Technical Report HCSU-029

STATUS AND TRENDS OF THE LAND BIRD AVIFAUNA ON TINIAN AND AGUIGUAN, MARIANA ISLANDS

Richard J. Camp[1], Thane K. Pratt[2], Fred Amidon[3], Ann P. Marshal[3], Shelly Kremer[3], and Megan Laut[3]

[1]Hawai`i Cooperative Studies Unit, Kilauea Field Station, P.O. Box 44, Hawai`i National Park, Hawai`i
[2]U.S. Geological Survey, Pacific Island Ecosystems Research Center, Kīlauea Field Station, P.O. Box 44, Hawai`i National Park, HI 96718
[3]U.S. Fish and Wildlife Service Pacific Islands Office, 300 Ala Moana Boulevard, Honolulu, Hawai`i

Technical Report HCSU-029

Status and Trends of the Land Bird Avifauna on Tinian and Aguiguan, Mariana Islands

Richard J. Camp[1], Thane K. Pratt[2], Fred Amidon[3], Ann P. Marshall[3], Shelly Kremer[3], and Megan Laut[3]

[1] Hawai`i Cooperative Studies Unit, Kīlauea Field Station,
P.O. Box 44, Hawai`i National Park, Hawai`i

[2] U.S. Geological Survey, Pacific Island Ecosystems Research Center,
Kīlauea Field Station, P.O. Box 44, Hawai`i National Park, Hawai`i

[3] U.S. Fish and Wildlife Service Pacific Islands Office
300 Ala Moana Boulevard, Honolulu, Hawai`i

Hawai`i Cooperative Studies Unit
University of Hawai`i at Hilo
200 W. Kawili St.
Hilo, HI 96720
(808)933-0706

May 2012

Table of Contents

List of Figures

List of Tables

Abstract

Avian surveys were conducted on the islands of Tinian and Aguiguan, Marianas Islands, in 2008 by the U.S. Fish and Wildlife Service to provide current baseline densities and abundances and assess population trends using data collected from previous surveys. On Tinian, during the three surveys (1982, 1996, and 2008), 18 species were detected, and abundances and trends were assessed for 12 species. Half of the 10 native species—Yellow Bittern (*Ixobrychus sinensis*), White-throated Ground-Dove (*Gallicolumba xanthonura*), Collared Kingfisher (*Todiramphus chloris*), Rufous Fantail (*Rhipidura rufifrons*), and Micronesian Starling (*Aplonis opaca*)—and one alien bird—Island Collared-Dove (*Streptopelia bitorquata*)—have increased since 1982. Three native birds—Mariana Fruit-Dove (*Ptilinopus roseicapilla*), Micronesian Honeyeater (*Myzomela rubratra*), and Tinian Monarch (*Monarcha takatsukasae*)—have decreased since 1982. Trends for the remaining two native birds—White Tern (*Gygis alba*) and Bridled White-eye (*Zosterops saypani*)—and one alien bird—Eurasian Tree Sparrow (*Passer montanus*)—were considered relatively stable. Only five birds—White-throated Ground-Dove, Mariana Fruit-Dove, Tinian Monarch, Rufous Fantail, and Bridled White-eye—showed significant differences among regions of Tinian by year. Tinian Monarch was found in all habitat types, with the greatest monarch densities observed in limestone forest, secondary forest, and tangantangan (*Leucaena leucocephala*) thicket and the smallest densities found in open fields and urban/residential habitats. On Aguiguan, 19 species were detected on one or both of the surveys (1982 and 2008), and abundance estimates were produced for nine native and one alien species. Densities for seven of the nine native birds—White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Rufous Fantail, Bridled White-eye, Golden White-eye (*Cleptornis marchei*), and Micronesian Starling—and the alien bird—Island Collared-Dove—were significantly greater in 2008 than 1982. No differences in densities were detected between the two surveys for White Tern and Micronesian Honeyeater. Three native land birds—Micronesian Megapode (*Megapodius laperouse*), Guam Swiftlet (*Collocalia bartschi*), and Nightingale Reed-Warbler (*Acrocephalus luscinia*)—were either not detected during the point-transect counts or the numbers of birds detected were too small to estimate densities for either island. Increased military operations on Tinian may result in increases in habitat clearings and the human population, which would expand human-dominated habitats, and declines in some bird populations would be likely to continue or be exacerbated with these actions. Expanded military activities on Tinian would also mean increased movement between Guam and Tinian, elevating the probability of transporting the brown tree snake (*Boiga irregularis*) to Tinian.

Introduction

The Department of Defense (DOD) has proposed expanding military operations in the Mariana Islands. To determine the future impacts of military operations on bird populations on these islands, the DOD contracted the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, to coordinate avian surveys on the islands of Tinian and Aguiguan in the Commonwealth of the Northern Mariana Islands (CNMI). The survey data will be used to establish population baseline information to compare with any later change in status and distribution of the birds.

Current avian population estimates were calculated for the whole island for both Tinian and Aguiguan and by regions for Tinian Island. These estimates were compared with results from a previous survey of both islands that was undertaken in 1982 by Engbring *et al.* (1986), yielding trends spanning 27 years. On Tinian, trends in bird populations across the island and within regions were compared from three surveys: the 1982 Engbring *et al.* survey, a survey in 1996 by the U.S. Fish and Wildlife Service (unpublished data, Lusk *et al.* 2000), and again in 2008. Aguiguan was surveyed in 1982 and 2008, and end-point comparisons were used to assess population changes. Particular attention was given to assess the status of the Tinian Monarch. Formerly listed as an endangered species, the monarch was delisted on September

21, 2004 (69 FR 65367) and is being monitored by the U.S. Fish and Wildlife Service through field surveys of distribution and abundance and tracking of land use and development on Tinian.

Methods

Survey area

Tinian: Tinian is the second largest of the CNMI islands at 101.01 km^2 (15° 00` N, 145$^o$ 35` E). The island consists of low-lying plateaus and a gentle limestone ridge dominated by Puntan Carolinas (elevation 196 m). The vegetation of Tinian currently consists of mixed second-growth forests, grassy savannas, and introduced forests, most of which are tangantangan (*Leucaena leucocephala*) thickets (Engbring *et al*. 1986). The little native vegetation that remains on Tinian (5%; Engbring *et al*. 1986) has been greatly altered by centuries of human use and non-native species and is basically confined to a few cliffs and adjacent steep limestone slopes (Engbring *et al*. 1986).

Aguiguan: Aguiguan is a small, uninhabited island located 8 km southwest of Tinian (7.09 km^2; 14° 51` N, 145$^o$ 33` E). It is made up of several concentric plateaus bounded by steep scarps, and the topmost plateau is about 150 m in elevation. Like other CNMI islands, the vegetation on Aguiguan has been extensively altered by human activity, so the available native forest is limited. In addition, the island has a large feral goat (*Capra hircus*) population, which continues to alter the native forest.

Bird surveys
On Tinian, the baseline survey conducted between 27 April and 8 May 1982 sampled a total of 216 stations on 10 transects with representative island-wide coverage across geography and habitats (Engbring *et al*. 1986; Figure 1). Placement of transects was random-systematic (Engbring *et al*. 1986). These transects were located and resurveyed during both the 1996 (28 August–1 September) and 2008 (14–19 June) surveys. An additional four transects were sampled during the 2008 survey for a total of 253 stations (transect 11 – 9 stations; transect 12 – 9 stations; transect 13 – 14 stations; and transect 14 – 5 stations). The four transects were added to increase the sampling of native limestone forest and improve density estimates for Tinian Monarch.

On Aguiguan, an island-wide survey consisting of 66 stations on four transects (random-systematic placement) was conducted on 2 and 3 June 1982, and a partial survey (transects 1 and 2 only) was conducted on 10 and 11 March 1982 (Engbring *et al*. 1986; Figure 2). Data from only the June survey were used in this study because all stations were sampled and the survey month coincides with the 2008 survey. All four transects were located and resurveyed during the 2008 (25–27 June) survey. An additional transect of 14 stations was sampled during the 2008 survey for a total of 80 stations. This transect was added to increase the numbers of birds detected and to sample the top-most plateau; however, placement of this transect on the plateau was random.

All surveys followed standard point-transect methods, consisting of eight-minute counts, where horizontal distances to all birds heard and/or seen were measured and recorded (see Engbring *et al*. 1986 for details). Sampling conditions recorded included cloud cover, rain, wind, noise level, and habitat type, and these were later used as covariates in density calculations (see Population status below). Counts commenced at sunrise and continued up to four hours and were conducted only under prescribed conditions.

Stations were surveyed by two observers in 1982 and one observer in 1996 and 2008. Data from only one counter were used for each station from the 1982 Tinian surveys, and the best counters were identified based on their experience and survey proficiency. Engbring *et al*. (1986) analyzed bird detections from all observers to estimate bird densities. For our analysis, we used detections from only one observer to
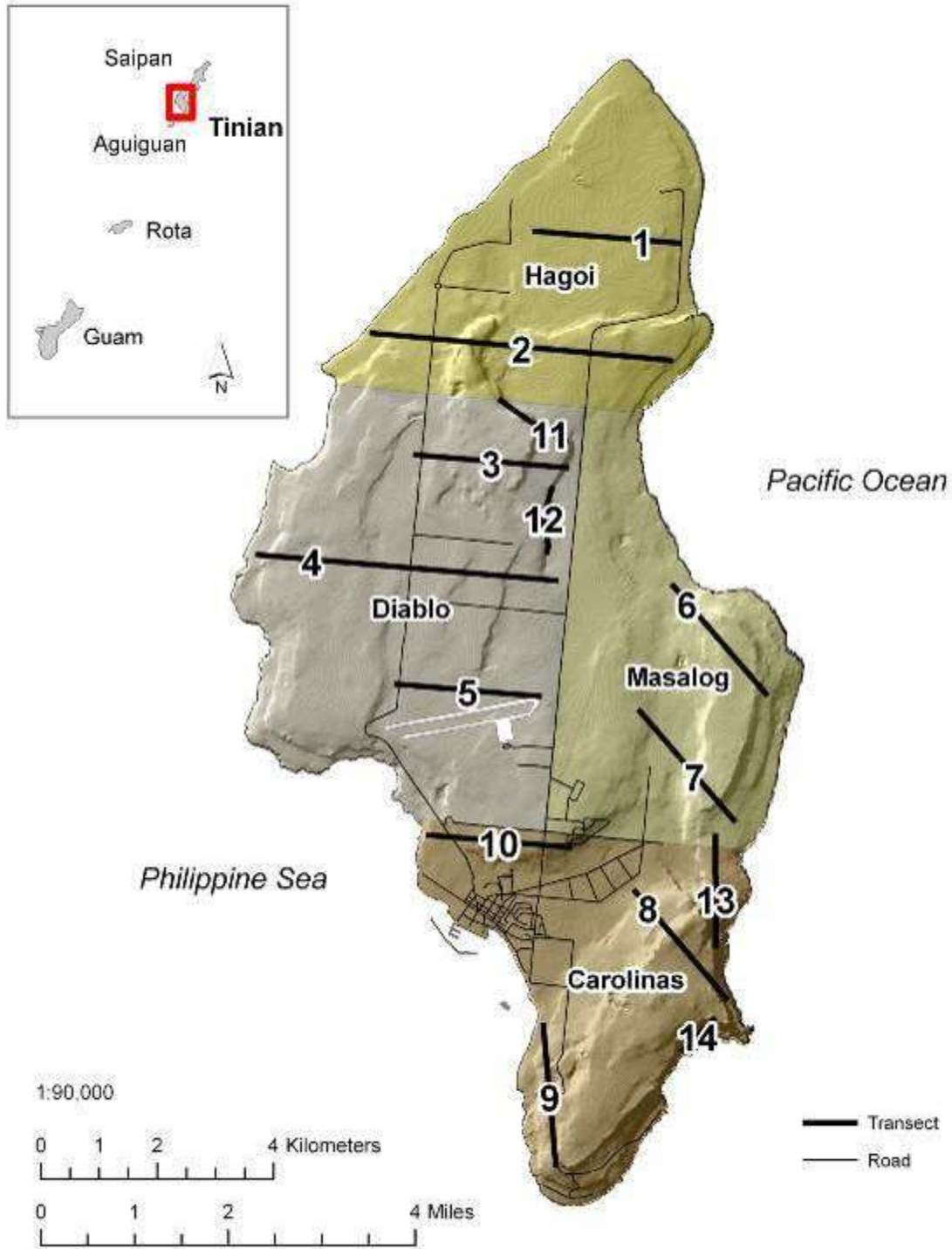
Figure 1. Island of Tinian, Commonwealth of the Northern Mariana Islands, showing the survey transects and regions (as defined by Engbring *et al.* 1986). Transects 1–10 were counted during all three surveys, and transects 11–14 were established and counted during the 2008 survey.

recalculate densities for the 1982 Tinian survey, thus matching the 1996 and 2008 survey effort. Calculating densities from only one of the counters is a conservative approach and ensures sampling independence. This approach approximately halved the number of birds detected; however, our density
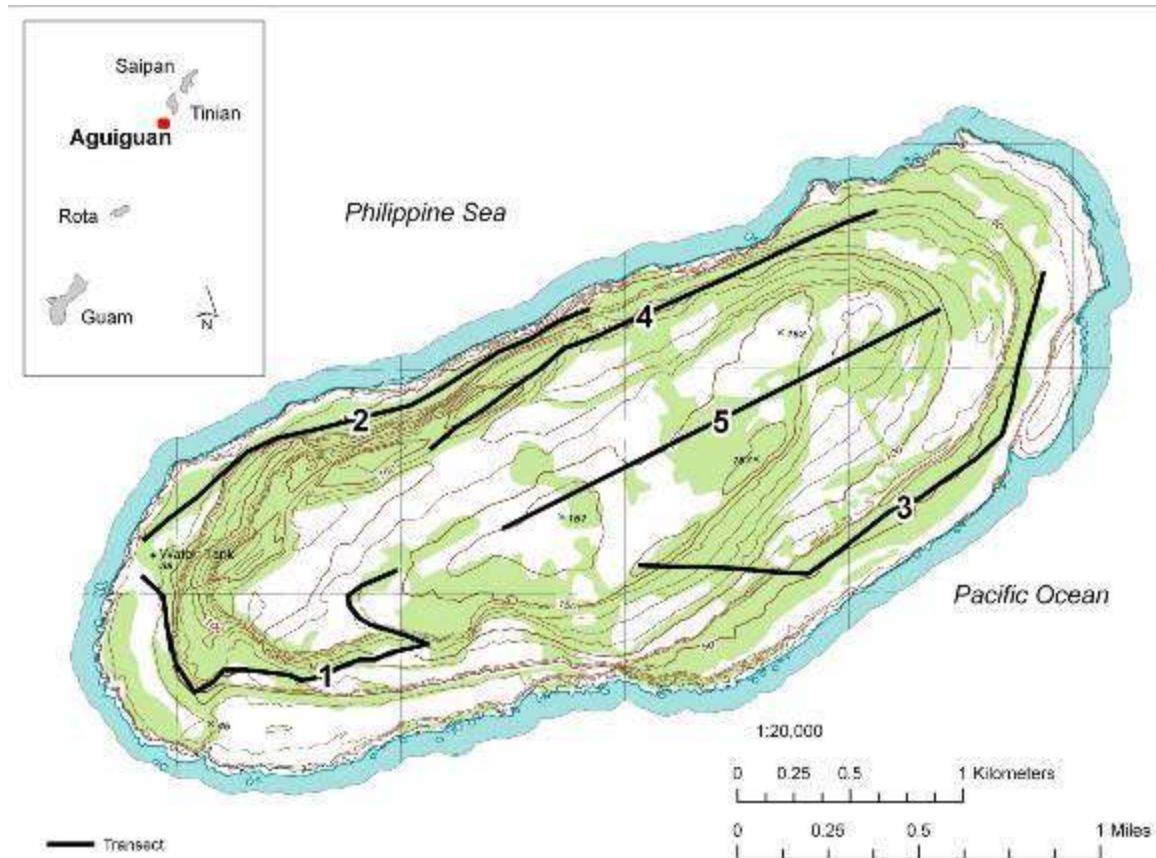
Figure 2. Island of Aguiguan, Commonwealth of the Northern Mariana Islands, showing the survey transects. Transects 1–4 were counted during both the 1982 and 2008 surveys, whereas transect 5 was established and counted during the 2008 survey.

estimates were generally greater than, but otherwise similar to, those of Engbring *et al.* (see their Table 8; 1986). On Tinian the 95% confidence intervals bracketed Engbring *et al.*'s estimates for all but four birds—Mariana Fruit-Dove, Tinian Monarch, Rufous Fantail, and Bridled White-eye. Differences may have resulted from analytical procedures such as selecting different truncation distances, selecting different models to estimate densities, and analytical advances in distance sampling (see Johnson *et al.* 2006), in addition to estimating densities using detections from only one of the counts (Tinian only). Data from both counters were used to estimate 1982 densities on Aguiguan because it was a small data set, and the sampling effort was adjusted appropriately.

Population status
Population status was calculated as density (birds/km^2) and number of birds (density by habitat type multiplied by habitat type area). Density was calculated using the program DISTANCE, version 5.0, release 2 (Thomas *et al.* 2006) from species-specific global detection functions, where data were post-stratified by survey. Data were right-truncated to facilitate model fitting (Buckland *et al.* 2001:16). Candidate models included half-normal and hazard-rate detection functions with expansion series of order two (Buckland *et al.* 2001:361, 365). Sampling covariates were modeled in the multiple-covariate distance engine of DISTANCE (Thomas *et al.* 2006, Marques *et al.* 2007). The model with the lowest Akaike Information Criterion (AIC) was used to select the detection function that best approximated the data. Covariates (sampling conditions, habitat types, and survey year) were used to generate the global detection function when the best approximating model was improved by four or more AIC units (Appendix 1). Variances and confidence intervals were derived by log-normal based methods. Survey-

4

specific, density-by-station values were generated for the population trends analyses (see Population trends below) from the global detection function using the post-stratification-by-sample option.

Area of habitat types came from Engbring *et al*. (1986) and U.S. Fish and Wildlife Service (2008). The area of habitat types was not available for the 1996 Tinian survey; therefore, we used the area by habitat types from Engbring *et al*. to calculate the 1996 numbers of birds. This may slightly underestimate the population size if there was more secondary forest in 1996 than 1982. Agriculture habitat type (combined agroforestry and cultivated habitat type classifications) was not used to calculate numbers of birds because the area of this habitat is very small relative to the island (< 2%), the area of the agriculture habitat type has declined (190 ha in 1982 to 174 ha in 2008; U.S. Fish and Wildlife Service 2008), and insufficient numbers of stations were established in the agriculture habitat type to produce reliable density estimates (one in 1982, four in 1996, and two in 2008), thus it was under-sampled. In addition, coastal and urban/residential habitat types were inconsistently and under-sampled (coastal: three stations in 1982, one in 1996, and zero in 2008; urban/residential: zero stations in 1982 and 1996, and seven in 2008), and were not used in calculating population estimates. On Aguiguan, the 1982 estimates of the area of habitat types were not reliable; therefore, numbers of birds were calculated only for the 2008 survey.

Population trends

Change in bird density among the three annual estimates on Tinian was assessed with repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, NC). To stabilize the error variance, density-by-station values were ln(density+1) transformed. Repeated measures ANOVA also was used to assess change in bird density within regions among the three annual estimates. Stations were treated as the random factor, and because the number of repeated measures was too small to fit a covariance model, we assumed the variance-covariance structure was a compound symmetry, homogeneous-variance model (Littell *et al*. 1996). Degrees of freedom was adjusted using the Kenward-Roger adjustment statement, and a Tukey's adjustment was used to control experiment-wise alpha = 0.05 for multiple-comparison procedures. A further analysis was conducted to assess differences by habitat type for Tinian Monarch from the 2008 survey using a one-way ANOVA (PROC MIXED) with the same options as those used in the repeated measures models. The agriculture habitat was dropped from this analysis because only two stations were sampled within the habitat during the 2008 survey.

End-point comparisons of the Aguiguan bird densities were compared using a two-sample *z*-test. Comparing density estimates using *z*-tests is the recommended method (L. Thomas, pers. comm.) and is an extension of the method listed in Buckland *et al*. (2001:353).

Results

Tinian

A total of 18 species was detected during one or more of the three surveys on Tinian (Table 1). Sufficient numbers of individuals were detected for 10 native and two alien species to calculate density and abundance estimates. Bridled White-eye and Rufous Fantail were the most abundant birds, whereas White-throated Ground-Dove and Yellow Bittern were the least abundant birds (Table 2). Half of the 10 native species—Yellow Bittern, White-throated Ground-Dove, Collared Kingfisher, Rufous Fantail, and Micronesian Starling—have increased since 1982 (Table 3, Figure 3). Three native birds—Mariana Fruit-Dove, Micronesian Honeyeater, and Tinian Monarch—have decreased in the same period. Although these declines were not linear (Figure 3), the overall changes between 1982 and 2008 were significant (Table 3). Trends for the remaining two native birds—White Tern and Bridled White-eye—were considered relatively stable. The alien bird—Island Collared-Dove—increased since 1982 or remained relatively stable, respectively (Tables 2 and 3, Figure 3). Although Eurasian Tree Sparrow densities increased 98% from 2 to 110 birds/km^2 between 1982 and 2008, their densities were not estimated well enough to make strong conclusions, and we conclude they have remained relatively stable.

Table 1. List of birds detected from three different point-transect surveys on Tinian. In 1982 and 1996, 216 stations were sampled on 10 transects, and in 2008, 253 stations were sampled on 14 transects (one station sampled twice). The number of stations occupied (# Stns Ocpd), birds detected (# Dect), indices of percent occurrence (% Occ), and birds per station (BPS) were calculated. Nomenclature generally follows the AOU checklist and Reichel and Glass (1991) with updates. Density estimates were produced for birds in bold.

Species	Scientific Name	1982				1996				2008			
		# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS
Red Junglefowl	*Gallus gallus*	45	105	20.8	0.49	0	0	0.0	0.00	45	77	17.7	0.30
White-tailed Tropicbird	*Phaethon lepturus*	0	0	0.0	0.00	0	0	0.0	0.00	3	5	1.2	0.02
Yellow Bittern	*Ixobrychus sinensis*	10	10	4.6	0.05	16	18	7.4	0.08	34	38	13.3	0.15
Pacific Reef-Egret	*Egretta sacra*	1	1	0.5	<0.01	1	1	0.5	<0.01	0	0	0.0	0.00
Pacific Golden-Plover	*Pluvialis fulva*	1	1	0.5	0.00	0	0	0.0	0.00	3	11	1.2	0.04
Ruddy Turnstone	*Arenaria interpres*	0	0	0.0	0.00	0	0	0.0	0.00	1	1	0.4	<0.01
Brown Noddy	*Anous stolidus*	0	0	0.0	0.00	0	0	0.0	0.00	1	1	0.4	<0.01
White Tern	*Gygis alba*	128	344	59.3	1.59	22	52	10.2	0.24	122	322	48.0	1.27
Island Collared-Dove	*Streptopelia bitorquata*	51	66	23.6	0.31	136	256	63.0	1.19	79	116	31.1	0.46
White-throated Ground-Dove	*Gallicolumba xanthonura*	13	16	6.0	0.07	23	23	10.6	0.11	64	82	25.2	0.32
Mariana Fruit-Dove	*Ptilinopus roseicapilla*	189	623	87.5	2.88	150	240	69.4	1.11	212	462	83.4	1.82
Collared Kingfisher	*Todiramphus chloris*	150	294	69.4	1.36	124	285	57.4	1.32	190	374	74.8	1.47
Micronesian Honeyeater	*Myzomela rubratra*	131	236	60.6	1.09	60	96	27.8	0.44	87	125	34.3	0.49
Tinian Monarch	*Monarcha takatsukasae*	187	539	86.6	2.50	173	500	80.1	2.31	178	361	70.1	1.42
Rufous Fantail	*Rhipidura rufifrons*	202	786	93.5	3.64	188	502	87.0	2.32	235	686	92.5	2.70
Bridled White-eye	*Zosterops saypani*	216	2,222	100.0	10.29	216	1,770	100.0	8.19	253	2,024	99.6	7.97
Micronesian Starling	*Aplonis opaca*	177	513	81.9	2.38	106	226	49.1	1.05	215	614	84.7	2.42
Eurasian Tree Sparrow	*Passer montanus*	1	1	0.5	<0.01	3	13	1.4	0.06	13	62	5.1	0.24

6

Table 2. Population density and abundance estimates for native and alien Tinian land birds from three point-transect surveys. Data from Engbring *et al.* (1986) transects only. First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: bird abundance (sum of density by habitat type times the area of habitat types) with 95% CI. Agriculture, coastal, and urban/residential habitat types were dropped for calculating bird abundance due to small sample size.

Species	1982	1996	2008
Yellow Bittern	1.5 ± 0.89 (0.5–4.4)	7.4 ± 2.49 (3.9–14.1)	18.2 ± 4.56 (11.2–29.6)
	127 (30–550)	764 (270–2,302)	1,695 (835–3,575)
White Tern	144.1 ± 17.24 (113.9–182.2)	25.3 ± 7.01 (14.8–43.2)	169.9 ± 19.66 (135.4–213.2)
	13,980 (9,349–21,512)	2,846 (1,121–7,300)	15,147 (10,067–23,041)
Island Collared-Dove	12.4 ± 2.04 (9.0–17.1)	34.3 ± 3.67 (27.8–42.3)	23.9 ± 3.24 (18.4–31.2)
	1,093 (642–2,024)	3,291 (2,296–4,777)	2,198 (1,374–3,648)
White-throated Ground-Dove	4.1 ± 1.45 (2.0–8.0)	4.6 ± 1.30 (2.7–8.0)	20.2 ± 3.91 (13.8–29.5)
	434 (136–1,421)	440 (174–1,147)	1,827 (1,045–3,226)
Mariana Fruit-Dove	42.6 ± 2.64 (37.7–48.1)	15.8 ± 1.23 (13.6–18.4)	33.1 ± 1.96 (29.4–37.1)
	3,909 (3,185–4,826)	1,539 (1,155–2,065)	3,029 (2,506–3,677)
Collared Kingfisher	7.0 ± 1.46 (4.7–10.5)	22.9 ± 3.28 (17.3–30.3)	61.3 ± 4.33 (53.3–70.4)
	570 (305–1,130)	2,268 (1,329–3,883)	5,439 (4,212–7,090)
Micronesian Honeyeater	77.2 ± 6.79 (64.9–91.7)	31.2 ± 4.26 (23.9–40.8)	41.3 ± 4.86 (32.8–52.0)
	7,859 (5,877–10,700)	2,847 (1,684–4,838)	3,716 (2,458–5,667)
Tinian Monarch	634.5 ± 37.88 (564.3–713.4)	705.7 ± 43.96 (624.3–797.6)	431.3 ± 30.75 (374.9–496.2)
	60,898 (49,484–75,398)	62,863 (50,476–78,758)	38,449 (29,992–49,849)
Rufous Fantail	641.2 ± 39.30 (568.4–723.3)	766.3 ± 40.85 (690.1–851.0)	975.0 ± 48.26 (884.6–1,074.6)
	58,336 (48,119–71,134)	67,191 (55,510–82,000)	86,112 (72,786–102,594)
Bridled White-eye	3,190.9 ± 101.79 (2,996.8–3,397.6)	2,731.9 ± 81.96 (2,575.5–2,897.8)	2,997.2 ± 105.80 (2,795.8–3,213.0)
	302,477 (270,218–338,821)	253,407 (225,258–286,044)	270,785 (239,579–306,772)
Micronesian Starling	133.9 ± 13.53 (109.8–163.3)	125.1 ± 13.34 (101.5–154.2)	349.5 ± 22.47 (308.0–396.6)
	11,543 (7,994–17,041)	10,841 (7,270–16,296)	30,088 (23,633–38,565)
Eurasian Tree Sparrow	2.1 ± 2.07 (0.4–10.7)	26.7 ± 16.42 (8.7–81.5)	110.2 ± 40.54 (54.7–222.2)
	155 (29–817)	1,244 (232–6,662)	2,111 (429–10,666)

Table 3. Repeated measures analysis of variance results for trends in Tinian land bird densities among years. Data from Engbring *et al.* (1986) transects only, excluding stations from agriculture, coastal, and urban/residential habitat types. Trends are denoted as increasing (▲), decreasing (▼), or stable (▬). Significant changes are marked in bold. Degrees of freedom for the differences of least squares means (Diff LSM) are 398.

| | | Fixed Effects | | Diff LSM | | | | | | | | |
| | | | | 82-96 | | | 82-08 | | | 96-08 | | |
Species	Trend	$F_{2,398}$	p	Est (SE)	t	Adj-p	Est (SE)	t	Adj-p	Est (SE)	t	Adj-p
Yellow Bittern	▲	13.57	<0.001	-0.04 (0.02)	-1.86	0.153	-0.10 (0.02)	-5.14	<0.001	-0.07 (0.02)	-3.29	0.003
White Tern	▬	43.18	<0.001	0.47 (0.06)	7.55	<0.001	-0.06 (0.06)	-0.91	0.634	-0.53 (0.06)	-8.46	<0.001
Island Collared-Dove	▲	16.22	<0.001	-0.14 (0.03)	-5.66	<0.001	-0.09 (0.03)	-3.38	0.002	0.06 (0.03)	2.28	0.060
White-throated Ground-Dove	▲	27.87	<0.001	<0.01 (0.02)	-0.42	0.906	-0.12 (0.02)	-6.67	<0.001	-0.11 (0.02)	-6.24	<0.001
Mariana Fruit-Dove	▼	64.54	<0.001	0.19 (0.02)	10.92	<0.001	0.05 (0.02)	2.73	0.018	-0.14 (0.02)	-8.19	<0.001
Collared Kingfisher	▲	87.05	<0.001	-0.11 (0.03)	-3.79	<0.001	-0.36 (0.03)	-12.84	<0.001	-0.26 (0.03)	-9.05	<0.001
Micronesian Honeyeater	▼	31.76	<0.001	0.27 (0.04)	7.59	<0.001	0.20 (0.04)	5.90	<0.001	-0.06 (0.04)	-1.69	0.209
Tinian Monarch	▼	10.65	<0.001	-0.09 (0.09)	-0.97	0.597	0.31 (0.09)	3.42	0.002	0.40 (0.09)	4.39	<0.001
Rufous Fantail	▲	19.55	<0.001	-0.24 (0.09)	-2.75	0.017	-0.54 (0.09)	-6.24	<0.001	-0.30 (0.09)	-3.49	0.002
Bridled White-eye	▬	5.26	0.006	0.16 (0.05)	3.24	0.004	0.07 (0.05)	1.42	0.330	-0.09 (0.05)	-1.81	0.166
Micronesian Starling	▲	67.87	<0.001	0.04 (0.07)	0.57	0.836	-0.64 (0.07)	-9.79	<0.001	-0.68 (0.07)	-10.36	<0.001
Eurasian Tree Sparrow	▬	0.96	0.384	-0.02 (0.02)	-0.78	0.713	-0.03 (0.02)	-1.38	0.352	-0.01 (0.02)	-0.60	0.822
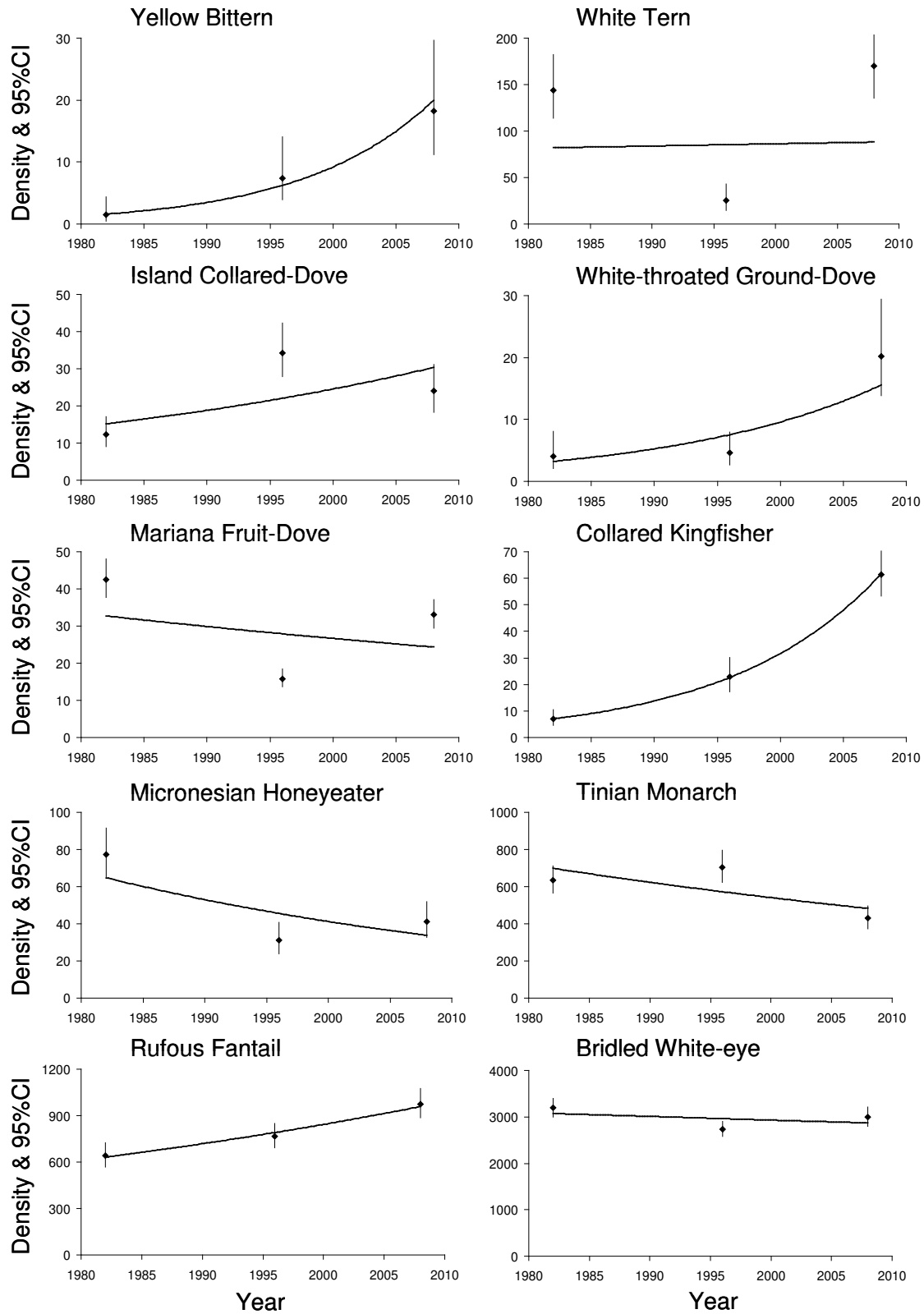
Figure 3. Density estimates (birds/km^2 and 95% CI) for native and alien Tinian land birds from three point-transect surveys (1982, 1996, and 2008). Densities were fitted with a line from an exponential model to illustrate population trends.
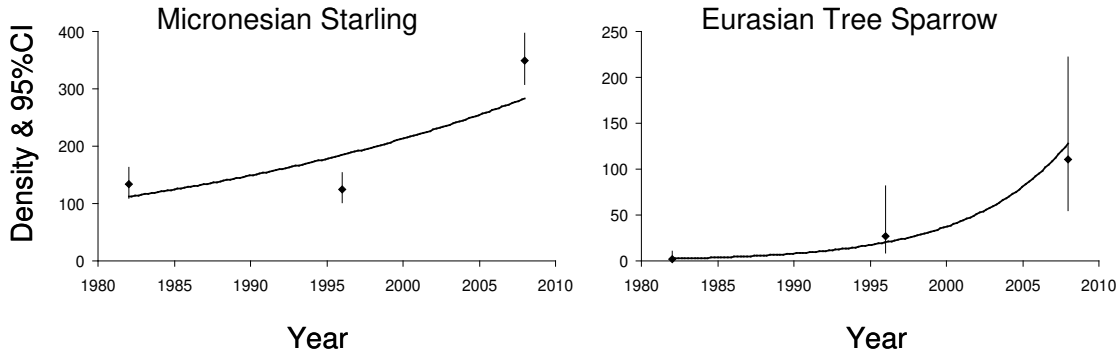
9

Figure 3. Continued.

Only five birds—White-throated Ground-Dove, Mariana Fruit-Dove, Tinian Monarch, Rufous Fantail, and Bridled White-eye—showed significant differences among regions by year (Table 4, Appendix 2). Between 1982 and 2008, White-throated Ground-Dove densities increased in the Diablo and Hagoi regions, and Rufous Fantail densities increased in the Carolinas and Masalog regions (Figure 4). Mariana Fruit-Dove densities declined in the Carolinas, and Tinian Monarch and Bridled White-eye densities declined in the Diablo region. In addition, densities of three birds—White Tern, Micronesian Honeyeater, and Micronesian Starling—differed by year and region but the year-region interaction was not significant (Table 4, Figure 4, Appendix 2). White Tern densities were greater in Diablo than in Hagoi, but densities in those regions were not different from densities in Carolinas and Masalog. Densities of Micronesian Honeyeater were greater in the Carolinas and Diablo regions than in the Hagoi and Masalog regions. Micronesian Starling densities were lower in Masalog than in the other regions.

Table 4. Repeated measures analysis of variance results for year, region, and year-region interaction fixed effects in Tinian land bird densities. Data from Engbring *et al.* (1986) transects only. Dash indicates interaction test not conducted because one or both main effects results were non-significant. Differences of least squares means for the significant fixed effects (bold for interaction, italics for region) are presented in Appendix 2 and summarized in Figure 3.

| | Fixed Effects | | | | | |
| | Year | | Region | | Interaction | |
Species	$F_{2,392}$	P	$F_{3,196}$	P	$F_{6,392}$	P
Yellow Bittern	10.17	<0.001	0.20	0.899	—	—
White Tern	40.78	<0.001	4.15	0.007	1.71	0.116
Island Collared-Dove	19.67	<0.001	1.47	0.224	—	—
White-throated Ground-Dove	16.98	<0.001	5.19	0.002	6.60	<0.001
Mariana Fruit-Dove	66.10	<0.001	5.99	<0.001	3.76	0.001
Collared Kingfisher	81.67	<0.001	2.17	0.093	—	—
Micronesian Honeyeater	25.99	<0.001	10.89	<0.001	1.73	0.113
Tinian Monarch	8.94	<0.001	7.61	<0.001	3.10	0.006
Rufous Fantail	28.31	<0.001	5.23	0.002	6.63	<0.001
Bridled White-eye	9.29	<0.001	6.04	<0.001	11.58	<0.001
Micronesian Starling	62.05	<0.001	3.60	0.014	1.43	0.200
Eurasian Tree Sparrow	1.29	0.276	1.36	0.256	—	—

Yellow Bittern
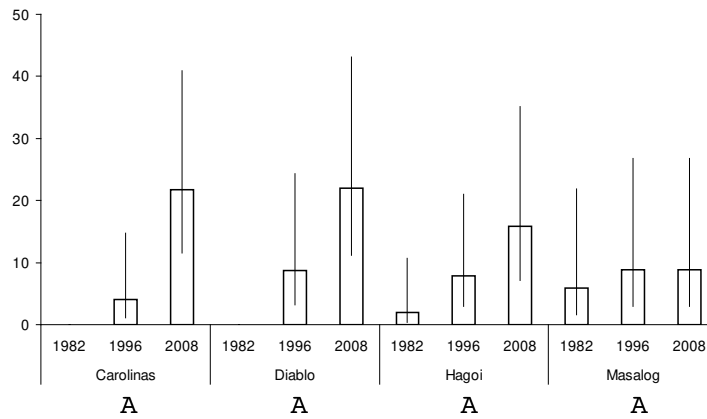
White Tern
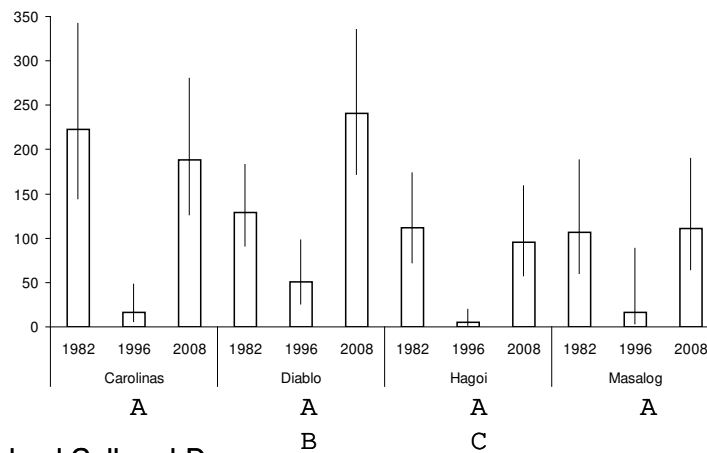
Island Collared-Dove
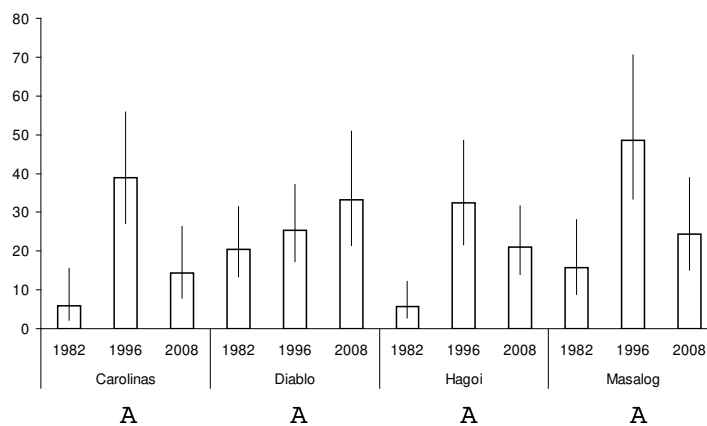
Figure 4. Density estimates (birds/km^2 and 95% CI) for native and alien Tinian land birds by region and year from three point-transect surveys (1982, 1996, and 2008). Differences of least squares means were assessed with repeated measures ANOVA (see Appendix 2 for details). Comparisons that share the same letter are not significantly different at the 0.05 level, adjusted for multiple comparisons. Comparisons below species name are year within region results (i.e., significant year, region and interaction effects), whereas comparisons below x-axis indicate fixed effects results (i.e., region or interaction effects were not significant).

11

White-throated Ground-Dove

Mariana Fruit-Dove

Collared Kingfisher
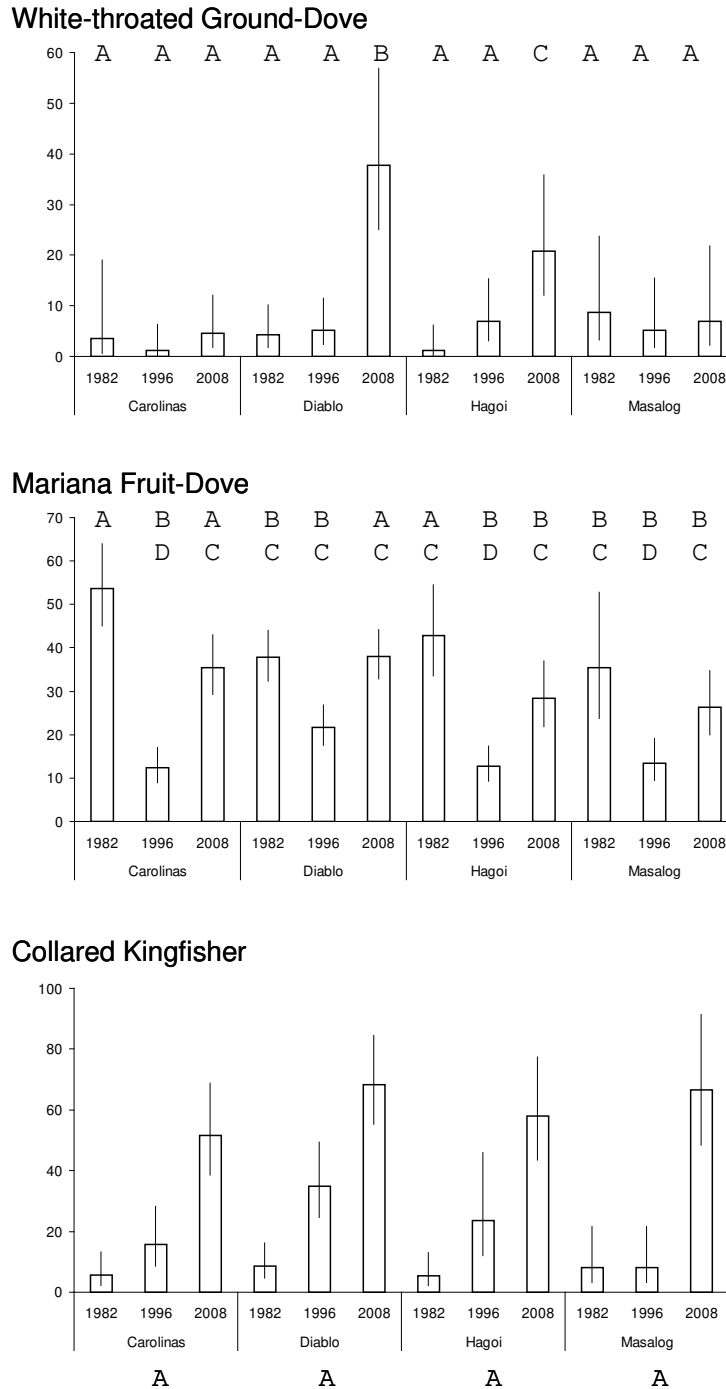
Figure 4. Continued.

Tinian Monarch densities have declined both temporally (survey year comparisons) and spatially (regional comparisons). We also tested for differences in Tinian Monarch densities among the different habitat types. Tinian Monarchs were found in all habitat types, but their densities were not distributed evenly among the habitats (Figure 5). Based on the 2008 survey, the greatest monarch densities were observed in limestone forest, secondary forest, and tangantangan thicket. The smallest densities were found in open field and urban/residential habitats. Monarch densities in limestone and secondary forests

12

Micronesian Honeyeater
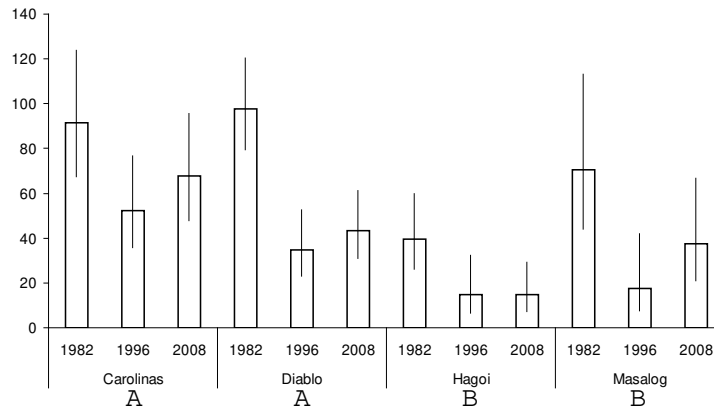
Tinian Monarch
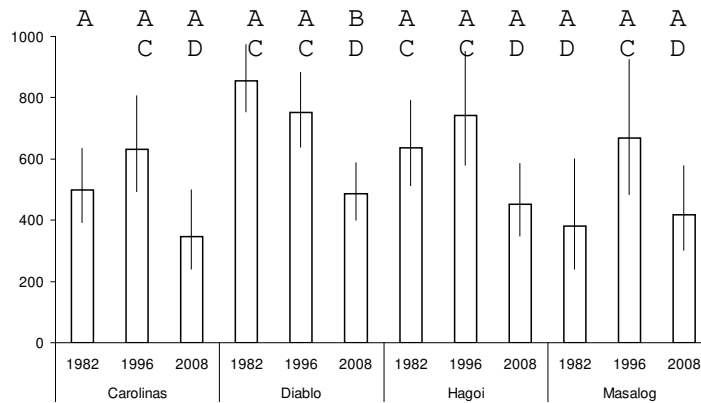
Rufous Fantail
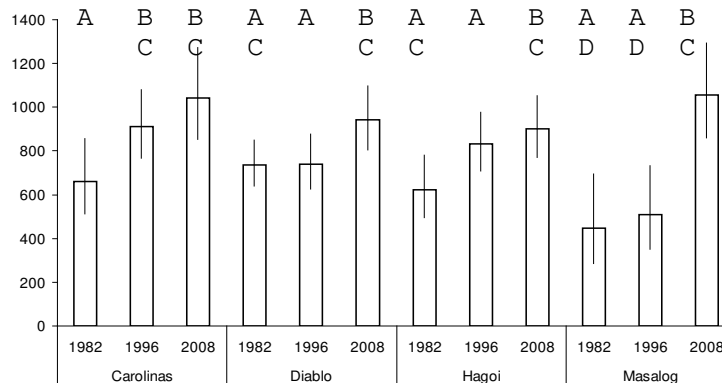
Figure 4. Continued.

were greater than those in open field and urban/residential habitat but not different from densities in tangantangan thicket (Table 5, Appendix 3).

We used the coefficient of variation (CV = SE/density) to evaluate Tinian Monarch estimator certainty by comparing the variability in densities calculated with and without the newly established transects. During the 2008 survey, 37 stations were sampled on four new transects. All of the stations were in limestone forest habitat; except for two stations on transect 13 that were located in tangantangan thicket habitat. Both of these habitats contain high densities of Tinian Monarch (Table 5). Incorporating the new transects

Bridled White-eye
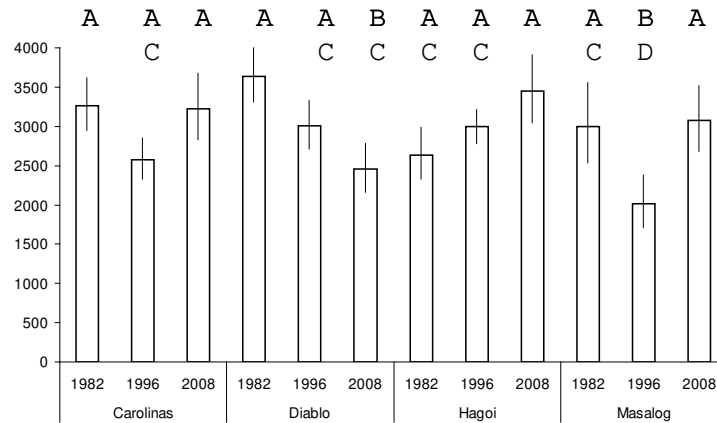
Micronesian Starling
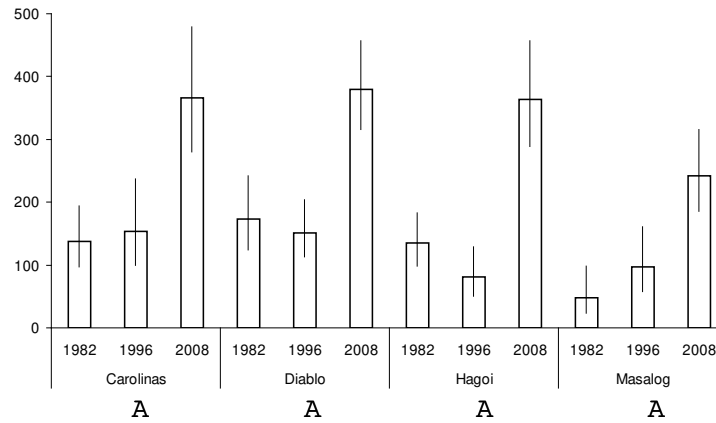
Eurasian Tree Sparrow
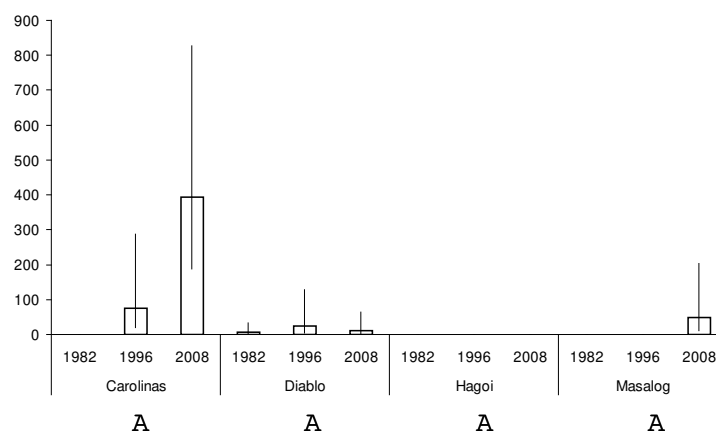
Figure 4. Continued**.**

increased the precision of monarch estimates in limestone forest habitat by more than 50% compared to estimates from just the original transects (Table 6). Sampling the new transects helped to improve precision in monarch densities by 15% in the Carolinas and Diablo regions, and most of the improvement was in estimates from the Carolinas Region. Overall, the precision of the island-wide monarch estimate was increased by almost 9%.
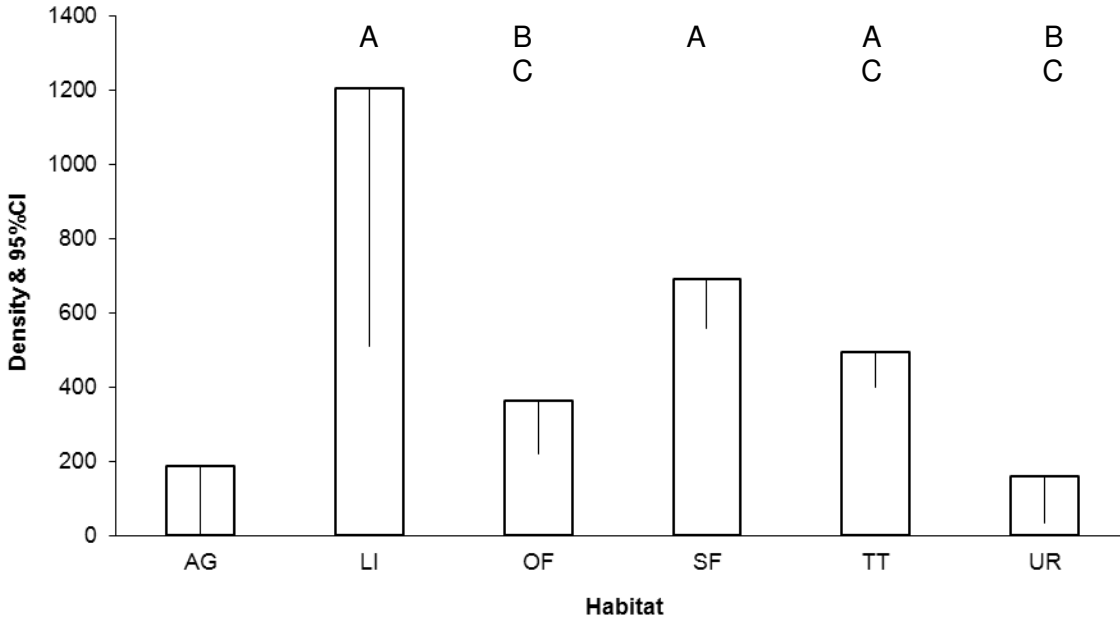
Figure 5. Density estimates (birds/km^2 and lower 95% CI) for the Tinian Monarch from all 14 transects sampled during the 2008 point-transect survey (data from all 14 transects). Habitat types are AG–agriculture, LI–limestone forest, OF–open field, SF–secondary forest, TT–tangantangan thicket, and UR–urban/residential. Differences of least squares means were assessed with a one-way ANOVA. Agriculture habitat was dropped from this analysis and coastal habitat was not sampled in 2008 (see Methods). Comparisons that share the same letter are not significantly different at the 0.05 level, adjusted for multiple comparisons.

Aguiguan
A total of 19 species was detected on the Aguiguan surveys (Table 7). Sufficient numbers of individuals were detected to calculate density and abundance estimates for nine native and one alien species. Bridled White-eye was the most abundant bird at over 44,000 birds on the 7 km^2 island, and Collared Kingfisher and Island Collared-Dove were the least abundant birds (Table 8). Densities for seven of the nine native birds—White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Rufous Fantail, Bridled White-eye, Golden White-eye, and Micronesian Starling—were significantly greater in 2008 than 1982 (Table 8, Figure 6). No differences in densities were detected between the two surveys for White Tern and Micronesian Honeyeater. Densities of the alien Island Collared-Dove had increased significantly between 1982 and 2008.

Trends across islands
Densities have increased or remained stable for 84% (21 of 25 populations) of the nine native land bird species shared between Saipan (Camp *et al*. 2009) and one or both of the islands covered in this study (Table 9). White-throated Ground-Dove and Micronesian Starling populations increased on all three islands. Yellow Bittern, Collared Kingfisher, and Bridled White-eye populations either increased or remained stable. Change in the status of the Mariana Fruit-Dove, Micronesian Honeyeater, Rufous Fantail, and Golden White-eye populations was mixed among the islands.

Table 5. One-way ANOVA and multiple comparisons results of Tinian Monarch densities by habitat types from the 2008 survey (all 14 transects). Agriculture habitat type was dropped from the analysis due to small sample size. Significance was assessed at the alpha 0.05 level using Tukey's adjustment for multiple comparisons with 247 degrees of freedom (highlighted in bold). Habitat codes: LI–limestone forest; OF–open field; SF–secondary forest; TT–tangantangan thicket; and UR–urban/residential.

Fixed Effect	Num DF	Den DF	F Value	Pr > F	
Habitat	4	247	6.24	<0.001	
Habitat	Habitat	Estimate	Error	t Value	Adj P
LI	**OF**	0.76	0.203	3.75	**0.002**
LI	SF	0.01	0.173	0.04	1.000
LI	TT	0.31	0.165	1.85	0.348
LI	**UR**	1.11	0.382	2.91	**0.032**
OF	**SF**	-0.75	0.194	-3.89	**0.001**
OF	TT	-0.46	0.187	-2.43	0.111
OF	UR	0.35	0.392	0.89	0.900
SF	TT	0.30	0.154	1.94	0.298
SF	**UR**	1.10	0.377	2.93	**0.030**
TT	UR	0.80	0.374	2.15	0.201

Table 6. Measures of precision in Tinian Monarch 2008 densities for newly established transects, the original transects, the original transects in the same regions, and transects in limestone forest habitat [1].

Group	Density	SE	CV	Increased Precision
Original & New Transects	4.87	0.316	6.48	
Original Transects	4.51	0.32	7.09	8.6%
Limestone Forest Original & New Transects	6.41	0.735	11.48	
Limestone Forest Original Transects	4.97	1.152	23.20	50.5%
Carolinas & Diablo Regions Original & New Transects	5.03	0.392	7.80	
Carolinas & Diablo Regions Original Transects	4.46	0.409	9.18	15.0%
Carolinas Region Original & New Transects	3.73	0.544	14.56	
Carolinas Region Original Transects	3.62	0.661	18.23	20.1%
Diablo Region Original & New Transects	6.07	0.507	8.36	
Diablo Region Original Transects	5.07	0.488	9.62	13.1%

[1] New transects include 35 stations located in limestone forest and 2 stations in tangantangan thicket habitats and were pooled for this analysis.

Table 7. List of birds detected from the 1982 and 2008 point-transect surveys on Aguiguan. In 1982, 66 stations were sampled on 4 transects (88 counts; several stations were counted more than once), and in 2008, 80 stations were sampled in 5 transects. The number of stations occupied (Stns Ocpd), birds detected (# Dect), indices of percent occurrence (% Occ), and birds per station (BPS) were calculated. Nomenclature generally follows the AOU checklist and Reichel and Glass (1991) with updates. Density estimates were produced for birds in bold. Scientific names are provided in footnotes for select species.

	1982				2008			
Species	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS
Micronesian Megapode	8	14	9.1	0.16	11	15	13.8	0.19
White-tailed Tropicbird	1	1	1.1	0.01	—	—	—	—
Red-tailed Tropicbird [1]	8	13	9.1	0.15	—	—	—	—
Great Frigatebird [2]	1	2	1.1	0.02	—	—	—	—
Yellow Bittern	1	1	1.1	0.01	—	—	—	—
Brown Noddy	14	20	15.9	0.23	—	—	—	—
Black Noddy [3]	31	75	35.2	0.85	1	1	1.2	0.01
White Tern	54	218	61.4	2.48	34	84	42.5	1.05
Sooty Tern [4]	1	1	1.1	0.01	—	—	—	—
Island Collared-Dove	9	16	10.2	0.18	28	50	35	0.63
White-throated Ground-Dove	10	18	11.4	0.20	25	37	31.2	0.46
Mariana Fruit-Dove	87	757	98.9	8.60	75	240	93.8	3.00
Guam Swiftlet	26	157	29.6	1.78	9	27	11.2	0.34
Collared Kingfisher	56	154	63.6	1.75	53	101	66.2	1.26
Micronesian Honeyeater	87	745	98.9	8.47	74	174	92.5	2.18
Rufous Fantail	84	453	95.5	5.15	77	219	96.2	2.74
Golden White-eye	83	444	94.3	5.05	74	268	92.5	3.35
Bridled White-eye	88	823	100.0	9.35	77	758	96.2	9.48
Micronesian Starling	71	207	80.7	2.35	69	167	86.2	2.09

[1] = *Phaethon rubricauda*
[2] = *Fregata minor*
[3] = *Anous minutus*
[4] = *Onychoprion fuscatus*

Discussion

Island trends

Abundances of half of the 10 native birds on Tinian—Yellow Bittern, White-throated Ground-Dove, Collared Kingfisher, Rufous Fantail, and Micronesian Starling—and seven of nine native birds on Aguiguan—White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Rufous Fantail,

Table 8. Population density and abundance estimates for native and alien Aguiguan land birds from two point-transect surveys (1982 and 2008). First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: 2008 bird abundance (density by habitat times the habitat area) with 95% CI. Significance was assessed at the alpha 0.05 level using two-sample z-test (in bold). Change was defined as increasing (▲), decreasing (▼), or not significantly different (▬).

Species	1982	2008	z Value	P	Change
White Tern	169.6 ± 27.0 (124.2–231.6)	218.8 ± 44.2 (147.3–325.1)	-0.95	0.341	▬
		1,214 (604–3,651)			
Island Collared-Dove	4.4 ± 1.8 (2.0–9.7)	66.9 ± 16.7 (41.1–108.8)	-3.72	<0.001	▲
		307 (151–658)			
White-throated Ground-Dove	13.1 ± 4.8 (6.6–26.3)	100.2 ± 26.5 (59.9–167.6)	-3.23	0.001	▲
		484 (260–953)			
Mariana Fruit-Dove	107.5 ± 6.5 (95.4–121.1)	141.0 ± 10.8 (121.3–164.0)	-2.67	0.008	▲
		818 (604–1,170)			
Collared Kingfisher	13.1 ± 2.0 (9.7–17.8)	50.3 ± 6.6 (38.9–65.0)	-5.39	<0.001	▲
		347 (184–1,186)			
Micronesian Honeyeater	368.3 ± 19.6 (331.8–408.7)	336.2 ± 27.1 (286.7–394.1)	-0.96	0.337	▬
		2,128 (1,564–3,046)			
Rufous Fantail	568.8 ± 39.6 (496.0–652.2)	1.157.9 ± 89.3 (995.0–1,347.5)	-6.41	<0.001	▲
		6,429 (4,765–13,666)			
Golden White-eye	529.1 ± 40.6 (455.1–615.2)	1,292.6 ± 111.9 (1,089.7–1,533.4)	-6.41	<0.001	▲
		7,496 (4,983–17,387)			
Bridled White-eye	1,685.6 ± 102.3 (1,495.7–1,899.6)	6,771.2 ± 490.2 (5,867.6–7,814.1)	-10.15	<0.001	▲
		44,293 (32,246–63,031)			
Micronesian Starling	86.5 ± 10.9 (67.6–110.7)	505.2 ± 52.7 (411.5–620.3)	-7.78	<0.001	▲
		3,531 (1,902–12,374)			

Bridled White-eye, Golden White-eye, and Micronesian Starling—have increased since the 1982 survey. In addition, three native birds on both islands have remained stable—White Tern on both islands, Bridled White-eye on Tinian, and Micronesian Honeyeater on Aguiguan. Large increases in densities of Yellow Bittern, Rufous Fantail, and Micronesian Starling on Tinian, and Rufous Fantail on Aguiguan support increasing their status classification. Changes in the other birds were not sufficient to warrant reclassification. Reichel and Glass (1991) listed Yellow Bittern
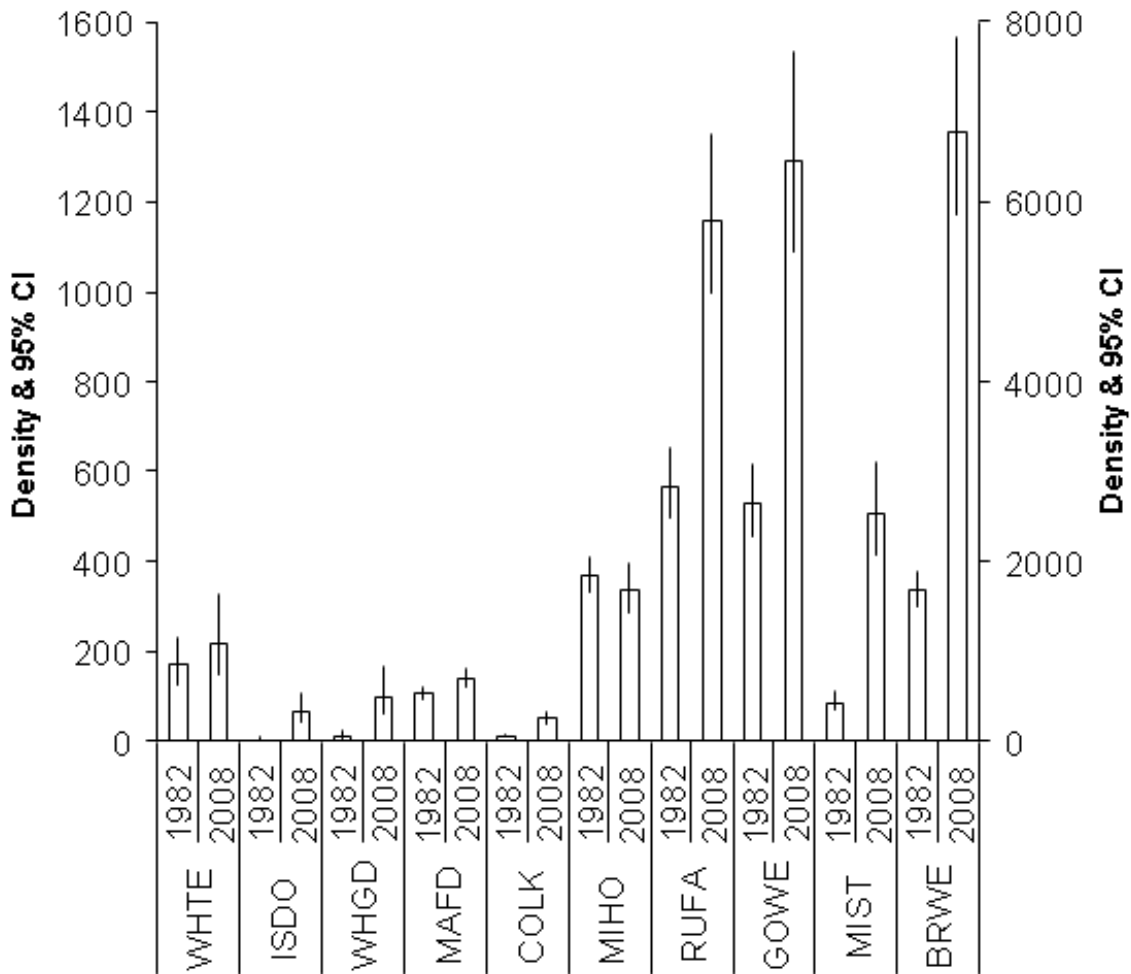
Figure 6. Density estimates (birds/km^2 and 95% CI) for native and alien Aguiguan land birds from two point-transect surveys (1982 and 2008). The primary y-axis is for the first nine species, and the secondary y-axis is for Bridled White-eye. Species codes are WHTE–White Tern; ISDO–Island Collared-Dove; WHGD–White-throated Ground-Dove; MAFD–Mariana Fruit-Dove; COLK–Collared Kingfisher; MIHO–Micronesian Honeyeater; RUFA–Rufous Fantail; GOWE–Golden White-eye; MIST–Micronesian Starling; and BRWE–Bridled White-eye.

as rare, and now, at more than 1,600 birds, the species can be considered uncommon—observing them in representative habitat is not certain but likely. Rufous Fantail and Micronesian Starling on Tinian may be considered abundant. Abundances of about 86,000 and 30,000 birds, respectively, make finding them in large numbers within representative habitat a certainty. Likewise, Rufous Fantail on Aguiguan may be considered abundant at more than 6,400 birds. Alien birds—Island Collared-Dove and Eurasian Tree Sparrow—densities increased on both islands and Tinian, respectively, and both species may be categorized as common or abundant.

No species had declined on Aguiguan, whereas Mariana Fruit-Dove, Micronesian Honeyeater, and Tinian Monarch declined on Tinian. Relatively large numbers of these birds remain on Tinian (> 3,000 individuals), and changes to their abundance status are unwarranted. However, declines for these native species are a concern, especially for the Tinian Monarch, which is endemic to Tinian and listed as threatened by the CNMI and vulnerable by the IUCN. Likely causes for these declines include predation

Table 9. Comparison of density (birds/km^2 and 95% confidence intervals) and change in the status of nine native land bird populations from the most recent point-transect surveys (Tinian and Aguiguan 2008, Saipan 2007) by island. A "—" denotes the species was not detected on the island. Changes are denoted as increasing (▲), decreasing (▼), or stable (▬). Results for Saipan are from Camp *et al*. (2009).

Species	Tinian Density (95% CI)	Change	Aguiguan Density (95% CI)	Change	Saipan Density (95% CI)	Change
Yellow Bittern	18.2 (11.2–29.6)	▲	—		11.4 (4.8–21.2)	▲
White-Throated Ground-Dove	20.2 (13.8–29.5)	▲	100.2 (59.9–167.6)	▲	100.5 (77.1–127.9)	▲
Mariana Fruit-Dove	33.1 (29.4–37.1)	▼	141.0 (121.3–164.0)	▲	65.5 (53.0–79.8)	▬
Collared Kingfisher	61.3 (53.3–70.4)	▲	50.3 (38.9–65.0)	▲	25.8 (16.8–39.1)	▬
Micronesian Honeyeater	41.3 (32.8–52.0)	▼	336.2 (286.7–394.1)	▬	482.3 (383.5–651.5)	▲
Rufous Fantail	975.0 (884.6–1,074.6)	▲	1,157.9 (995.0–1,347.5)	▲	469.1 (394–1,601.5)	▼
Golden White-Eye	—		1,292.6 (1,089.7–1,533.4)	▲	711.8 (534.8–975.3)	▼
Bridled White-eye	2,997.2 (2,795.8–3,213.0)	▬	6,771.2 (5,867.6–7,814.1)	▲	4,713.3 (3,982.7–5,488.9)	▬
Micronesian Starling	349.5 (308.0–396.6)	▲	505.2 (411.5–620.3)	▲	161.9 (96.8–257.5)	▲

and habitat loss/degradation. One possible explanation for increases in Aguiguan birds has been extensive expansion of secondary forest and brush habitats. About half of the island was cleared for agriculture during the 1930s and 1940s, and those fallow fields are now dominated by *Lantana camara* and other alien plants and secondary forest (Figure 7). Forests currently cover about 70% of the island, and an additional 20% of the island is occupied primarily by *L. camara* fields, providing habitat for birds.

Trends across islands
The U.S. Fish and Wildlife Service conducted a land bird survey on Saipan in 2007 and assessed population trends (Camp *et al*. 2009). Comparing trends among the neighboring Mariana Islands of Tinian, Aguiguan, and Saipan provides an index of the species' regional trends. The carnivorous birds—Yellow Bittern and Collared Kingfisher—increased or remained stable. Densities of Yellow Bittern have increased on Tinian and Saipan, but the species is found in very low numbers on Aguiguan. In fact, no birds were detected on counts during the 2008 Aguiguan survey, although one was seen along a transect (APM, pers. obs.), and only one bird was detected during the 1982 survey. Yellow Bittern inhabit swamps, marshes, and other grassy habitats, and secondary forest, and bittern may be absent from Aguiguan because very little grass-dominated habitat now occurs on this island. In contrast, bittern may be increasing on Tinian and Saipan where grassy and open habitats have increased.

Trends among the fruit-eating birds—White-throated Ground-Dove and Mariana Fruit-Dove—were mixed, and the pattern does not appear to correspond to increases in human populations. Micronesian Starling, a largely frugivorous species, increased on all three islands. Camp *et al*.

20

Figure 7. Vegetation changes in central Aguiguan, as shown by a series of aerial photos of the center of the island. About half of the island was cleared for agriculture during the 1930s and 1940s (represented in the 1948 photo). Agriculture halted after WWII, and the fallow fields were dominated by grass (labeled G in the 1964 photo, and represented in yellow in the 1994 photo). Secondary forest expanded into the fallow fields and is represented in dark green in the bottom two photos. By 2000, the non-native shrub *Lantana camara* had replaced the grass in the fallow fields, and is represented in light green in the 2000 photo. One of the few remaining patches of grass is visible in the 2000 photo (just below the right corner of the central panel).

21

(2009) speculated that fruit-eating birds on Saipan may have benefited from the expansion of scarlet gourd (*Coccinia grandis*). This alien, smothering vine also occurs on Tinian but only locally and has not formed dense canopies. Scarlet gourd is not reported from Aguiguan. Thus, it is likely that scarlet gourd does not account for much of the increases in the fruit-eating bird populations on Tinian and Aguiguan. Another explanation is that there may be different patterns of hunting across the islands that account for the mixed trends. For example, people have traditionally hunted White-throated Ground-Dove and Mariana Fruit-Dove; it is not legal to hunt these doves, but current hunting prevalence is unknown.

The insectivorous Rufous Fantail increased on Tinian and Aguiguan but decreased on the more densely human-populated Saipan. Trends for birds with diets including insects, nectar, and fruits were mixed. The Aguiguan population of Bridled White-eye may have increased in response to expansion of secondary forest and lantana field habitats. Habitat change and increased human populations may not be strong enough drivers to affect Bridled White-eye populations on Saipan and Tinian. Golden White-eye is known from the recent fossil record to have formerly occurred on Tinian, where it is now extinct (Craig 1999). The species was detected in large numbers on Aguiguan, and the population there has more than doubled (529 to 1,293 birds/km^2) between 1982 and 2008. Craig (1996, as cited in Craig 1999) estimated Golden White-eye densities on Saipan at about 1,200 birds/km^2, an estimate that roughly matches the 1997 point-transect density (Camp *et al*. 2009). The current Golden White-eye densities on Aguiguan were almost twice that reported from Saipan (1,300 and 700 birds/km^2, respectively), and their trends were in opposite directions—increasing on Aguiguan and decreasing on Saipan (Camp *et al*. 2009).

The Golden White-eye decline on Saipan may be a result of increasing human populations and habitat loss/degradation, whereas these factors are not affecting the population on uninhabited Aguiguan. Generally, the birds on Tinian, Aguiguan, and Saipan are doing comparatively well for insular species. This is surprising given that nearly all of the native forests on Tinian and Saipan have been lost and that all habitats on Aguiguan suffer from heavy browsing by feral goats, and forest regeneration is thus severely selective. Recent surveys on Rota showed that seven of eight bird trends have declined (Amar *et al*. 2008). The only bird to increase on Rota was the Micronesian Starling, which has also increased on the other three islands. Similar to our findings, Amar *et al*. concluded that the loss of forests or the spread of scarlet gourd does not fully explain bird population trends on Rota. Likewise, large-scale climate change, increases in human populations on Rota, Saipan, and Tinian, and Malathion insecticide spraying do not appear to be consistent drivers of bird trends. The status of brown tree snake on Rota, Tinian, and Aguiguan is unknown, but reports of sightings are very rare. Brown tree snakes have been frequently sighted on Saipan (Rodda and Savidge 2007). However, declines in the bird populations do not follow the geographic pattern of snakes spreading across an island, as they did on Guam (Savidge 1987). Further research is needed to identify the causative agents of population change in these four islands.

Rare species and those not appropriate for point-transect sampling
Three native land birds—Micronesian Megapode, Guam Swiftlet, and Nightingale Reed-Warbler—were either not detected during the point-transect counts or the numbers of birds detected were too few to estimate densities. Point-transect methods may not be appropriate for the very rare megapode and reed-warbler, and the behavior of the swiftlet violates modeling assumptions. A remnant population of a few Micronesian Megapode may persist on Tinian (Wiles *et al*. 1987, U.S. Fish and Wildlife Service 1998a), although no individuals were detected during any of the three point-transect surveys. Wiles *et al*. (1987) speculated that the megapode population on Tinian may originate from birds being brought in by humans or possibly dispersing from nearby populations on Aguiguan or Saipan. Aguiguan supports a small Micronesian Megapode population (U.S. Fish and Wildlife Service 1998a), and about equal numbers of birds were detected during the 1982 and 2008 surveys (14 and 15 birds, respectively). During the 1982 survey on Aguiguan, four Nightingale Reed-Warbler incidental sightings were recorded, but not during the eight-minute counts (Engbring *et al*. 1986). The reed-warbler has not been observed on Aguiguan since the mid-1990s and may be extirpated on Aguiguan (U.S. Fish and Wildlife Service 1998b, Esselstyn

et al. 2003). The Nightingale Reed-Warbler was not detected by the 2008 survey, neither during counts nor incidentally. The Guam Swiftlet historically occurred on Tinian but is extinct on the island (U.S. Fish and Wildlife Service 1991, Cruz *et al*. 2008); no swiftlets were detected during the three point-transect surveys. Cruz *et al*. (2008) noted that the Aguiguan swiftlet population has probably remained fairly stable between 1987 and 2002; however, it is notable that the numbers of birds detected in 2008 were only 17% of those detected in 1982 (27 and 157 birds, respectively). This apparent decline was further supported by the drop in numbers of birds detected at roosting cave counts between 1985 and 1997–2002 (Cruz *et al*. 2008).

The 1996 White Tern estimate on Tinian was markedly lower than from the other surveys. It is likely that the low tern estimate was an artifact of when the survey was conducted and not an actual change in the tern population. The original survey in 1982 and the most recent 2008 survey occurred early in the year and early in the breeding season (although terns can breed in all months of the year; Niethammer and Patrick-Castilaw 1998), whereas the 1996 survey was conducted in late August and after the breeding season. When not nesting, most individuals spend extended periods at sea (Niethammer and Patrick-Castilaw 1998); therefore portions of the population in 1996 were outside the sampling frame. In addition, the 1996 survey focused on passerines, and not all tern detections may have been recorded (F. Amidon, pers. comm.).

Tinian Monarch concerns
Lusk *et al*. (2000) calculated the 1996 Tinian Monarch abundance at about 55,700 birds, which is 11% less than our estimate of 62,900 birds. This change is due to differences between the analytical procedures. For example, Lusk *et al*. (2000) did not extrapolate densities to abundance for 2,375 ha of open fields, although monarchs were detected in this habitat. After dropping densities from the open fields and adjusting for this area difference, our densities resulted in 48,424 birds, an estimate that fell within their 95% CI. This difference is easily accounted for in differences between our methods, specifically differences in the model selected and advances within program DISTANCE. Lusk *et al*. (2000) calculated their density estimate from a half-normal model with polynomial adjustments and an effective detection radius (EDR) of just over 34 m. We estimated the EDR at 30.18 m from a hazard-rate detection function (without adjustments) and incorporating observers as a covariate, where the smaller EDR resulted in greater densities. Lastly, Lusk *et al*. (2000) used program VCPADJ (Fancy 1997) and a previous version of DISTANCE (Laake *et al*. 1994) to standardize the survey conditions and estimate densities. The updated version of DISTANCE (Thomas *et al*. 2006) we used incorporates all of the modeling in one program and uses an improved technique to account for differences in sampling conditions (Thomas *et al*. 2006, Marques *et al*. 2007).

Estimator certainty usually declines with decreasing density estimates; however, this pattern was not observed for the 2008 Tinian Monarch estimate. There was an almost three-fold decrease in estimator certainty for the 2008 estimate than that observed for either the 1982 or 1996 estimates. Variability in monarch densities on the new transects was substantially less than that observed on the entire set of original transects and the subset of original transects within the same regions. In the two regions where additional transects were sampled—Carolinas and Diablo—variability in the Tinian Monarch density diverged (see Appendix 2). Variability in the monarch density in the Diablo region remained low even though densities declined. In contrast, uncertainty increased four-fold in the Carolinas region. The additional stations sampled during the 2008 survey in the Carolinas region reduced variability to the Tinian Monarch estimate, but estimator certainty was poorer than in previous surveys. Adding stations to the limestone forest habitat improved estimator certainty by 50%. Thus, additional stations may be needed to further improve estimator certainty. Allocation of stations for monitoring Tinian Monarch should consider additional sampling in habitats with uncertain estimates including agriculture (CV > 100%), urban/residential (CV = 69%), and lastly in open field habitat where 23% CV is adequate for trends

monitoring. Also, additional sampling could be allocated in the Carolinas region to help reduce the almost 50% CV.

The U.S. Fish and Wildlife Service (2005) post-delisting plan for the Tinian Monarch identified the loss of habitat as a primary threat. The USFWS identified limestone and secondary forests and tangantangan thicket as quality habitat for the monarch (densities of 30.7, 7.7, and 6.0 birds/ha, respectively). Monarch densities in 2008 declined dramatically by 79% in limestone forests and substantially by 24% and 27% in secondary forest and tangantangan thicket, respectively, from those reported by U.S. Fish and Wildlife Service (2005). We also show that the monarch population declined over the 27-year period, and the decline between 1996 and 2008 may be attributed to reduced bird density in open field habitat. Continued monitoring of the Tinian Monarch will be necessary to track its long-term survival, especially when the species is faced with population declines, threats such as the potential invasion of the brown tree snake, and habitat lost to the increasing development of Tinian Island.

Bird monitoring for conservation on Tinian
The current status of the brown tree snake on Tinian is unknown, but there have been several reports of snakes from Tinian and other CNMI islands (Colvin *et al.* 2005). Interdiction measures to prevent the introduction and establishment of snakes are crucial for the survival of CNMI land birds. If established, the brown tree snake will decimate the avifauna (Savidge 1987, Wiles *et al.* 2003). Military operations are likely to increase traffic between Guam and Tinian, increasing the probability of transporting brown tree snake to Tinian.

Military operations are likely to result in increases in the human population and land use conversion, which will expand human-dominated habitats. Between 1980 and 2000, the human population on Tinian increased 309% from 866 to 3,540 people, respectively (CNMI Department of Commerce 2001). Human increases were concentrated in and around the main settlement, San Jose, and not in the northern two-thirds of the island leased by the military. Humans have predominantly increased in the Carolinas region (which includes much of San Jose), where both alien birds and four native birds—Yellow Bittern, Collared Kingfisher, Rufous Fantail, and Micronesian Starling—increased. In contrast, Tinian Monarch, a native bird typically associated with forests, especially limestone forests, declined in the Carolinas region where housing, roads, and services have expanded. These bird trend patterns could well continue or be exacerbated by increasing military actions.

Acknowledgements

Literature Cited

Amar, A., F. Amidon, B. Arroyo, J. A. Esselstyn, and A. P. Marshall. 2008. Population trends of the forest bird community on the Pacific island of Rota, Mariana Islands. Condor 110:421–427.

Buckland, S.T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. Oxford: Oxford University Press.

Camp, R. J., T. K. Pratt, A. P. Marshall, F. Amidon, and L.L. Williams. 2009. Recent status and trends of the land bird avifauna on Saipan, Mariana Islands, with emphasis on the endangered Nightingale Reed-Warbler *Acrocephalus luscinia*. Bird Conservation International 19:323–337.

CNMI Department of Commerce. 2001. Census 2000 update. CNMI Department of Commerce website: http://www.commerce.gov.mp/new/PDF/central_statistic/Cen/2000%20Cen%20Update.pdf. Accessed 11 August 2008.

Colvin, B. A., M. W. Fall, L. A. Fitzgerald, and L. L. Loope. 2005. Review of brown treesnake problems and control programs: report of observations and recommendations. Unpublished report to the U.S. Department of Interior, Office of Insular affairs, March 2005.

Craig, R. J. 1999. Conservation of endangered White-eyes (Zosteropidae) in the tropical Pacific. Published by Bird Conservation Research, Inc., Putnam, CT. 8 pp.

Cruz, J. B., S. R. Kremer, G. Martin, L. L. Williams, and V. A. Camacho. 2008. Relative abundance and distribution of Mariana Swiftlets (Aves: Apodidea) in the Northern Mariana Islands. Pacific Science 62:233–246.

Engbring, J., F. L. Ramsey, and V. J. Wildman. 1986. Micronesian forest bird survey, 1982: Saipan, Tinian, Aguijan, and Rota. U.S. Fish and Wildlife Service Report. 143 pp.

Esselstyn, J., J. B. Cruz, L. L. Williams, and N. Hawley. 2003. Wildlife and vegetation surveys Aguiguan 2002. CNMI Division of Fish and Wildlife Technical Report #9.

Fancy, S. G. 1997. A new approach for analyzing bird densities from variable circular-plot counts. Pacific Science 50:107–114.

Johnson, L., R. J. Camp, K. W. Brinck, and P. C. Banko. 2006. Long-term population monitoring: lessons learned from an endangered passerine in Hawai`i. Wildlife Society Bulletin 34:1055–1063.

Laake, J. L., S. T. Buckland, D. R. Anderson, and K. P. Burnham. 1994. DISTANCE user's guide V2.1. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system for mixed models. SAS Institute Inc., Cary, NC.

Lusk, M., S. Hess, M. Reynolds, and S. Johnston. 2000. Population status of the Tinian Monarch (*Monarcha takatsukasae*) on Tinian, Commonwealth of the Northern Mariana Islands. Micronesica 32:181–190.

Marques, T. A., L. Thomas, S. G. Fancy, and S. T. Buckland. 2007. Improving estimates of bird density using multiple-covariate distance sampling. Auk 124:1229–1243.

Niethammer, K. R., and L. B. Patrick-Castilaw. 1998. White Tern (Gygis alba). *In* A. Poole and F. Gill (editors). The Birds of North America, No. 371. The Birds of North America, Inc., Philadelphia, PA.

Reichel, J. D., and P. O. Glass. 1991. Checklist of the birds of the Mariana Islands. `Elepaio 51:3–11.

Rodda, G. H., and J. A. Savidge. 2007. Biology and impacts of Pacific island invasive species. 2. *Bioga irregularis*, the Brown Tree Snake (Reptilia: Columbridae). Pacific Science 61:307–324.

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

Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2006. Distance 5.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, U.K. http://www.ruwpa.st-and.ac.uk/distance/.

U.S. Fish and Wildlife Service. 1998a. Recovery plan for the Micronesian Megapode (*Megapodius laperouse laperouse*). Portland, OR.

U.S. Fish and Wildlife Service. 1998b. Recovery plan for the Nightingale Reed-warbler, *Acrocephalus luscinia*. Portland, OR.

U.S. Fish and Wildlife Service. 1991. Recovery plan for the Mariana Islands population of the Vanikoro Swiftlet, *Aerodramus vanikorensis bartschi*. Portland, OR.

U.S. Fish and Wildlife Service. 2005. Post-delisting monitoring plan for the Tinian Monarch, *Monarcha takatsukasae*. Endangered Species Division, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

U.S. Fish and Wildlife Service. 2008. Terrestrial resource surveys of Tinian and Aguiguan, Mariana Islands. U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.

Wiles, G. J., J. Bart, R. E. Beck, Jr., and C. F. Aguon. 2003. Impacts of the brown tree snake: patterns of decline and species persistence in Guam's avifauna. Conservation Biology 17:1350–1360.

Wiles, G. J., R. E. Beck, and A. B. Amerson. 1987. The Micronesian Megapode on Tinian, Mariana Islands. `Elepaio 47:1–3.

Appendix 1. Species data and models

Appendix 1, Table 10. Detection function parameters used to derive population densities for each species on Tinian.

Species	Truncation	Key Model	Adjustment Terms	Covariates
Yellow Bittern	78.0	Half normal	None	None
White Tern	92.7	Half normal	None	None
Island Collared-Dove	133.0	Half normal	None	Observer
White-throated Ground-Dove	115.0	Hazard rate	None	None
Mariana Fruit-Dove	250.0	Hazard rate	None	Observer
Collared Kingfisher	91.2	Hazard rate	None	Observer
Micronesian Honeyeater	100.0	Hazard rate	None	Year
Tinian Monarch	68.6	Hazard rate	None	Observer
Rufous Fantail	58.7	Half normal	None	Observer
Bridled White-eye	56.0	Hazard rate	None	Observer
Micronesian Starling	78.3	Half normal	None	Observer
Eurasian Tree Sparrow	37.0	Hazard rate	None	None
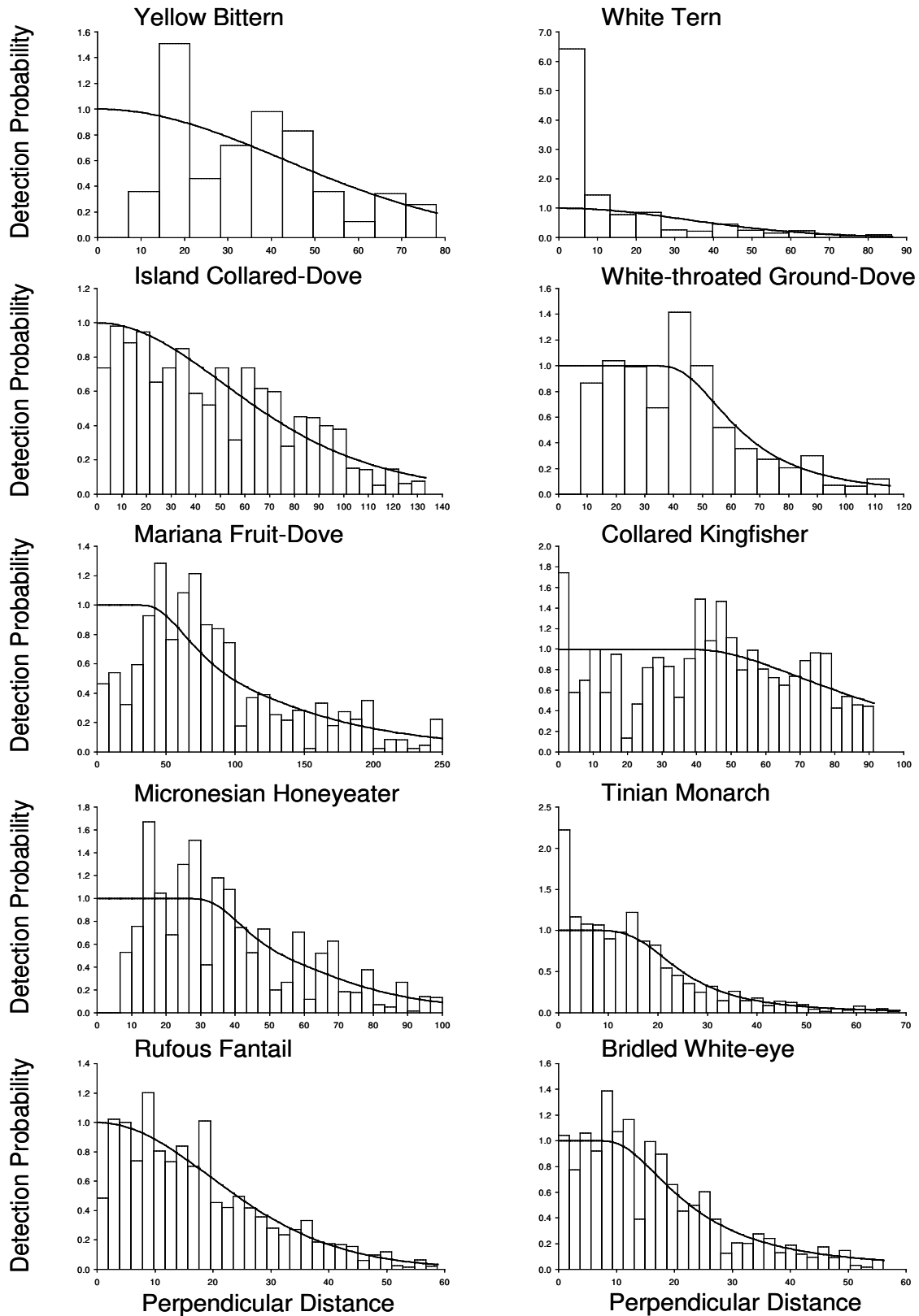
Appendix 1, Figure 8. Histograms of bird detections used to calculate population estimates on Tinian. The best fit lines for these data were modeled with program DISTANCE.
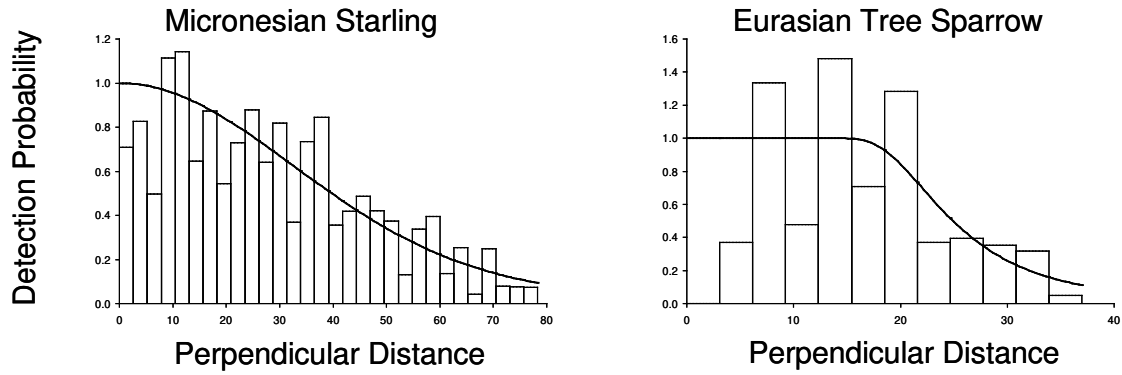
Appendix 1, Figure 8. Continued.

Appendix 1, Table 11. Detection function parameters used to derive population densities for each species on Aguiguan.

Species	Truncation	Key Model	Adjustment Terms	Covariates
White Tern	95.8	Half normal	Cosine (2,3)	Observer
Island Collared-Dove	70.0	Hazard rate	None	None
White-throated Ground-Dove	81.8	Half normal	None	None
Mariana Fruit-Dove	191.0	Hazard rate	Cosine (2)	Observer
Collared Kingfisher	193.0	Hazard rate	None	Year
Micronesian Honeyeater	90.0	Hazard rate	None	Observer
Rufous Fantail	70.0	Hazard rate	None	Observer
Golden White-eye	65.3	Hazard rate	None	Observer
Bridled White-eye	40.0	Hazard rate	None	Cloud
Micronesian Starling	75.1	Half normal	None	Observer
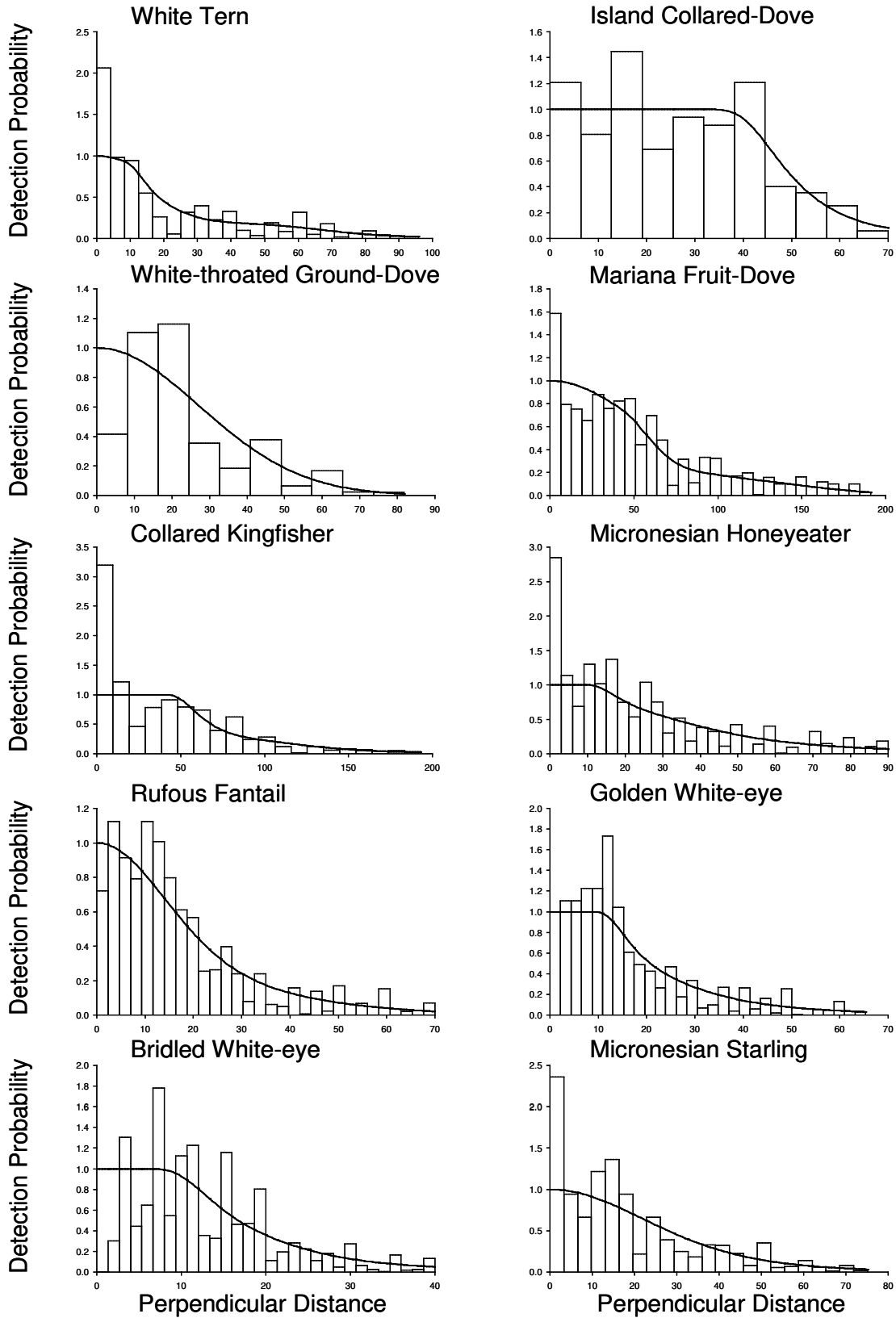
Appendix 1, Figure 9. Histograms of bird detections used to calculate population estimates on Aguiguan. The best fit lines for these data were modeled with program DISTANCE.

Appendix 2. Results from region and year analyses for Tinian land birds

Appendix 2, Table 12. Density estimates (birds/km^2), standard error (SE), and 95% confidence intervals (Lower and Upper 95% CI) by region and year.

Yellow Bittern

| Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	0.0	0.00	0.0	0.0
	1996	4.0	2.92	1.1	14.8
	2008	21.8	7.10	11.6	40.9
Diablo	1982	0.0	0.00	0.0	0.0
	1996	8.8	4.81	3.2	24.3
	2008	22.0	7.69	11.2	43.1
Hagoi	1982	2.0	2.01	0.4	10.7
	1996	7.9	4.10	3.0	21.0
	2008	15.8	6.59	7.1	35.1
Masalog	1982	5.9	4.27	1.6	21.9
	1996	8.9	5.25	3.0	26.8
	2008	8.9	5.25	3.0	26.8

White Tern

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	222.6	48.36	144.7	342.2
	1996	16.7	9.48	5.8	48.2
	2008	188.4	37.91	126.4	280.7
Diablo	1982	129.3	22.75	91.3	183.0
	1996	50.5	17.20	26.1	97.7
	2008	240.4	40.57	172.2	335.5
Hagoi	1982	112.0	24.79	72.2	173.5
	1996	5.5	3.83	1.5	19.4
	2008	95.6	24.72	57.4	159.1
Masalog	1982	106.5	30.64	60.1	188.6
	1996	16.4	16.40	3.0	88.9
	2008	110.6	29.96	64.5	189.7

Island Collared-Dove

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	5.8	3.01	2.2	15.4
	1996	38.8	7.08	27.0	55.7
	2008	14.3	4.45	7.8	26.3
Diablo	1982	20.4	4.48	13.3	31.4
	1996	25.4	4.91	17.3	37.1
	2008	33.1	7.27	21.5	51.0
Hagoi	1982	5.7	2.24	2.7	12.2
	1996	32.4	6.65	21.6	48.6
	2008	21.0	4.34	13.9	31.6
Masalog	1982	15.7	4.58	8.8	28.0
	1996	48.6	9.06	33.5	70.6
	2008	24.3	5.75	15.1	39.0

White-throated Ground-Dove

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	3.5	3.58	0.7	19.0
	1996	1.2	1.19	0.2	6.3
	2008	4.6	2.35	1.8	12.0
Diablo	1982	4.3	1.96	1.8	10.2
	1996	5.1	2.15	2.3	11.4
	2008	37.7	7.94	25.0	56.9
Hagoi	1982	1.2	1.17	0.2	6.2
	1996	7.0	2.88	3.1	15.4
	2008	20.9	5.79	12.1	35.8
Masalog	1982	8.7	4.60	3.2	23.7
	1996	5.2	3.02	1.8	15.5
	2008	7.0	4.27	2.2	21.8

Mariana Fruit-Dove

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	53.7	4.72	45.1	64.0
	1996	12.4	1.98	9.0	17.0
	2008	35.4	3.44	29.2	43.0
Diablo	1982	37.8	2.94	32.4	44.1
	1996	21.7	2.32	17.6	26.9
	2008	38.0	2.85	32.8	44.1
Hagoi	1982	42.8	5.19	33.6	54.5
	1996	12.8	1.99	9.4	17.4
	2008	28.4	3.77	21.8	37.0
Masalog	1982	35.4	7.04	23.8	52.8
	1996	13.4	2.33	9.5	19.0
	2008	26.3	3.64	19.9	34.8

Collared Kingfisher

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	5.5	2.52	2.3	13.2
	1996	15.7	4.72	8.7	28.3
	2008	51.6	7.47	38.7	68.9
Diablo	1982	8.7	2.76	4.7	16.1
	1996	34.8	6.13	24.6	49.3
	2008	68.3	7.33	55.2	84.5
Hagoi	1982	5.4	2.48	2.3	13.0
	1996	23.5	8.07	12.1	45.9
	2008	57.9	8.41	43.4	77.4
Masalog	1982	8.1	4.14	3.1	21.5
	1996	8.1	4.14	3.1	21.5
	2008	66.5	10.47	48.5	91.4

Micronesian Honeyeater

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	91.3	14.03	67.3	123.9
	1996	52.4	10.06	35.8	76.7
	2008	67.6	11.77	47.8	95.5
Diablo	1982	97.8	10.21	79.6	120.3
	1996	34.8	7.26	23.1	52.5
	2008	43.5	7.52	30.9	61.2
Hagoi	1982	39.7	8.25	26.3	59.9
	1996	14.7	6.00	6.7	32.3
	2008	14.7	5.21	7.4	29.3
Masalog	1982	70.5	16.66	44.0	113.1
	1996	17.6	7.86	7.4	41.8
	2008	37.5	10.85	21.1	66.6

Tinian Monarch

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	498.2	59.84	392.1	633.1
	1996	630.7	77.83	493.1	806.7
	2008	346.6	63.26	241.2	498.1
Diablo	1982	856.3	55.40	753.3	973.3
	1996	750.9	61.05	639.1	882.3
	2008	485.4	46.84	400.8	587.8
Hagoi	1982	637.6	69.30	513.3	791.9
	1996	742.8	92.48	579.6	952.0
	2008	451.9	58.83	348.6	585.7
Masalog	1982	380.7	86.11	242.0	598.9
	1996	668.5	107.43	483.8	923.8
	2008	417.8	66.85	302.8	576.5

Rufous Fantail

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	661.9	85.71	511.2	857.0
	1996	910.1	78.08	766.9	1079.9
	2008	1042.1	104.31	853.5	1272.4
Diablo	1982	735.8	52.83	638.1	848.5
	1996	740.8	63.56	624.8	878.4
	2008	941.1	73.59	805.8	1099.0
Hagoi	1982	622.5	70.41	496.8	780.2
	1996	832.3	66.17	710.3	975.4
	2008	900.0	70.38	770.1	1051.7
Masalog	1982	446.6	98.39	287.2	694.6
	1996	507.5	93.23	350.8	734.3
	2008	1055.6	106.93	860.5	1295.0

Bridled White-eye

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	3266.8	167.26	2949.0	3618.8
	1996	2575.7	129.82	2328.6	2849.1
	2008	3226.9	210.72	2831.7	3677.1
Diablo	1982	3638.8	174.30	3308.4	4002.1
	1996	3005.3	155.07	2712.0	3330.2
	2008	2452.9	153.80	2165.2	2778.8
Hagoi	1982	2637.7	162.75	2331.4	2984.2
	1996	2993.9	108.38	2785.5	3218.0
	2008	3452.9	216.50	3045.8	3914.5
Masalog	1982	3000.8	251.17	2533.1	3554.7
	1996	2014.2	165.16	1706.3	2377.6
	2008	3072.7	204.33	2686.2	3514.8

Micronesian Starling

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	137.1	23.93	96.9	194.0
	1996	153.5	33.59	99.5	236.8
	2008	365.9	49.47	279.5	479.1
Diablo	1982	173.2	29.13	124.2	241.5
	1996	151.3	22.61	112.5	203.4
	2008	380.2	35.28	316.3	456.9
Hagoi	1982	134.5	20.97	98.6	183.5
	1996	80.7	19.21	50.4	129.2
	2008	363.2	42.03	288.4	457.5
Masalog	1982	48.4	17.42	23.9	98.3
	1996	96.9	24.71	58.2	161.2
	2008	242.2	31.92	185.7	315.8

Eurasian Tree Sparrow

Region	Year	Estimate	SE	L 95% CI	U 95% CI
Carolinas	1982	0.0	0.00	0.0	0.0
	1996	75.2	56.71	19.6	288.4
	2008	393.8	151.68	187.6	826.7
Diablo	1982	6.1	6.13	1.1	32.3
	1996	24.3	24.53	4.6	129.1
	2008	12.1	12.27	2.3	64.5
Hagoi	1982	0.0	0.00	0.0	0.0
	1996	0.0	0.00	0.0	0.0
	2008	0.0	0.00	0.0	0.0
Masalog	1982	0.0	0.00	0.0	0.0
	1996	0.0	0.00	0.0	0.0
	2008	49.2	39.24	11.9	203.8

Appendix 2, Table 13. Comparison of densities by region and year using repeated measures ANOVA for eight species with significant main effects (Table 4). Effect codes are Yr–year, Reg–region, and Y*R–interaction between year and region main effects.

White Tern

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	0.4920	0.0649	392	7.58	<.001
Yr		1982		2008	-0.0298	0.0649	392	-0.46	0.890
Yr		1996		2008	-0.5218	0.0649	392	-8.04	<.001
Reg	Carolina		Diablo		-0.0054	0.0795	196	-0.07	1.000
Reg	Carolina		Hagoi		0.2214	0.0855	196	2.59	0.050
Reg	Carolina		Masalog		0.1707	0.0947	196	1.80	0.275
Reg	Diablo		Hagoi		0.2268	0.0749	196	3.03	0.015
Reg	Diablo		Masalog		0.1761	0.0852	196	2.07	0.168
Reg	Hagoi		Masalog		-0.0507	0.0909	196	-0.56	0.944

White-throated Ground-Dove

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	-0.0042	0.0181	392	-0.23	0.971
Yr		1982		2008	-0.0934	0.0181	392	-5.16	<.001
Yr		1996		2008	-0.0891	0.0181	392	-4.93	<.001
Reg	Carolina		Diablo		-0.0845	0.0225	196	-3.75	0.001
Reg	Carolina		Hagoi		-0.0433	0.0242	196	-1.79	0.282
Reg	Carolina		Masalog		-0.0264	0.0268	196	-0.98	0.759
Reg	Diablo		Hagoi		0.0412	0.0212	196	1.94	0.214
Reg	Diablo		Masalog		0.0581	0.0241	196	2.41	0.079
Reg	Hagoi		Masalog		0.0169	0.0257	196	0.66	0.913
Yr*Reg	Carolina	1982	Diablo	1982	-0.0081	0.0355	576	-0.23	1.000
Yr*Reg	Carolina	1982	Hagoi	1982	0.0156	0.0382	576	0.41	1.000
Yr*Reg	Carolina	1982	Masalog	1982	-0.0416	0.0423	576	-0.98	0.998
Yr*Reg	Carolina	1982	Carolina	1996	0.0136	0.0380	392	0.36	1.000
Yr*Reg	Carolina	1982	Diablo	1996	-0.0148	0.0355	576	-0.42	1.000
Yr*Reg	Carolina	1982	Hagoi	1996	-0.0320	0.0382	576	-0.84	1.000
Yr*Reg	Carolina	1982	Masalog	1996	-0.0177	0.0423	576	-0.42	1.000
Yr*Reg	Carolina	1982	Carolina	2008	-0.0211	0.0380	392	-0.56	1.000
Yr*Reg	Carolina	1982	Diablo	2008	-0.2381	0.0355	576	-6.70	<.001
Yr*Reg	Carolina	1982	Hagoi	2008	-0.1210	0.0382	576	-3.16	0.072
Yr*Reg	Carolina	1982	Masalog	2008	-0.0273	0.0423	576	-0.64	1.000
Yr*Reg	Diablo	1982	Hagoi	1982	0.0238	0.0335	576	0.71	1.000
Yr*Reg	Diablo	1982	Masalog	1982	-0.0335	0.0381	576	-0.88	0.999
Yr*Reg	Diablo	1982	Carolina	1996	0.0217	0.0355	576	0.61	1.000
Yr*Reg	Diablo	1982	Diablo	1996	-0.0067	0.0288	392	-0.23	1.000
Yr*Reg	Diablo	1982	Hagoi	1996	-0.0239	0.0335	576	-0.71	1.000
Yr*Reg	Diablo	1982	Masalog	1996	-0.0096	0.0381	576	-0.25	1.000
Yr*Reg	Diablo	1982	Carolina	2008	-0.0130	0.0355	576	-0.37	1.000
Yr*Reg	Diablo	1982	Diablo	2008	-0.2299	0.0288	392	-7.99	<.001
Yr*Reg	Diablo	1982	Hagoi	2008	-0.1129	0.0335	576	-3.37	0.039

Yr*Reg	Diablo	1982	Masalog	2008	-0.0192	0.0381	576	-0.50	1.000
Yr*Reg	Hagoi	1982	Masalog	1982	-0.0572	0.0406	576	-1.41	0.962
Yr*Reg	Hagoi	1982	Carolina	1996	-0.0020	0.0382	576	-0.05	1.000
Yr*Reg	Hagoi	1982	Diablo	1996	-0.0304	0.0335	576	-0.91	0.999
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.0476	0.0345	392	-1.38	0.966
Yr*Reg	Hagoi	1982	Masalog	1996	-0.0334	0.0406	576	-0.82	1.000
Yr*Reg	Hagoi	1982	Carolina	2008	-0.0368	0.0382	576	-0.96	0.998
Yr*Reg	Hagoi	1982	Diablo	2008	-0.2537	0.0335	576	-7.57	<.001
Yr*Reg	Hagoi	1982	Hagoi	2008	-0.1366	0.0345	392	-3.97	0.005
Yr*Reg	Hagoi	1982	Masalog	2008	-0.0429	0.0406	576	-1.06	0.996
Yr*Reg	Masalog	1982	Carolina	1996	0.0552	0.0423	576	1.30	0.978
Yr*Reg	Masalog	1982	Diablo	1996	0.0268	0.0381	576	0.70	1.000
Yr*Reg	Masalog	1982	Hagoi	1996	0.0096	0.0406	576	0.24	1.000
Yr*Reg	Masalog	1982	Masalog	1996	0.0239	0.0422	392	0.57	1.000
Yr*Reg	Masalog	1982	Carolina	2008	0.0205	0.0423	576	0.48	1.000
Yr*Reg	Masalog	1982	Diablo	2008	-0.1965	0.0381	576	-5.16	<.001
Yr*Reg	Masalog	1982	Hagoi	2008	-0.0794	0.0406	576	-1.95	0.724
Yr*Reg	Masalog	1982	Masalog	2008	0.0143	0.0422	392	0.34	1.000
Yr*Reg	Carolina	1996	Diablo	1996	-0.0284	0.0355	576	-0.80	1.000
Yr*Reg	Carolina	1996	Hagoi	1996	-0.0456	0.0382	576	-1.19	0.989
Yr*Reg	Carolina	1996	Masalog	1996	-0.0313	0.0423	576	-0.74	1.000
Yr*Reg	Carolina	1996	Carolina	2008	-0.0347	0.0380	392	-0.91	0.999
Yr*Reg	Carolina	1996	Diablo	2008	-0.2517	0.0355	576	-7.08	<.001
Yr*Reg	Carolina	1996	Hagoi	2008	-0.1346	0.0382	576	-3.52	0.024
Yr*Reg	Carolina	1996	Masalog	2008	-0.0409	0.0423	576	-0.97	0.998
Yr*Reg	Diablo	1996	Hagoi	1996	-0.0172	0.0335	576	-0.51	1.000
Yr*Reg	Diablo	1996	Masalog	1996	-0.0029	0.0381	576	-0.08	1.000
Yr*Reg	Diablo	1996	Carolina	2008	-0.0063	0.0355	576	-0.18	1.000
Yr*Reg	Diablo	1996	Diablo	2008	-0.2233	0.0288	392	-7.75	<.001
Yr*Reg	Diablo	1996	Hagoi	2008	-0.1062	0.0335	576	-3.17	0.070
Yr*Reg	Diablo	1996	Masalog	2008	-0.0125	0.0381	576	-0.33	1.000
Yr*Reg	Hagoi	1996	Masalog	1996	0.0143	0.0406	576	0.35	1.000
Yr*Reg	Hagoi	1996	Carolina	2008	0.0109	0.0382	576	0.28	1.000
Yr*Reg	Hagoi	1996	Diablo	2008	-0.2061	0.0335	576	-6.15	<.001
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.0890	0.0345	392	-2.58	0.293
Yr*Reg	Hagoi	1996	Masalog	2008	0.0047	0.0406	576	0.12	1.000
Yr*Reg	Masalog	1996	Carolina	2008	-0.0034	0.0423	576	-0.08	1.000
Yr*Reg	Masalog	1996	Diablo	2008	-0.2204	0.0381	576	-5.78	<.001
Yr*Reg	Masalog	1996	Hagoi	2008	-0.1033	0.0406	576	-2.54	0.317
Yr*Reg	Masalog	1996	Masalog	2008	-0.0096	0.0422	392	-0.23	1.000
Yr*Reg	Carolina	2008	Diablo	2008	-0.2170	0.0355	576	-6.10	<.001
Yr*Reg	Carolina	2008	Hagoi	2008	-0.0999	0.0382	576	-2.61	0.277
Yr*Reg	Carolina	2008	Masalog	2008	-0.0062	0.0423	576	-0.15	1.000
Yr*Reg	Diablo	2008	Hagoi	2008	0.1171	0.0335	576	3.50	0.026
Yr*Reg	Diablo	2008	Masalog	2008	0.2108	0.0381	576	5.53	<.001
Yr*Reg	Hagoi	2008	Masalog	2008	0.0937	0.0406	576	2.31	0.474

Mariana Fruit-Dove

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	0.1941	0.0175	392	11.11	<.001
Yr		1982		2008	0.0522	0.0175	392	2.99	0.008
Yr		1996		2008	-0.1418	0.0175	392	-8.12	<.001
Reg	Carolina		Diablo		0.0185	0.0214	196	0.86	0.824
Reg	Carolina		Hagoi		0.0551	0.0230	196	2.39	0.082
Reg	Carolina		Masalog		0.0965	0.0255	196	3.78	0.001
Reg	Diablo		Hagoi		0.0366	0.0202	196	1.82	0.269
Reg	Diablo		Masalog		0.0780	0.0230	196	3.40	0.005
Reg	Hagoi		Masalog		0.0414	0.0245	196	1.69	0.332
Yr*Reg	Carolina	1982	Diablo	1982	0.1129	0.0341	578	3.31	0.047
Yr*Reg	Carolina	1982	Hagoi	1982	0.0836	0.0367	578	2.28	0.495
Yr*Reg	Carolina	1982	Masalog	1982	0.1822	0.0406	578	4.48	0.001
Yr*Reg	Carolina	1982	Carolina	1996	0.3105	0.0367	392	8.47	<.001
Yr*Reg	Carolina	1982	Diablo	1996	0.2347	0.0341	578	6.88	<.001
Yr*Reg	Carolina	1982	Hagoi	1996	0.3066	0.0367	578	8.35	<.001
Yr*Reg	Carolina	1982	Masalog	1996	0.3030	0.0406	578	7.46	<.001
Yr*Reg	Carolina	1982	Carolina	2008	0.0922	0.0367	392	2.52	0.333
Yr*Reg	Carolina	1982	Diablo	2008	0.1105	0.0341	578	3.24	0.058
Yr*Reg	Carolina	1982	Hagoi	2008	0.1779	0.0367	578	4.85	0.000
Yr*Reg	Carolina	1982	Masalog	2008	0.2070	0.0406	578	5.09	<.001
Yr*Reg	Diablo	1982	Hagoi	1982	-0.0293	0.0322	578	-0.91	0.999
Yr*Reg	Diablo	1982	Masalog	1982	0.0693	0.0366	578	1.89	0.763
Yr*Reg	Diablo	1982	Carolina	1996	0.1976	0.0341	578	5.79	<.001
Yr*Reg	Diablo	1982	Diablo	1996	0.1218	0.0278	392	4.38	0.001
Yr*Reg	Diablo	1982	Hagoi	1996	0.1937	0.0322	578	6.03	<.001
Yr*Reg	Diablo	1982	Masalog	1996	0.1901	0.0366	578	5.20	<.001
Yr*Reg	Diablo	1982	Carolina	2008	-0.0207	0.0341	578	-0.61	1.000
Yr*Reg	Diablo	1982	Diablo	2008	-0.0024	0.0278	392	-0.08	1.000
Yr*Reg	Diablo	1982	Hagoi	2008	0.0650	0.0322	578	2.02	0.679
Yr*Reg	Diablo	1982	Masalog	2008	0.0941	0.0366	578	2.57	0.298
Yr*Reg	Hagoi	1982	Masalog	1982	0.0986	0.0390	578	2.53	0.326
Yr*Reg	Hagoi	1982	Carolina	1996	0.2270	0.0367	578	6.18	<.001
Yr*Reg	Hagoi	1982	Diablo	1996	0.1511	0.0322	578	4.70	0.000
Yr*Reg	Hagoi	1982	Hagoi	1996	0.2231	0.0333	392	6.71	<.001
Yr*Reg	Hagoi	1982	Masalog	1996	0.2194	0.0390	578	5.63	<.001
Yr*Reg	Hagoi	1982	Carolina	2008	0.0086	0.0367	578	0.23	1.000
Yr*Reg	Hagoi	1982	Diablo	2008	0.0270	0.0322	578	0.84	1.000
Yr*Reg	Hagoi	1982	Hagoi	2008	0.0943	0.0333	392	2.84	0.170
Yr*Reg	Hagoi	1982	Masalog	2008	0.1234	0.0390	578	3.17	0.072
Yr*Reg	Masalog	1982	Carolina	1996	0.1284	0.0406	578	3.16	0.073
Yr*Reg	Masalog	1982	Diablo	1996	0.0525	0.0366	578	1.44	0.956
Yr*Reg	Masalog	1982	Hagoi	1996	0.1245	0.0390	578	3.19	0.066
Yr*Reg	Masalog	1982	Masalog	1996	0.1208	0.0407	392	2.97	0.123
Yr*Reg	Masalog	1982	Carolina	2008	-0.0900	0.0406	578	-2.21	0.540
Yr*Reg	Masalog	1982	Diablo	2008	-0.0716	0.0366	578	-1.96	0.721

Yr*Reg	Masalog	1982	Hagoi	2008	-0.0043	0.0390	578	-0.11	1.000
Yr*Reg	Masalog	1982	Masalog	2008	0.0249	0.0407	392	0.61	1.000
Yr*Reg	Carolina	1996	Diablo	1996	-0.0758	0.0341	578	-2.22	0.534
Yr*Reg	Carolina	1996	Hagoi	1996	-0.0039	0.0367	578	-0.11	1.000
Yr*Reg	Carolina	1996	Masalog	1996	-0.0076	0.0406	578	-0.19	1.000
Yr*Reg	Carolina	1996	Carolina	2008	-0.2184	0.0367	392	-5.96	<.001
Yr*Reg	Carolina	1996	Diablo	2008	-0.2000	0.0341	578	-5.86	<.001
Yr*Reg	Carolina	1996	Hagoi	2008	-0.1327	0.0367	578	-3.61	0.018
Yr*Reg	Carolina	1996	Masalog	2008	-0.1035	0.0406	578	-2.55	0.314
Yr*Reg	Diablo	1996	Hagoi	1996	0.0719	0.0322	578	2.24	0.523
Yr*Reg	Diablo	1996	Masalog	1996	0.0683	0.0366	578	1.87	0.779
Yr*Reg	Diablo	1996	Carolina	2008	-0.1425	0.0341	578	-4.18	0.002
Yr*Reg	Diablo	1996	Diablo	2008	-0.1242	0.0278	392	-4.47	0.001
Yr*Reg	Diablo	1996	Hagoi	2008	-0.0568	0.0322	578	-1.77	0.834
Yr*Reg	Diablo	1996	Masalog	2008	-0.0277	0.0366	578	-0.76	1.000
Yr*Reg	Hagoi	1996	Masalog	1996	-0.0037	0.0390	578	-0.09	1.000
Yr*Reg	Hagoi	1996	Carolina	2008	-0.2145	0.0367	578	-5.84	<.001
Yr*Reg	Hagoi	1996	Diablo	2008	-0.1961	0.0322	578	-6.10	<.001
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.1288	0.0333	392	-3.87	0.007
Yr*Reg	Hagoi	1996	Masalog	2008	-0.0996	0.0390	578	-2.55	0.310
Yr*Reg	Masalog	1996	Carolina	2008	-0.2108	0.0406	578	-5.19	<.001
Yr*Reg	Masalog	1996	Diablo	2008	-0.1924	0.0366	578	-5.26	<.001
Yr*Reg	Masalog	1996	Hagoi	2008	-0.1251	0.0390	578	-3.21	0.063
Yr*Reg	Masalog	1996	Masalog	2008	-0.0960	0.0407	392	-2.36	0.439
Yr*Reg	Carolina	2008	Diablo	2008	0.0184	0.0341	578	0.54	1.000
Yr*Reg	Carolina	2008	Hagoi	2008	0.0857	0.0367	578	2.33	0.454
Yr*Reg	Carolina	2008	Masalog	2008	0.1148	0.0406	578	2.83	0.173
Yr*Reg	Diablo	2008	Hagoi	2008	0.0673	0.0322	578	2.09	0.627
Yr*Reg	Diablo	2008	Masalog	2008	0.0965	0.0366	578	2.64	0.262
Yr*Reg	Hagoi	2008	Masalog	2008	0.0292	0.0390	578	0.75	1.000

Micronesian Honeyeater

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	0.2518	0.0363	392	6.94	<.001
Yr		1982		2008	0.1876	0.0363	392	5.17	<.001
Yr		1996		2008	-0.0642	0.0363	392	-1.77	0.182
Reg	Carolina		Diablo		0.0323	0.0478	196	0.68	0.906
Reg	Carolina		Hagoi		0.2413	0.0514	196	4.70	<.001
Reg	Carolina		Masalog		0.1799	0.0569	196	3.16	0.010
Reg	Diablo		Hagoi		0.2090	0.0450	196	4.64	<.001
Reg	Diablo		Masalog		0.1476	0.0512	196	2.88	0.023
Reg	Hagoi		Masalog		-0.0615	0.0546	196	-1.13	0.674

Tinian Monarch

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	-0.1750	0.0925	392	-1.89	0.143
Yr		1982		2008	0.2156	0.0925	392	2.33	0.053

Yr		1996		2008	0.3905	0.0925	392	4.22	<.001
Reg	Carolina		Diablo		-0.4019	0.1180	196	-3.40	0.004
Reg	Carolina		Hagoi		-0.2164	0.1270	196	-1.70	0.324
Reg	Carolina		Masalog		0.1388	0.1406	196	0.99	0.757
Reg	Diablo		Hagoi		0.1854	0.1112	196	1.67	0.344
Reg	Diablo		Masalog		0.5406	0.1265	196	4.27	0.000
Reg	Hagoi		Masalog		0.3552	0.1349	196	2.63	0.045
Yr*Reg	Carolina	1982	Diablo	1982	-0.7112	0.1837	572	-3.87	0.007
Yr*Reg	Carolina	1982	Hagoi	1982	-0.3605	0.1976	572	-1.82	0.804
Yr*Reg	Carolina	1982	Masalog	1982	0.4406	0.2188	572	2.01	0.684
Yr*Reg	Carolina	1982	Carolina	1996	-0.3105	0.1942	392	-1.60	0.909
Yr*Reg	Carolina	1982	Diablo	1996	-0.4804	0.1837	572	-2.62	0.275
Yr*Reg	Carolina	1982	Hagoi	1996	-0.3738	0.1976	572	-1.89	0.764
Yr*Reg	Carolina	1982	Masalog	1996	-0.1663	0.2188	572	-0.76	1.000
Yr*Reg	Carolina	1982	Carolina	2008	0.2374	0.1942	392	1.22	0.987
Yr*Reg	Carolina	1982	Diablo	2008	-0.0871	0.1837	572	-0.47	1.000
Yr*Reg	Carolina	1982	Hagoi	2008	0.0120	0.1976	572	0.06	1.000
Yr*Reg	Carolina	1982	Masalog	2008	0.0689	0.2188	572	0.32	1.000
Yr*Reg	Diablo	1982	Hagoi	1982	0.3507	0.1731	572	2.03	0.675
Yr*Reg	Diablo	1982	Masalog	1982	1.1518	0.1969	572	5.85	<.001
Yr*Reg	Diablo	1982	Carolina	1996	0.4007	0.1837	572	2.18	0.564
Yr*Reg	Diablo	1982	Diablo	1996	0.2308	0.1473	392	1.57	0.920
Yr*Reg	Diablo	1982	Hagoi	1996	0.3374	0.1731	572	1.95	0.727
Yr*Reg	Diablo	1982	Masalog	1996	0.5449	0.1969	572	2.77	0.198
Yr*Reg	Diablo	1982	Carolina	2008	0.9486	0.1837	572	5.16	<.001
Yr*Reg	Diablo	1982	Diablo	2008	0.6241	0.1473	392	4.24	0.002
Yr*Reg	Diablo	1982	Hagoi	2008	0.7231	0.1731	572	4.18	0.002
Yr*Reg	Diablo	1982	Masalog	2008	0.7801	0.1969	572	3.96	0.005
Yr*Reg	Hagoi	1982	Masalog	1982	0.8011	0.2100	572	3.82	0.009
Yr*Reg	Hagoi	1982	Carolina	1996	0.0500	0.1976	572	0.25	1.000
Yr*Reg	Hagoi	1982	Diablo	1996	-0.1199	0.1731	572	-0.69	1.000
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.0133	0.1762	392	-0.08	1.000
Yr*Reg	Hagoi	1982	Masalog	1996	0.1942	0.2100	572	0.92	0.999
Yr*Reg	Hagoi	1982	Carolina	2008	0.5979	0.1976	572	3.03	0.105
Yr*Reg	Hagoi	1982	Diablo	2008	0.2734	0.1731	572	1.58	0.916
Yr*Reg	Hagoi	1982	Hagoi	2008	0.3725	0.1762	392	2.11	0.613
Yr*Reg	Hagoi	1982	Masalog	2008	0.4294	0.2100	572	2.05	0.662
Yr*Reg	Masalog	1982	Carolina	1996	-0.7511	0.2188	572	-3.43	0.032
Yr*Reg	Masalog	1982	Diablo	1996	-0.9210	0.1969	572	-4.68	0.000
Yr*Reg	Masalog	1982	Hagoi	1996	-0.8144	0.2100	572	-3.88	0.007
Yr*Reg	Masalog	1982	Masalog	1996	-0.6069	0.2158	392	-2.81	0.179
Yr*Reg	Masalog	1982	Carolina	2008	-0.2033	0.2188	572	-0.93	0.999
Yr*Reg	Masalog	1982	Diablo	2008	-0.5278	0.1969	572	-2.68	0.240
Yr*Reg	Masalog	1982	Hagoi	2008	-0.4287	0.2100	572	-2.04	0.664
Yr*Reg	Masalog	1982	Masalog	2008	-0.3717	0.2158	392	-1.72	0.857
Yr*Reg	Carolina	1996	Diablo	1996	-0.1699	0.1837	572	-0.92	0.999
Yr*Reg	Carolina	1996	Hagoi	1996	-0.0633	0.1976	572	-0.32	1.000

Yr*Reg	Carolina	1996	Masalog	1996	0.1442	0.2188	572	0.66	1.000
Yr*Reg	Carolina	1996	Carolina	2008	0.5479	0.1942	392	2.82	0.175
Yr*Reg	Carolina	1996	Diablo	2008	0.2234	0.1837	572	1.22	0.988
Yr*Reg	Carolina	1996	Hagoi	2008	0.3225	0.1976	572	1.63	0.896
Yr*Reg	Carolina	1996	Masalog	2008	0.3794	0.2188	572	1.73	0.851
Yr*Reg	Diablo	1996	Hagoi	1996	0.1066	0.1731	572	0.62	1.000
Yr*Reg	Diablo	1996	Masalog	1996	0.3141	0.1969	572	1.60	0.910
Yr*Reg	Diablo	1996	Carolina	2008	0.7177	0.1837	572	3.91	0.006
Yr*Reg	Diablo	1996	Diablo	2008	0.3932	0.1473	392	2.67	0.245
Yr*Reg	Diablo	1996	Hagoi	2008	0.4923	0.1731	572	2.84	0.166
Yr*Reg	Diablo	1996	Masalog	2008	0.5493	0.1969	572	2.79	0.188
Yr*Reg	Hagoi	1996	Masalog	1996	0.2075	0.2100	572	0.99	0.998
Yr*Reg	Hagoi	1996	Carolina	2008	0.6112	0.1976	572	3.09	0.088
Yr*Reg	Hagoi	1996	Diablo	2008	0.2867	0.1731	572	1.66	0.887
Yr*Reg	Hagoi	1996	Hagoi	2008	0.3857	0.1762	392	2.19	0.559
Yr*Reg	Hagoi	1996	Masalog	2008	0.4427	0.2100	572	2.11	0.617
Yr*Reg	Masalog	1996	Carolina	2008	0.4037	0.2188	572	1.85	0.792
Yr*Reg	Masalog	1996	Diablo	2008	0.0792	0.1969	572	0.40	1.000
Yr*Reg	Masalog	1996	Hagoi	2008	0.1783	0.2100	572	0.85	1.000
Yr*Reg	Masalog	1996	Masalog	2008	0.2352	0.2158	392	1.09	0.995
Yr*Reg	Carolina	2008	Diablo	2008	-0.3245	0.1837	572	-1.77	0.835
Yr*Reg	Carolina	2008	Hagoi	2008	-0.2254	0.1976	572	-1.14	0.993
Yr*Reg	Carolina	2008	Masalog	2008	-0.1685	0.2188	572	-0.77	1.000
Yr*Reg	Diablo	2008	Hagoi	2008	0.0991	0.1731	572	0.57	1.000
Yr*Reg	Diablo	2008	Masalog	2008	0.1561	0.1969	572	0.79	1.000
Yr*Reg	Hagoi	2008	Masalog	2008	0.0570	0.2100	572	0.27	1.000

Rufous Fantail

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	-0.2980	0.0868	392	-3.43	0.002
Yr		1982		2008	-0.6521	0.0868	392	-7.52	<.001
Yr		1996		2008	-0.3542	0.0868	392	-4.08	0.000
Reg	Carolina		Diablo		0.0887	0.1147	196	0.77	0.866
Reg	Carolina		Hagoi		0.0847	0.1234	196	0.69	0.902
Reg	Carolina		Masalog		0.4970	0.1367	196	3.64	0.002
Reg	Diablo		Hagoi		-0.0040	0.1081	196	-0.04	1.000
Reg	Diablo		Masalog		0.4082	0.1230	196	3.32	0.006
Reg	Hagoi		Masalog		0.4122	0.1312	196	3.14	0.010
Yr*Reg	Carolina	1982	Diablo	1982	-0.4308	0.1748	564	-2.46	0.366
Yr*Reg	Carolina	1982	Hagoi	1982	-0.1465	0.1881	564	-0.78	1.000
Yr*Reg	Carolina	1982	Masalog	1982	0.4411	0.2083	564	2.12	0.610
Yr*Reg	Carolina	1982	Carolina	1996	-0.7967	0.1821	392	-4.38	0.001
Yr*Reg	Carolina	1982	Diablo	1996	-0.2829	0.1748	564	-1.62	0.902
Yr*Reg	Carolina	1982	Hagoi	1996	-0.5348	0.1881	564	-2.84	0.166
Yr*Reg	Carolina	1982	Masalog	1996	0.2863	0.2083	564	1.37	0.968
Yr*Reg	Carolina	1982	Carolina	2008	-0.7584	0.1821	392	-4.17	0.002
Yr*Reg	Carolina	1982	Diablo	2008	-0.5752	0.1748	564	-3.29	0.050

Yr*Reg	Carolina	1982	Hagoi	2008	-0.6196	0.1881	564	-3.29	0.049
Yr*Reg	Carolina	1982	Masalog	2008	-0.7916	0.2083	564	-3.80	0.009
Yr*Reg	Diablo	1982	Hagoi	1982	0.2843	0.1648	564	1.73	0.856
Yr*Reg	Diablo	1982	Masalog	1982	0.8719	0.1874	564	4.65	0.000
Yr*Reg	Diablo	1982	Carolina	1996	-0.3659	0.1748	564	-2.09	0.628
Yr*Reg	Diablo	1982	Diablo	1996	0.1479	0.1381	392	1.07	0.996
Yr*Reg	Diablo	1982	Hagoi	1996	-0.1040	0.1648	564	-0.63	1.000
Yr*Reg	Diablo	1982	Masalog	1996	0.7171	0.1874	564	3.83	0.008
Yr*Reg	Diablo	1982	Carolina	2008	-0.3276	0.1748	564	-1.87	0.775
Yr*Reg	Diablo	1982	Diablo	2008	-0.1444	0.1381	392	-1.05	0.997
Yr*Reg	Diablo	1982	Hagoi	2008	-0.1887	0.1648	564	-1.15	0.992
Yr*Reg	Diablo	1982	Masalog	2008	-0.3608	0.1874	564	-1.92	0.743
Yr*Reg	Hagoi	1982	Masalog	1982	0.5875	0.1999	564	2.94	0.131
Yr*Reg	Hagoi	1982	Carolina	1996	-0.6502	0.1881	564	-3.46	0.030
Yr*Reg	Hagoi	1982	Diablo	1996	-0.1364	0.1648	564	-0.83	1.000
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.3883	0.1652	392	-2.35	0.443
Yr*Reg	Hagoi	1982	Masalog	1996	0.4328	0.1999	564	2.17	0.576
Yr*Reg	Hagoi	1982	Carolina	2008	-0.6120	0.1881	564	-3.25	0.056
Yr*Reg	Hagoi	1982	Diablo	2008	-0.4287	0.1648	564	-2.60	0.282
Yr*Reg	Hagoi	1982	Hagoi	2008	-0.4731	0.1652	392	-2.86	0.159
Yr*Reg	Hagoi	1982	Masalog	2008	-0.6451	0.1999	564	-3.23	0.060
Yr*Reg	Masalog	1982	Carolina	1996	-1.2377	0.2083	564	-5.94	<.001
Yr*Reg	Masalog	1982	Diablo	1996	-0.7240	0.1874	564	-3.86	0.007
Yr*Reg	Masalog	1982	Hagoi	1996	-0.9759	0.1999	564	-4.88	<.001
Yr*Reg	Masalog	1982	Masalog	1996	-0.1548	0.2024	392	-0.76	1.000
Yr*Reg	Masalog	1982	Carolina	2008	-1.1995	0.2083	564	-5.76	<.001
Yr*Reg	Masalog	1982	Diablo	2008	-1.0163	0.1874	564	-5.42	<.001
Yr*Reg	Masalog	1982	Hagoi	2008	-1.0606	0.1999	564	-5.31	<.001
Yr*Reg	Masalog	1982	Masalog	2008	-1.2326	0.2024	392	-6.09	<.001
Yr*Reg	Carolina	1996	Diablo	1996	0.5138	0.1748	564	2.94	0.132
Yr*Reg	Carolina	1996	Hagoi	1996	0.2618	0.1881	564	1.39	0.965
Yr*Reg	Carolina	1996	Masalog	1996	1.0830	0.2083	564	5.20	<.001
Yr*Reg	Carolina	1996	Carolina	2008	0.0382	0.1821	392	0.21	1.000
Yr*Reg	Carolina	1996	Diablo	2008	0.2215	0.1748	564	1.27	0.983
Yr*Reg	Carolina	1996	Hagoi	2008	0.1771	0.1881	564	0.94	0.999
Yr*Reg	Carolina	1996	Masalog	2008	0.0051	0.2083	564	0.02	1.000
Yr*Reg	Diablo	1996	Hagoi	1996	-0.2519	0.1648	564	-1.53	0.932
Yr*Reg	Diablo	1996	Masalog	1996	0.5692	0.1874	564	3.04	0.102
Yr*Reg	Diablo	1996	Carolina	2008	-0.4755	0.1748	564	-2.72	0.221
Yr*Reg	Diablo	1996	Diablo	2008	-0.2923	0.1381	392	-2.12	0.611
Yr*Reg	Diablo	1996	Hagoi	2008	-0.3366	0.1648	564	-2.04	0.663
Yr*Reg	Diablo	1996	Masalog	2008	-0.5087	0.1874	564	-2.71	0.223
Yr*Reg	Hagoi	1996	Masalog	1996	0.8211	0.1999	564	4.11	0.003
Yr*Reg	Hagoi	1996	Carolina	2008	-0.2236	0.1881	564	-1.19	0.990
Yr*Reg	Hagoi	1996	Diablo	2008	-0.0404	0.1648	564	-0.25	1.000
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.0847	0.1652	392	-0.51	1.000
Yr*Reg	Hagoi	1996	Masalog	2008	-0.2568	0.1999	564	-1.28	0.981

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr*Reg	Masalog	1996	Carolina	2008	-1.0447	0.2083	564	-5.02	<.001
Yr*Reg	Masalog	1996	Diablo	2008	-0.8615	0.1874	564	-4.60	0.000
Yr*Reg	Masalog	1996	Hagoi	2008	-0.9058	0.1999	564	-4.53	0.001
Yr*Reg	Masalog	1996	Masalog	2008	-1.0779	0.2024	392	-5.33	<.001
Yr*Reg	Carolina	2008	Diablo	2008	0.1832	0.1748	564	1.05	0.996
Yr*Reg	Carolina	2008	Hagoi	2008	0.1389	0.1881	564	0.74	1.000
Yr*Reg	Carolina	2008	Masalog	2008	-0.0332	0.2083	564	-0.16	1.000
Yr*Reg	Diablo	2008	Hagoi	2008	-0.0443	0.1648	564	-0.27	1.000
Yr*Reg	Diablo	2008	Masalog	2008	-0.2164	0.1874	564	-1.15	0.992
Yr*Reg	Hagoi	2008	Masalog	2008	-0.1720	0.1999	564	-0.86	0.999

Bridled White-eye

| Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	0.1766	0.0464	392	3.81	0.001
Yr		1982		2008	0.0071	0.0464	392	0.15	0.987
Yr		1996		2008	-0.1695	0.0464	392	-3.65	0.001
Reg	Carolina		Diablo		0.1128	0.0523	196	2.16	0.139
Reg	Carolina		Hagoi		0.0699	0.0563	196	1.24	0.601
Reg	Carolina		Masalog		0.2577	0.0623	196	4.14	0.000
Reg	Diablo		Hagoi		-0.0429	0.0493	196	-0.87	0.820
Reg	Diablo		Masalog		0.1449	0.0561	196	2.58	0.051
Reg	Hagoi		Masalog		0.1878	0.0598	196	3.14	0.010
Yr*Reg	Carolina	1982	Diablo	1982	-0.0421	0.0878	587	-0.48	1.000
Yr*Reg	Carolina	1982	Hagoi	1982	0.2615	0.0945	587	2.77	0.198
Yr*Reg	Carolina	1982	Masalog	1982	0.2141	0.1046	587	2.05	0.661
Yr*Reg	Carolina	1982	Carolina	1996	0.2121	0.0974	392	2.18	0.566
Yr*Reg	Carolina	1982	Diablo	1996	0.1620	0.0878	587	1.84	0.792
Yr*Reg	Carolina	1982	Hagoi	1996	0.1099	0.0945	587	1.16	0.991
Yr*Reg	Carolina	1982	Masalog	1996	0.6562	0.1046	587	6.27	<.001
Yr*Reg	Carolina	1982	Carolina	2008	-0.0335	0.0974	392	-0.34	1.000
Yr*Reg	Carolina	1982	Diablo	2008	0.3972	0.0878	587	4.52	0.001
Yr*Reg	Carolina	1982	Hagoi	2008	0.0169	0.0945	587	0.18	1.000
Yr*Reg	Carolina	1982	Masalog	2008	0.0813	0.1046	587	0.78	1.000
Yr*Reg	Diablo	1982	Hagoi	1982	0.3037	0.0828	587	3.67	0.015
Yr*Reg	Diablo	1982	Masalog	1982	0.2563	0.0942	587	2.72	0.220
Yr*Reg	Diablo	1982	Carolina	1996	0.2542	0.0878	587	2.89	0.147
Yr*Reg	Diablo	1982	Diablo	1996	0.2041	0.0739	392	2.76	0.200
Yr*Reg	Diablo	1982	Hagoi	1996	0.1520	0.0828	587	1.84	0.797
Yr*Reg	Diablo	1982	Masalog	1996	0.6983	0.0942	587	7.42	<.001
Yr*Reg	Diablo	1982	Carolina	2008	0.0086	0.0878	587	0.10	1.000
Yr*Reg	Diablo	1982	Diablo	2008	0.4393	0.0739	392	5.95	<.001
Yr*Reg	Diablo	1982	Hagoi	2008	0.0590	0.0828	587	0.71	1.000
Yr*Reg	Diablo	1982	Masalog	2008	0.1235	0.0942	587	1.31	0.977
Yr*Reg	Hagoi	1982	Masalog	1982	-0.0474	0.1004	587	-0.47	1.000
Yr*Reg	Hagoi	1982	Carolina	1996	-0.0495	0.0945	587	-0.52	1.000
Yr*Reg	Hagoi	1982	Diablo	1996	-0.0996	0.0828	587	-1.20	0.989
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.1517	0.0884	392	-1.72	0.860

Yr*Reg	Hagoi	1982	Masalog	1996	0.3946	0.1004	587	3.93	0.006
Yr*Reg	Hagoi	1982	Carolina	2008	-0.2950	0.0945	587	-3.12	0.081
Yr*Reg	Hagoi	1982	Diablo	2008	0.1357	0.0828	587	1.64	0.894
Yr*Reg	Hagoi	1982	Hagoi	2008	-0.2447	0.0884	392	-2.77	0.198
Yr*Reg	Hagoi	1982	Masalog	2008	-0.1802	0.1004	587	-1.79	0.820
Yr*Reg	Masalog	1982	Carolina	1996	-0.0021	0.1046	587	-0.02	1.000
Yr*Reg	Masalog	1982	Diablo	1996	-0.0522	0.0942	587	-0.55	1.000
Yr*Reg	Masalog	1982	Hagoi	1996	-0.1043	0.1004	587	-1.04	0.997
Yr*Reg	Masalog	1982	Masalog	1996	0.4420	0.1082	392	4.09	0.003
Yr*Reg	Masalog	1982	Carolina	2008	-0.2476	0.1046	587	-2.37	0.431
Yr*Reg	Masalog	1982	Diablo	2008	0.1831	0.0942	587	1.94	0.730
Yr*Reg	Masalog	1982	Hagoi	2008	-0.1972	0.1004	587	-1.96	0.717
Yr*Reg	Masalog	1982	Masalog	2008	-0.1328	0.1082	392	-1.23	0.987
Yr*Reg	Carolina	1996	Diablo	1996	-0.0501	0.0878	587	-0.57	1.000
Yr*Reg	Carolina	1996	Hagoi	1996	-0.1022	0.0945	587	-1.08	0.995
Yr*Reg	Carolina	1996	Masalog	1996	0.4441	0.1046	587	4.25	0.002
Yr*Reg	Carolina	1996	Carolina	2008	-0.2455	0.0974	392	-2.52	0.329
Yr*Reg	Carolina	1996	Diablo	2008	0.1851	0.0878	587	2.11	0.617
Yr*Reg	Carolina	1996	Hagoi	2008	-0.1952	0.0945	587	-2.07	0.648
Yr*Reg	Carolina	1996	Masalog	2008	-0.1307	0.1046	587	-1.25	0.985
Yr*Reg	Diablo	1996	Hagoi	1996	-0.0521	0.0828	587	-0.63	1.000
Yr*Reg	Diablo	1996	Masalog	1996	0.4942	0.0942	587	5.25	<.001
Yr*Reg	Diablo	1996	Carolina	2008	-0.1954	0.0878	587	-2.23	0.532
Yr*Reg	Diablo	1996	Diablo	2008	0.2352	0.0739	392	3.19	0.068
Yr*Reg	Diablo	1996	Hagoi	2008	-0.1451	0.0828	587	-1.75	0.842
Yr*Reg	Diablo	1996	Masalog	2008	-0.0806	0.0942	587	-0.86	0.999
Yr*Reg	Hagoi	1996	Masalog	1996	0.5463	0.1004	587	5.44	<.001
Yr*Reg	Hagoi	1996	Carolina	2008	-0.1433	0.0945	587	-1.52	0.935
Yr*Reg	Hagoi	1996	Diablo	2008	0.2874	0.0828	587	3.47	0.028
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.0930	0.0884	392	-1.05	0.996
Yr*Reg	Hagoi	1996	Masalog	2008	-0.0285	0.1004	587	-0.28	1.000
Yr*Reg	Masalog	1996	Carolina	2008	-0.6897	0.1046	587	-6.59	<.001
Yr*Reg	Masalog	1996	Diablo	2008	-0.2590	0.0942	587	-2.75	0.206
Yr*Reg	Masalog	1996	Hagoi	2008	-0.6393	0.1004	587	-6.37	<.001
Yr*Reg	Masalog	1996	Masalog	2008	-0.5748	0.1082	392	-5.31	<.001
Yr*Reg	Carolina	2008	Diablo	2008	0.4307	0.0878	587	4.90	<.001
Yr*Reg	Carolina	2008	Hagoi	2008	0.0504	0.0945	587	0.53	1.000
Yr*Reg	Carolina	2008	Masalog	2008	0.1148	0.1046	587	1.10	0.995
Yr*Reg	Diablo	2008	Hagoi	2008	-0.3803	0.0828	587	-4.60	0.000
Yr*Reg	Diablo	2008	Masalog	2008	-0.3159	0.0942	587	-3.35	0.041
Yr*Reg	Hagoi	2008	Masalog	2008	0.0645	0.1004	587	0.64	1.000

Micronesian Starling

Effect	Region	Year	Region	Year	Estimate	SE	DF	t Value	Adj P
Yr		1982		1996	0.0097	0.0677	392	0.14	0.989
Yr		1982		2008	-0.6479	0.0677	392	-9.57	<.001
Yr		1996		2008	-0.6576	0.0677	392	-9.72	<.001

Reg	Carolina	Diablo	-0.0766	0.0877	196	-0.87	0.819
Reg	Carolina	Hagoi	0.0316	0.0944	196	0.34	0.987
Reg	Carolina	Masalog	0.2310	0.1045	196	2.21	0.124
Reg	Diablo	Hagoi	0.1082	0.0827	196	1.31	0.558
Reg	Diablo	Masalog	0.3076	0.0941	196	3.27	0.007
Reg	Hagoi	Masalog	0.1994	0.1003	196	1.99	0.196

Appendix 3. Break down of the Tinian Monarch population by habitat and year
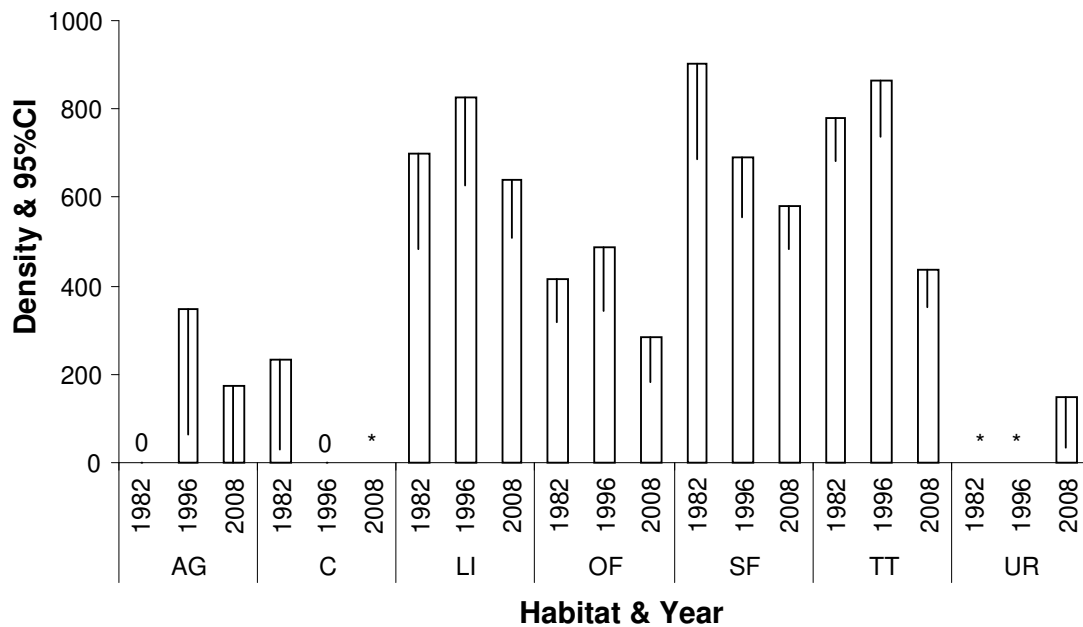
Appendix 3, Figure 10. Plot of Tinian Monarch density estimates (birds/km^2) and lower 95% confidence interval by habitat and year from all transects (10 in 1982 and 1996, and 14 in 2008). Habitat types are AG–agriculture, C–coastal, LI–limestone forest, OF–open field, SF–secondary forest, TT–tangantangan thicket, and UR–urban/residential. No birds were detected in the agriculture habitat in 1982 or coastal habitat in 1996. No stations (indicated with *) were surveyed in the coastal habitat in 2008, and urban/residential habitat in 1996 and 2008.

Appendix 3, Table 14. Tinian Monarch density estimates (birds/km^2), standard error (SE), and 95% confidence intervals (Lower and Upper 95% CI) by habitat and year from all transects (10 in 1982 and 1996, and 14 in 2008). Habitat types are AG–agriculture, C–coastal, LI–limestone forest, OF–open field, SF–secondary forest, TT–tangantangan thicket, and UR–urban/residential. No birds were detected in the agriculture habitat in 1982 or coastal habitat in 1996. No stations (indicated with *) were surveyed in the coastal habitat in 2008, and urban/residential habitat in 1996 and 2008.

Habitat	Year	Estimate	SE	L 95% CI	U 95% CI
AG	1982	0.0			
	1996	349.4	201.96	63.561	1920.800
	2008	174.7	174.77	†	†
C	1982	232.9	116.66	30.770	1763.400
	1996	0.0			
	2008	*			
LI	1982	698.8	123.97	483.410	1010.200
	1996	825.9	111.49	625.330	1090.700
	2008	640.6	73.54	509.490	805.400
OF	1982	414.9	56.68	316.340	544.230
	1996	485.8	84.62	342.690	688.560
	2008	283.3	63.74	180.590	444.440
SF	1982	901.1	117.05	687.880	1180.400
	1996	691.2	76.45	553.930	862.540
	2008	582.4	54.28	483.960	700.740
TT	1982	778.2	51.52	682.940	886.810
	1996	863.2	68.80	737.510	1010.400
	2008	435.7	46.84	352.230	539.030
UR	1982	*			
	1996	*			
	2008	149.8	103.99	32.300	694.240

† Sample size was insufficient to estimate reliable confidence intervals.

Appendix 3, Table 15. Comparison of Tinian Monarch densities by habitat and year using repeated measures ANOVA from all transects (10 in 1982 and 1996, and 14 in 2008). Year and habitat fixed effects were significant but the year and habitat interaction was non-significant ($F_{8, 623} = 0.62$, $p = 0.764$); therefore, only effects by habitat are presented here. Differences among years are presented in Table 4. Significant differences are highlighted in bold. Habitat types are LI–limestone forest, OF–open field, SF–secondary forest, and TT–tangantangan thicket; agriculture, coastal, and urban/residential (ACU) habitats were combined because insufficient numbers of stations were sampled in those habitats.

Effect	Num DF	Den DF	*F* Value	Pr > *F*	
Habitat	4	645	15.04	<.0001	

Effect	Effect	Estimate	Error	*t* Value	Adj *P*
ACU	**LI**	**-1.002**	**0.250**	**-4.00**	**<.001**
ACU	OF	-0.354	0.243	-1.45	0.592
ACU	**SF**	**-0.958**	**0.245**	**-3.91**	**<.001**
ACU	**TT**	**-0.999**	**0.236**	**-4.23**	**<.001**
LI	**OF**	**0.648**	**0.132**	**4.91**	**<.001**
LI	SF	0.044	0.134	0.33	0.998
LI	TT	0.003	0.118	0.03	1.000
OF	**SF**	**-0.604**	**0.119**	**-5.10**	**<.001**
OF	**TT**	**-0.645**	**0.100**	**-6.43**	**<.001**
SF	TT	-0.041	0.102	-0.40	0.995