we attempted to place all study plots at least 200-m apart, from 100 - 450 m elevation, and within habitat classified as LI2H (mature native limestone forest with crown closure > 70 % and trees averaging > 30 cm diameter at breast height (dbh)) by Falanruw et al. (1989). We placed our study plots within this habitat classification because over 80% of the locations in which Fancy and Snetsinger (1996) detected Rota BWEs (n = 70) were in this habitat type.

Eighteen study plots were set up during the 1998 field season and two additional study plots (3HC and 3HD) were added in the 1999 field season. The 18 study plots set up in 1998 were divided equally into high ($\geq$ 2 white-eyes/ha) and low (< 2 white-eyes/ha) density Rota BWE areas as designated by Fancy and Snetsinger (1996). The density estimates we obtained for the study plots after the 1998 field season determined that fewer then half (n = 7) of the study plots actually contained high densities of Rota BWEs. Therefore, we placed the two study plots added in 1999 in areas that could be designated high density Rota BWE areas based on observations of Rota BWEs by Fancy and Snetsinger (1996).

DATA COLLECTION

Rota Bridled White-eye Life History

Breeding Biology- We intensively searched for Rota BWE nests in six study plots to obtain demographic and nest site characteristic information. Nests were monitored a minimum of every four days using either a mirror on a telescoping pole or a spotting scope. We also used precautions proposed by Martin and Geupel (1993) to minimize observer-induced mortality. When possible we recorded clutch size, number of nestlings, and number of fledged young and assessed reasons for nest or clutch failure. When nests were accessible we attempted to band chicks with a USFWS aluminum band and distinct combination of color bands prior to fledging.

We took the following measurements on all inactive nests: (1) dbh of nest tree, (2) nest height, (3) tree height, (4) tree species, (5) distance from nest to bole, (6) orientation of nest, and (7) elevation. When nests were accessible, we also recorded nest dimensions (nest depth, inner diameter, outer diameter, total nest height, and material used). We also recorded nest site characteristics and nest dimensions of inactive Saipan and Tinian BWE nests for comparison with Rota BWE nests.

Behavior- We collected discrete behavioral observations on Rota BWEs to examine seasonal differences in behavior and differences in foraging method and microhabitat use between Rota and Saipan BWEs (Craig 1989, 1990). We recorded the following at each behavioral observation: the activity (foraging, resting, flying, maintenance, singing, and intra-and inter-specific agonism), foraging mode (search, glean, reach, hang, pick, probe, lunge, leap, sally, and sally-hover), location (canopy or understory tree; vertical zone: < 3 m, 3-6 m, and > 6 m; horizontal zone: inner and outside tree), foraging substrate (branch, dead branch, trunk, leaf, dead leaf, rolled leaf, bud, flower, fruit, epiphyte and air) to species if possible, perch diameter (in relation to body size), and size and type of prey (in relation to bill size) (Craig 1989, 1990; Remsen and Robinson 1990). In addition, for the 1999 field season, we collected discrete behavioral observations of Saipan BWEs and recorded data on Rota and Saipan BWE flock size at each observation. We only recorded data on behavioral observations after a 13 second monitoring period to avoid visibility bias (Bradley 1985). We determined the duration of the monitoring period by taking continuous observations of eight individuals and determining the average time (13 sec) necessary before a change in horizontal location occurred. We also sampled only one Rota BWE from each 50-m radius point count station during any time of day category (0600-1000, 1000-1400, 1400-1800) on a given day in a study plot to minimize bias.

Seasonal Effects

We examined seasonal effects by looking at differences in fruiting, flowering, insect and snail numbers, and bird abundance estimates between the wet and dry seasons. We assessed percentage of tree species fruiting and flowering at two week intervals by recording if a tree species was fruiting or flowering in each study region using methods similar to those used by J. M. Morton (unpubl. data) for a study on the Mariana crow (*Corvus kubaryi*). We used the fruiting and flowering data to calculate the percentage of tree species in a study region fruiting or flowering in the dry or wet season. To calculate this percentage we divided the number of tree species fruiting or flowering in the region by the total number of tree species found in that region. We also used the fruiting and flowering data to calculate the percentage of study regions with a tree species fruiting or flowering in the dry and wet season. We calculated this percentage by dividing the number of study regions with the tree species fruiting and flowering by the total number of study regions (5).

We examined seasonal changes in insect and snail numbers using a branch clipping technique described by Schowalter et al. (1981). Branches of four tree species (*Elaeocarpus joga*, *Hernandia labyrinthica*, *Merrilliodendron megacarpum*, and *Premna obtusifolia*) were covered in a plastic bag with a drawstring attached to a telescoping pole, clipped with a branch pruner, sprayed with insecticide and searched for insects and snails. We systematically sampled eight branches (approximately equal size) from eight trees of each species among three high (> 2.5 Rota BWEs/ha) and three low (< 1.0 Rota BWE/ha) abundance Rota BWE study plots. We calculated the number of insects or snails per branch for each tree species and overall.

We assessed seasonal differences in bird abundance estimates by calculating an abundance index for Rota BWEs, black drongos, and other forest birds in each study plot using point count methods described by Ralph et al. (1995). We collected bird detection distance data at three point count stations in each study plot. The three corners used for the point counts were determined by using a random numbers table to select one corner to not sample. One observer censused each point count station within a study plot on the same day for 10 minutes between sunrise and 1100. We censused each study plot a minimum of three times on non-consecutive days during the wet season (June - August) of 1998 and the wet (June - August) and dry (February - March) seasons of 1999. We calculated the effective detection radius for each species (Appendix C) and for each point count station (Appendix D) using the DISTANCE program (Laake et al. 1998). We determined that Rota BWEs had the smallest detection radius (25 m) and that this detection radius was below the effective detection radii of each point count station. We then used 25-m radius as the cut off point to determine bird abundance in each point count station. We averaged the abundance estimates of each point count station in a study plot for a particular survey day to calculate an abundance index for the study plot. We then used the highest abundance index estimate within each survey period (wet season 1998, dry season 1999, wet season 1999) as the abundance index estimate for that survey period.

White-eye Population Estimate

We calculated a crude population estimate for Rota BWEs over the study period using bird abundance indices for each study plot in each survey period (see Seasonal Effects for methods). We averaged the abundance indices for all study plots within a region to produce an overall abundance index for that region. We then calculated the approximate area of forest represented by the study plots in a region. This area was then multiplied by the abundance index for that region to produce a population estimate for that region. The population estimates from each region were then totaled to give an overall population estimate for Rota BWEs within our study area.

Habitat Alteration

Microhabitat Relationships- We examined foraging habitat selection by comparing habitat characteristics of Rota BWE foraging sites and systematically sampled locations in each study plot using methods similar to those used by VanderWerf (1993) and Sillet (1994). The locations of Rota BWE foraging habitat sites were determined by the first recordable foraging observation within a study plot (See Behavior section for methods). We assessed foraging habitat use by recording habitat characteristics of foraging sites at three hierarchically-nested scales (fine, intermediate, and broad) during the 1999 field season (February - August). At the fine scale, we recorded the foraging substrate and percent foliage volume within a 0.5-m radius sphere around the foraging location. At the intermediate scale, we measured percent canopy cover and foliage volume at three height classes (0-3 m, 3-9 m, 9-15 m) within 1.5 m of the foraging location. We measured canopy cover by recording the presence or absence of canopy while standing directly below the foraging location and at 0.5 m intervals along a 1.5 m transect in each of the four cardinal directions. We measured percent foliage volume at each height interval directly below the foraging location and at 1.5 m in each of the four cardinal directions using a 15-m telescoping pole. The number of 10-cm sections intercepted by vegetation within the five height classes was recorded and divided by the total number of 10-cm sections available at each height class (0-3 m = 150, 3-9 m = 300, 9-15 m = 300). At the broad scale, we measured the dbh and species of all woody vegetation $\geq$ 10 cm dbh in a 400-m^2 sampling area centered on the foraging location.

We determined availability of foraging habitat by taking the measurements described above by randomly selecting (using a random numbers table) one of the two systematically sampled habitat sampling areas within the same 50-m radius point count station as the foraging observation. At each 50-m radius point count station within a study plot we set up two 400-m^2 circular habitat sampling areas (radius = 11.3 m). We centered one habitat sampling area on the center of each point count station and the remaining habitat sampling area was placed a random distance (23-39 m) and compass direction from the center of the station. The broad scale habitat characteristics were recorded in the 1998 and 1999 field seasons. The fine and intermediate foraging habitat characteristics were measured at the center of the habitat sampling area during the 1999 field season (February - August). We took the percent foliage volume measurement on a randomly selected substrate (using a random numbers table) intersecting an imaginary 0.5-m radius cylinder extending from 1.5 m above the ground to the top of the canopy. We determined the availability of substrates by recording the species, substrate type, and height of all substrates that intersected the 0.5-m radius cylinder.

Within Range Relationships- To assess Rota BWE within range relationships we calculated the mean Rota BWE abundance index over the three survey periods for each study plot (see Seasonal Effects for methods) and characterized the habitat in each study plot using methods recommended by Noon (1981). We characterized the habitat in each study plot by setting up two 400-m^2 circular habitat sampling areas within each of the three 50-m radius point count stations censused within a study plot (see Microhabitat Relationships for methods). We then recorded the dbh and species (based on the taxonomic classification reported in Raulerson and Rhinehart (1991)) of all woody vegetation $\geq$ 10 cm dbh, shrub density, canopy cover, and canopy height within each habitat sampling area during the 1998 and 1999 field season. Epiphyte volume and foliage volume were recorded within each habitat sampling area during the 1999 field season (February - August). The estimates for each habitat variable in each habitat sampling area were then averaged across the study plot to produce an estimate for the study plot.

We measured shrub density (< 10 cm) by counting the number of stems at breast height within a 11 x 1.8 m (length of outstretched arms = 1.8 m) transect in each of the cardinal directions within the habitat sampling areas. We determined percentage canopy cover by recording the presence or absence of canopy at 24 points 2 m apart along 11-m transects in the four cardinal directions. We measured average canopy height to the nearest meter using a 15-m telescoping pole. We measured foliage and epiphyte volume using a 15-m telescoping pole marked at 10-cm intervals using a method described by MacArthur and Horn (1969). We set up the pole at the center of the habitat sampling area and 1.5 m and 3.5 m from the center in the four cardinal directions. Foliage volume was determined by calculating the total number of 10-cm sections intercepted by vegetation at three height intervals (0-3 m, 3-9 m, 9-15 m) and dividing by the total number of 10-cm sections available at each height interval (0-3 m = 270, 3-9 m = 540, 9-15 m = 540). Epiphyte volume was calculated by determining the number of 10-cm sections intercepted by an epiphyte in each epiphyte class (compound fern, simple fern, bird nest fern, orchid, moss, and native vine) and dividing by the total number of 10-cm sections available (150 10-cm sections x 9 sampling stations = 1350).

Sabana-wide Relationships- To obtain habitat and abundance data on Rota BWEs outside the study plots we set up a survey of the Sabana region. We attempted to sample forested habitat in all compass directions around the Sabana. To allocate transects around the Sabana we divided the Sabana into nine blocks and placed one transect into seven of the nine blocks and randomly selected two blocks for placement of a second transect to obtain a total of nine transects. We excluded the block on the south side of the Sabana because it contained large areas of open grassland, pasture, and cropland, which we avoided because Rota BWEs have rarely been detected in these areas. We also excluded the block on the top of the Sabana because this region is all the same elevation and we were interested in examining changes in Rota BWE abundance with changes in elevation. We determined the starting point for each transect by overlaying a grid on each block and selecting a point within each block using a random numbers table. We then started each transect at the nearest road to the point and headed toward the highest elevation through as much forested area as possible. As we stated above, we avoided large sections of treeless areas such as grassland, pastures, and croplands and we avoided cliffs and other impassable terrain for safety reasons and to make the transects as long as possible. We surveyed each transect with the assistance of USFWS personnel and volunteers in teams consisting of a designated bird observer and habitat data recorder. We ran each transect from sunrise to completion or 1000 depending on which came first.

At 150-m intervals along each transect, we set up a survey station, consisting of a 35-m radius and 15-m radius sampling area, to record information on birds and habitat characteristics. Inside and outside the 35-m radius sampling area we recorded the number of Rota BWEs, black drongos, and Mariana crows over a 10 minute survey period. In addition, we recorded the presence or absence of other forest birds. We also recorded percent cover of the following habitat types within the 35-m radius sampling area: (1) mature limestone forest, (2) young limestone forest, (3) faniok forest, (4) introduced forest, (5) tangen-tangen thicket, (6) bamboo thicket, (7) screw pine thicket, (8) secondary vegetation, (9) agroforest, (10) cropland/pasture, and (11) grassland. Definitions of the habitat types used were based on descriptions given by Falanruw et al. (1989) with some modifications. We defined mature limestone forest as native forest with trees averaging ≥ 30 cm dbh and we defined young limestone forest as all remaining native limestone forest size classes. We defined faniok forest as forest dominated by *Merrilliodendron megacarpum*. We defined tangen-tangen thicket and bamboo thicket as introduced forest areas dominated by *Leucaena leucocephala* and *Bambusa vulgaris* respectively. Finally, we defined screw pine thicket as areas dominated by thick growth of *Pandanus dubius* or *P. tectorius*.

Within the 15-m radius survey area, we recorded the number of trees ≥ 30 cm dbh as well as a rating of the presence of succulent ground cover plants (*Elatostema* spp. and *Procris* spp.). We determined the presence rating of these plants by dividing the 15-m radius sampling area into four quarters using the four cardinal directions. We then used the presence or absence of these plants in each quarter to calculate a presence rating from 0 to 4 (4 being present in all quarters). In addition to the above measurements, we recorded the elevation, survey conditions (percent cloud cover, wind speed, wind direction, time, and presence or absence of rain), and elevation of first Rota BWE observation (even if observed outside sampling stations).

Island-wide Relationships- To compare the presence and absence of tree species within the current range of the Rota BWE with other areas of the island (primarily low elevations), we compared habitat data we collected in each Rota BWE study site (see Within Range Relationships for methods) with habitat data collected by J. M. Morton (unpubl. data). Field crews under Morton's direction collected habitat data in 1998 and 1999 as part of a Mariana crow study in six study sites (Fig. 4). In each of the six Mariana crow study sites, they sampled habitat in ten 500-m^2 circular habitat plots (12.6-m radius). They determined the locations of habitat sampling plots by overlaying a grid system on a map of each Mariana crow study site, dividing the site into sections, and using a random numbers table to determine the latitude and longitude of the habitat sampling plot in each section of the site. Within each habitat sampling plot, they recorded the dbh and species of all woody stems $\geq$ 2.5 cm dbh. They then calculated the density and basal area of all woody species $\geq$ 10 cm dbh in each Mariana crow study site.

Insect Relationships- Because the Rota BWE appears to be primarily insectivorous (pers. obs.), we gathered some data on insect numbers to look for relationships between insects, elevations, and Rota BWE abundance. We also examined relationships between the Rota BWE and rufous fantail, a small insectivorous passerine we observed foraging with Rota BWEs. Data on insect and snail numbers per branch were collected in three high and low abundance Rota BWE study plots (see Seasonal Effects for methods). In addition, we gathered data on insect and snail numbers at high and low elevations. Rota BWE and rufous fantail relationships were examined using abundance estimates for both species within the Rota BWE's current range and along transects on the Sabana (see Seasonal Effects and Sabana-wide Relationships for methods) and using habitat data collected within the Rota BWE's current range (see Within Range Relationships for methods).

Data on insect numbers at different elevations were collected by setting up three transects that passed through contiguous native limestone forest from low elevations (150 - 250 m) to high elevations (380 - 450 m). The location of each transect was determined by the presence of *Elaeocarpus joga* and contiguous limestone forest between high and low elevations. At the extreme upper and lower elevations of each transect we sampled five *Elaeocarpus joga* trees at least 20 m apart. We selected only *Elaeocarpus joga* trees for sampling because of their high use by Rota BWEs, wide distribution among elevations, and time constraints. We selected the first tree for sampling at each end of the transect by entering the forest a random distance and direction and selecting the closest tree. We selected the remaining trees by picking the closest tree > 20 m from the last tree along the same general elevation gradient. At each tree sampled, we collected the highest accessible branch (approximately 6 m above the ground) on opposite sides of the tree (North and South if available). We covered each branch to be collected in a plastic bag attached to a telescoping pole and closed it with a drawstring. The branch was clipped with a tree pruner and insecticide was sprayed in the bag.

We searched the contents of each bag and preserved all insects (in formalin) and branch samples (in bags) for weighing and identification at the lab. We counted all snails found on each branch sample but did not weigh them because of potential problems with importing them to the mainland United States. We identified all insects collected to order and family (if possible), dried them for 24 hrs at 50°C, and weighed them. All branch samples were divided into leaves and woody tissue, dried for 24 hrs at 50°C, and weighed. To make the samples comparable, we then divided insect mass by the total mass of leaves and branches in the sample to obtain the insect biomass per gram of plant mass for that sample. We then took the mean of the samples for the high and low elevation section of each transect.

Black Drongos

We used black drongo data collected in this study and from previous bird surveys to look at black drongo and Rota BWE relationships in several ways. First, we tried to determine if black drongo numbers were lower on the Sabana than other regions of the island as was previously reported by Craig and Taisacan (1994). Then we used data on bird numbers collected in this study and from previous surveys to look for relationships between black drongos and small passerines, like Rota BWEs and rufous fantails, that could be potential prey for black drongos. We also used previous survey data to look at differences in black drongo, small passerine, and other bird numbers on the Sabana over time. Finally, we tried to assess black drongo habitat relationships within the Rota BWE's current range and at the Sabana-wide level.

The data used from this study were collected at each Rota BWE study plot and along each transect on Sabana using methods described earlier (see Within Range Relationships and Sabana-wide Relationships for methods). The previous bird survey data were collected using the variable circular plot (VCP) method (Reynolds et al. 1980) and included data collected in 1982 (Engbring et al. 1986) and 1987 (Engbring 1987) and unpublished data from 1994, 1995, and 1998 (USFWS, unpubl. data). Over the five survey periods, 25 transects (Fig. 5) with sampling stations located 150-m apart were sampled.

Due to inconsistencies in how and when the data for these previous surveys were collected (Appendix E), we made a series of changes to the survey data to make them more manageable. First, we calculated the effective detection radiuses of Rota BWEs, black drongos, and four other bird species in 1982 and 1994 using the DISTANCE program (Laake et al. 1998) (Appendix F). We then calculated the abundance of each species by limiting observations to 50-m radius or the smallest effective detection radius for each species in both years (if < 50-m radius). We used 50-m radius or the effective detection radius because of concerns over detectability at long distances and the independence of each survey station. In 1995 and 1998 survey sites were only censused by one observer, while during the remaining years (1982, 1987, and 1994) each station was censused by two observers. To deal with this inconsistency, we calculated abundance estimates for each survey station by taking the mean of both observers. To make comparisons between years, we used only data from survey stations that were censused in multiple years at the same time of year (March-May). Finally, to compare black drongo numbers on the Sabana with other areas of the island we divided the island into the Sabana, Sinapalo, and intermediate regions (Fig. 6).

Rat Populations

We surveyed rat populations in Rota BWE areas for comparison with rat population estimates of Mariana crow study sites. In Rota BWE areas, we set up one 100-m trapping transect on each of eight study plots (2HA, 1HB, 1LB, 1HC, 1LC, 1HD, 2HD, 1LD) distributed among four different study regions. Each transect consisted of five snaptraps spaced 25 m apart for a total of 40 traps. In Mariana crow study sites, two 500-m transects were set up in each study site (Morton et al. 1999). Each transect consisted of 20 traps spaced 25 m apart for a total of 160 traps. Traps on all transects were alternately set in a tree or on the ground and all transects were trapped for five consecutive nights. All traps were checked each morning and baited with fresh coconut and peanut butter. We recorded the status of each trap as: (1) empty, (2) rat, (3) missing, (4) tripped and empty, and (5) tripped and containing a non-target species (e.g. hermit crab). We also recorded morphometrics, weights, and stomach contents of most rats trapped in Rota BWE study areas. Morphometrics and weights of rats trapped in Mariana crow sites were also recorded by Morton et al. (1999).

We determined rat population estimates for each study area by calculating rats per trap-night using two different versions of trap-night. One estimate was based on the total number of traps per night (potential trap-nights). The second estimate was based on the number of traps that were not missing, accidently sprung, or containing non-target species (actual trap-nights).

STATISTICAL ANALYSIS

Prior to analysis we checked all data for normality using the Shapiro-Wilk normality test. Statistical methods were then selected based upon the outcome of these analyses. In instances where parametric and non-parametric tests were appropriate for different measurements within a data set (e.g. measurements of nest site characteristics) we always used non-parametric procedures. All analyses were considered significant at $P \leq 0.10$.

Rota Bridled White-eye Life History

We compared nest site characteristics and nest dimensions of Rota and Saipan BWE nests using the Wilcoxon rank sum procedure. We assessed differences in foraging behavior and microhabitat use between Rota and Saipan BWE using descriptive statistics. We also examined differences in behavior between the wet and dry season using descriptive statistics. We defined the wet season as June-August and the dry season as February-April based on monthly rainfall data collected at the Rota Airport (National Weather Service website: www.nws.noaa.gov) during the 1998 and 1999 field seasons (Fig. 7).

Seasonal Effects

We tested for differences in percentage of trees fruiting and flowering between the dry (February - April) and wet (June - August) seasons using Wilcoxon signed-rank tests. Differences in percentage fruiting and flowering of tree species across different study sites were examined using descriptive statistics. Differences in insect and snail numbers between seasons were also examined using descriptive statistics. Seasonal differences in bird abundance indices were examined using a two-way ANOVA with Tukey multiple comparison procedures.

Habitat Alteration

Microhabitat Relationships- We analyzed foraging habitat selection using a paired t-test or, if several of the variables were related, with a Hotelling's T^2 (Rencher 1995) and paired t-tests. We analyzed foraging substrate type and species selection in each study plot with $\geq$ 20 foraging observations using methods described by Manly et al. (1993). First, we used a G-test to test the hypothesis of no selection. If this hypothesis was false, we calculated selection ratios and confidence intervals for those ratios.

Within Range Relationships- We assessed Rota BWE within range relationships by looking at differences in habitat variables and bird abundance indices in areas designated high and low density Rota BWE areas by Fancy and Snetsinger (1996) and by looking at the relationship between Rota BWEs and habitat. We used Wilcoxon rank sum tests to examine differences in habitat variables and a two-way ANOVA to examine differences in mean bird abundance indices in areas designated high and low density Rota BWE areas by Fancy and Snetsinger (1996). Not all tree species were analyzed for differences between high and low density Rota BWE areas. Only *Hernandia labyrinthica*, *Merrilliodendron megacarpum*, and *Elaeocarpus joga* were examined because we believed they were important to Rota BWEs.

We used stepwise multiple linear regression (SAS Institute 1990) to determine which habitat variables best predicted mean Rota BWE abundance indices. Any habitat variables that we believed were important to Rota BWEs that were not included in regression analysis were analyzed using Pearson correlations. Because we had so few samples and so many independent variables, we reduced the total number of variables in our stepwise regression in two ways. First, we eliminated all variables with zero values in 25% or more of the study plots. Then we looked at the relationships between the remaining variables by using PROC FACTOR (SAS Institute 1990) to calculate the first three principal components of the habitat data (Table 1). We then selected the habitat variables that were the most independent based on their correlation coefficients.

*Sabana-wide Relationships***-** We analyzed the Sabana-wide survey data for relationships between abundance estimates of Rota BWEs and different habitat variables. We tested for these relationships using stepwise multiple linear regression analysis on Rota BWE abundance estimates and eight habitat variables. In this test, we assumed all survey stations were independent and used data from all transects.

Insect Relationships- We looked at potential relationships between Rota BWEs and insects in several ways. First, we examined differences in insect and snail numbers between high and low Rota BWE abundance study plots and in insect biomass per gram of plant mass between high and low elevations using descriptive statistics. Then we tested for relationships between the insectivorous rufous fantail and Rota BWEs. We used Pearson correlations on rufous fantail and Rota BWE numbers with our study plots and along the transects on the Sabana. We also used stepwise multiple linear regression on mean rufous fantail abundance indices to determine which habitat variables best predicted rufous fantail abundance within the Rota BWE's range.

Black Drongos

We tested for differences in each region in each year using Kruskal-Wallis tests with Bonferroni joint ranking multiple comparison procedures (Hollander and Wolfe 1999). Each year was examined separately because the 1982 data were not comparable to the 1995 and 1998 data. Black drongo and small passerine relationships were assessed using Pearson correlations on abundance data collected within our study plots (25-m radius), along the Sabana transects (35-m radius), and in previous surveys (35-m radius). We used two-sample T-tests to look at differences in abundance estimates between 1982 and 1994 along four transects (6, 7, 8, and 12) on the Sabana. Sabana-wide black drongo habitat relationships were assessed using step-wise multiple linear regression. Black drongo habitat relationships within the Rota BWE's current range were assessed using step-wise multiple linear regression and by comparing black drongo use of interior and exterior study plots. All study plots > 200 m from a non-forest habitat (as defined by Falanruw et al. 1989) were defined as interior forest plots while the remainder were classified exterior forest plots. We then looked for differences in black drongo abundance indices in each plot type for each survey period using two-way ANOVAs with Tukey's multiple comparison procedures.

Rat Populations

We used estimates of potential and actual rats per trap-night to test for differences in rat population estimates between Rota BWE and Mariana crow study areas using a one-way ANOVA and Tukey's multiple comparison procedure. We summarized rat stomach contents by calculating the percentage of stomachs containing each food category.

RESULTS

Rota Bridled White-eye Life History

Breeding Biology- We found a total of 19 Rota BWE nests during the 1998 and 1999 field seasons (Appendix G). A USFWS employee, Sheldon Plentovich, found an additional nest in December 1997 during preliminary field work for this project. We also found eight BWE nests on Saipan and one on Tinian during May and June of 1999. All nests found on Saipan and Tinian were inactive and their fate was unknown. Nine of the Rota BWE nests were active when found and of these six produced one or two fledglings. One active nest appeared to be depredated at the nestling stage and the 1997 nest appeared to be destroyed during typhoon Paka in December 1997. The remaining nest was abandoned or depredated, potentially due to observer disturbance.

We found active nests in December (n = 1), March (n = 4), May (n = 2), and July (n = 2). Fledging dates of two nests also indicate that breeding occurs in April and June and an observation of a Rota BWE carrying nest material (spider webs) in August indicates that breeding occurs then as well. In addition, we observed what appeared to be two recently fledged Rota BWEs (no eye-rings and scruffy appearance) in late January.

We observed clutch sizes of one and two eggs and observed the fledging of two nestlings. Incubation and nestling periods appeared to be at least 10 and up to 12 days based on our observations of seven active nests (Appendix H). During the incubation and brooding stages we observed adults switching and observed two adults simultaneously bringing food to nestlings. We also banded one nestling (Appendix I) and observed a fledgling period of at least eight days. (This bird was seen approximately 10 m from the nest with both parents and another fledgling, possibly its one nest mate which fledged prior to banding).

We recorded nest dimension information on four Rota BWE, four Saipan BWE, and one Tinian BWE nest (Table 2). The dimensions of Rota and Saipan BWE nests did not differ except for nest wall width which was larger in Saipan BWE nests (Table 2). The Rota BWE nests we found appeared to be composed of rootlets, woven grass or *Pandanus* spp. fibers, spider webs, light green moss, and a yellow cottony material (Appendix J). The inner cup appeared to be of woven grass or *Pandanus* spp. fibers. The Saipan and Tinian BWE nests we found appeared to be of a similar composition.

We described nest site characteristics for 18 of the Rota BWE nests and for eight of the Saipan BWE nests (Table 3). Rota BWE nests were found in *Acacia confusa* (n = 3), *Elaeocarpus joga* (n = 7), *Hernandia labyrinthica* (n = 6), and *Merrilliodendron megacarpum* (n = 4) trees at elevations between 320 and 460 m. Saipan BWE nests were found in *Cynometra ramiflora* (n = 2) and *Guamia mariannae* (n = 6) trees and the Tinian BWE nest was found in a *Leucaena leucocephala* tree. Rota BWE nests were higher and farther from the trunk of the tree than Saipan BWE nests (Table 3). Rota BWE nest trees were also taller and had larger diameters than Saipan BWE nest trees. Distances from the nest to the top of the tree did not differ between Rota BWE and Saipan BWE nests.

Behavior- We collected a total of 204 discrete Rota BWE behavioral observations during the 1998 and 1999 field seasons with 116 of foraging and 88 of non-foraging behaviors. In 1999, we also recorded 154 discrete behavioral observations of Rota BWE flock size and 10 discrete behavioral observations of Saipan BWEs. We recorded no discrete behavioral observations of Tinian BWEs.

Of the 116 Rota BWE foraging observations, 43 were in the dry season (February - April) and 51 were in the wet season (June - August). Over 75% of the foraging observations in both seasons were of Rota BWEs searching for food (Fig. 8). The most commonly used foraging technique was gleaning. In both the dry and wet seasons, five different substrate types were used for foraging. In both seasons, leaves were the primary foraging substrate type followed by branches (Fig. 9). Nine tree species were used for foraging. Over 25% of the foraging observations in both seasons were recorded in *Elaeocarpus joga* and over 10% of the observations were recorded in each of *Hernandia labyrinthica* and *Premna obtusifolia* trees (Fig. 10). Foraging microhabitat was also similar between the wet and dry seasons. In both seasons over 60% of the Rota BWE foraging observations were on perches < 1.0 cm in diameter (Fig. 11), in the canopy

(Fig. 12), and ≥ 3 m high (Fig. 13).

Of the foraging observations we recorded, only the 24 observations of Rota BWEs attempting to capture food were comparable to Saipan BWE (n = 146) foraging observations reported in Craig (1989, 1990). Over 75% of the Rota and Saipan BWE foraging observations were of gleaning (Fig. 14) and the use of perches < 1.0 cm diameter (Fig. 15). Observations of foraging substrate use (Fig. 16) between this study and those described for Saipan BWEs were also similar except for the use of flowers. Both Rota and Saipan BWEs both used leaves/buds in 50% or more of the observations. However, Rota BWEs were observed foraging in flowers (21%) more frequently than Saipan BWEs (6%) (Fig. 16).

Of the 88 Rota BWE non-foraging observations, 41 were recorded in the dry season and 16 were recorded in the wet season. The majority of the observations in both seasons were of maintenance behavior (preening) and vocalizations (singing, calling, and alarm calling) (Fig. 17). Over 20% of the maintenance observations (n = 22) were of Rota BWEs mutual preening or allopreening in groups of two. The most commonly heard vocalization was the call that Pratt et al. (1987) described as "a low-pitched *tsheip*." We also observed Rota BWEs giving a scolding alarm call, often in response to collared kingfishers, which could be described as a series of the *tsheip* calls described above. We also observed Rota BWEs singing from the upper branches of canopy trees throughout the study period. Their song could be described as a discontinuous series of their calls produced in a very abrupt manner. Carola Haas observed that the calls of Rota, Tinian, and Saipan BWE all differed. The Rota BWE's call was more buzzy than the calls of the Tinian and Saipan BWEs. The Tinian BWE calls were a series of whistles, while the Saipan BWE calls were a series of short "cheeps." We did not observe Tinian or Saipan BWEs singing when visiting these islands.

Behavioral observations of inter and intra-specific interactions were also recorded. Five percent of the foraging observations recorded in 1999 (n = 84) were of Rota BWEs foraging with one to two rufous fantails. On 3 July 1999 we recorded one behavioral observation of a group of 10 Saipan BWEs foraging with a rufous fantail. We observed groups of two to three Rota BWEs in 53% of the behavioral observations in 1999 (n = 154). We observed flocks of up to 14 birds on two occasions (17 February and 7 March 1999) and 18% of the behavioral observations (n = 154) included groups of four to five Rota BWEs. On Saipan, as part of behavioral observations (n = 10) we recorded Saipan BWE flock sizes that ranged from 2 - 10 birds.

Seasonal Effects

We sampled insect and snail numbers per branch on four tree species seven times in the 1999 field season (Appendix K) and assessed percent fruiting and flowering on 22 tree species at 11 two-week intervals through the 1999 field season (Appendix L). We also assessed differences in abundance indices of six bird species over three survey periods. Both total number of insects and snails per branch appeared higher in the wet season than in the dry season (Fig. 18). Total insects and snails per branch also appeared higher in the wet season for all tree species sampled, except *Elaeocarpus joga* (insects) and *Hernandia labyrinthica* (snails) (Figs. 19 and 20). We found that percentage of trees flowering in all five study regions decreased (Wilcoxon signed-rank, T = 15.0, P = 0.06) and the percentage of trees fruiting increased (Wilcoxon signed-rank, T = 0.0, P = 0.06) between the dry and wet seasons (Fig. 21). A similar pattern was observed in the percentage of *Elaeocarpus joga*, *Hernandia labyrinthica*, *Eugenia thompsonii*, *Premna obtusifolia*, *Pipturus argenteus*, and *Macaranga thompsonii* (species where Rota BWEs were observed foraging for fruits or flowers) trees fruiting and flowering between the dry and wet seasons (Fig. 22). However, *Pipturus argenteus* had high levels of flowering in both seasons along with an increase in fruiting in the wet season (Fig. 22).

Abundance indices of all bird species, except Rota BWEs, did not differ between survey periods (Fig. 23) (two-way ANOVA, F = 3.04, df = 10, P = 0.001). Rota BWE abundance indices were higher in the wet season of 1998 than in the wet season of 1999 (Fig. 23) (Tukey test, P < 0.05). However, no difference in Rota BWE abundance indices between wet seasons and dry season were observed. We analyzed the Rota BWE data again using means instead of maximum abundance indices for each study plot in each survey period because of concern over rare observations of Rota BWEs influencing results. No difference in Rota BWE abundance indices between survey periods were observed when we used mean instead of maximum abundance indices for each study plot (One-way ANOVA, F = 1.53, df = 2, P = 0.23).

<u>White-eye Population Estimate</u>

We estimated a population size of 1,092 Rota BWEs within our study area.

However, the 95% confidence interval for this estimate was 147 to 2,710 Rota BWEs. Over 85% of our population estimate was from study areas A, B, and C (Table 4). Area E had the lowest estimated Rota BWE population within our study area.

Habitat Alteration

Microhabitat Relationships- We collected foraging habitat (foliage volume, intermediate scale characteristics, and broad scale characteristics) information on 32 Rota BWEs in 12 study plots (Table 5). At the fine scale, Rota BWEs selected for areas with higher foliage volume than available within their current range. However, no overall differences in use versus availability of foraging habitat characteristics at the intermediate (Hotelling's T^2, $T^2 = 4.15$, $F = 0.94$, $df = 3$, $P = 0.46$) or broad scales (Hotelling's T^2, $T^2 = 4.24$, $F = 2.05$, $df = 4$, $P = 0.15$) were detected. Because we detected no overall differences at the broad and intermediate scales we did not examine differences in individual variables at these scales.

We recorded foraging substrate type and species use information from observations of 116 Rota BWEs (other habitat characteristics were not recorded due to time constraints). Only study sites 1HA and 1HB contained more than 20 observations of Rota BWE foraging. We compared foraging use with the availability of substrates and substrate species and detected no overall differences in the use and availability of substrate types and substrate species in these study plots (Table 6).

Within Range Relationships- We calculated the mean abundance indices of 11 bird species in areas designated high and low density Rota BWE areas by Fancy and

Snetsinger (1996) over three survey periods (Table 7). All bird species, except Rota BWEs, did not differ in mean abundance indices between high and low density Rota BWE areas. Rota BWE mean abundance indices were higher in areas designated high density Rota BWE areas by Fancy and Snetsinger (1996).

We also calculated estimates of descriptive habitat characteristics (Table 8) and density and basal areas of woody species (Table 9) for areas designated high and low density Rota BWE areas by Fancy and Snetsinger (1996). We detected lower tree basal area and higher epiphyte density and elevation in high density Rota BWE areas than low density Rota BWE areas. No differences in tree density estimates for *Elaeocarpus joga*, *Hernandia labyrinthica*, and *Merrilliodendron megacarpum* were detected between areas designated high and low density Rota BWE areas (Wilcoxon rank sum test, $P > 0.10$).

We used eight habitat variables as independent variables in stepwise multiple linear regression analysis of mean Rota BWE abundance indices over the three survey periods (Table 10). The model was significant and canopy height, *Ficus prolixa* density, foliage volume (3-9 m), and *Elaeocarpus joga* density were selected as significant predictors of Rota BWE abundance indices. Both canopy height and *Ficus prolixa* density were negatively related to Rota BWE abundance while foliage volume and *Elaeocarpus joga* density were positively related to Rota BWE abundance. We detected no relationship between mean Rota BWE abundance indices and *Hernandia labyrinthica* density (Pearson's correlation, $r = 0.02$, $P = 0.94$, $n = 18$). However, we did detect a positive relationship between *Merrilliodendron megacarpum* density and mean Rota

BWE abundance indices (Pearson's correlation, r = 0.61, P = 0.01, n = 18).

Sabana-Wide Relationships- We sampled a total of 57 stations on nine transects as part of the Sabana-wide survey (Fig. 24). All transects began between 100 and 370 m elevation and ended between 250 and 450 m elevation. We detected Rota BWEs at nine stations on six transects in areas classified as mature limestone forest, young limestone forest, or disturbed limestone forest. We detected no Rota BWEs in any other habitat type (35% of the 57 stations were not classified as limestone forest) and all Rota BWEs were detected at the stations above 250 m elevation (82% of the 57 stations were above 250 m elevation). We used eight habitat variables as independent variables in a step-wise multiple linear regression analysis of Rota BWE abundance estimates along the nine transects (Table 11). The model was significant and *Hernandia labyrinthica* and *Ficus* spp. densities and *Elatostema* and *Procris* spp. index were selected as predictors of Rota BWE abundance along the transects. Both *Hernandia labyrinthica* density and *Elatostema* and *Procris* spp. index were positively related to Rota BWE abundance while *Ficus* spp. density was negatively related.

Island-Wide Relationships- We sampled a total of 41 woody species in the five Rota BWE study areas and J. M. Morton (unpubl. data) sampled 35 woody species in the six Mariana crow study sites (Table 12). Fourteen woody species were recorded only in Rota BWE study areas and eight woody species were recorded only in Mariana crow study sites. Of the 14 species recorded only in Rota BWE study areas, three were introduced species (*Areca cathecu*, *Bambusa vulgaris*, and *Persea americana*) and six

(*Geniostoma micranthum*, *Allophylus spp*., *Ixora triantha*, *Tarenna sambucina*, *Eugenia thompsonii* and *Eugenia spp*.) were observed in Mariana crow study sites but not recorded during habitat sampling (J. M. Morton, USFWS, pers. comm.). Of the eight species recorded only in Mariana crow study sites, two were introduced (*Casuarina littorea* and *Citrus spp.*) and two (*Maytenus thompsonii* and *Morinda citrifolia*) were recorded in Rota BWE study areas as trees with diameters at breast height of < 10 cm. Therefore, we recorded five native tree species that were found only in Rota BWE study areas and J. M. Morton recorded four species that were found only in Mariana crow study sites.

To assess which of the five species recorded only in Rota BWE study areas were important components of the forests in these areas we determined which five woody species in each study plot had the highest densities and basal areas (Table 13). We did not determine this for the Mariana crow sites because only 10 plots were sampled in each site, which was probably not enough to characterize each site. Of the five tree species, only *Hernandia labyrinthica* and *Merrilliodendron megacarpum* were considered important forest components in more than one of the Rota BWE study plots. Rota BWEs were recorded in all study plots in which *Hernandia labyrinthica* or *Merrilliodendron megacarpum* was an important forest component. However, Rota BWE abundance estimates were not high in all study plots with *Hernandia labyrinthica* as an important forest component.

Insect Relationships- We collected a total of 30 high elevation (380-450 m) and 30 low elevation (150-250 m) samples from three transects (10 samples per transect) (Fig. 25). Of the eight insect orders sampled (Fig 26), we were able to identify individual insects to family in four orders (Fig. 27) using identification keys in Borror et al. (1987). We were unable to identify Dipteran and Lepidopteran adult and larvae to family because of damage to the specimens in those orders. In addition, we sampled three high and three low Rota BWE abundance sites for total insect and snail numbers per branch (Fig. 28). We found the number of snails per sample appeared higher for high elevation sites than low elevation sites (Fig. 29). In addition, we found milligrams of Homoptera appeared lower at high elevations than low elevations (Fig. 26). We found one family of Coleopteran (Curculionidae), consisting of nine specimens, only at high elevation sites and one family of Homopteran (Membracidae), consisting of one specimen, only at low elevation sites (Fig. 27). In addition snail numbers per branch appeared higher in Rota BWE high abundance areas than low abundance areas (Fig. 28).

We detected rufous fantails in 100% of the 20 Rota BWE study plots we surveyed and in 75% of the transect survey stations ($n = 57$) on the Sabana. There was a positive relationship between mean rufous fantail abundance estimates and mean Rota BWE abundance indices (Pearson's correlation, $r = 0.67$, $P < 0.01$, $n = 18$) within the Rota BWE's current range. There was also a positive relationship between Rota BWE abundance estimates and the presence of rufous fantails along the transects of the Sabana (Pearson's correlation, $r = 0.23$, $P = 0.09$, $n = 57$). The stepwise multiple linear regression analysis of mean rufous fantail abundance indices and eight habitat variables was significant and 3-9 m foliage volume and *Elaeocarpus joga* density were selected as good predictors of mean rufous fantail abundance indices (Table 10). Both variables were positively related to mean rufous fantail abundance indices.

<u>Black Drongos</u>

On 18 August 1998 we observed a black drongo eating a Rota BWE in an *Elaeocarpus joga* tree in study plot 2HA. When the black drongo was first observed, it was plucking the feathers of the white-eye while a nearby Rota BWE gave alarm calls. When we attempted to approach the drongo a Micronesian starling chased it out of view. The Rota BWE was not a nestling (eye ring was present) but we were unable to determine if it was an adult or juvenile. No other observations of attempted or successful predation of drongos on Rota BWEs were observed.

We looked at black drongo and small passerine relationships within the Rota BWE's current range, along transects on the Sabana, and along transects surveyed in 1982 and 1994. No relationship between mean black drongo abundance index estimates and the abundance estimates of Rota BWEs, rufous fantails, and Micronesian honeyeaters were detected within the Rota BWE's current range (Pearson correlations, $P > 0.10$). In addition, no significant relationship between black drongo abundance estimates along the transects on the Sabana and the abundance estimates of Rota BWEs was detected (Pearson's correlation, $r = -0.109$, $P = 0.42$, $n = 57$). Results of Pearson correlations on Rota BWE and black drongo abundance within 35-m of all stations on the Sabana were not significant in 1982 but were significant in 1994 (Table 14). Significant relationships between black drongo detections and Micronesian honeyeater detections were observed in 1982 and 1994 (Table 14). In addition, a significant relationship between rufous fantail and black drongo detections was observed in 1994 (Table 14).

We were able to look at differences in black drongo abundance between the Sabana and other regions of the island in three years (Table 15) and to look at changes in black drongo and small passerine detections between 1982 and 1994 (Fig. 30). In each year there was a difference in black drongo detections between regions with significantly fewer black drongos detected on the Sabana than in other regions of the island (Table 15). There was also an increase in black drongo detections per station between years and a decrease in Rota bridled white-eyes (Fig. 30). No difference in rufous fantail and Micronesian honeyeater detections were detected between 1982 and 1994 but Micronesian starling and collared kingfisher numbers did increase (Fig. 30).

We detected black drongos from 150 - 420 m elevation along transects on the Sabana. Sixty-nine percent of the observations (n = 17) were in non-forested habitats (secondary vegetation, cropland, and pasture) while the remainder were in partially forested habitats. No habitat variable meet the 0.15 significance level for stepwise multiple linear regression analysis of black drongo abundance along transects on the Sabana.

Black drongo abundance estimates within the Rota BWE study plots were also used to look at black drongo habitat relationships. We used eight habitat variables as independent variables in a stepwise multiple linear regression analysis of mean black drongo abundance (Table 10). The model was significant and canopy height and *Pandanus tectorius* density were selected as significant predictors of mean black drongo abundance. Canopy height was negatively related to mean black drongo abundance while *Pandanus tectorius* density was positively related to mean abundance. We detected no difference in black drongo abundance estimates for forest interior study plots in the dry season (when the canopy is more open because of leaf-fall) compared to the wet seasons of 1998 and 1999 (two-way ANOVA, F = 0.14, df = 2, P = 0.87) (Fig. 31).

<u>Rat Populations</u>

We trapped a total of 31 rats over 200 potential trapnights (40 traps x 5 nights) in the Rota BWE areas. However, 132 traps were either missing, unbaited, or were tripped and did not contain rats when checked. Therefore, the actual number of trapnights equaled 68. Actual and potential number of rats per trapnight for Mariana crow study sites were obtained from Morton et al. (1999) (Table 16). There was a difference in number of rats per potential trapnight among all study areas but no difference in rats per actual trapnight was detected among all study areas (Table 16). Results of Tukey's multiple comparison procedure on rats per potential trapnight indicate no difference in rats per potential trapnight between Rota BWE study areas and any Mariana crow study site.

We collected the stomach contents of 22 rats (Fig. 32). The stomach contents of the rats captured in Mariana crow study sites were not recorded. None of the stomachs examined contained any bird remains (feathers, bones, etc.) or eggs. The majority of the stomachs collected contained some sort of vegetation (leaves, fruit, seeds, etc.) though animal remains were also found.

DISCUSSION

Rota Bridled White-eye Life History

Limited research had been done on the life history of the Rota BWE prior to this study. However, the limited data available on Rota BWE nesting (Yamashina 1932, Pratt 1985, Lusk and Taisacan 1997) and foraging (Craig and Taisacan 1994) are similar overall to the data collected in this study. Two of the previous three nests were reported in *Hernandia labyrinthica* (Lusk and Taisacan 1997) or *Hernandia* spp. (presumably *H. labyrinthica*) (Pratt 1985). We observed the use of three other tree species including one introduced species, *Acacia confusa*. Lusk and Taisacan (1997) reported that the Rota BWE breeding season extended from at least March until June. The observations of breeding activity from this study indicate a breeding season from at least December until August. We also expanded upon the foraging data previously reported by Craig and Taisacan (1994). We noted the use of flowers for foraging and that Rota BWEs will occasionally forage with rufous fantails.

The breeding biology of the Rota BWE is similar in most respects to that of several other white-eye species (Table 17) (Appendix M). However, we found that Saipan and Rota BWEs differ in their nest site characteristics and vocalizations. Data collected on Saipan BWEs by Craig (1989, 1996) also indicate that they may differ from Rota BWEs in habitat use, flock size, and interspecific interactions. We believe some of these differences may be related to the restricted range and small population size of Rota BWEs.

Rota BWEs are restricted to elevations > 200 m and are found primarily in high elevation wet forest. These forests tend to have a higher canopy, larger diameter trees, and a different composition than the forests where we found Saipan BWE nests. So, the differences in nest site characteristics may be related to differences in the structure of the forests used by each species. In addition, Rota BWEs are primarily found in native and introduced forests at high elevations while Saipan BWEs are found in urban areas, grassland, and both introduced and native forests (Craig 1989, 1996) at a wide range of elevations (pers. obs.). This difference appears to be related to the apparent specialization to high elevation forest by Rota BWEs.

The small size of the Rota BWE population in comparison to the Saipan BWE may explain differences in flock size and interspecific interactions. Craig (1989) reported that Saipan BWE flocks were normally 10-40 birds (maximum: 50) while our normal flock size was only 2-3 birds (maximum: 14). Rota BWEs also appear to forage in mixed species flocks more often than reported for Saipan BWEs (Craig 1989, 1996). The low population size of Rota BWEs may have led to their small flock sizes. Jenkins (1983) reported that Guam BWE flock size was lower when the population had decreased. Since their flock sizes are smaller, Rota BWEs may also become more involved in mixed species flocks to receive the benefits of flocking, such as increased foraging efficiency (Krebs 1973) and reduced risk of predation with group vigilance (Powell 1974, Popp

1988).

Seasonal Effects

The decline in Rota BWE abundance indices between the wet seasons of 1998 and 1999 may or may not reflect a true decline of Rota BWEs. The 1998 survey period was preceded by typhoon Paka in December 1997 and a severe drought in early 1998. These conditions may have effected the overall distribution of Rota BWEs during the 1998 survey causing Rota BWEs to be observed in some study plots only once in 1998 and not being reported in these study plots in subsequent surveys. This may have biased the overall abundance estimates for these plots since we used the highest estimates of Rota BWE abundance for each plot in the analysis. When we used the means for each study plot we no longer observed a difference between survey periods so the differences noted earlier may have been due to changes in movement or forest use by Rota BWEs and not a population decline. This is important to note because the conditions (seasonal or otherwise) during a survey could have serious impacts on attempts to estimate the Rota BWE's population size or distribution.

White-eye Population Estimate

Our population estimate was very similar to one provided by Fancy and Snetsinger (1996). This may be an indication that the Rota BWE population has not changed since 1996. However, this sort of conclusion needs to be approached with caution for two reasons. First, the methods used to determine the number of birds in an area were very different and may have affected the population estimate in different ways.

Second, the basis for determining study areas for this study was the work done by Fancy and Snetsinger (1996), which may have biased our estimate by focusing our efforts in areas previously surveyed. However, whether the population has increased or decreased since 1996, it is clear from our estimate that the population is much lower than the 1982 estimate and that the Rota BWE population is still threatened with extinction.

In addition to a population estimate, we learned more about the distribution of Rota BWEs. Our study plot and survey data indicate that the Rota BWE's distribution is more fragmented than reported in Fancy and Snetsinger (1996). Rota BWEs were not observed in large numbers in many areas that were defined as high density areas. Therefore, the classification of high and low density areas by Fancy and Snetsinger (1996) should be used with caution. Instead the locations where they detected Rota BWEs during their 1996 survey (Figure 9 in Fancy and Snetsinger (1996)) would be more useful in determining where the highest densities of Rota BWEs occur.

<u>Habitat Alteration</u>

For the past 25 years, Rota BWEs have only been consistently recorded above 200 m elevation on Rota. We believe that this high elevation distribution is related to the distribution of wet forests on Rota and that Rota BWEs prefer this forest type. We are not certain what characteristics of this forest type are important to Rota BWEs but we believe that the alteration of this forest type may have played a major role in the decline of Rota BWEs from 1982 until today.

Native high elevation wet forests appear to be restricted to elevations $\geq$ 200 m and can be divided into either *Hernandia labyrinthica* mixed forest or *Merrilliodendron megacarpum* forest. The distributions of both species appear to be related to the high rainfall levels that occur on the Sabana. Raulerson and Rhinehart (1991) report that *Merrilliodendron megacarpum* only grows where abundant water supplies are available and L. Raulerson (Univ. of Guam, pers. comm.) believes the distribution of *Hernandia labyrinthica* may also be limited by moisture levels. We found that these two tree species were important components of the forest in study plots with the highest Rota BWE abundance estimates and that both species were used for nesting and foraging. We also found that *Hernandia labyrinthica* density was a good predictor of Rota BWE abundance along transects on the Sabana.

The importance of high elevation wet forest may also be reflected in the Rota BWEs relationship with *Elatostema* and *Procris* spp. and *Ficus prolixa*. *Elatostema* and *Procris* spp. are succulent ground cover species whose distribution may be limited by humidity levels (L. Raulerson, Univ. of Guam, pers. comm.). In addition, Rota BWEs negative relationship with *Ficus prolixa* (within range) and *Ficus* spp. (Sabana-wide) may be due to the limited distribution of *Ficus prolixa* in high elevation wet forests. However, we need to know more about the distribution and habitat requirements of *Ficus prolixa* to confirm this.

Though high elevation wet forest appears to be important to the overall distribution of Rota BWEs it is not clear what affects the distribution of Rota BWEs within their range or why high elevation wet forest is important. We had originally thought that their distribution may be related to native forest or native tree species found only at high elevations, such as *Hernandia labyrinthica* and *Merrilliodendron megacarpum*. However, within the Rota BWE's current range we found no relationship between Rota BWE abundance indices and *Hernandia labyrinthica* and found large concentrations of Rota BWEs outside *Merrilliodendron meagacarpum* forest. We also recorded Rota BWEs foraging and nesting in the introduced tree, *Acacia confusa*, at high elevations. The forests which contain *Acacia confusa* lack a well defined understory which can be found in native forests containing *Hernandia labyrinthica* and *Merrilliodendron meagacarpum*. Since the distribution of Rota BWEs does not appear to be related to the distribution of native forest within their range there must be something about both native and non-native high elevation wet forest which is important to Rota BWEs. One possibility is prey availability.

Mid-story foliage volume was found to be a good predictor of Rota BWE and rufous fantail abundance indices within the Rota BWE's range in native forest. Both species prey on insects and higher mid-story foliage volume may indicate a more complex forest structure, which may increase the overall area available for both species to forage for insects. In addition, we found that Rota BWEs selected for areas with higher foraging volume when foraging, which could reflect higher insect availability in these areas. We attempted to address the possibility of differences in insect availability with some limited sampling but were unsuccessful. However, prey availability is still a possible explanation for the Rota BWEs distribution.

The apparent preference for high elevation wet forest by Rota BWEs may partially explain their population decline from 1982 to 1996. The population decline reported over this period was primarily based upon a decline in Rota BWE detections along four transects located in native limestone forest (Falanruw et al. 1989) on the Sabana. If we assume that these forests were similar to the high elevation wet forests currently used by Rota BWEs, then the alteration of these forests by supertyphoon Roy in 1988 may explain their decline.

Supertyphoon Roy was reported to have done extensive damage to the forests of the Sabana (Fancy and Snetsinger 1996). The level of damage caused by this storm may have been affected by the amount of land cleared on the Sabana for agricultural purposes which may have increased the exposure of the forest to high winds. Our personal observations of the areas damaged by supertyphoon Roy indicate that the emergent canopy trees in these areas appear to be heavily damaged and have less extensive crowns than trees on other areas of the island. The damage to these canopy trees may be related to the increased susceptibility of large trees to typhoon damage (Brokaw and Walker 1991, Basnet et al. 1992). We also found that the understory of these forests were overgrown with *Pandanus tectorius* and that the forest structure differed markedly from forests currently used by Rota BWEs. Rota BWEs primarily forage and nest in canopy trees and the highest densities of this species are found in forests with well developed canopies. The alteration of the canopy and the overall forest composition by the storm may have made the habitat less desirable for Rota BWEs.

The habitat alteration caused by the storm may also be related to other changes in the bird community on the Sabana. Black drongo, collared kingfisher, and Micronesian starling numbers all increased on the Sabana between 1982 and 1994. Damage to the canopy of the forest on the Sabana may have lead to an increase in forest openings and dead and dying trees. This may have provided better foraging habitat for black drongos and collared kingfishers and an increase in potential nesting cavities for Micronesian starlings and collared kingfishers. The increase in black drongos and collared kingfishers may have also impacted Rota BWEs by exposing Rota BWEs to a potential increase in black drongo and collared kingfisher predation.

There are two potential problems associated with our belief that Rota BWEs prefer high elevation wet forest and that this preference can explain their decline. First, the alteration of this habitat type does not explain the apparent range restriction from low to high elevations from the mid-1960s to mid-1970s. The second problem is explaining why the Rota BWE is a habitat specialist while the BWEs on Saipan and Tinian are habitat generalists.

High elevation wet forest only occurs on the Sabana and there is no evidence that it occurred at lower elevations when Rota BWEs were reported near the village of Songsong (Baker 1948, Engbring et al. 1986). If Rota BWEs were found in high numbers throughout the year or were breeding at low elevations then Rota BWEs were not high elevation wet forest specialists. However, no data are available on the island-wide distribution of Rota BWEs, their population size, and their breeding status at low elevations prior to 1975. Therefore we are forced to come up with possible explanations for the contradiction between current data and past distribution information. One possible explanation proposed by Fancy and Snetsinger (1996) is that what occurred was not a range restriction but a decline in dispersing birds from high elevation wet forest. Based upon observations from this study, we believe this hypothesis may be true.

On 29 July 1999 we observed two Rota BWEs foraging in a flame tree (*Delonix regia*) in the Taiapu region (140 m elevation), approximately 800 m from where they were commonly encountered. Flame trees are introduced ornamental trees with bright red flowers (easily observed from long distances) which were commonly planted along streets or in gardens (Stone 1970, Raulerson and Rhinehart 1991) and are used by foraging Saipan BWEs (pers. obs.). These flame trees were flowering at the time of our observation and we believe the Rota BWEs may have traveled to low elevations specifically to forage in these trees. If this was the case, we believe that Rota BWEs may occasionally foray outside their normal range to visit particular flowering tree species.

Safford (1997) reported that Mauritius olive white-eyes were observed wandering below their altitudinal limits (350-400 m elevation) to exploit isolated habitats over 3 km away. He also reported that most of these recorded forays were to exceptional nectar sources. It is therefore quite possible that the Rota BWEs previously observed at low elevations in the village of Songsong could have been wandering or dispersing from their normal range approximately 3 km away at high elevations.

Unfortunately we do not know why the number of dispersers declined. One potential explanation is the heavy use of pesticides that was reported in the Mariana Islands (Baker 1946). Sheath-tailed bats (*Emballonura semicaudata*) and island swiftlets (*Aerodramus vanikorensis*) both went extinct on the island of Rota in the mid-1960s and 1970s (Engbring et al. 1986, Lemke 1986) at approximately the same time Rota BWEs were no longer observed at low elevations. All three species prey on insects and a reduction in prey base from pesticide use may explain the decline of all three species.

Understanding why the Rota BWE may be a habitat specialist is very difficult. First, less than half of the island of Rota is within the elevation range for high elevation wet forest. So, historically it was probably not the dominant habitat type on the island. Second, there does not appear to be any potential niche competition between Rota BWEs and other species at low elevations which would restrict Rota BWEs to high elevations. All the bird species whose niche is potentially similar to that of the Rota BWE are found on the neighboring islands of Saipan and Tinian at all elevations with Saipan and Tinian BWEs. Therefore we could find no obvious reason to explain this apparent specialization for high elevation wet forest. However, this does not imply the Rota BWE has to be a habitat generalist. Even though many white-eye species are described as habitat generalists (Skead and Ranger 1958, Ali and Ripley 1974, Greig-Smith 1979, Jenkins 1983, Cheke 1987, Pratt et al. 1987, Craig 1989, Langrand 1990, Brazil 1991, Kennedy et al. 2000), there are some species that appear to be habitat specialists. The Mauritius olive white-eye (*Zosterops chloronthus*) is reported to prefer very wet areas of native forest at high elevations on Mauritius (Cheke 1987). In the Philippines, the mountain white-eye

(*Zosterops montanus*) and black-masked white-eye (*Lophozosterops goodfellowi*) are both confined to forests above 1,000 m elevation (Kennedy et al. 2000). The Samoan white-eye (*Zosterops samoanensis*) is believed to be restricted to cloud forests above 900 m elevation on the island of Savaii (Reed 1980, Bellingham and Davis 1988). Further work is clearly needed on the interactions of Rota BWEs with other forest birds and its preferred habitat to explain their apparent habitat specialization.

<u>Black Drongos</u>

Our results indicate that black drongos do prey on Rota BWEs, black drongo numbers are lower on the Sabana than other regions of the island as reported by Craig and Taisacan (1994), and that black drongo numbers have increased on the Sabana from 1982 to 1994 while Rota BWEs numbers have decreased. However, we detected no negative relationship between black drongo numbers and any of the small native passerines, including Rota BWEs, that drongo predation could impact. Therefore, we are still uncertain what role black drongos played in the decline and range restriction of the Rota BWE. We believe that the habitat alteration discussed earlier may have played the major role in the decline by reducing the availability of preferred Rota BWE habitat. However, this habitat alteration may have also helped increase the incidence of black drongo and collared kingfisher predation on Rota BWEs by making the habitat more suitable for black drongo and collared kingfishers and increasing their populations on the Sabana.

The impact of habitat alteration is important because it could reflect on management of black drongo numbers. Maben (1982) found that black drongos forage predominately in open areas surrounded by disturbed vegetation on perches well outside the foliage. We also found that black drongos were normally found near openings or disturbed vegetation along our Sabana transects. Therefore, the differences in black drongo numbers on the sabana between years and between different parts of the island could be related to habitat differences. If this is the case then habitat protection for Rota BWEs could also impact black drongo and potentially collared kingfisher predation by minimizing the availability of habitat suitable for these two avian predators. Research on black drongo and collared kingfisher habitat selection is needed however.

Rat Populations

We found no difference between rat densities within the Rota BWE's range and the rat densities within Mariana crow study sites at low elevations on the island of Rota. Therefore, we do not believe that the distribution of Rota BWEs is limited by rat densities at lower elevations. However, the impact of introduced rats on Rota BWEs has not been addressed so the role of rats in the decline of the Rota BWE is still unclear.

Management Recommendations

1. The biggest potential threat to the Rota BWE and other native birds on Rota is the accidental introduction of the brown tree snake. Therefore, we recommend that the Rota BWE management priority should be to prevent the introduction of the brown tree snake to Rota. This should include increased interdiction efforts to check all cargo transported to Rota from Guam and perhaps Saipan by sea or air.

2. All high elevation wet forests (forests above 200 m elevation) should be protected for Rota BWEs, including native and non-native forests as well as areas of damaged forest. Our research indicates that Rota BWEs have been restricted to these high elevation wet forests for at least the past 25 years and these areas are likely critical to the continued existence of the Rota BWE. This protection is especially important due to the increased risk of extinction from potential future catastrophes (e.g. typhoons) on Rota (Mangel and Tier 1994). Potentially this habitat could be designated critical habitat under the Endangered Species Act, protected under a Habitat Conservation Plan (Section 10, ESA), or preserved by some other mechanism. However, it should be emphasized that the Rota BWE is the rarest endemic vertebrate species in the Marianas and is clearly a candidate for critical habitat designation. It should also be emphasized that this protection is urgent before further land clearing reduces the connectivity of the forest and increases the exposure of the forest to the full force of high winds from tropical storms.

3. A captive breeding program for the Rota BWE is probably warranted. The Rota BWE has experienced a 90% population decline in the last 14 years, it appears to be a high elevation wet forest specialist, and it is found only on the island of Rota. This makes the Rota BWE the rarest species in the Mariana Islands. Since the causes of the population decline are not well understood it is imperative that a captive breeding program be started to establish a second

population off the island of Rota.

4. An active population monitoring program for the Rota BWE is needed to keep track of changes in the Rota BWE population. This monitoring program should consist of a series of permanent survey stations within the current and historical range of the Rota BWE. These survey stations should be placed along previous survey transects, within the study plots used in this study, and in areas which have not been well studied. In addition, we recommend that the variable circular plot technique be used to allow for both density and abundance estimates and that monitoring be undertaken under similar conditions. These conditions include trained observers, the time of year, and good weather.

5. Our understanding of why the Rota BWE population declined and why it is restricted to high elevation wet forest is still unclear. Therefore, further research (see Appendix N for other research methods used in this study) in the following areas are needed:

   a. Population dynamics - Active nest monitoring and color banding are needed to provide information on nest success and both juvenile and adult survival. This information would help determine the main causes of mortality (e.g. native and non-native predators) in the different age classes and allow more effective management of the species.

   b. Habitat and prey selection - It is not clear from this study what characteristics of high elevation forest affect the distribution of Rota BWEs within this forest type. Therefore, a better understanding of nesting and foraging habitat selection (with larger sample sizes than those obtained in this study and a focus on the importance of flowers as foraging substrates) as well as prey selection may provide us with information to explain their distribution within their range.

c. Predators - We know very little about the impacts of native and non-native predators on the Rota BWE population. Therefore research on the impact of potential predators like black drongos, rats, monitor lizards, collared kingfishers, and feral cats is needed. This is especially true for introduced rats and the black drongo which have both been implicated in the decline of the Rota BWE. Research on these two introduced predators may included research on effective control measures. However, we feel this should not be a priority over brown tree snake interdiction efforts and protection of habitat. In addition, we feel that any predator control should be undertaken as a well designed research study (including replicated treatment and control plots) that would not have negative effects on native wildlife populations and the environment (e.g. Fancy and Snetsinger's (1996) proposed use of satellite dumping for black drongo control).

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Table 1. Correlations between habitat variables and the first three principal components extracted from data recorded at 20 Rota bridled white-eyes study sites on Rota, 1998 and 1999.

	Component		
Habitat variable	I	II	III
Elaeocarpus joga density	0.33	0.71	0.12
Pandanus tectorius density	0.71	-0.03	0.35
Guettarda speciosa density	-0.45	0.30	0.50
Premna obtusifolia density	0.30	-0.21	-0.23
Ficus tinctoria density	0.26	0.10	-0.76
Ficus prolixa density	0.31	-0.14	0.27
Hernandia labyrinthica density	0.53	0.67	0.28
Total tree basal area	-0.49	0.50	0.27
Total tree density	0.69	-0.16	0.12
Stem density	0.59	-0.40	0.55
Canopy height	-0.58	0.41	0.09
Epiphyte density	0.17	0.66	-0.40
Foliage volume (3-9m)	-0.17	-0.27	-0.51
Elevation	0.68	0.45	-0.39
Percent of total variance	23	17	15
Cumulative percent of variance	23	40	55

Table 2. Nest dimensions of Rota, Saipan, and Tinian bridled white-eye nests recorded in the Commonwealth of the Northern Mariana Islands, 1999. Wilcoxon rank-sum tests were used to determine the difference between Rota and Saipan bridled white-eye nests.

	Tinian	Rota (n = 4)			Saipan (n = 4)			Wilcoxon rank-sum	
Nest Dimension (mm)	(n = 1)	Mean ± SE	Median	Range	Mean ± SE	Median	Range	Z	P
Nest depth	35.0	27.8 ± 1.0	28.5	25.0 - 29.0	29.0 ± 0.8	29.0	27.0 - 31.0	15.0	0.44
Inner diameter	39.1	45.9 ± 0.7	45.6	44.6 - 47.7	43.5 ± 1.8	43.9	39.3 - 47.0	21.0	0.47
Outer diameter	67.0	59.0 ± 0.7	58.7	57.7 - 60.8	57.5 ± 1.9	57.4	53.0 - 62.3	21.0	0.47
Total nest height	53.0	39.8 ± 1.0	39.5	36.0 - 44.0	46.8 ± 3.0	45.5	41.0 - 55.0	12.0	0.11
Nest wall width	14.6	8.0 ± 0.4	8.2	7.0 - 8.8	9.3 ± 0.2	9.4	8.9 - 9.6	10.0	0.03

Table 3. Nest site characteristics of Rota and Saipan bridled white-eye nests recorded on the islands of Rota and Saipan, CNMI, 1998 and 1999.

	Rota				Saipan				Wilcoxon rank-sum	
Nest Site Characteristic	n	Mean ± SE	Median	Range	n	Mean ± SE	Median	Range	Z	P
Nest height (m)	18	8.3 ± 0.7	9.2	2.5 - 12.8	8	1.7 ± 0.2	1.5	1.2 - 2.6	37.5	<0.01
Nest-bole distance (m)	17	3.1 ± 0.4	2.7	0.9 - 6.7	8	1.1 ± 0.2	1.0	0.5 - 1.7	50.0	<0.01
Nest tree height (m)	16	10.3 ± 0.8	10.8	3.3 - 14.6	8	4.1 ± 0.5	4.0	1.5 - 6.3	44.0	<0.01
Nest tree dbh (cm)	17	29.9 ± 40.2	291.0	23.0 - 602.0	7	3.8 ± 8.3	35.0	7.0 - 70.0	36.0	<0.01
Distance from nest to top of tree (m)	16	2.2 ± 0.5	1.3	0.4 - 6.0	8	2.3 ± 0.5	2.1	0.1 - 5.1	113.0	0.44

Table 4. Method used to produce a crude estimate of the Rota bridled white-eye population size within five study regions on Rota in 1998 and 1999.

Study area	n	Actual area surveyed (ha)	Estimated area represented (ha)	Mean (± SE) abundance index (no./ha)	Population estimate	95% CI
A	4	0.8	26.5	9.9 ± 1.8	262	111 - 413
B	2	0.4	40.6	8.4 ± 1.9	341	0 - 1,320
C	5	1.0	37.2	9.5 ± 3.5	353	0 - 714
D	5	1.0	59.4	2.0 ± 0.5	119	36 - 202
E	4	0.8	17.3	1.0 ± 0.8	17	0 - 61
					1092	Total

Table 5. Mean habitat characteristics for Rota bridled white-eye foraging habitat use (n = 32) and availability (n = 32). See text for description of habitat measurements.

		Use		Available	
Habitat scale	Habitat characteristic	Mean[a]	SE	Mean	SE
Broad scale ($400\ m^2$)					
	Tree basal area (≥ 10 cm)(m^2/ha)	32.6	3.0	31.5	2.6
	Total tree density (≥ 10 cm) (no./ha)	628	37.5	719	50.7
	Density by size class (no./ha)				
	10.0 - 19.9 cm	398	32.3	461	43.6
	20.0 - 29.9 cm	125	15.6	142	15.9
	≥ 30 cm	105	12.3	118	13.8
Intermediate scale (3-m radius)					
	Foliage volume (%)				
	0-3 m	12.8	1.0	13.4	1.2
	3-9 m	13.1	1.1	10.8	1.1
	9-15 m	4.4	0.9	3.0	0.6
	Canopy cover (%)	91	2.0	82	4.7
Fine scale (0.5-m radius)					
	Foliage volume (%)	31*	3.8	20*	3.5

[a] Means marked with an asterisk are different (Paired t-test, $P < 0.10$).

Table 6. Proportion of Rota bridled white-eye foraging substrate types and substrate species used and available in two Rota bridled white-eye study plots on Rota, 1998 and 1999.

Study plot	Substrate	Proportion used	Proportion available	G-test X^2	df	P
1HA	Type:			0.00	3	> 0.10
	Branch	0.217	0.240			
	Leaves	0.348	0.362			
	Flowers	0.174	0.000			
	Other	0.261	0.398			
	Total	1.000	1.000			
		(n = 23)	(n = 228)			
	Species:			0.00	3	> 0.10
	Hernandia labyrinthica	0.087	0.205			
	Elaeocarpus joga	0.609	0.000			
	Premna obtusifolia	0.174	0.031			
	Other	0.130	0.764			
	Total	1.000	1.000			
		(n = 23)	(n = 228)			
1HB	Type			0.00	3	> 0.10
	Branch	0.238	0.204			
	Leaves	0.429	0.404			
	Flowers	0.143	0.000			
	Other	0.190	0.392			
	Total	1.000	1.000			
		(n = 21)	(n = 155)			
	Species:			0.00	2	> 0.10
	Hernandia labyrinthica	0.286	0.025			
	Elaeocarpus joga	0.238	0.036			
	Other	0.476	0.939			
	Total	1.000	1.000			
		(n = 21)	(n = 155)			

Table 7. Mean density per hectare indices and frequency of birds detected over three survey periods in study plots designated high ($\geq$ 2 white-eyes/ha) and low (< 2 white-eyes/ha) density Rota bridled white-eye areas by Fancy and Snetsinger (1996) on Rota, 1998 and 1999.

	High (n = 9)			Low (n = 9)		
Bird species	Frequency	Mean[a]	SE	Frequency	Mean	SE
Rota bridled white-eye (*Zosterops rotensis*)	9	9.8*	2.6	6	2.0*	0.8
Black drongo (*Dicrurus macrocercus*)	8	1.8	0.5	8	1.8	0.5
Rufous fantail (*Rhipidura rufifrons*)	9	7.0	0.8	9	5.2	0.5
Micronesian honeyeater (*Myzomela rubratra*)	9	2.6	0.5	8	1.7	0.4
Micronesian starling (*Aplonis opaca*)	9	8.9	0.7	9	13.1	1.3
Mariana crow (*Corvus kubaryi*)	1	0.1	0.1	4	0.3	0.1
Collared kingfisher (*Halcyon chloris*)	7	2.2	0.5	8	1.8	0.4
Mariana fruit-dove (*Ptilinopus roseicapilla*)	8	1.7	0.4	9	2.3	0.3
White-throated ground-dove (*Gallicolumba xanthonura*)	6	1.0	0.4	5	0.5	0.2
Philippine turtle-dove (*Streptopelia bitorquata*)	0	0.0	0.0	1	0.1	0.1
Common fairy-tern (*Gygis alba*)	9	6.2	1.3	9	9.2	1.2

[a] Means with an asterisk are different (Tukey test preceded by two-way ANOVA for species and density classification interaction, $F = 6.73$, $df = 7$, $P < 0.01$). Philippine turtle-dove and Mariana crow estimates were not tested because of low frequencies.

Table 8. Mean descriptive habitat characteristics for areas designated high ($\geq$ 2 white-eyes/ha) and low (< 2 white-eyes/ha) density Rota bridled white-eye areas by Fancy and Snetsinger (1996) on Rota, 1998 and 1999. See text for descriptions of habitat measurements.

	High (n = 10)		Low (n = 10)	
Habitat Characteristic	Mean	SE	Mean	SE
Total tree basal area ($\geq$ 10 cm) (m^2/ha)	31.17*	2.06	35.57*	2.97
Tree Density ($\geq$ 10 cm) (no./ha)	665.8	51.7	625.4	68.0
Stem Density (< 10 cm) (no./ha)	4813	476	4663	474
Canopy Height (m)	12.1	0.6	12.1	0.6
Canopy Cover (%)	74	4	79	2
Epiphyte Density (no./ha)	0.109*	0.018	0.057*	0.017
Foliage Volume (3-9 m) (%)	9.8	1.4	15.7	5.4
Elevation (m)	386*	11	289*	19

[a] Means with an asterisk are different (Wilcoxon rank sum test, $P \leq 0.10$).

Table 9. Composition of woody flora (≥10 cm dbh) per hectare within ten study plots designated low (< 2 white-eyes/ha) and ten study plots designated high (≥ 2 white-eyes/ha) density Rota bridled white-eye areas by Fancy and Snetsinger (1996).

	Frequency[a]		Density		Dominance	
Species	Low	High	Low	High	Low	High
Aglaia mariannensis	8	5	8.8	3.8	0.12	0.04
Allophylus spp.	2	2	0.4	1.7	TR[b]	0.02
Areca cathecu	0	1	0.0	0.8	0.00	0.01
Artocarpus altilis	7	5	15.0	4.6	6.51	1.52
Artocarpus mariannensis	1	1	0.4	0.8	0.20	0.01
Bambusa vulgaris	0	1	0.0	1.7	0.00	0.01
Barringtonia asiatica	3	3	15.8	3.3	0.98	0.14
Cocos nucifera	0	1	0.0	0.8	0.00	0.03
Cycas circinalis	1	0	0.4	0.0	0.01	0.00
Cynometra ramiflora	1	0	7.5	0.0	0.27	0.00
Dendrocnide latifolia	7	3	21.7	2.1	0.41	0.05
Elaeocarpus joga	9	10	17.5	35.0	4.81	4.61
Erythrina variegata	2	0	1.7	0.0	0.50	0.00
Eugenia thompsonii	4	4	3.3	7.9	0.04	0.11
Eugenia spp.	2	0	0.8	0.0	0.01	0.00
Fagraea berteriana	2	3	1.7	4.2	0.06	0.16
Ficus prolixa	10	5	12.1	11.3	0.74	0.32
Ficus tinctoria	8	9	15.0	19.6	2.24	0.61
Geniostoma micranthum	1	2	0.4	1.3	0.01	0.02
Guamia mariannae	8	4	9.2	3.3	0.11	0.04
Guettarda speciosa	9	7	17.1	18.7	0.42	0.78
Hernandia labyrinthica	6	8	85.4	162.9	5.96	14.16
Hernandia sonora	3	0	20.8	0.0	3.13	0.00
Hibiscus tiliaceus	0	2	0.0	0.8	0.00	0.04
Intsia bijuga	2	0	0.8	0.0	0.04	0.00
Ixora triantha	1	2	0.4	0.8	TR	0.01
Macaranga thompsonii	8	8	17.9	14.6	0.79	0.54
Melanolepis multiglandulosa	2	0	2.1	0.0	0.02	0.00
Merrilliodendron megacarpum	2	2	60.4	111.3	1.90	3.99
Neisosperma oppositifolia	9	3	10.4	8.3	0.30	0.25
Ochrosia mariannensis	2	0	3.3	0.0	0.06	0.00
Pandanus dubius	9	4	45.0	17.5	0.62	0.22
Pandanus tectorius	10	9	137.5	166.7	1.76	1.90
Persea americana	0	1	0.0	4.6	0.00	0.17

Table 9. Continued

Species	Frequency		Density		Dominance	
	Low	High	Low	High	Low	High
Pipturus argenteus	7	2	23.3	1.3	0.27	0.01
Pisonia grandis	2	1	2.1	1.7	0.83	0.05
Pisonia umbellifera	5	5	10.9	5.4	0.39	0.22
Polyscias grandifolia	2	2	1.3	2.1	0.01	0.04
Pongamia pinnata	1	0	0.8	0.0	0.06	0.00
Pouteria obovata	2	1	0.8	0.4	0.05	0.01
Premna obtusifolia	10	10	39.6	47.5	1.15	1.09
Psychotria mariana	6	0	7.1	0.0	0.10	0.00
Randia cochinchinensis	1	0	0.4	0.0	TR	0.00
Serianthes nelsonii	1	0	0.4	0.0	0.05	0.00
Tarenna sambucina	1	3	0.8	1.7	0.01	0.03
Tristiropsis obtusangula	2	0	4.6	0.0	0.62	0.00

[a] Frequency indicates the number of study plots in which each species was observed out of 20 study plots in 1999.
[b] TR = trace, where mean values are < 0.005.

Table 10. Regression coefficients from stepwise multiple linear regression analyses for three bird species occurring in Rota bridled white-eye study plots on Rota, 1998 and 1999. Sample size for all regressions was 18.

	Dependent variable		
Independent variable	Rota bridled white-eye (*Zosterops rotensis*)	Rufous fantail (*Rhipidura rufifrons*)	Black drongo (*Dicrurus macrocercus*)
Elaeocarpus joga density	0.101	0.053	
Pandanus tectorius density			0.003
Ficus tinctoria density			
Ficus prolixa density	-0.239		
Stem density			
Canopy height	-1.352		-0.295
Epiphyte density			
Foliage volume (3-9m)	99.918	45.324	
Intercept	13.038	0.359	4.888
R^2	0.71	0.54	0.44
F	7.92	8.75	5.80
df	4	2	2
P	0.002	0.003	0.014

Table 11. Regression coefficients from stepwise multiple linear regression analysis for Rota bridled white-eye abundance estimates on nine transects with 57 stations in the Sabana region of Rota, 1999. Model was significant ($P < 0.001$) with an R^2 of 0.57.

Independent variable	Coefficient	SE	F	P
Hernandia labyrinthica density	0.201	0.038	27.6	< 0.01
Ficus spp. density	-1.140	0.502	5.16	0.03
Elatostema and *Procris* spp. index	0.418	0.121	11.9	< 0.01
Intercept	-0.074	0.155	0.2	0.63

Table 12. Presence and absence of woody flora (≥10 cm dbh) within five Rota bridled white-eye study areas on the Sabana and six Mariana crow study sites at various locations around the island of Rota, CNMI.

	Rota Bridled White-eye Study Areas					Mariana Crow Study Sites					
Species	A	B	C	D	E	1	2	3	4	5	6
Aglaia mariannensis	x	x	x	x	x	x	x			x	x
Allophylus spp.	x		x		x						
Areca cathecu			x								
Artocarpus spp.	x		x	x	x			x			x
Bambusa vulgaris			x								
Barringtonia asiatica	x		x	x	x	x	x			x	x
Casuarina equisetifolia								x	x		
Citrus sp.								x			
Cocos nucifera	x						x				
Cordia subcordata						x				x	
Cycas circinalis					x	x	x				x
Cynometra ramiflora					x				x	x	x
Dendrocnide latifolia	x	x	x	x	x			x	x		x
Drypetes dolichocarpa						x			x	x	
Elaeocarpus joga	x	x	x	x	x			x	x		x
Erythrina variegata			x	x							x
Eugenia thompsonii	x	x		x	x						
Eugenia spp.	x			x							
Fagraea berteriana	x	x	x	x							
Ficus spp.	x	x	x	x	x	x		x	x	x	x
Geniostoma micranthum	x			x							
Guamia mariannae	x	x	x	x	x			x		x	x
Guettarda speciosa	x	x	x	x	x	x	x	x	x	x	x
Hernandia labyrinthica	x	x	x	x	x						
Hernandia sonora			x	x			x				
Hibiscus tiliaceus	x		x			x		x		x	
Intsia bijuga			x	x		x		x	x	x	x
Ixora triantha	x		x		x						
Macaranga thompsonii	x	x	x	x	x	x	x	x		x	x
Mammea odorata						x	x			x	
Maytenus thompsonii							x	x	x	x	x
Melanolepis multiglandulosa				x	x						x
Merrilliodendron megacarpum			x								
Morinda citrifolia											x

Table 12. Continued

	Rota Bridled White-eye Study Areas					Mariana Crow Study Sites					
Species	A	B	C	D	E	1	2	3	4	5	6
Neisosperma oppositifolia	x		x	x	x	x	x	x	x	x	x
Ochrosia mariannensis					x					x	x
Pandanus spp.	x	x	x	x	x	x	x	x	x	x	x
Persea americana			x								
Pipturus argenteus	x	x	x	x	x		x	x	x		x
Pisonia spp.	x	x	x	x	x	x	x			x	x
Polyscias grandifolia	x	x		x	x			x			x
Pongamia pinnata				x							x
Pouteria obovata					x	x	x	x	x	x	
Premna obtusifolia	x	x	x	x	x	x	x	x	x	x	x
Psychotria mariana	x		x	x	x	x	x		x	x	x
Randia cochinchinensis					x					x	
Serianthes nelsonii			x								
Tarenna sambucina	x		x		x						
Tournefortia argentea							x				
Tristiropsis obtusangula	x				x						

Table 13. The five woody species (≥ 10 cm d.b.h.) in each of the twenty Rota bridled white-eye study plots with the highest basal areas and densities on Rota, CNMI, 1998 and 1999.

Species	1HA	2HA	1LA	2LA	1HB	1LB	1HC	2HC	3HC	1LC	2LC	1HD	2HD	3HD	1LD	2LD	1HE	2HE	1LE	2LE
Artocarpus spp.				x							x	x			x	x	x	x	x	x
Barringtonia asiatica				x															x	
Cynometra ramiflora																			x	
Dendrocnide latifolia																x				x
Elaeocarpus joga	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x			
Erythrina variegata									x											
Fagraea berteriana														x						
Ficus spp.					x	x		x	x	x			x			x		x	x	
Guettarda speciosa	x	x								x		x					x			
Hernandia labyrinthica	x	x	x		x	x					x	x	x	x	x		x	x		
Hernandia sonora										x	x									
Hibiscus tiliaceus							x													
Macaranga thompsonii				x				x	x			x	x							
Merrilliodendron megacarpum							x	x	x											
Pandanus spp.	x	x	x	x	x	x				x	x		x	x	x	x	x	x		
Persea americana							x													
Pipturus argenteus																			x	
Pisonia spp.			x							x					x					x
Premna obtusifolia	x	x	x	x	x	x	x	x						x				x		x
Tristiropsis obtusangula																				x

Table 14. Pearson's correlation coefficients for abundance estimates of six bird species within 35-m radius sampling stations along transects on the Sabana region of Rota in 1982 (n = 66) and 1994 (n = 136).

Year	Species[a]	Black drongo[b]	Rota bridled white-eye	Rufous fantail
1982				
	Black drongo	1.000		
	Rota bridled white-eye	-0.178	1.000	
	Rufous fantail	0.247*	0.134	1.000
	Micronesian honeyeater	0.394*	-0.115	0.169
1994				
	Black drongo	1.000		
	Rota bridled white-eye	0.149*	1.000	
	Rufous fantail	0.104	0.106	1.000
	Micronesian honeyeater	0.146*	0.091	0.504*

[a] Black drongo (*Dicrurus macrocercus*), Rota bridled white-eye (*Zosterops rotensis*), rufous fantail (*Rhipidura rufifrons*), and Micronesian honeyeater (*Myzomela rubratra*).
[b] An asterisk indicates a relationship between the two bird species (P < 0.10).

Table 15. Mean black drongo detection per transect estimates for the Sinapalo, Sabana, and intermediate regions of Rota in 1982, 1995, and 1998.

	Sabana		Intermediate		Sinapalo		Kruskal-Wallis	
Year	n	Mean ± SE[a]	n	Mean ± SE	n	Mean ± SE	H	P
1982	4	0.26 ± 0.10A	5	0.60 ± 0.16B	5	0.68 ± 0.07B	4.56	0.10
1995	4	0.19 ± 0.09A	7	0.81 ± 0.17B	6	0.90 ± 0.21C	6.66	0.04
1998	4	0.45 ± 0.28A	7	1.93 ± 0.42B	6	1.16 ± 0.28B	6.28	0.04

[a] Regions with the same letter are not different (Bonferroni Joint Ranking P< 0.10).

Table 16. Number of rats captured in 40 snaptraps in Rota bridled white-eye and four Mariana crow study areas in April 1999 on Rota, CNMI.

Study Area	Number of Rats Captured	Actual Trap-nights[a]	Potential Trap-nights[b]	Rats/Trap-night Actual	Rats/Trap-night Potential[c]
Rota Bridled White-eye	31	68	200	0.456	0.155AB
Mochong	32	72	200	0.582	0.160A
Rail-release	49	99	200	0.495	0.245B
Golf Course	23	72	200	0.319	0.115AB
Palii	13	29	200	0.448	0.065A

[a] Number of trap-nights excluding traps that were missing, unbaited, or were tripped and did not contain rats when checked.
[b] Number of trap-nights including all traps that were missing, unbaited, or were tripped and did not contain rats when checked.
[c] Areas with same letter are not different (Tukey test preceded by one-way ANOVA, $F = 5.61$, $df = 4$, $P < 0.01$).

Table 17. Approximate duration (days) of incubation period, nestling stage, and fledgling stage for four white-eye species (Zosteropidae).

Species	Incubation	Nestling stage	Fledgling stage
Rota bridled white-eye[a] (*Zosterops rotensis*)	8 - 12	10 - 12	$\geq$ 8
Green-bellied white-eye[b] (*Z. virens*)	11 - 12	10 - 12	-
Heron Island white-eye[c] (*Z. lateralis chlorocephala*)	12 - 14	12 - 14	14
Japanese white-eye[def] (*Z. japonicus*)	11	10 - 12	15 - 20

[a] This study
[b] Broekhuysen and Winterbottom (1968)
[c] Kikkawa and Wilson (1983)
[d] Brazil (1991)
[e] Isobe (1997)
[f] van Riper (2000)

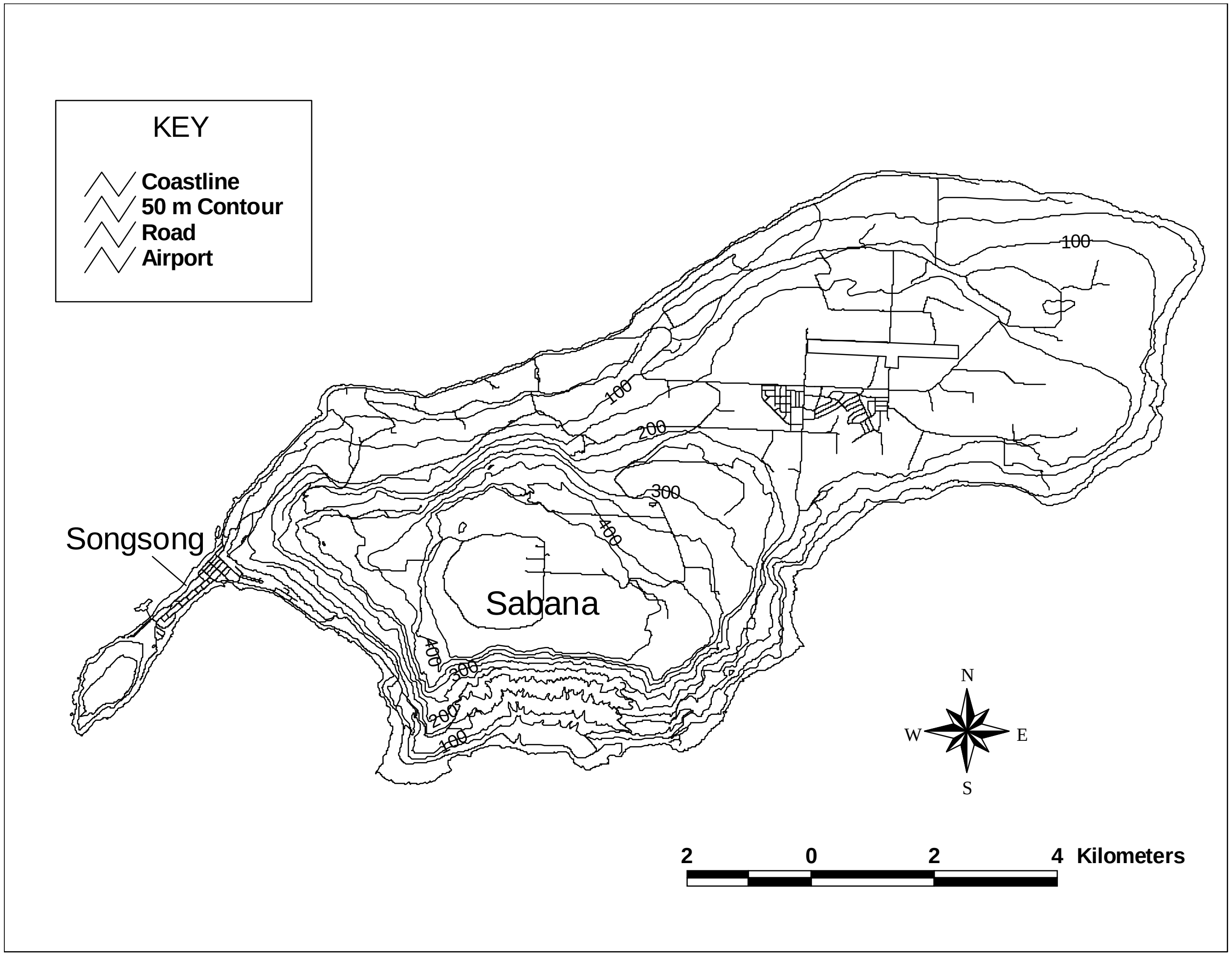


Figure 1. Locations of the Sabana and the village of Songsong on the island of Rota, CNMI.

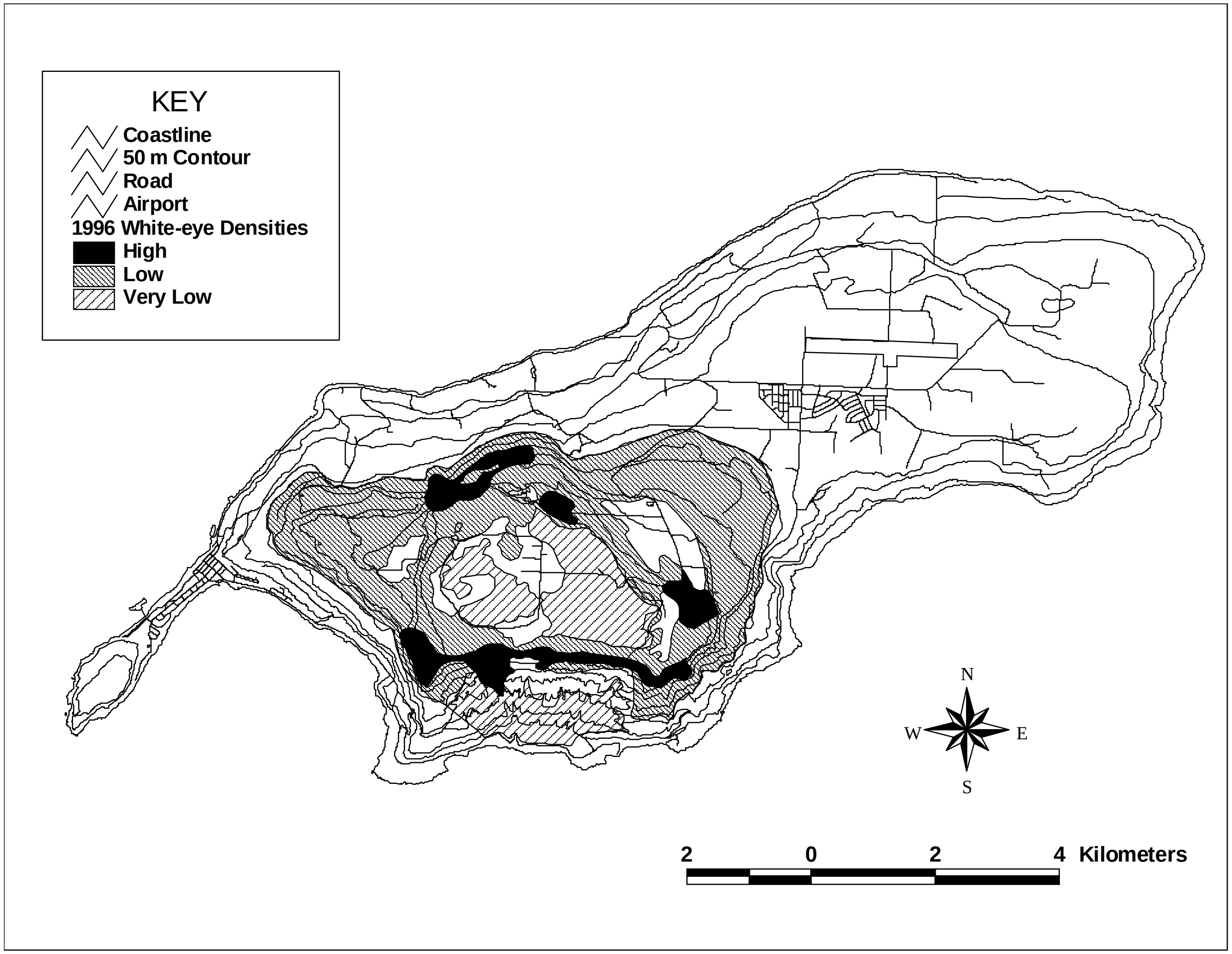


Figure 2. Locations of areas designated high and low density Rota bridled white-eye areas by Fancy and Snetsinger (1996).

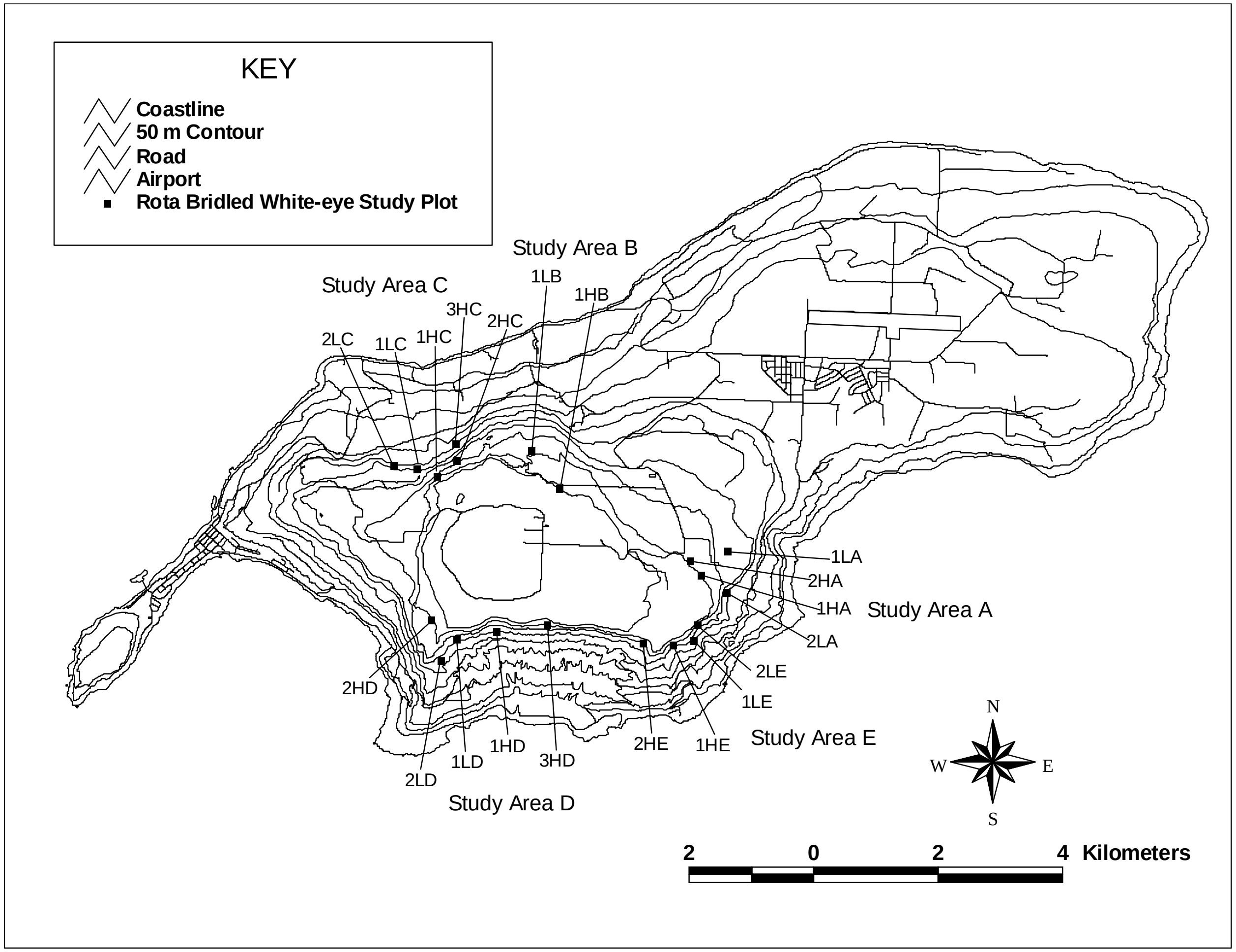


Figure 3. Locations of Rota bridled white-eye study areas and study plots on the island of Rota, CNMI.

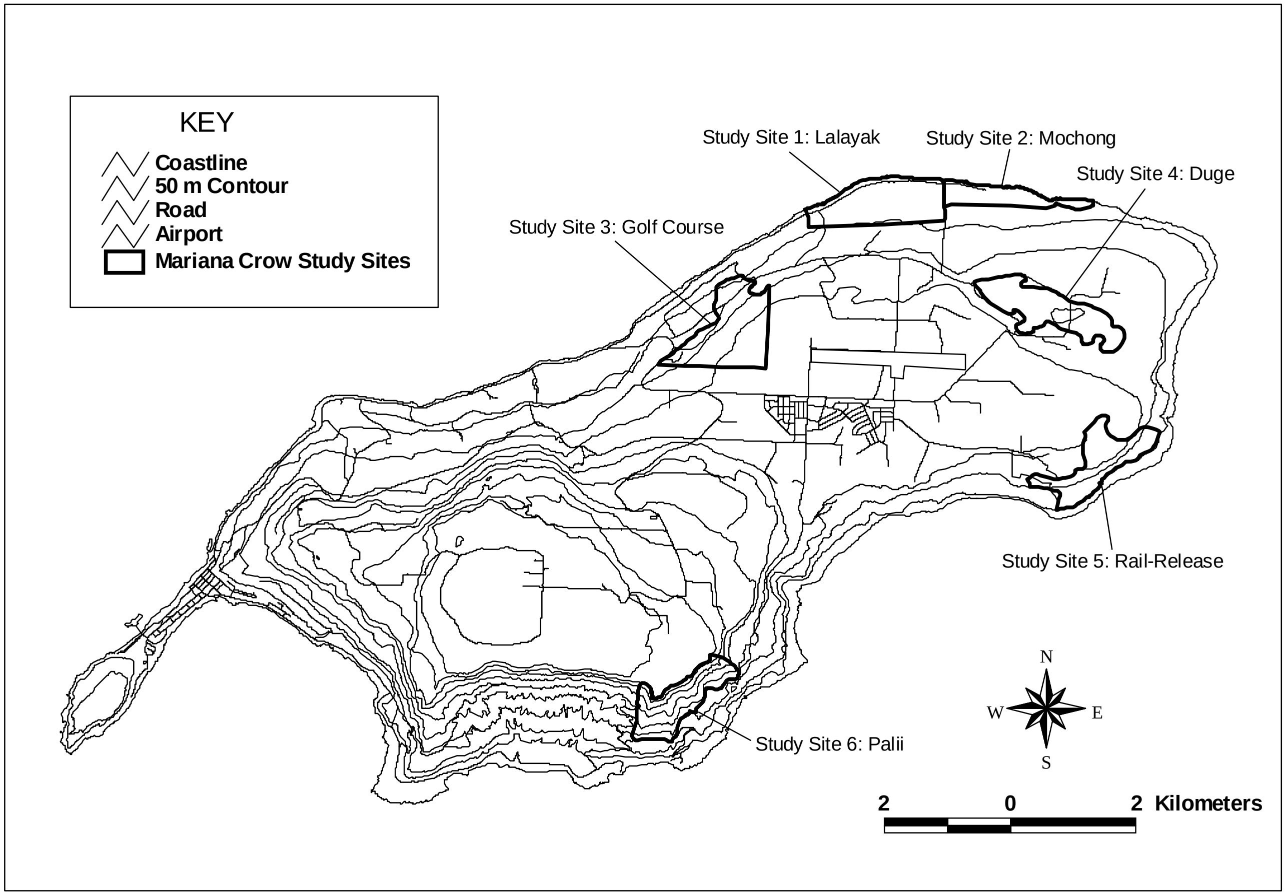


Figure 4. Locations of Mariana crow study sites on the island of Rota, CNMI.

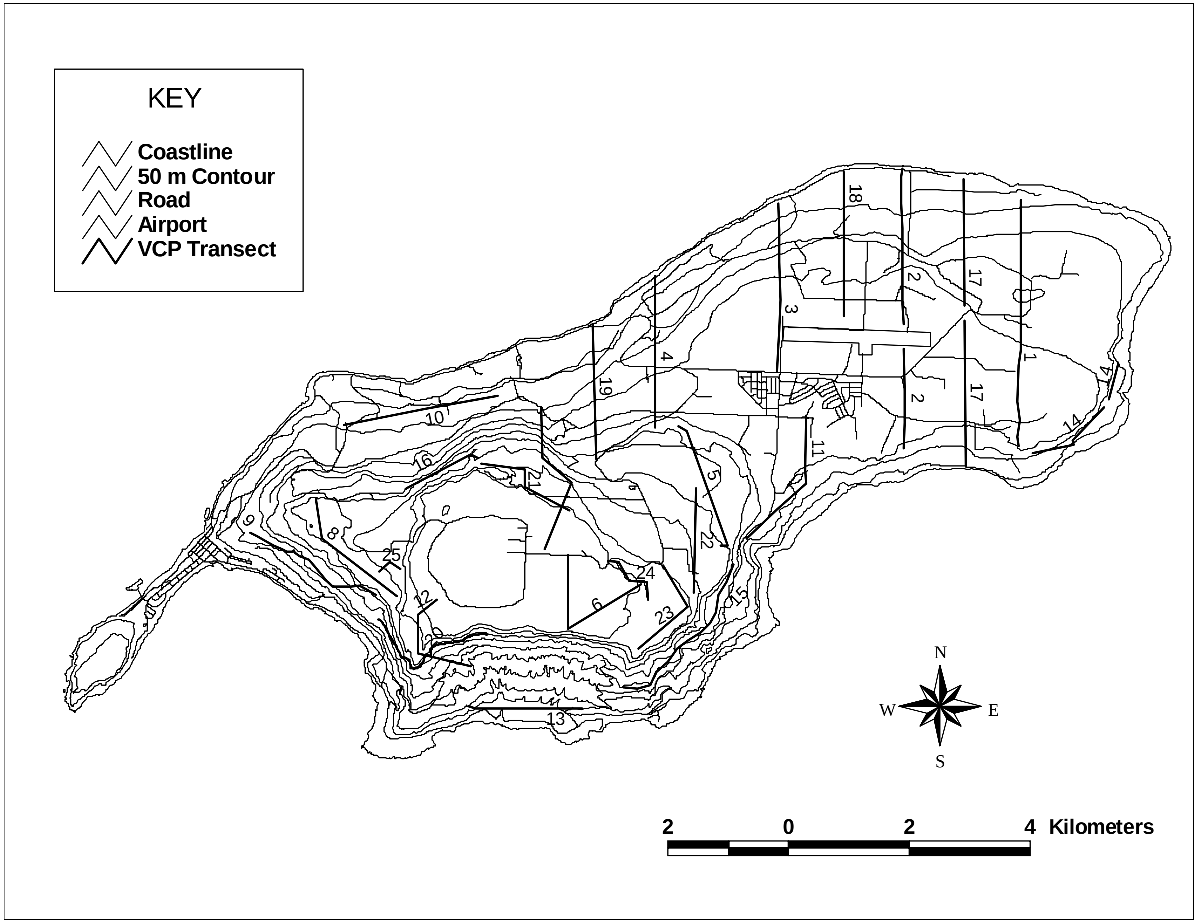


Figure 5. Locations of the 25 transects surveyed using the variable circular plot method in 1982, 1987, 1994, 1995, and 1998 on Rota, CNMI. See Appendix E for information on how transect labels changed across years.

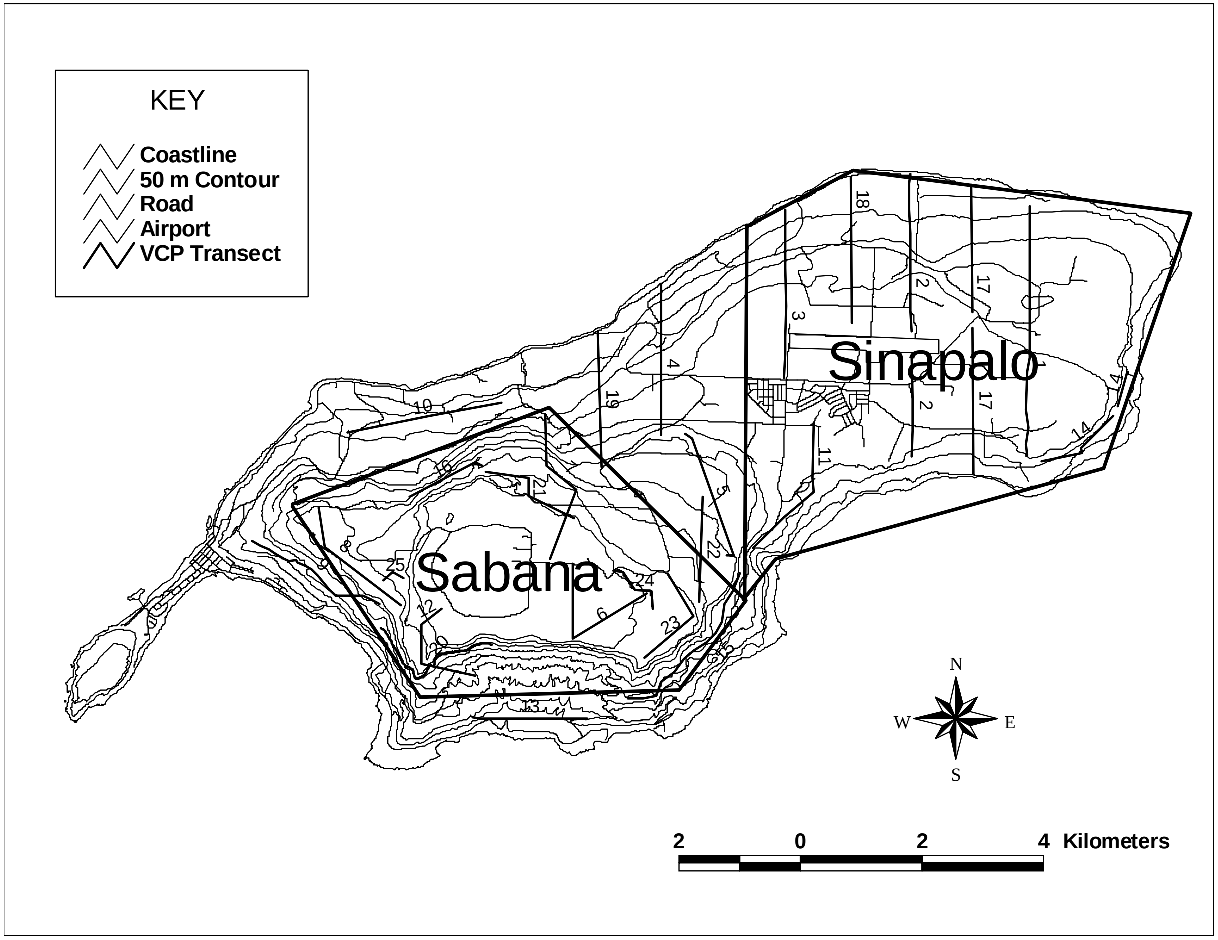


Figure 6. Locations of variable circular plot transects considered part of the Sabana, Sinapalo, and intermediate (areas not included in Sabana and Sinapalo regions) regions of Rota, CNMI.

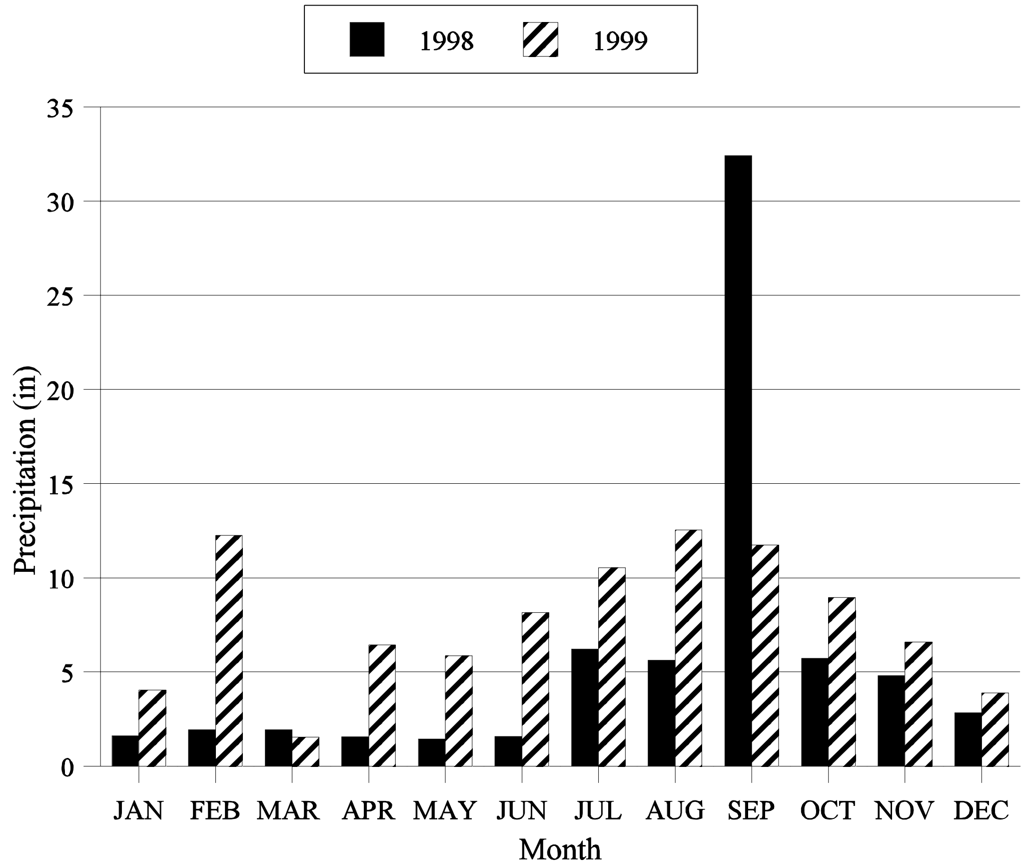


Figure 7. Monthly rainfall levels (inches) recorded at the Rota Airport on the island of Rota, CNMI in 1998 and 1999. Data from the NOAA webpage for the Rota Airport (see text for details).

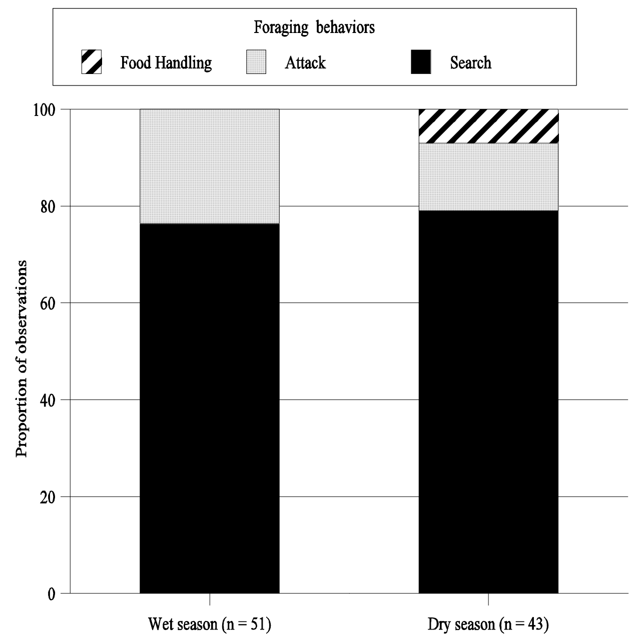


Figure 8. Rota bridled white-eye foraging behaviors observed during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.

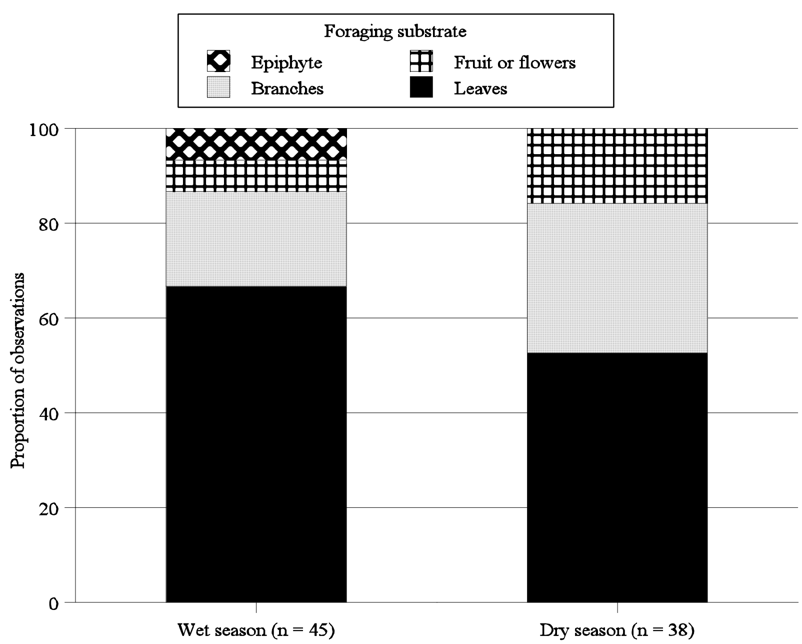


Figure 9. Foraging substrate types used by Rota bridled white-eyes in the wet (June - August) and dry (February - August) seasons on Rota in 1998 and 1999.

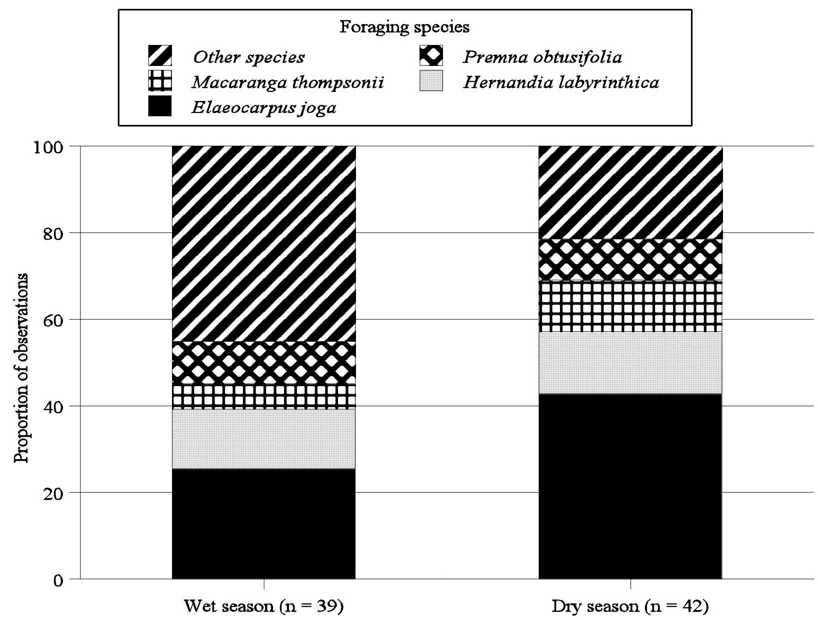


Figure 10. Tree species used for foraging by Rota bridled white-eyes in the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.

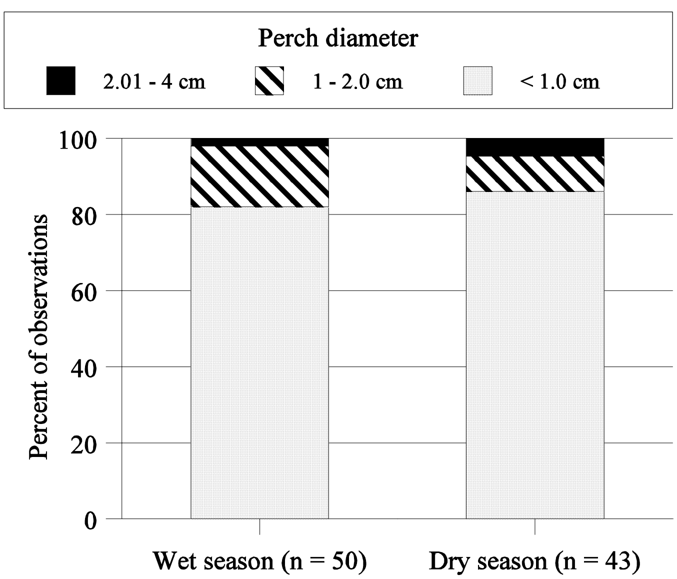


Figure 11. Perch diameters used by foraging Rota bridled white-eyes during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.

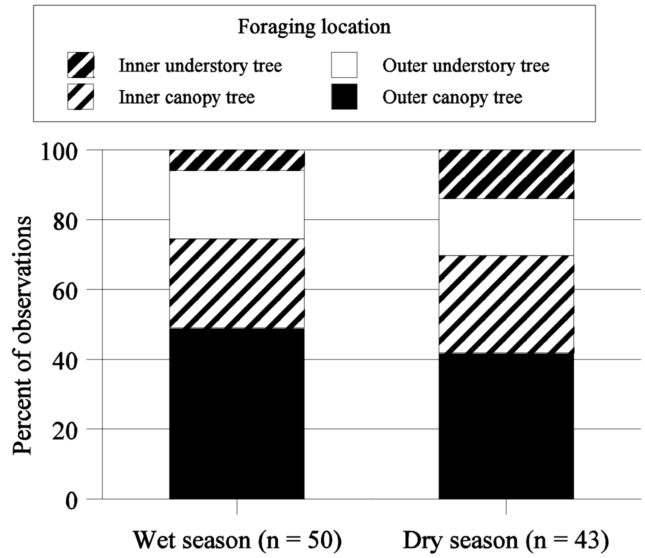


Figure 12. Foraging locations of Rota bridled white-eyes observed during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.

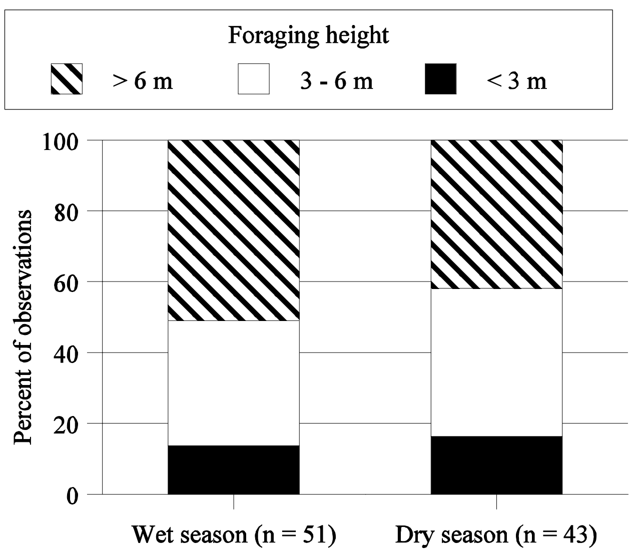


Figure 13. Foraging heights used by Rota bridled white-eyes during the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.

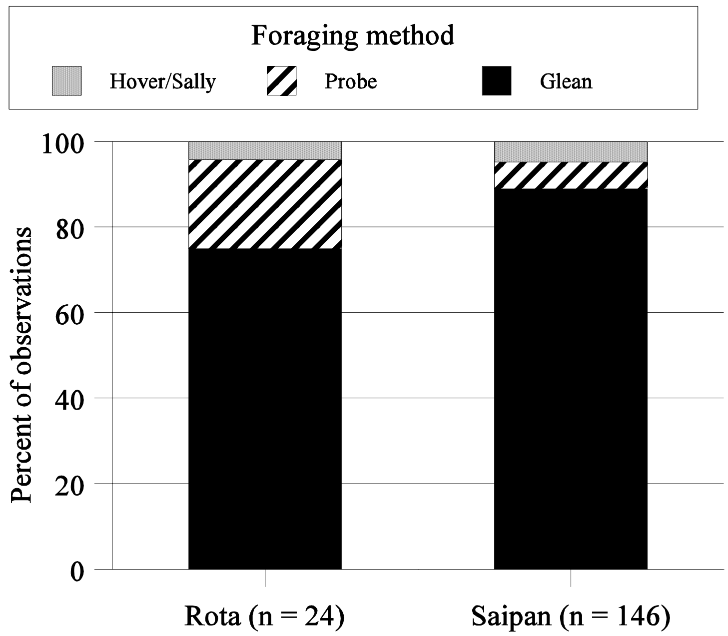


Figure 14. Foraging methods used by Rota bridled white-eyes on Rota in 1998 and 1999 and Saipan bridled white-eyes on Saipan (Craig 1989,1990), CNMI.

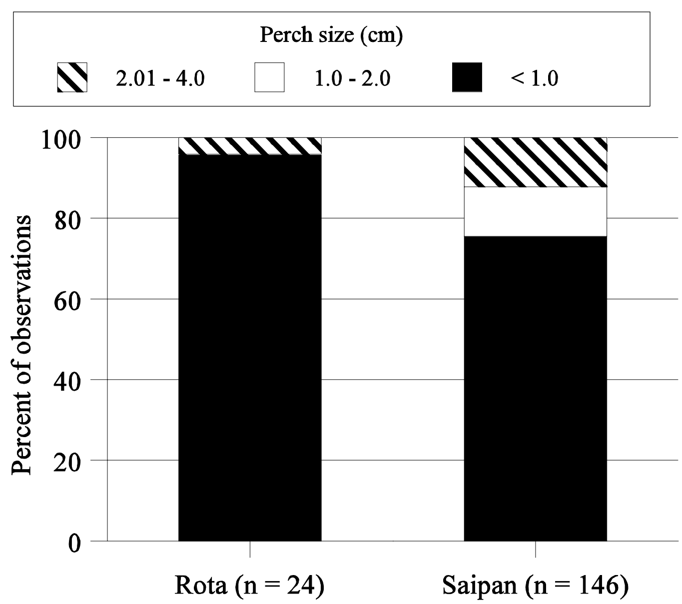


Figure 15. Perch sizes used by foraging Rota bridled white-eyes on Rota in 1998 and 1999 and Saipan bridled white-eyes on Saipan (Craig 1989,1990), CNMI.

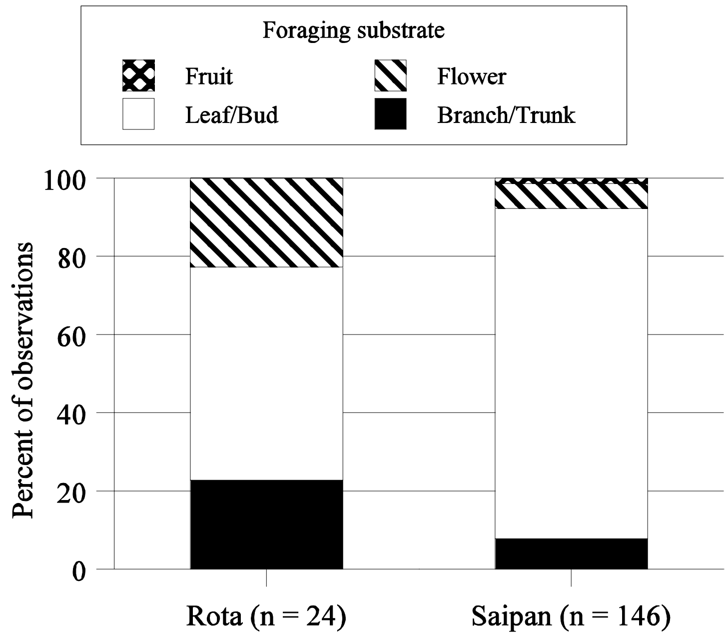


Figure 16. Foraging substrates used by Rota bridled white-eyes on Rota in 1998 and 1999 and Saipan bridled white-eyes on Saipan (Craig 1989,1990), CNMI.

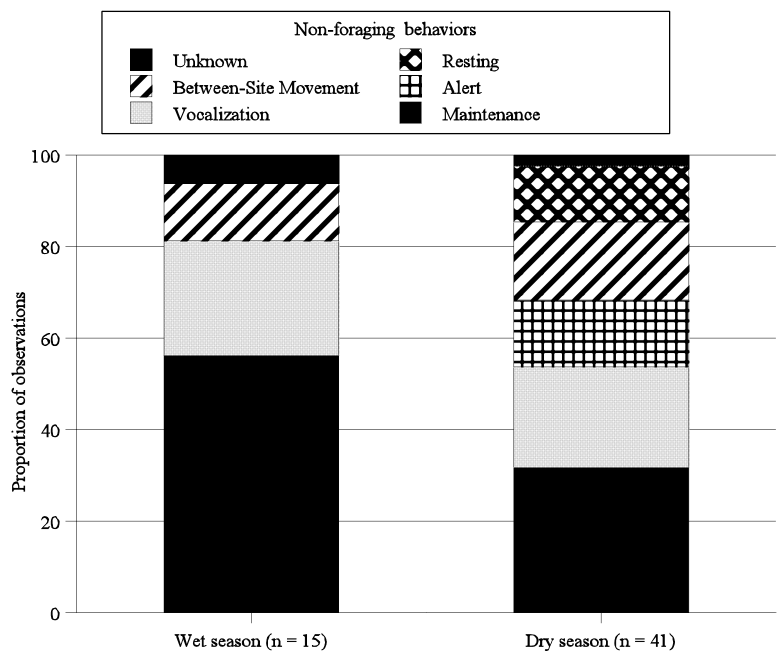


Figure 17. Rota bridled white-eye non-foraging behaviors recorded in the wet (June - August) and dry (February - April) seasons on Rota in 1998 and 1999.

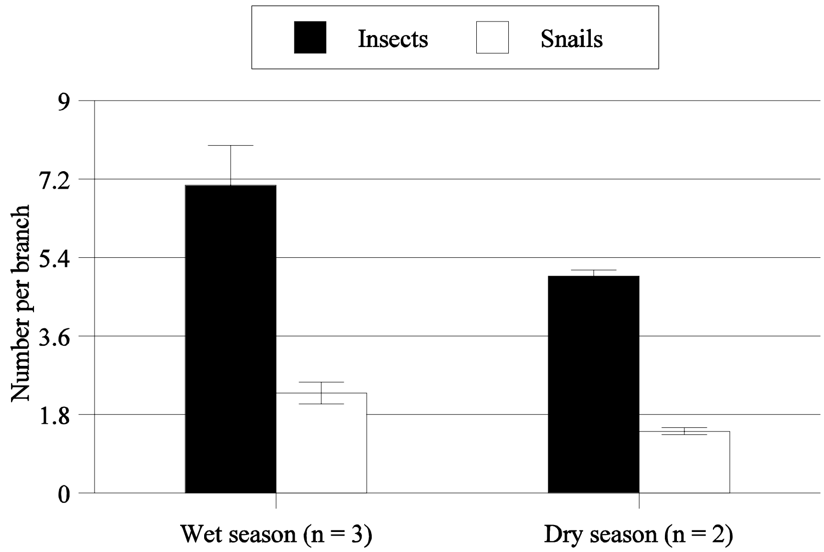


Figure 18. Mean (± SE) number of insects and snails per branch recorded during the wet (June - August) and dry (February - April) seasons in Rota bridled white-eye study areas on Rota, 1999.

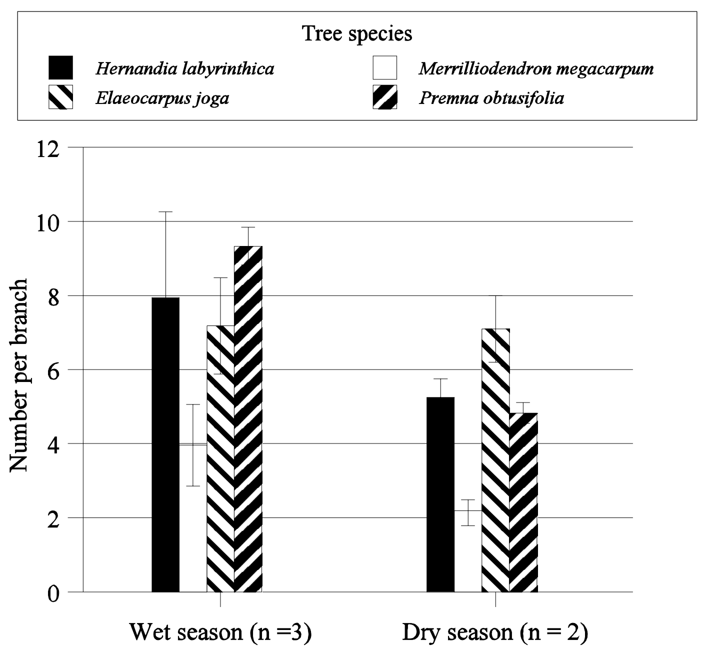


Figure 19. Mean (± SE) number of insects recorded per branch in the wet (June - August) and dry (February - April) seasons on four tree species sampled in Rota bridled white-eye study areas on Rota in 1999.

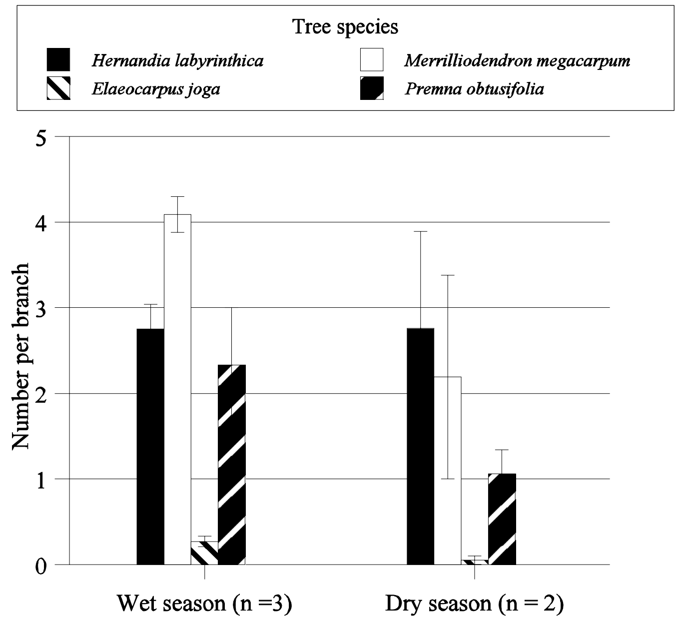


Figure 20. Mean (± SE) number of snails recorded per branch in the wet (June - August) and dry (February - April) seasons on four tree species sampled in Rota bridled white-eye study areas on Rota in 1999.

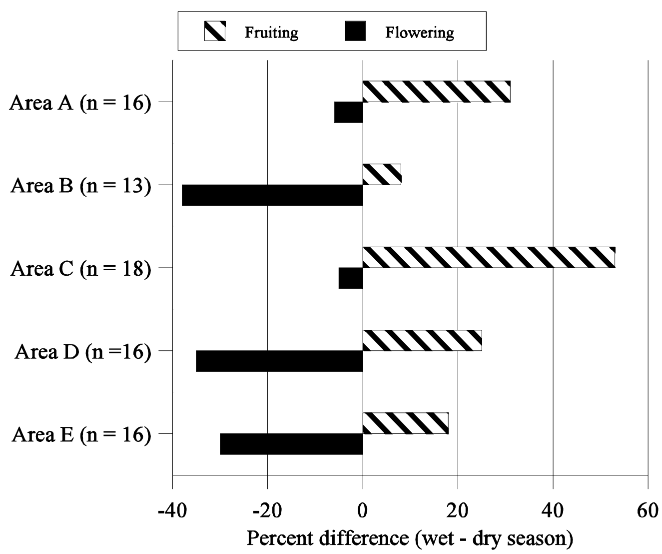


Figure 21. Difference in the percentage of trees fruiting or flowering between the wet (June - August) and dry (February - April) seasons in five Rota bridled white-eye study areas on Rota in 1999

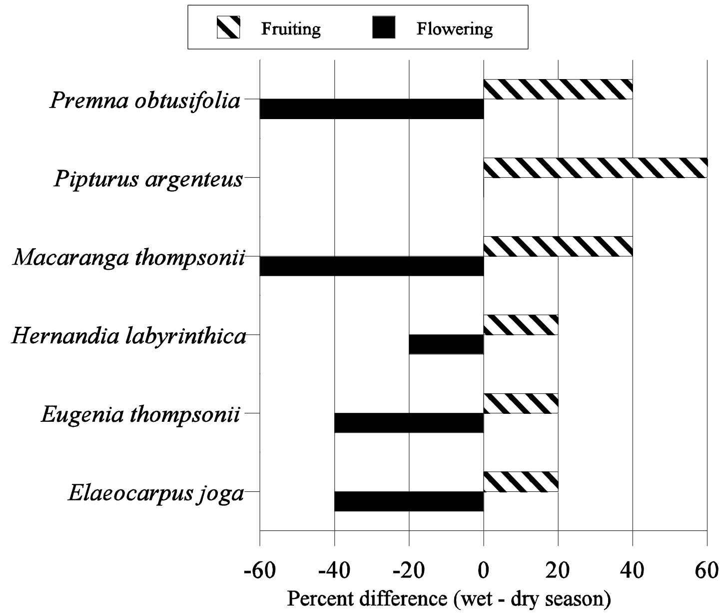


Figure 22. Difference in percentage of selected tree species fruiting and flowering between the wet (June - August) and dry (February - April) seasons in five Rota bridled white-eye study areas on Rota in 1999.

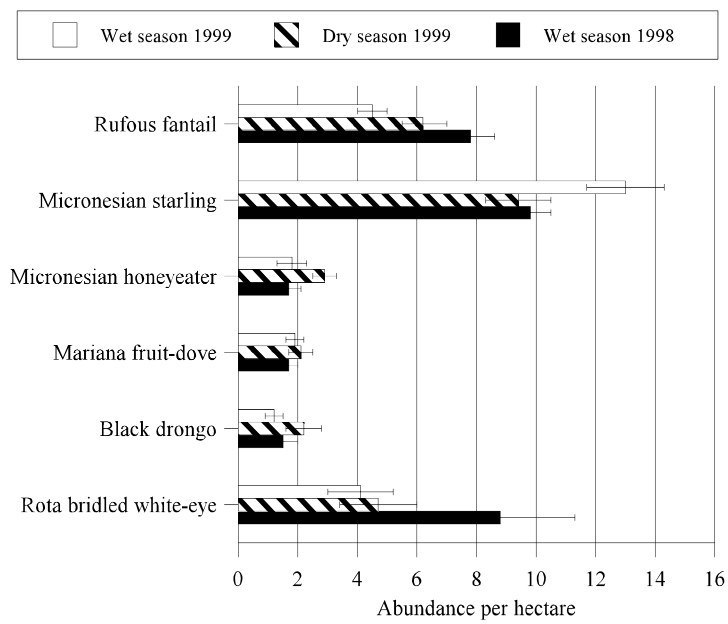


Figure 23. Mean (± SE) abundance per hectare indices of six bird species in Rota bridled white-eye study plots in three survey periods on Rota, 1998 and 1999.

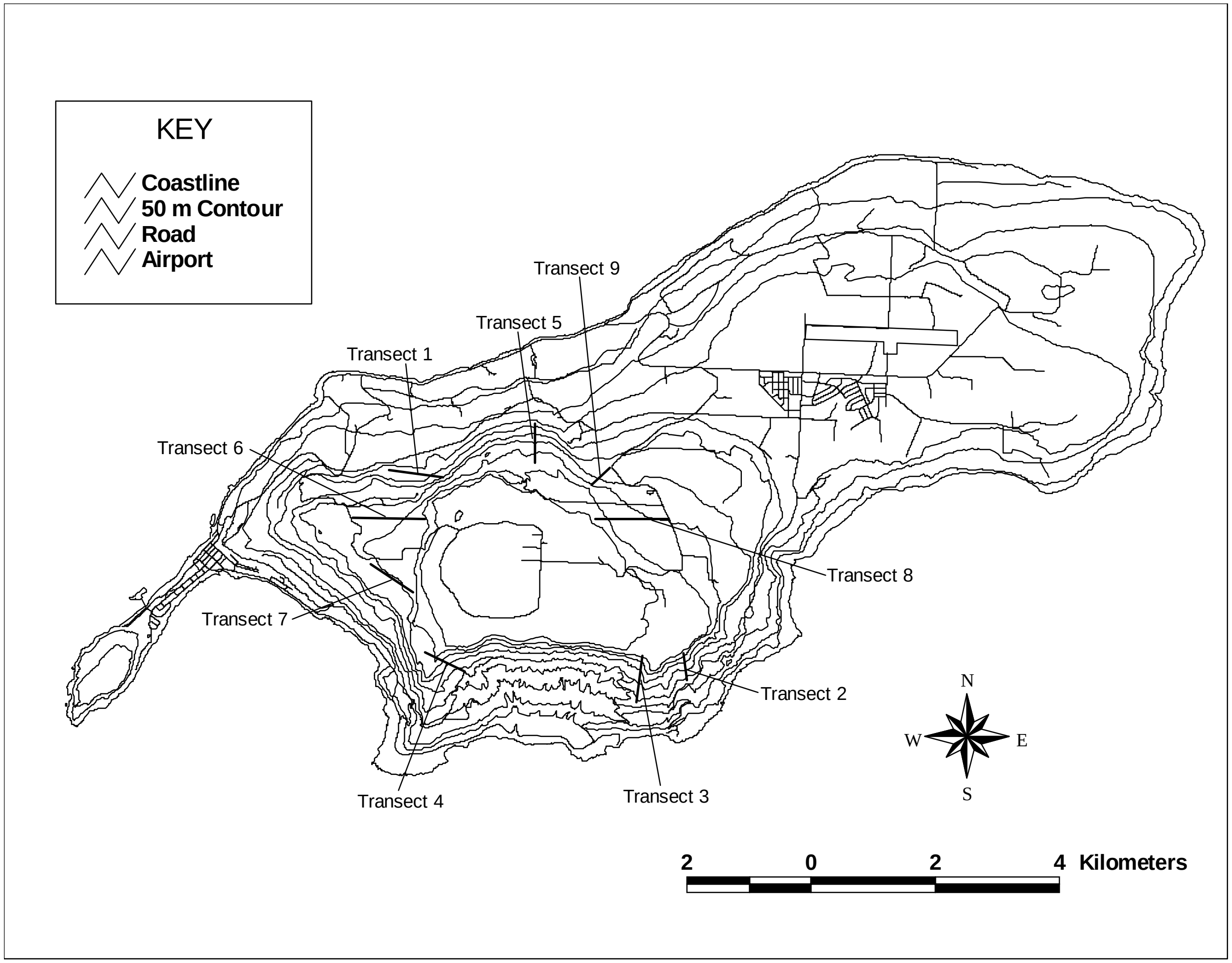


Figure 24. Locations of transects surveyed on the Sabana in April 1999 on Rota, CNMI.

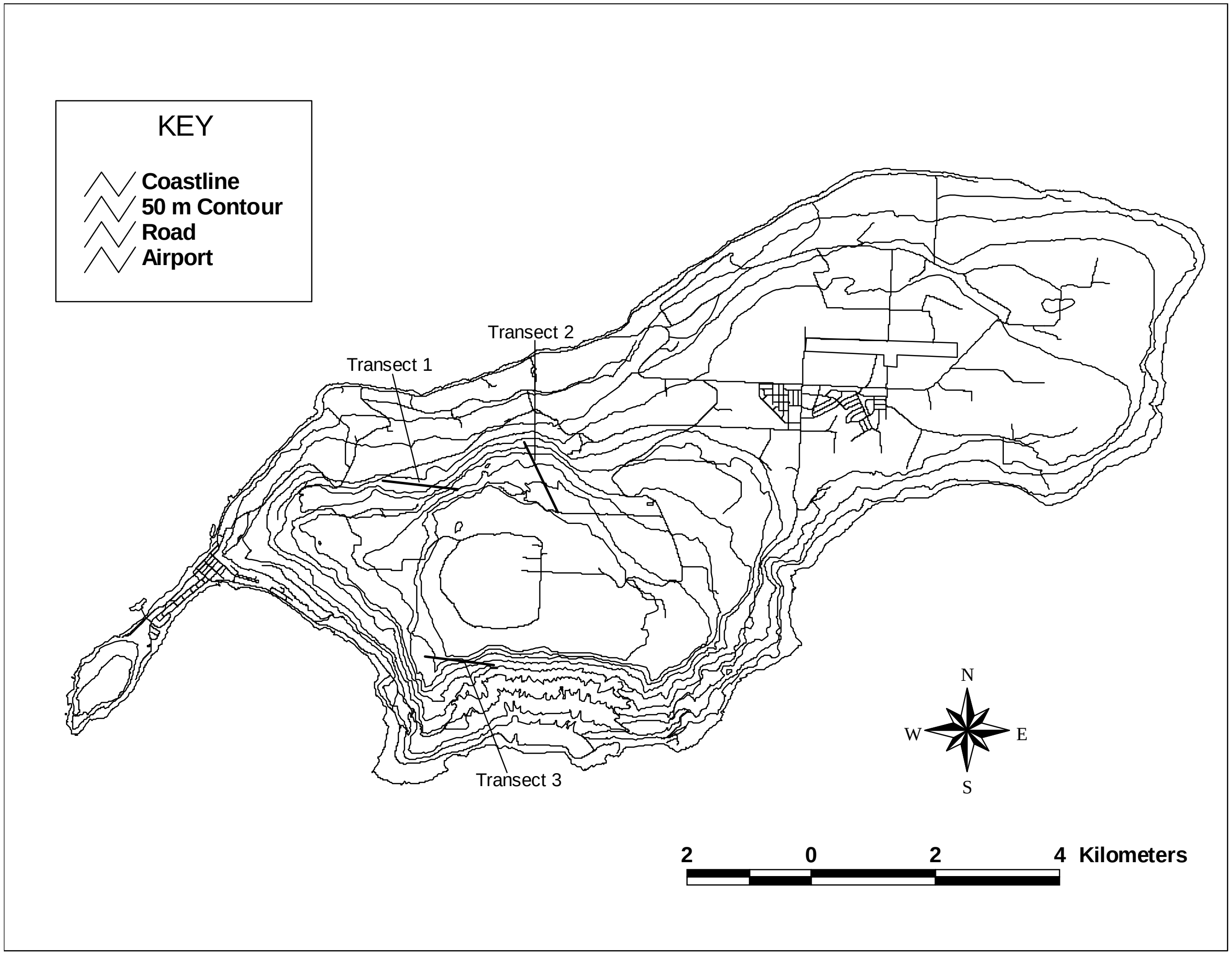


Figure 25. Locations of upper and lower elevation insect biomass transects sampled in July 1999 on Rota, CNMI.

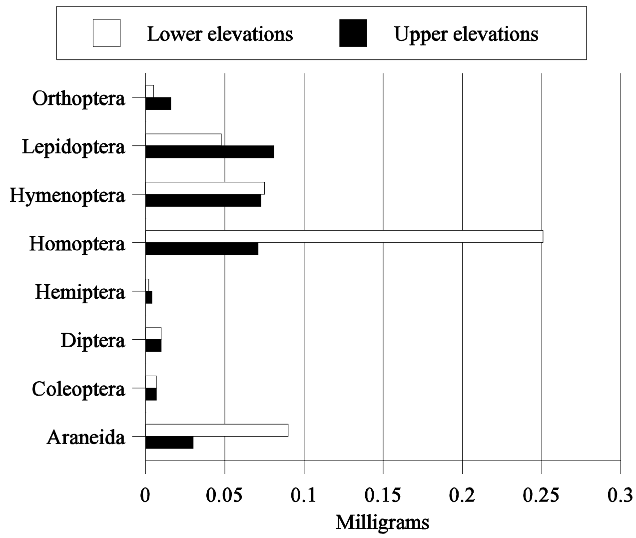


Figure 26. Mean milligrams of eight insect orders per gram of plant mass between upper (380-450 m) and lower (150-250 m) elevations in mature *Elaeocarpus joga* trees along three transects on Rota in July 1999.

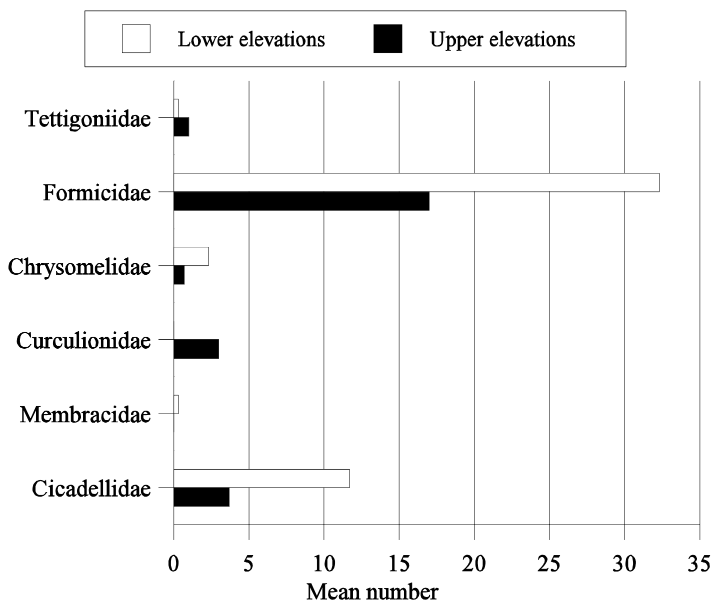


Figure 27. Mean number of insects in six families sampled at upper (380-450 m) and lower (150-250 m) elevations in mature *Elaeocarpus joga* trees along three transects on Rota in July 1999.

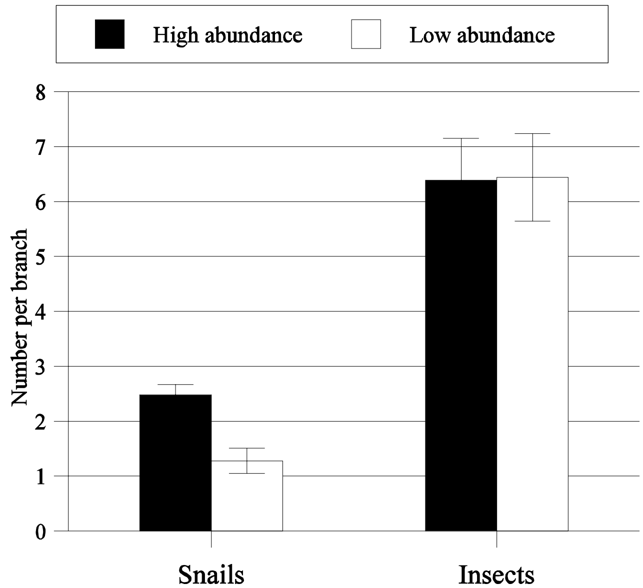


Figure 28. Mean (± SE) number of snails and insects per branch sampled at three high (≥ 2.5 white-eyes) and three low (< 1.0 white-eye) abundance Rota bridled white-eye study plots on Rota in 1999.

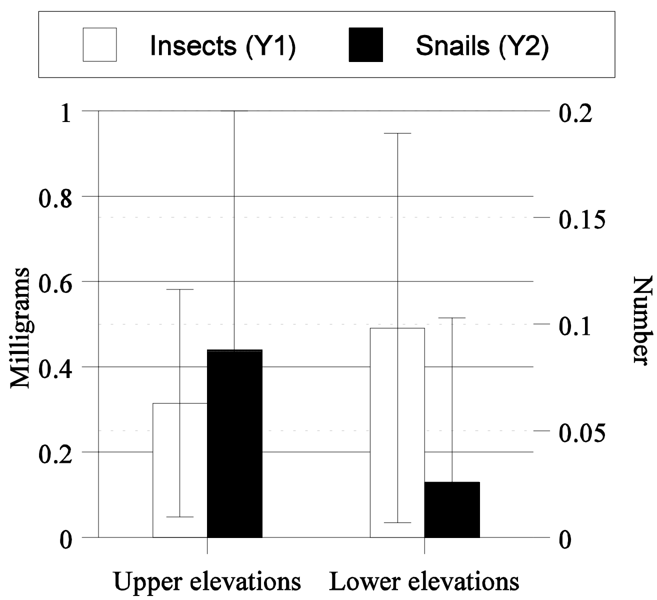


Figure 29. Mean (± SE) milligrams of insects per gram of plant mass and mean number of snails per gram of plant mass sampled at upper (380-450 m) and lower (150-250 m) elevations in mature *Elaeocarpus joga* trees along three transects on Rota in July 1999.

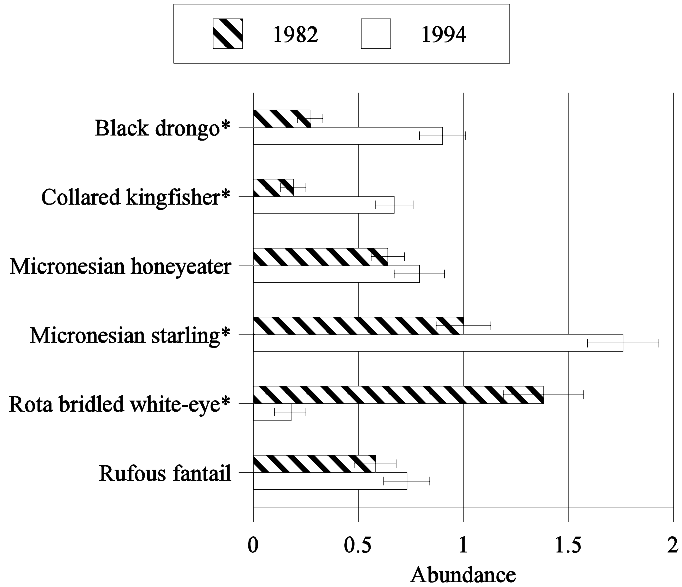


Figure 30. Mean (± SE) abundance estimates of six bird species recorded along four transects on the Sabana in 1982 (Engbring et al. 1986) and 1994 (USFWS, unpubl. data) on Rota, CNMI. An asterisk by the species indicates a difference between years (T-test, P < 0.10).

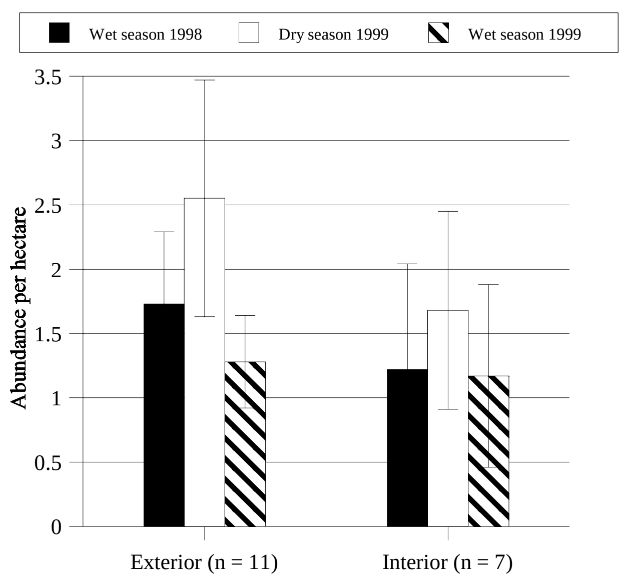


Figure 31. Mean (± SE) black drongo abundance indices in exterior (< 150 m from edge) and interior (≥ 150 m from edge) Rota bridled white-eye study plots in three survey periods on Rota in 1998 and 1999.

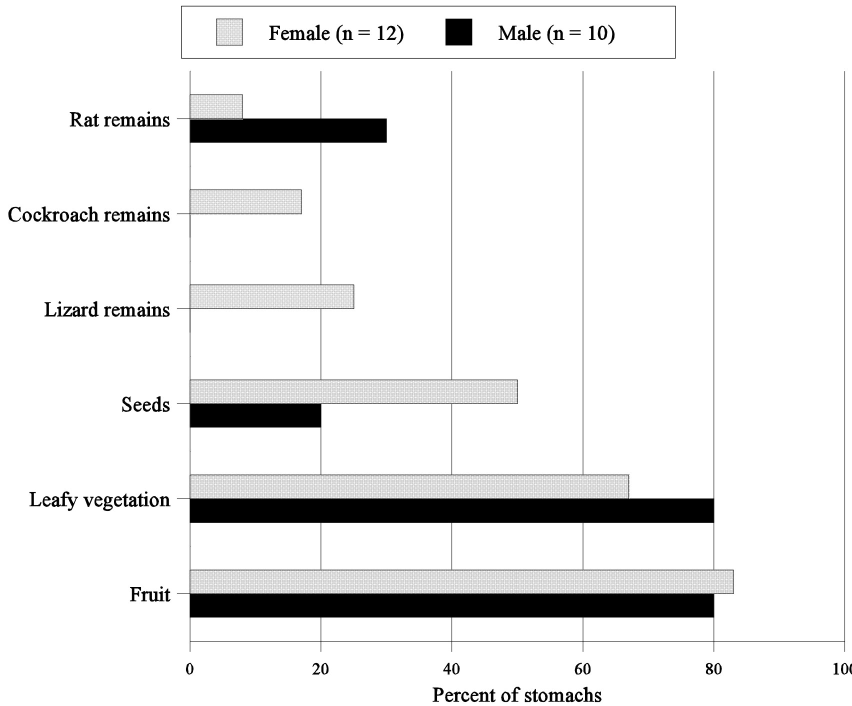


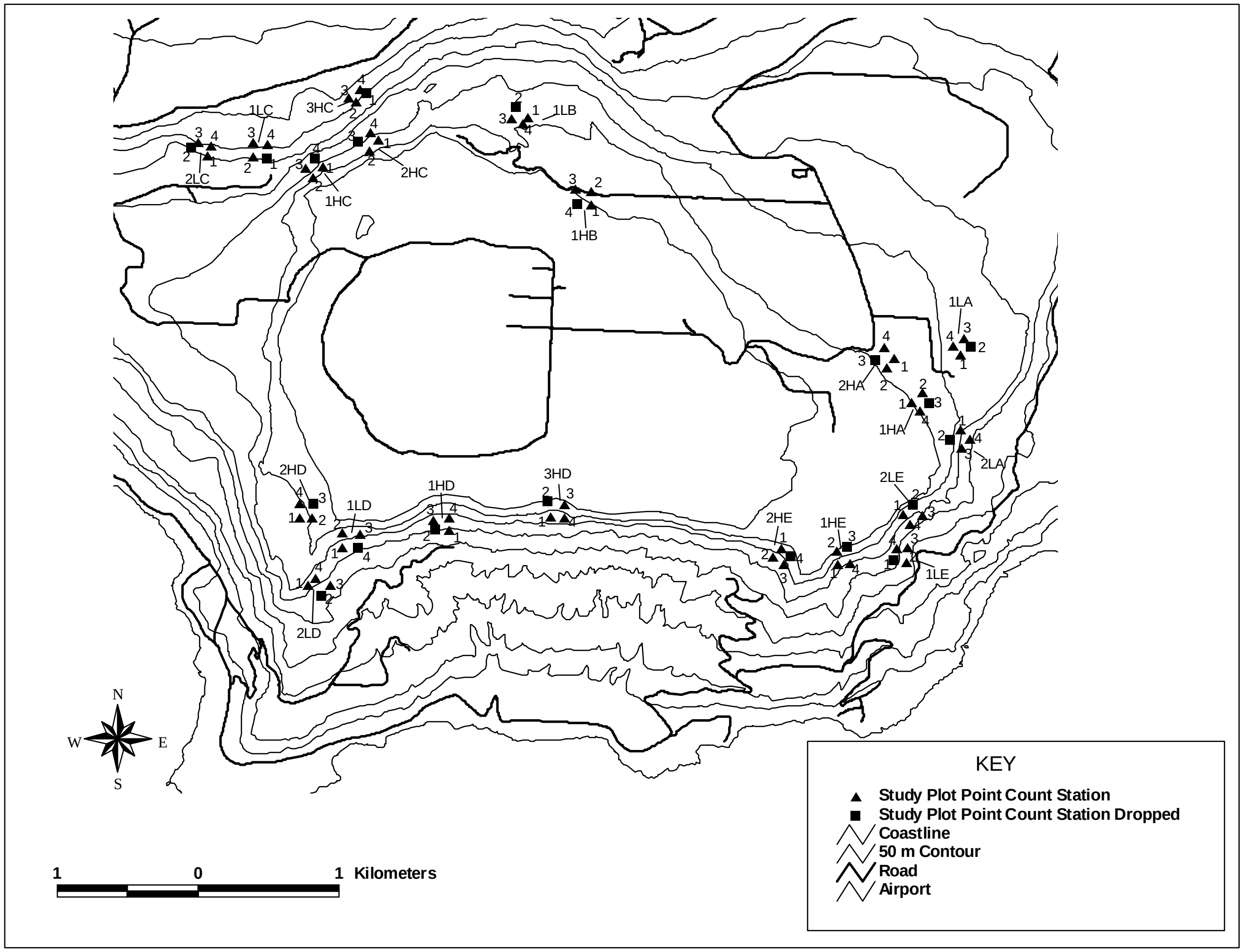
Figure 32. Stomach contents of female and male rats (*Rattus tanezumi*) trapped on Rota bridled white-eye study sites in April 1999 on Rota, CNMI.

Appendix A. GPS locations of the Rota bridled white-eye study plots on Rota, CNMI in 1998 and 1999.

Plot	Corner	Easting	Northing	Elevation (m)	Error (m)
1HA	1	0307115	1563347	396	12.0
	2	0307194	1563414	375	15.0
	3	0307250	1563337	370	13.0
1HB	2	0304848	1564837	450	7.1
	4	0304755	1564743	464	9.3
1HC	2	0302878	1564939	410	6.3
	3	0302826	1565008	352	17.0
1HD	1	0303841	1562444	305	8.2
	4	0303814	1562515	355	8.2
1HE	1	0306594	1562195	332	8.7
	2	0306585	1562295	370	9.7
	4	0306680	1562212	304	8.0
1LA	2	0307545	1563735	323	8.9
	3	0307492	1563794	371	11.0
	4	0307414	1563746	318	8.9
1LB	4	0304401	1565362	398	14.0
1LC	1	0302556	1565067	257	11.0
1LE	3	0307093	1562317	219	8.0
	4	0307011	1562308	231	7.8
2HA	2	0306944	1563587	390	12.0
	3	0306862	1563646	391	16.0
2HC	2	0303272	1565124	391	13.0
	3	0303201	1565188	375	7.5

Appendix A. Continued.

Plot	Corner	Easting	Northing	Elevation (m)	Error (m)
2HD	1	0302783	1562531	413	7.9
	2	0302868	1562531	429	9.0
	3	0302881	1562621	455	16.0
	4	0302782	1562631	411	7.7
2HE	1	0306196	1562314	399	12.0
2LA	2	0307398	1563080	282	27.0
	3	0307470	1563021	281	13.0
	4	0307533	1563083	253	8.4
2LC	4	0302177	1565685	178	8.2
2LD	2	0302933	1561974	283	8.8
	3	0302996	1562048	288	9.1
2LE	1	0307059	1562559	321	7.9
	4	0307108	1562485	285	9.4
3HC	2	0303176	1565475	329	11.0
	3	0303129	1565498	211	12.0
	4	0303208	156563	211	14.0
3HD	3	0304656	1562629	455	16.0



Appendix B. Locations of study plot point count stations on Rota, CNMI during 1998 and 1999. All point count stations marked with a square were not included in estimates of bird abundance.

Appendix C. Program Distance (Laake et al. 1998) estimates of effective detection radii of 11 bird species recorded in Rota bridled white-eye study plots in 1998 and 1999.

Bird Species	Number observed	Effective detection radius (m)	95% CI
Collared kingfisher (*Halcyon chloris*)	617	74.4	67.8 - 81.6
Common fairy tern (*Gygis alba*)	842	32.3	30.5 - 34.3
Mariana crow (*Corvus kubaryi*)	64	76.6	70.1 - 83.7
Mariana fruit-dove (*Ptilinopus roseicapilla*)	826	66.3	63.3 - 70.4
Micronesian honeyeater (*Myzomela rubratra*)	254	34.7	32.6 - 37.0
Micronesian starling (*Aplonis opaca*)	2018	33.0	32.2 - 33.7
Philippine turtle-dove (*Streptopelia bitorquata*)	21	90.8	74.6 - 110.6
Rota bridled white-eye (*Zosterops rotensis*)	1215	25.5	23.5 - 27.6
Rufous fantail (*Rhipidura rufifrons*)	877	33.0	31.7 - 34.3
White-throated ground-dove (*Gallicolumba xanthonura*)	61	31.0	26.8 - 35.8

Appendix D. Program Distance (Laake et al. 1998) estimates of effective detection radius (EDR) in meters for three point count stations in 20 Rota bridled white-eye study plots on Rota in 1998 and 1999.

		Station A		Station B		Station C	
Study plot	n	EDR	95% CI	EDR	95% CI	EDR	95% CI
1HA	11	48.2	44.8 - 51.8	42.1	38.5 - 46.1	46.2	43.5 - 49.1
2HA	10	34.2	30.9 - 37.8	29.2	26.8 - 31.9	20.4	18.0 - 23.0
1LA	10	30.3	26.5 - 34.8	48.9	45.6 - 52.4	30.0	26.9 - 33.3
2LA	11	48.9	45.7 - 52.4	44.5	42.4 - 46.8	38.7	35.2 - 42.4
1HB	9	44.1	35.1 - 55.5	46.7	44.2 - 49.5	46.4	43.6 - 49.5
1LB	9	39.6	35.4 - 44.3	47.4	42.6 - 52.7	48.5	45.2 - 52.1
1HC	10	31.3	27.3 - 35.9	24.6	21.2 - 28.4	30.1	28.1 - 32.2
2HC	11	33.7	31.8 - 35.8	35.2	33.2 - 37.4	36.9	33.7 - 40.5
3HC	6	58.8	37.3 - 92.7	49.7	43.9 - 56.2	49.0	45.1 - 53.3
1LC	11	42.3	39.1 - 45.8	44.1	41.5 - 46.9	32.0	29.5 - 34.8
2LC	11	32.6	30.2 - 35.2	33.1	30.6 - 35.7	39.4	33.2 - 46.7
1HD	10	36.5	34.3 - 38.8	43.9	40.1 - 48.0	36.9	34.5 - 39.4
2HD	9	36.2	32.6 - 40.2	39.0	36.0 - 42.2	40.8	36.8 - 45.3
3HD	6	36.8	34.0 - 39.8	57.7	37.4 - 89.0	37.1	32.1 - 42.9
1LD	10	39.0	32.2 - 47.2	37.9	35.1 - 40.9	30.8	27.8 - 34.2
2LD	9	40.7	36.4 - 45.7	48.5	43.8 - 54.2	25.3	20.7 - 31.1
1HE	9	56.7	52.1 - 61.7	61.4	46.9 - 80.4	48.8	44.7 - 53.3
2HE	9	46.8	44.2 - 49.5	46.0	40.6 - 52.2	48.0	45.0 - 51.1
1LE	9	39.4	36.9 - 42.0	47.8	44.2 - 51.7	33.6	30.2 - 37.4
2LE	9	38.7	36.1 - 41.6	38.5	34.6 - 42.8	31.1	28.0 - 34.5

Appendix E. Number of stations and observers for each transect sampled using variable circular plot counts of birds in five survey periods on Rota, CNMI. See Figure 5 for locations of transects.

Transect	March - April 1982		April 1987[a]		May 1994[b]		October - November 1995		October - November 1998	
	Stations	Observers	Stations	Observers	Stations	Observers	Stations	Observers	Stations	Observers
1	28	2	-	-	-	-	29	1	29	1
2	30	2	-	-	-	-	30	1	29	1
3	19	2	-	-	-	-	18	1	18	1
4	17	2	15	2	-	-	17	1	18	1
5	17	2	16	2	-	-	17	1	17	1
6	18	2	7	2	18	2	-	-	-	-
7	19	2	3	2	20	2	-	-	-	-
8	15	2	14	2	15	2	14	1	14	1
9	17	2	11	2	-	-	17	1	17	1
10	18	2	-	-	-	-	18	1	18	1
11	16	2	-	-	-	-	14	1	14	1
12	14	2	-	-	14	2	-	-	-	-
13	16	2	-	-	15	2	13	1	15	1
14	10	2	-	-	-	-	15	1	15	1
15	-	-	-	-	-	-	12	1	13	1
16	-	-	10	2	10	2	10	1	10	1
17	-	-	-	-	-	-	32	1	32	1

Appendix E. Continued.

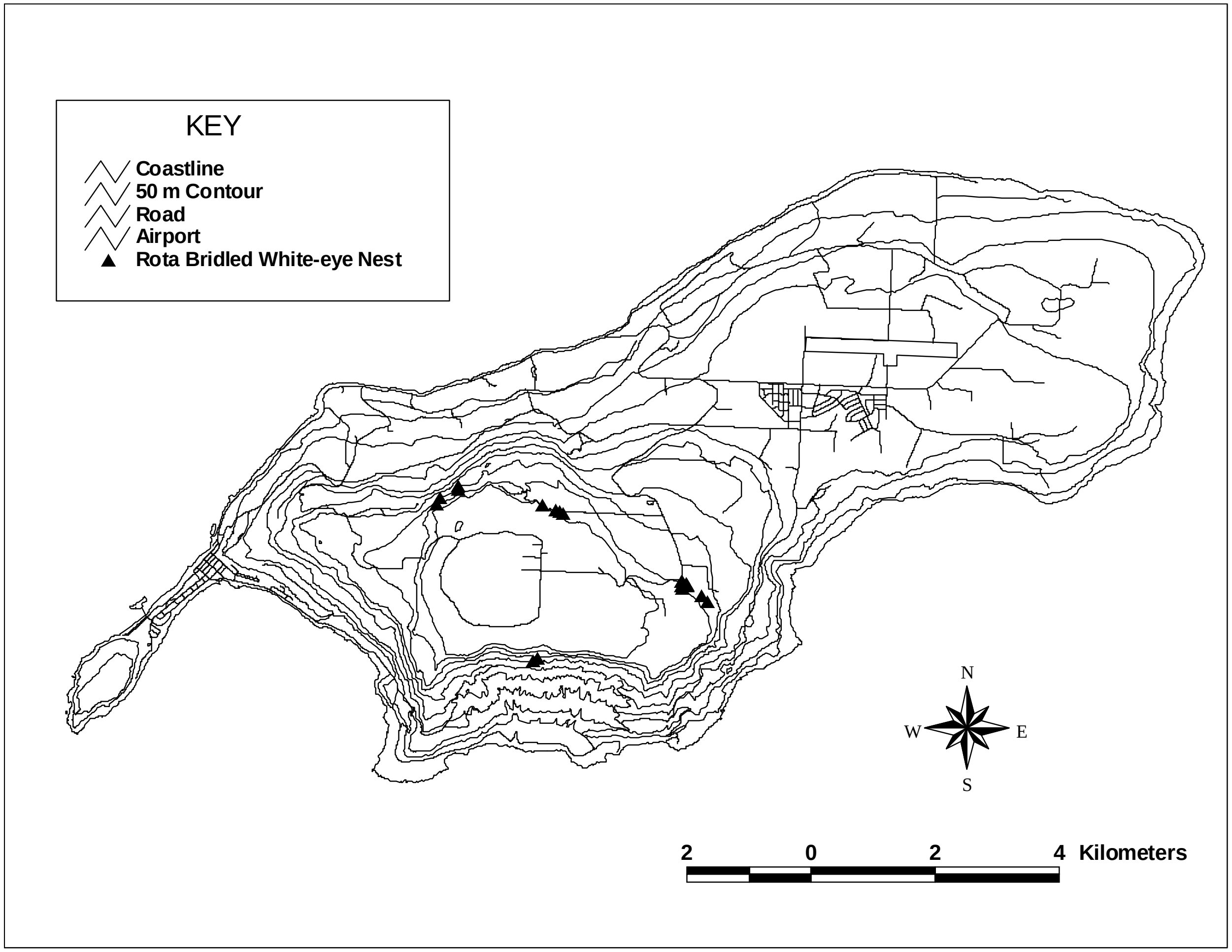
Transect	March - April 1982		April 1987		May 1994		October - November 1995		October - November 1998	
	Stations	Observers	Stations	Observers	Stations	Observers	Stations	Observers	Stations	Observers
18	-	-	-	-	-	-	17	1	17	1
19	-	-	-	-	-	-	16	1	16	1
20	-	-	-	-	20	2	18	1	19	1
21	-	-	-	-	14	2	-	-	-	-
22	-	-	-	-	13	2	-	-	-	-
23	-	-	-	-	6	1	-	-	-	-
24	-	-	-	-	11	2	-	-	-	-
25	-	-	-	-	5	1	-	-	-	-

[a] In 1987, transects 6 and 7 were sampled as one transect (transect 6) and transect 16 was labeled transect 15. See Engbring (1987) for more details.

[b] In 1994, data collected from transects 16, 21, 22, 23, 24, and 25 were recorded as transects 22, 15, 16, 17, 18, and 19 respectively.

Appendix F. Program Distance (Laake et al. 1998) estimates of effective detection radius (EDR) in meters for six bird species during 1982 and 1994 surveys on Rota, CNMI.

Species	1982		1994	
	n	EDR (± SE)	n	EDR (± SE)
Black drongo (*Dicrurus macrocercus*)	471	103.3 ± 3.8	384	60.5 ± 5.2
Collared kingfisher (*Halcyon chloris*)	464	164.7 ± 3.5	524	81.5 ± 8.4
Micronesian honeyeater (*Myzomela rubratra*)	509	60.2 ± 2.0	426	34.2 ± 0.7
Micronesian starling (*Aplonis opaca*)	488	71.6 ± 3.0	903	41.6 ± 0.7
Rota bridled white-eye (*Zosterops rotensis*)	92	38.1 ± 1.8	119	35.2 ± 13.8
Rufous fantail (*Rhipidura rufifrons*)	449	56.5 ± 2.5	361	38.6 ± 4.0



Appendix G. Locations of Rota bridled white-eye nests found in 1997, 1998, and 1999 on Rota, CNMI.

Appendix H. Nest discovery dates, fledging dates, and approximate durations of the incubation and nestling stages for all known Rota bridled white-eye nests discovered as active nests on Rota, CNMI.

Nest Number	Discovery Date	Fledging Date	Approximate Incubation Stage Duration (Days)	Approximate Nestling Stage Duration (Days)
Y32[a]	3/7/32	?	?	?
P84[b]	5/19/84	?	?	?
L93[c]	6/9/93	?	?	?
197	12/3/97	?	?	?
199	3/01/99	?	?	?
299	3/31/99	4/22/99	?	10-12
399	3/3/99	3/18/99	?	10
499	3/5/99	4/3/99	9	8-10
1199	5/26/99	5/31/99	?	> 5
1299	5/26/99	6/19/99	8-10	10
1599	7/6/99	7/16/99	?	10
1699	7/6/99	NA	10-12	Predated

[a] Yamashina (1932).
[b] Pratt (1985).
[c] Lusk and Taisacan (1997).

Appendix I. Banding and resighting information on nine Rota bridled white-eyes banded in 1998 and 1999 on Rota, CNMI.

Band number	Color band placement[a]				Sex	Age[b]	Banded		Last observed	
	Left		Right				Date	Location	Date	Location
	Top	Bottom	Top	Bottom						
190083183	red	USFWS	white	red	?	AF	98/08/09	Plot 1HA	-	-
190083186	white	blue	USFWS	red	?	AF	99/03/24	Plot 1HA	99/05/20	Plot 1HA: near banding site
190083187	-	red	-	USFWS	?	AF	99/05/12	Plot 1HA	-	-
190083188	-	blue	-	USFWS	?	AF	99/05/14	Plot 1HA	99/05/20	Plot 1HA: near banding site
190083189	-	green	-	USFWS	?	AF	99/05/19	Plot 1HA	-	-
190083191	-	white	-	USFWS	?	AF	99/05/19	Plot 1HA	99/05/20	Plot 1HA: near banding site
190083192	blue	red	blue	USFWS	?	AF	99/06/29	Plot 1HB	00/05/17	Plot 1HB
190083193	green	white	USFWS	white	?	AF	99/06/29	Plot 1HB	-	-
190083194	red	blue	red	USFWS	?	Nestling	99/07/14	Plot 1HC	99/07/23	Plot 1HC: near nest site

[a] USFWS = aluminum U.S. Fish and Wildlife Service band.
[b] AF = after fledging. Bird had complete eyerings.

Appendix J. Photograph of a Rota bridled white-eye nest found in a *Merrilliodendron megacarpum* in 1999 on Rota, CNMI (GIF, 156k).

Appendix K. Average number of insects and snails recorded per branch during six sampling periods in Rota bridled white-eye study plots on the island of Rota, CNMI in 1999.

Order	15 April (n = 35)	29 April (n = 35)	17 May (n = 32)	01 June (n = 32)	16 June (n = 32)	10 July (n = 40)	26 July (n = 32)
Araneida	0.74	0.34	0.47	0.59	0.34	0.45	1.06
Hymenoptera	2.83	2.60	1.66	2.97	2.16	1.70	2.53
Hemiptera	0.03	0	0.06	0.03	0	0	0
Homoptera	0.89	0.34	0.94	2.72	3.38	0.95	1.16
Orthoptera	0.14	0.17	0.03	0.13	0.06	0.25	0.13
Diptera	0.14	0.17	0.19	0.31	0.19	0.50	0.28
Coleoptera	0.14	0.31	0.34	0.31	0.25	0.20	0.53
Lepidoptera (Larvae)	0.14	0.20	0.13	0.31	0.19	0.18	0.13
Lepidoptera (Adult)	0	0	0.07	0.03	0	0.08	0.19
Unknown	0.06	0.69	0.75	1.59	1.28	0.95	2.09
Total Insect	5.11	4.83	4.63	9.00	7.84	5.25	8.09
Snail	1.49	1.34	1.88	1.50	2.78	2.10	1.97

Appendix L. Percentage of five study areas containing fruiting (S) or flowering (F) members of 22 woody plant species over 12 two-week periods on Rota, CNMI in 1999.

Species	Feb. 7-20		Feb. 21-Mar. 6		Mar. 6-20	
	F	S	F	S	F	S
Aglaia mariannensis [ABCDE]	20%	0%	80%	0%	100%	0%
Artocarpus atilis[ACDE]	0%	20%	20%	40%	20%	40%
Barringtonia asiatica [ACDE]	20%	0%	20%	20%	60%	60%
Carica papaya [BC]	0%	0%	0%	20%	20%	20%
Dendrocnide latifolia[ABCDE]	40%	0%	20%	0%	60%	0%
Discocalyx megacarpa[ACDE]	20%	0%	20%	40%	0%	80%
Elaeocarpus joga[ABCDE]	0%	0%	0%	60%	80%	20%
Eugenia thompsonii[ABDE]	40%	20%	80%	20%	40%	0%
Guamia mariannae	20%	20%	40%	40%	20%	20%
Guettarda speciosa[ACDE]	0%	0%	0%	0%	20%	0%
Hernandia labyrinthica[ABCDE]	40%	40%	60%	60%	60%	60%
Hibiscus tiliaceus	0%	0%	20%	0%	0%	0%
Leucaena leucocephala[B]	0%	20%	20%	20%	40%	40%
Macaranga thompsonii[ABCDE]	0%	0%	0%	0%	100%	100%
Melanolepis multiglandulosa[ACDE]	0%	20%	0%	0%	40%	0%
Merrilliodendron megacarpum[C]	0%	0%	0%	0%	0%	0%
Neisosperma oppositifolia[ABCDE]	20%	50%	40%	60%	60%	80%
Pandanus dubius[ABCDE]	0%	20%	0%	60%	0%	60%
Pandanus tectorius[ABCDE]	0%	60%	20%	100%	40%	100%
Persea americana[C]	40%	0%	40%	20%	40%	40%
Pipturus argenteus[ABCDE]	40%	0%	80%	0%	100%	0%
Premna obtusifolia[ABCDE]	20%	0%	60%	0%	100%	0%

Appendix L. Continued.

Species	Mar. 21-Apr. 3		Apr. 4-17		Apr. 18-May 1	
	F	**S**	**F**	**S**	**F**	**S**
Aglaia mariannensis	20%	0%	0%	0%	20%	20%
Artocarpus atilis	0%	0%	0%	20%	0%	20%
Barringtonia asiatica	20%	20%	20%	40%	0%	20%
Carica papaya	20%	20%	0%	60%	40%	40%
Dendrocnide latifolia	0%	0%	0%	0%	0%	0%
Discocalyx megacarpa	0%	0%	0%	20%	20%	0%
Elaeocarpus joga	60%	60%	60%	20%	80%	60%
Eugenia thompsonii	40%	0%	0%	0%	0%	20%
Guamia mariannae	20%	40%	20%	20%	0%	20%
Guettarda speciosa	0%	0%	0%	0%	0%	0%
Hernandia labyrinthica	80%	80%	60%	60%	60%	60%
Hibiscus tiliaceus	20%	0%	20%	0%	0%	0%
Leucaena leucocephala	20%	40%	20%	20%	20%	40%
Macaranga thompsonii	60%	0%	80%	0%	100%	20%
Melanolepis multiglandulosa	20%	0%	0%	20%	0%	20%
Merrilliodendron megacarpum	0%	0%	0%	0%	0%	0%
Neisosperma oppositifolia	20%	60%	0%	80%	60%	20%
Pandanus dubius	0%	40%	0%	40%	0%	20%
Pandanus tectorius	0%	60%	0%	60%	0%	60%
Persea americana	0%	40%	0%	40%	0%	40%
Pipturus argenteus	20%	0%	100%	0%	80%	80%
Premna obtusifolia	100%	20%	100%	20%	60%	40%

Appendix L. Continued.

Species	May 2-15		May 16-29		May 30-Jun. 12	
	F	**S**	**F**	**S**	**F**	**S**
Aglaia mariannensis	0%	0%	0%	20%	40%	20%
Artocarpus atilis	0%	20%	0%	20%	0%	40%
Barringtonia asiatica	0%	40%	20%	20%	0%	40%
Carica papaya	0%	20%	0%	0%	0%	20%
Dendrocnide latifolia	0%	0%	20%	0%	20%	0%
Discocalyx megacarpa	40%	40%	60%	60%	20%	40%
Elaeocarpus joga	80%	40%	80%	80%	40%	80%
Eugenia thompsonii	0%	0%	20%	20%	40%	20%
Guamia mariannae	0%	0%	20%	40%	20%	0%
Guettarda speciosa	0%	0%	0%	0%	0%	0%
Hernandia labyrinthica	60%	60%	80%	80%	60%	60%
Hibiscus tiliaceus	20%	0%	0%	0%	20%	0%
Leucaena leucocephala	20%	20%	20%	20%	20%	20%
Macaranga thompsonii	80%	40%	60%	60%	40%	60%
Melanolepis multiglandulosa	0%	40%	0%	60%	20%	60%
Merrilliodendron megacarpum	20%	0%	20%	20%	20%	20%
Neisosperma oppositifolia	60%	40%	60%	80%	40%	80%
Pandanus dubius	0%	60%	0%	40%	0%	60%
Pandanus tectorius	0%	80%	0%	80%	20%	60%
Persea americana	0%	40%	0%	40%	0%	40%
Pipturus argenteus	40%	40%	60%	20%	80%	40%
Premna obtusifolia	60%	60%	60%	20%	40%	40%

Appendix L. Continued.

Species	Jun. 13-26		Jun. 27- Jul. 10		Jul. 11-24	
	F	**S**	**F**	**S**	**F**	**S**
Aglaia mariannensis	60%	40%	0%	20%	0%	20%
Artocarpus atilis	0%	60%	0%	60%	0%	60%
Barringtonia asiatica	40%	40%	60%	60%	60%	60%
Carica papaya	0%	0%	0%	20%	0%	0%
Dendrocnide latifolia	40%	40%	0%	0%	0%	0%
Discocalyx megacarpa	20%	40%	0%	60%	20%	60%
Elaeocarpus joga	0%	60%	0%	100%	0%	100%
Eugenia thompsonii	40%	20%	20%	20%	0%	20%
Guamia mariannae	0%	20%	0%	20%	0%	40%
Guettarda speciosa	0%	0%	0%	20%	20%	20%
Hernandia labyrinthica	20%	60%	0%	80%	0%	80%
Hibiscus tiliaceus	40%	0%	20%	0%	20%	0%
Leucaena leucocephala	0%	0%	0%	0%	0%	20%
Macaranga thompsonii	20%	20%	0%	0%	0%	0%
Melanolepis multiglandulosa	0%	40%	0%	20%	40%	40%
Merrilliodendron megacarpum	20%	20%	20%	20%	20%	20%
Neisosperma oppositifolia	80%	60%	80%	80%	20%	80%
Pandanus dubius	0%	60%	0%	60%	0%	80%
Pandanus tectorius	20%	80%	0%	100%	0%	80%
Persea americana	0%	40%	0%	40%	0%	40%
Pipturus argenteus	60%	20%	60%	60%	100%	100%
Premna obtusifolia	40%	20%	20%	100%	0%	20%

[A] Woody plant species used to determine percentage fruiting and flowering in study area A.
[B] Woody plant species used to determine percentage fruiting and flowering in study area B.
[C] Woody plant species used to determine percentage fruiting and flowering in study area C.
[D] Woody plant species used to determine percentage fruiting and flowering in study area D.
[E] Woody plant species used to determine percentage fruiting and flowering in study area E.

Appendix M. Breeding characteristics of 16 white-eye species (Zosteropidae).

Species	Clutch size	Egg dimensions (mm)		Parental involvement (sex)		
		Length	Width	Nest construction	Incubation	Tending young
Rota bridled white-eye (*Zosterops rotensis*)[ab]	1-2	17.0-17.2 (n = 2)	13.0 (n = 2)	?	Both	Both
Saipan/Tinian bridled white-eye (*Z. conspicillatus saypani*)[b]	2-3	15.0-15.5 (n = 3)	11.2-11.5 (n = 3)	?	?	?
Guam bridled white-eye (*Z. c. conspicillatus*)[c]	2-3	16.9 (n = 5)	12.9 (n = 5)	?	?	?
Caroline Islands white-eye (*Z. semperi takatsukasai*)[b]	1	17.2-18.2 (n = 3)	13.0-14.0 (n=3)	?	?	?
Gray white-eye (*Z. cinereus ponapensis*)[b]	1	18.5 (n = 1)	13.5 (n = 1)	?	?	?
Indian white-eye (*Z. palpebrosa*)[d]	2-4	15.2 (n = 48)	11.5 (n = 48)	Female	Both	Both
Ceylon white-eye (*Z. cylonensis*)[d]	2-3	16.5 (n = 33)	12.0 (n = 33)	Both	Both	Both
Green-bellied white-eye (*Z. virens*)[e]	1-3	17.3 (n = 24)	12.8 (n = 24)	Both	Both	Both
Mauritius grey white-eye (*Z. borbonicus*)[f]	2-3	?	?	?	?	?

Appendix M. Continued.

Species	Clutch size	Egg dimensions (mm)		Parental involvement (sex)		
		Length	Width	Nest construction	Incubation	Tending young
Mauritius olive white-eye (*Z. chloronthos*)[f]	2-3	?	?	?	?	?
Madagascar white-eye (*Z. maderaspatana*)[g]	2-3	15.4 (n = ?)	12.0 (n = ?)	?	?	?
Heron Island silvereye (*Z. lateralis chlorocephala*)[h]	3	?	?	Both	Both	Both
Pale white-eye (*Z. citrinella*)[i]	2-4	?	?	?	?	?
Yellow white-eye (*Z. lutea*)[i]	3-4	?	?	?	?	?
Japanese white-eye (*Z. japonicus*)[jk]	3-6	16.5 (n = 35)	12.7 (n = 35)	?	?	?
Oriental white-eye (*Z. palpebrosus*)[l]	2-4	15.2 (n = ?)	11.4 (n = ?)	?	?	?
Lowland white-eye (*Z. meyeni*)[m]	4	?	?	?	?	?

[a] This Study
[b] Yamashina (1932)
[c] Hartert (1898) as cited in Baker (1951)
[d] Ali and Ripley (1974)
[e] Broekhuysen and Winterbottom (1968)
[f] Cheke (1987)
[g] Langrand (1990)
[h] Kikkawa and Wilson (1983)
[i] Pizzey (1980)
[j] Brazil (1991)
[k] van Riper (2000)
[l] Robson (2000)
[m] Kennedy et al. (2000)

Appendix N. Unsuccessful research methods used during this study on Rota bridled white-eyes on Rota in 1998 and 1999.

Radio telemetry- We attempted to attach LB-2 radio transmitters (Holohil™, Ontario, Canada) to five Rota bridled white-eyes in May of 1999 using the glueing technique described by Raim (1978). All transmitters either fell off shortly after attachment or were preened off during the following 12 hour period. We recommend that future researchers use an alternative radio transmitter attachment technique like the figure-eight harness described by Rappole and Tipton (1991).

Blood smears- We collected blood samples from two Rota bridled white-eyes using a toe nail clipping technique. Previously, we attempted to collect blood samples from the brachial vein but were unsuccessful due to the size of the vein. We created blood smears on 24 mm x 60 mm cover slips and preserved the smears with 100% methanol. These stains were then stained and examined by Dr. Glenn Olsen at the Patuxent Wildlife Research Center for white blood cell counts and parasites. No white blood cell counts were possible due to problems with the blood smears. However, no blood parasites were observed in blood smears taken from either bird.

White-eye baiting- Bait stations were successfully employed in research on silvereyes (*Zosterops lateralis*) (Kikkawa 1961). We attempted to bait Rota bridled white-eyes by providing sugar water in hummingbird feeders and fruit (oranges and apples) displays. We never observed Rota bridled white-eyes using either bait station.

VITA

Frederick A. Amidon

EDUCATION

09/90 - 12/93 UNIVERSITY OF MAINE, ORONO, ME
B.S. with honors in Wildlife Management

WORK EXPERIENCE

01/96 - 12/97 U.S. FISH AND WILDLIFE SERVICE, HONOLULU, HI
Biological Technician. Worked on a project to develop recovery techniques for the endangered island swiftlet on Guam. Primary duties included using a closed-circuit video system to monitor nesting, swiftlet surveys, insect sampling, and trapping brown tree snakes at swiftlet nesting colony.

05/95 - 10/95 U.S. FISH AND WILDLIFE SERVICE, KING SALMON, AK
Intern Biologist. Carried out field work on the Becharof Ecosystem Study and Monitoring Avian Productivity Survey (MAPS) program. Primary duties included banding passerines during the breeding season and fall migration.

01/95 - 04/95 U.S. FISH AND WILDLIFE SERVICE, HONOLULU, HI
Field Assistant. Carried out field work as part of a study to determine the effects of aircraft disturbance on populations of endangered Mariana crows and Mariana fruit bats on Air Force lands. Primary duties included searching for and characterizing Mariana crow nests and collecting time budget data on crow nests and a Mariana fruit bat colony.

05/94 - 10/94 UNIVERSITY OF SOUTHERN MISSISSIPPI, HATTIESBURG, MS
Field Assistant. Mist-netted migrating passerines on the Gulf Coast during fall migration and censused forest birds in DeSoto National Forest, MS during spring migration and the breeding season.

01/94 - 04/94 MAINE DEPARTMENT OF INLAND FISH AND WILDLIFE, BANGOR, ME
Wildlife Technician. Censused populations of wintering Barrow’s Goldeneye, a species of special concern in Maine.

05/93 - 08/93 MISSOURI STATE UNIVERSITY, COLUMBIA, MO
Intern. Worked on the Missouri Ozark Forest Ecosystem Project, a long-term study of the effects of forest cutting practices on forest ecosystems. Primary duties included censusing breeding birds, banding passerines, and searching for and monitoring nests.