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Status of Forest Birds on Tinian Island, Commonwealth of the Northern Mariana Islands, with an Emphasis on the Tinian Monarch (*Monarcha takatsukasae*) (Passeriformes; Monarchidae)[1]

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Abstract: Landbird populations on Tinian Island have been periodically surveyed since 1982 to evaluate the status of non-native and native landbirds. We report the results of surveys in 2013 and the observed changes during 31 years in species population trends based on surveys since 1982. A total of 11 native and 3 non-native species were detected during the 2013 survey. Population sizes were estimated using point-transect distance sampling methods, and population trends were assessed using repeated measures analysis of variance for nine forest bird species. In all years, the Rufous Fantail (*Rhipidura rufifrons*) and Bridled White-eye (*Zosterops conspicillatus*) were the most abundant species, whereas the White-throated Ground Dove (*Pampusana xanthonura*) was the least abundant species in 1982, 1996, and 2008, and the Mariana Kingfisher (*Todiramphus albicilla*) was the least abundant in 2013. The less common species numbered in the low thousands included the Mariana Fruit Dove (*Ptilinopus roseicapilla*), White-throated Ground Dove, introduced Philippine Collared Dove (*Streptopelia dusumieri*), Mariana Kingfisher (*Todiramphus albicilla*), and Micronesian Myzomela (*Myzomela rubratra*). The Micronesian Starling (*Aplonis opaca*) and Tinian Monarch (*Monarcha takatsukasae*) were estimated to number in the tens of thousands. The most abundant species were the Rufous Fantail, numbering more than 100,000, and the Bridled White-eye, numbering more than 400,000. The overall trends in abundance between 1982 and 2013 showed an increase in the Mariana Kingfisher, Micronesian Starling, Rufous Fantail, White-throated Ground Dove, and Philippine Collared Dove, while populations were stable for the Bridled White-eye and Tinian Monarch. Declines were seen for the Mariana Fruit Dove and Micronesian Myzomela. These trends matched previous analyses with the exception that Tinian Monarch abundance showed an increase in the 2013 survey.

Keywords: Tinian, forest birds, abundance, population status, Northern Mariana Islands, density, habitat

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PERIODIC SURVEYS of vertebrate populations of the Mariana Islands are important to formulating conservation strategies because the biodiversity of these small, oceanic islands is at extreme risk to threats from habitat loss and degradation, climate change, and invasive species, in particular the introduction of the brown treesnake (*Boiga irregularis*) from Guam (U.S. Fish and Wildlife Service [USFWS] 2005, Keppel et al. 2014). Tinian Island (hereafter, Tinian) has a long history of disturbance and habitat conversion dating from when the indigenous Chamorro people first reached the Mariana Islands around 2000 B.C., through Spanish colonization beginning in the sixteenth century, German and Japanese occupation in the early twentieth century, and continuing through World War II (WWII; Camp et al. 2012). Due to this history of anthropogenic disturbance, approximately 549 ha (or about 5% of Tinian) is currently covered by native limestone forest. Approximately 92% of other forest cover on the island is composed of mixed-secondary vegetation and invasive non-native tangantangan (*Leucaena leucocephala*) (Liu and Fischer 2006, Amidon 2009).

In 1983, the United States government, with the Department of the Navy (DoN) as lease manager, entered into a long-term lease agreement with the Commonwealth of the Northern Mariana Islands (CNMI) government. The DoN now leases 6,232 ha of terrestrial lands covering the northern two-thirds of Tinian that is used for military training exercises and is known as the Military Lease Area.

The first quantitative bird surveys on Tinian were conducted by the USFWS in 1982 (Engbring et al. 1986). Additional surveys were conducted in 1996 and 2008, and those data were analyzed in Lusk et al. (2000) and Camp et al. (2012), respectively. Camp et al. (2012) provides an analysis of avian population trends based upon the 1982, 1996, and 2008 surveys.

Here we summarize the landbird detections from the 2013 survey on Tinian and provide updated abundance estimates for the native White-throated Ground-Dove (*Pampusana xanthonura*), Mariana Fruit Dove (*Ptilinopus roseicapilla*), Mariana Kingfisher (*Todiramphus albicilla*), Micronesian Myzomela (*Myzomela rubratra*), Tinian Monarch (*Monarcha takatsukasae*), Rufous Fantail (*Rhipidura rufifrons*), Bridled White-eye (*Zosterops conspicillatus*), and Micronesian Starling (*Aplonis opaca*), and the non-native Philippine Collared Dove (*Streptopelia dusumieri*). Common and scientific names of avian species follow Gill et al. (2021). Trends in bird populations on the island were compared across the four surveys completed in 1982, 1996, 2008, and 2013, yielding trends spanning 31 years. Particular attention was given to the status of the Tinian Monarch, which was formerly listed as endangered under the U.S. Endangered Species Act (ESA). Here we calculate abundance and densities of bird species on Tinian for each survey year, and for the 2008 and 2013 surveys we estimate densities by habitat cover type. We provide information necessary for monitoring the distribution and abundance of the Tinian Monarch and other forest birds over time with respect to land use and development.

MATERIALS AND METHODS

Survey Area

Tinian Island (15° 00′ N, 145° 35′ E) is approximately 19 km long, 8 km wide, with a total land area of 102 km^2, and is located in the Mariana archipelago, an arc of 15 islands approximately 2,300 km east of the Philippines and south of Japan. Tinian consists of five limestone plateaus separated by escarpments. Coastal limestone forest fringes the island while the island's interior exhibits limestone cliffs supporting native limestone forest. This vegetation community harbors native trees such as gulos (*Cynometra ramiflora*), twin apple (*Ochrosia oppositifolia*), chiute (*Cerbera dilatata*), *Psychotria* spp., *Eugenia* spp., fingersop (*Meiogyne cylindrocarpa*), *Pandanus* spp., coral tree (*Erythrina variegata*), banyan (*Ficus prolixa*), umumu (*Pisonia grandis*), and Pacific almond (*Terminalia catappa*). The plateaus consist of secondary forest dominated primarily by non-native tangantangan, crop and grazing lands, and urban and other developed areas (e.g., military airfields).

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Mixed-secondary vegetation contains a mixture of introduced trees, shrubs, and dense herbaceous plants. Tree species common in this vegetation community include ironwood (*Casuarina equisetifolia*), siris tree (*Albizia lebbeck*), Formosan koa (*Acacia confusa*), tangantangan, flame tree (*Delonix regia*), and Madras thorn (*Pithecellobium dulce*) (Liu and Fischer 2006, Amidon 2009).

Bird Surveys

In April/May 1982, a baseline survey was conducted on Tinian to assess trends in avian species populations. The survey established a total of 216 stations on 10 permanent transects with representative island-wide coverage across geography and habitat cover types (Engbring et al. 1986, Camp et al. 2012: Figure 1). These 10 transects were resurveyed in August/September 1996, June 2008, and June 2013. In 2013, 206 stations on 14 transects were surveyed. In total, 161 stations on the original 10 transects were surveyed in each of the four survey efforts. All surveys followed standard point-transect distance sampling methods (Buckland et al. 2015), consisting of 8-minute counts, where horizontal distances to all detected birds were estimated and recorded. Counts commenced at sunrise, continued up to 4 hr, and were conducted only under prescribed conditions (i.e., not exceeding light rain and winds no greater than 3 on the Beaufort scale). Refer to Camp et al. (2012) for further details on the point-transect distance sampling methods. Data used in this study are available upon request.

Abundance Estimation

Density estimates (birds/ha) were calculated from point-transect distance sampling data using program DISTANCE, version 6.0, release 2 (Thomas et al. 2010) and followed the procedures described in Camp et al. (2012). Distance analysis fits a detection function to estimate the probability of detecting a bird at a given distance from the observer. The fit of the detection function can be improved by including expansion series and covariates. With each additional year of data, estimates of these effects become more precise, and the improved detection function may cause recalculated population estimates of previous years to change relative to former estimates (Johnson et al. 2006).

In addition to the detections from the 1982 and 1996 surveys, detections from the additional four transects surveyed in 2008 and 2013 were used to fit the detection functions. However, detections from these additional four transects were not used to estimate densities. To match the 1996, 2008, and 2013 survey efforts, detections from only one observer were used to recalculate densities for the 1982 survey, where the most effective observers were identified based on their experience and survey proficiency. This approach minimizes estimator bias due to differing sampling protocols and incorporates advancements in analytical methods. Candidate detection function models were limited to half-normal and hazard-rate detection functions with expansion series of order two (Buckland et al. 2015). The uniform detection function was not considered because covariates cannot be modeled with this function. To improve model precision, sampling covariates were incorporated in the multiple covariate distance sampling (MCDS) engine of DISTANCE (Thomas et al. 2010). The covariates included in our analyses were weather conditions, time of sampling, type of detection, observer, habitat cover type, and year of survey. Models containing covariates were not considered for the White-throated Ground Dove because few were detected (385 detections across the 4 surveys; fewer than the approximately 100 minimum detections per survey needed to reliably model the detection function [Buckland et al. 2015]). We did not estimate White Tern (*Gygis alba*) detection probabilities because of their rapid and erratic flying behavior that results in violations of the non-movement model assumption (Buckland et al. 2015).

Bird detection distances were grouped to fit a species-specific global detection function. Interval cut-points were placed to minimize “heaping” to avoid expected values less than five and to ensure monotonicity. Right-tail

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truncation was set at the distance where the detection probability was approximately 10%. This procedure facilitates modeling by deleting outliers and reducing the number of adjustment parameters needed to modify the detection function. The detectability model selected was the one with the lowest Akaike's Information Criterion corrected (AICc) for small sample size (Burnham and Anderson 2002). Annual population densities for each survey were calculated using the global detection function, and the pooled data were post-stratified by year and by year-habitat for the original 10 permanent transects (Supplemental Materials – Appendix A). The 95% confidence intervals for the annual density estimates were derived from the 2.5^{th} and 97.5^{th} percentiles using bootstrap methods in DISTANCE for 999 iterations (Thomas et al. 2010). Population abundance estimates were the product of the density estimate multiplied by the area of the sampling frame (9,781 ha) and by habitat (area estimates from Liu and Fischer [2006] and Amidon [2009]).

Bird surveys occurred in habitat that we classified into four cover types, which in rank order of area were: tangantangan (3,453 ha; 34% of Tinian), secondary forest (3,020 ha; 30%), herbaceous-scrub (2,011 ha; 20%), and limestone forest (549 ha; 5%). We estimated bird densities by habitat from the 2008 and 2013 surveys only, because the area of habitat cover types was not available for the earlier surveys, and bird detections could not be associated with specific cover types for either the 1982 or the 1996 surveys. Our classification of habitat cover types was based on the 14 cover types delineated on the 2006 U.S. Forest Service (USFS) land cover map of Tinian (Liu and Fischer 2006) and revised by Amidon (2009). Habitat cover classified by the USFS as mixed introduced forest, *Casuarina equisetifolia* thicket, agroforest, and agroforest-coconut were categorized for the current study as secondary forest. Although tangantangan is a type of secondary forest, unlike other secondary forest types it typically forms large monospecific stands, so bird densities for tangantangan were calculated separately. Habitat cover classified as savanna complex and other shrubs and grasses by the USFS were categorized as herbaceous-scrub. We retained the USFWS classification of limestone forest but did not stratify our survey data according to other small habitat cover types recognized by USFWS including urban vegetation, urban, and developed (e.g., current and historical military infrastructure, memorials) (616 ha, 6% of Tinian); cropland (134 ha, 1%); wetland (26 ha, <1%); strand (223 ha, 2%); and barren (81 ha, <1%).

Population Trends

The change in bird density among the 1982, 1996, 2008, and 2013 estimates on Tinian was assessed with repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, North Carolina). Comparisons were conducted on only the original 10 permanent transects and limited to the stations that were sampled on all four surveys (161 stations). As done in Camp et al. (2012), density-by-station values were ln(density + 1) transformed to stabilize the error variance. 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 experimentwise Type I error ($\alpha = 0.05$) for multiple-comparison procedures (Littell et al. 1996). Population densities within habitat cover types during 2008 and 2013 were compared using a two-sample z-test, which is an extension of the method recommended in Buckland et al. (2001) to evaluate for differences between densities.

RESULTS

A total of 14 species (11 native and 3 non-native) was detected during the 2013 surveys on Tinian (Table 1). Sufficient numbers of detections were made for eight native and one non-native forest bird species to calculate density and abundance estimates. Of the five species for which detections were too few to

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TABLE 1

Species List and Occupancy of Birds Detected from Four Point-Transect Distance Surveys on Tinian

Common Name	Scientific Name	1982				1996				2008				2013			
		# Stns Ocpd	# Det	% Occ	BPS	# Stns Ocpd	# Det	% Occ	BPS	# Stns Ocpd	# Det	% Occ	BPS	# Stns Ocpd	# Det	% Occ	BPS
Red Junglefowl*	*Gallus gallus*	45	105	20.8	0.49	0	0	0	0	28	60	12.9	0.28	0	0	0	0
Philippine Collared Dove*	*Streptopelia dusumieri*	51	66	23.6	0.31	136	256	63.0	1.19	68	115	31.3	0.53	105	266	65.2	1.65
White-throated Ground Dove	*Pampusana xanthonura*	13	16	6.0	0.07	23	23	10.6	0.11	54	79	24.9	0.36	85	168	52.8	1.04
Mariana Fruit Dove	*Ptilinopus roseicapilla*	189	623	87.5	2.88	150	240	69.4	1.11	183	465	84.3	2.14	139	450	86.3	2.80
Pacific Golden Plover	*Pluvialis fulva*	1	1	0.5	<0.01	0	0	0	0	3	11	1.4	0.05	0	0	0	0
Ruddy Turnstone	*Arenaria interpres*	0	0	0	0	0	0	0	0	1	1	0.4	<0.01	0	0	0	0
Brown Noddy	*Anous stolidus*	0	0	0	0	0	0	0	0	1	1	0.5	<0.01	8	25	5.0	0.16
White Tern	*Gygis alba*	128	344	59.3	1.59	22	52	10.2	0.24	108	342	49.8	1.58	69	256	42.9	1.59
White-tailed Tropicbird	*Phaethon lepturus*	0	0	0	0	0	0	0	0	3	5	1.4	0.02	0	0	0	0
Yellow Bittern	*Ixobrychus sinensis*	10	10	4.6	0.05	16	18	7.4	0.08	33	40	15.2	0.18	24	36	14.9	0.22
Pacific Reef Heron	*Egretta sacra*	1	1	0.5	<0.01	1	1	0.5	<0.01	0	0	0	0	0	0	0	0
Mariana Kingfisher	*Todiramphus chloris*	150	294	69.4	1.36	124	285	57.4	1.32	168	361	77.4	1.66	134	318	83.2	1.98
Micronesian Myzomela	*Myzomela rubratra*	131	236	60.6	1.09	59	94	27.3	0.44	79	143	36.4	0.66	122	360	75.8	2.24
Rufous Fantail	*Rhipidura rufifrons*	202	786	93.5	3.64	188	502	87.0	2.32	199	680	91.7	3.13	161	730	100	4.53
Tinian Monarch	*Monarcha takatsukasae*	187	539	86.6	2.50	173	495	80.1	2.29	146	312	67.3	1.44	146	613	90.7	3.81
Bridled White-eye	*Zosterops conspicillatus*	216	2,222	100	10.29	216	1,770	100	8.19	216	1,991	99.5	9.18	161	2,868	100	17.81
Micronesian Starling	*Aplonis opaca*	177	513	81.9	2.38	106	226	49.1	1.05	185	594	85.3	2.74	148	769	91.9	4.78
Eurasian Tree Sparrow*	*Passer montanus*	1	1	0.5	<0.01	3	13	1.4	0.06	13	74	6.0	0.34	5	6	3.1	0.04
Orange-cheeked Waxbill*	*Estrilda melpoda*	0	0	0	0	0	0	0	0	0	0	0	0	3	6	1.9	0.04

Notes: In 1982 and 1996, 216 stations were sampled on 10 transects; in 2008, 253 stations were sampled on 14 transects (one station sampled twice); and in 2013, 206 stations were sampled on 14 transects. The values shown for 2008 and 2013 include only the original 10 transects and on-count detections. Density estimates were produced for species in boldface.
Stns Ocpd = number of stations occupied.
Det = number of detections.
% Occ = indices of percentage occurrence.
BPS = birds per station.
* = non-native species.

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calculate density and abundance estimates, three were waterbirds, either seabirds or wading birds: Brown Noddy (*Anous stolidus*), White Tern, and Yellow Bittern (*Ixobrychus sinensis*) (Table 1). These species detections were primarily due to flyovers. The remaining two species were non-native introduced species: Eurasian Tree Sparrow (*Passer montanus*) and Orange-cheeked Waxbill (*Estrilda melpoda*). The Eurasian Tree Sparrow was detected at stations near developed or urban areas. At the time of the 2013 surveys, the Orange-cheeked Waxbill was a relatively recent arrival on Tinian, having been first detected on the island in 2011 (Kohler 2019). NCJ has detected the Orange-cheeked Waxbill throughout the northern, central, and southern regions of Tinian during formal surveys and opportunistically between 2018 and 2021; thus, it is expected that waxbill detections will increase on transects in future surveys.

In all years, the Bridled White-eye and Rufous Fantail were the most abundant species, whereas the White-throated Ground Dove was the least abundant species in 1982, 1996, and 2008, and the Mariana Kingfisher was the least abundant in 2013 (Table 2). The trend for five of the nine species (Philippine Collared Dove, White-throated Ground Dove, Mariana Kingfisher, Rufous Fantail, and Micronesian Starling) was upward between 1982 and 2013 (Tables 2 and 3, Figure 1). The trend for two native birds (Mariana Fruit Dove and Micronesian Myzomela) was downward in the same period. Although these declines were not linear (Figure 1), the overall changes between 1982 and 2013 were significant (Table 3). The trend for the Bridled White-eye and Tinian Monarch was considered relatively stable (Figure 1).

Based on the differences in bird densities among the four habitat cover types using only the 2008 and 2013 data from the original 10 transects, all nine species had the lowest abundance in limestone forest and the highest in either secondary forest or tangantangan (Table 4). Seven of the nine species occurred in relatively high densities across all cover types, whereas the Tinian Monarch was detected in low densities within herbaceous-scrub habitat, and the White-throated Ground Dove was detected in low densities within tangantangan (Table 5, Figure 2).

Philippine Collared Dove

Abundance and density estimates varied across the surveys from a high of 4,555 birds and a density of 0.47 birds/ha in 2013, to a low of 1,246 birds and a density of 0.13 birds/ha in 1982 (Table 2 and Figure 1). In terms of density by habitat cover type, increases in density from 2008 to 2013 were significant in limestone forest and secondary forest (Table 5 and Figure 2). The overall trend for Philippine Collared Dove density between 1982 and 2013 was upward (Table 3).

White-throated Ground Dove

Abundance and density estimates varied greatly across the surveys and showed an increase from year to year, with a high of 4,479 birds and a density of 0.46 birds/ha in 2013, and a low of 535 birds and a density of 0.05 birds/ha in 1982 (Table 2 and Figure 1). In terms of density by habitat cover type, no changes in density from 2008 to 2013 were significant (Table 5 and Figure 2). Overall, the trend for White-throated Ground Dove density between 1982 and 2013 was upward (Table 3).

Mariana Fruit Dove

Abundance and density estimates varied across the surveys from a high of 6,600 birds and a density of 0.67 birds/ha in 1982, to a low of 2,445 birds and a density of 0.25 birds/ha in 1996 (Table 2 and Figure 1). In terms of density by habitat cover type, decreases in density from 2008 to 2013 were significant in herbaceous-scrub and tangantangan (Table 5 and Figure 2). The overall trend for Mariana Fruit Dove density between 1982 and 2013 was downward (Table 3).

Mariana Kingfisher

Abundance and density estimates varied greatly across the surveys, with a high of

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TABLE 2

Estimates of Tinian Forest Bird Species Abundance (density × area), Density (birds/ha), and 95% Confidence Intervals by Year

Species	Analysis	1982	1996	2008	2013
Philippine Collared Dove	Abun	1,246 (729–1,875)	3,419 (2,298–4,685)	2,983 (1,892–4,491)	4,555 (3,003–6,441)
	Dens	0.13 ± 0.03 (0.07–0.19)	0.35 ± 0.06 (0.23–0.48)	0.30 ± 0.07 (0.19–0.46)	0.47 ± 0.09 (0.31–0.66)
White-throated Ground Dove	Abun	535 (225–941)	612 (341–941)	2,595 (1,765–3,640)	4,479 (3,077–6,193)
	Dens	0.05 ± 0.02 (0.02–0.10)	0.063 ± 0.016 (0.03–0.10)	0.26 ± 0.05 (0.18–0.37)	0.46 ± 0.08 (0.31–0.63)
Mariana Fruit Dove	Abun	6,600 (5,203–8,777)	2,445 (1,858–3,274)	5,112 (3,934–6,698)	3,879 (2,970–5,152)
	Dens	0.67 ± 0.10 (0.53–0.90)	0.25 ± 0.04 (0.19–0.33)	0.52 ± 0.08 (0.40–0.68)	0.39 ± 0.06 (0.30–0.53)
Mariana Kingfisher	Abun	842 (516–1,263)	2,746 (1,920–3,815)	7,304 (5,661–9,336)	2,201 (1,605–2,906)
	Dens	0.09 ± 0.02 (0.05–0.13)	0.28 ± 0.05 (0.20–0.39)	0.74 ± 0.10 (0.58–0.95)	0.22 ± 0.04 (0.16–0.30)
Micronesian Myzomela	Abun	16,862 (13,473–21,754)	6,675 (4,896–9,247)	5,456 (4,560–6,462)	5,779 (4,768–6,918)
	Dens	1.72 ± 0.22 (1.38–2.22)	0.68 ± 0.111 (0.50–0.94)	0.56 ± 0.05 (0.47–0.66)	0.59 ± 0.06 (0.49–0.71)
Rufous Fantail	Abun	102,677 (86,577–120,007)	123,371 (102,771–142,561)	162,604 (132,469–192,409)	121,331 (104,641–139,837)
	Dens	10.50 ± 0.87 (8.85–12.27)	12.61 ± 1.02 (10.51–14.57)	16.62 ± 1.53 (13.54–19.67)	12.40 ± 0.92 (10.70–14.30)
Tinian Monarch	Abun	95,916 (77,491–116,202)	105,352 (84,237–127,758)	56,305 (43,343–70,909)	90,634 (69,311–112,535)
	Dens	9.81 ± 1.02 (7.92–11.88)	10.77 ± 1.14 (8.61–13.06)	5.76 ± 0.70 (4.43–7.25)	9.23 ± 1.12 (7.09–11.50)
Bridled White-eye	Abun	469,621 (437,718–505,745)	402,121 (374,857–432,099)	422,859 (364,671–486,656)	448,493 (404,327–496,508)
	Dens	48.01 ± 1.77 (44.75–51.71)	41.11 ± 1.56 (38.32–44.18)	43.23 ± 3.21 (37.28–49.75)	45.85 ± 2.45 (41.34–50.76)
Micronesian Starling	Abun	18,236 (14,743–21,985)	17,034 (13,375–20,918)	61,957 (50,374–74,221)	40,806 (32,987–49,547)
	Dens	1.86 ± 0.19 (1.51–2.25)	1.74 ± 0.19 (1.37–2.14)	6.33 ± 0.63 (5.15–7.60)	4.17 ± 0.43 (3.37–5.07)

Notes: Data from only the original 10 transects. Abun = abundance; Dens = density.

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TABLE 3

Results of Repeated Measures Analysis of Variance for Trends in Tinian Bird Densities among Different Time-Series

	Fixed Effects			Differences of Least Squares Means								
				1982–1996			1982–2008			1982–2013		
Species	Trend (1982–2013)	$F_{3,480}$	P	Est (SE)	t_{480}	Adj-P	Est (SE)	t_{480}	Adj-P	Est (SE)	t_{480}	Adj-P
Philippine Collared Dove	▲	18.67	<0.001	−0.12 (0.03)	−4.19	<0.001	−0.09 (0.03)	−3.11	0.011	−0.21 (0.03)	−7.40	<0.001
White-throated Ground Dove	▲	37.89	<0.001	−0.02 (0.03)	−0.69	0.902	−0.20 (0.03)	−7.27	<0.001	−0.23 (0.03)	−8.38	<0.001
Mariana Fruit Dove	▼	32.47	<0.001	0.23 (0.03)	8.11	<0.001	−0.01 (0.03)	−0.51	0.956	0.12 (0.03)	4.12	<0.001
Mariana Kingfisher	▲	72.84	<0.001	−0.12 (0.03)	−3.63	0.002	−0.47 (0.03)	−13.80	<0.001	−0.10 (0.03)	−2.79	0.028
Micronesian Myzomela	▼	59.86	<0.001	0.06 (0.03)	1.85	0.251	−0.28 (0.03)	−9.40	<0.001	−0.22 (0.03)	−7.28	<0.001
Rufous Fantail	▲	19.86	<0.001	−0.27 (0.10)	−2.90	0.018	−0.71 (0.10)	−7.21	<0.001	−0.57 (0.10)	−3.89	<0.001
Tinian Monarch	—	5.07	0.002	0.07 (0.12)	0.60	0.932	0.28 (0.12)	2.37	0.085	−0.18 (0.12)	−1.48	0.452
Bridled White-eye	—	1.03	0.378	0.09 (0.07)	1.40	0.499	−0.01 (0.07)	−0.10	1.000	0.01 (0.07)	0.01	1.000
Micronesian Starling	▲	60.84	<0.001	0.12 (0.08)	1.45	0.467	−0.77 (0.08)	−9.27	<0.001	−0.68 (0.08)	−8.21	<0.001

	Fixed Effects			Differences of Least Squares Means								
				1996–2008			1996–2013			2008–2013		
Species	Trend (1982–2013)	$F_{3,480}$	P	Est (SE)	t_{480}	Adj-P	Est (SE)	t_{480}	Adj-P	Est (SE)	t_{480}	Adj-P
Philippine Collared Dove	▲	18.67	<0.001	0.03 (0.03)	1.08	0.700	−0.09 (0.03)	−3.21	0.008	−0.12 (0.03)	−4.29	<0.001
White-throated Ground Dove	▲	37.89	<0.001	−0.18 (0.03)	−6.58	<0.001	−0.22 (0.03)	−7.70	<0.001	−0.03 (0.03)	−1.12	0.680
Mariana Fruit Dove	▼	32.47	<0.001	−0.25 (0.03)	−8.62	<0.001	−0.11 (0.03)	−3.99	<0.001	0.13 (0.03)	4.63	<0.001
Mariana Kingfisher	▲	72.84	<0.001	−0.35 (0.03)	−10.17	<0.001	0.03 (0.03)	0.84	0.834	0.38 (0.03)	11.02	<0.001
Micronesian Myzomela	▼	59.86	<0.001	−0.33 (0.03)	−11.25	<0.001	−0.27 (0.03)	−9.13	<0.001	0.06 (0.03)	2.11	0.150
Rufous Fantail	▲	19.86	<0.001	−0.44 (0.10)	−5.07	<0.001	−0.30 (0.10)	−1.02	0.700	0.15 (0.10)	4.83	<0.001
Tinian Monarch	—	5.07	0.002	0.21 (0.12)	1.77	0.289	−0.25 (0.12)	−2.08	0.162	−0.46 (0.12)	−3.85	<0.001
Bridled White-eye	—	1.03	0.378	−0.10 (0.07)	−1.50	0.437	−0.09 (0.07)	−1.40	0.502	0.01 (0.07)	0.11	1.000
Micronesian Starling	▲	60.84	<0.001	−0.89 (0.08)	−10.73	<0.001	−0.81 (0.08)	−9.66	<0.001	0.09 (0.08)	1.07	0.710

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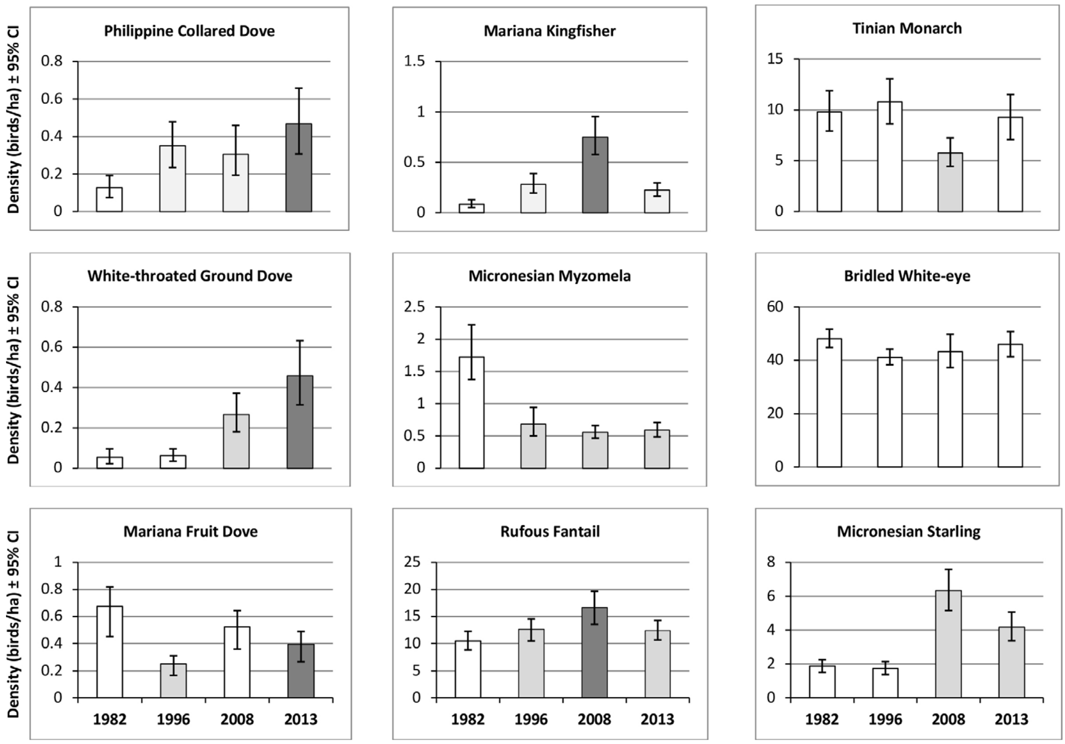

FIGURE 1. Density estimates with 95% CI for native and non-native Tinian birds from 1982, 1996, 2008, and 2013 point-transect distance surveys. Data only from the original 10 transects. Years that share the same shade were not significantly different at the 0.05 level, adjusted for multiple comparisons.

7,304 birds and a density of 0.74 birds/ha in 2008, and a low of 842 birds and a density of 0.09 birds/ha in 1982 (Table 2 and Figure 1). While the 2013 estimates showed a strong decrease in kingfisher abundance and density compared to 2008, the 2013 estimates were similar to the 1996 estimates. In terms of density by habitat cover type, decreases in density from 2008 to 2013 were significant in limestone forest, secondary forest, and tangantangan (Table 5 and Figure 2). Although abundance and density decreased from 2008 to 2013, the overall trend for Mariana Kingfisher density between 1982 and 2013 was upward (Table 3).

Micronesian Myzomela

Abundance and density estimates varied across the surveys from a high of 16,862 birds and a density of 1.72 birds/ha in 1982, to a low of 5,456 birds and a density of 0.56 birds/ha in 2008 (Table 2 and Figure 1). In terms of density by habitat cover type, a decrease in density from 2008 to 2013 was significant only in tangantangan (Table 5 and Figure 2). The overall trend for Micronesian Myzomela density between 1982 and 2013 was downward (Table 3).

Rufous Fantail

Abundance and density estimates varied greatly across the surveys, with a high of 162,604 birds and a density of 16.62 birds/ha in 2008, and a low of 102,677 birds and a density of 10.50 birds/ha in 1982 (Table 2 and Figure 1). While the 2013 estimates showed a strong decrease in abundance and density compared to 2008, the 2013 estimates were similar to the 1996 estimates. In terms of density by habitat cover type, decreases in

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TABLE 4

Estimates of Tinian Forest Bird Species Abundance (density × area) and 95% Confidence Intervals by Habitat Cover Type

Species	Year	Limestone Forest	Herbaceous-Scrub	Secondary Forest	Tangantangan
Philippine Collared Dove	2008	67 (15–155)	514 (168–995)	893 (499–1,390)	1,068 (647–1,594)
	2013	317 (109–554)	707 (368–1,155)	1,788 (1,215–2,428)	1,086 (627–1,701)
White-throated Ground Dove	2008	199 (78–334)	793 (311–1,329)	1,323 (814–1,929)	491 (252–769)
	2013	312 (81–608)	954 (485–1,517)	1,817 (1,323–2,457)	546 (330–819)
Mariana Fruit Dove	2008	199 (106–316)	1,582 (1,131–2,188)	1,944 (1,496–2,583)	1,704 (1,260–2,307)
	2013	226 (138–340)	754 (477–1,102)	1,423 (1,046–1,924)	1,050 (768–1,420)
Mariana Kingfisher	2008	360 (185–555)	1,178 (734–1,677)	2,599 (1,939–3,486)	2,969 (2,297–3,824)
	2013	82 (25–151)	729 (443–1,072)	679 (394–1,014)	504 (314–736)
Micronesian Myzomela	2008	225 (108–360)	1,814 (1,268–2,428)	2,882 (2,332–3,479)	2,143 (1,689–2,647)
	2013	314 (217–411)	1,199 (796–1,704)	2,187 (1,739–2,672)	1,489 (1,196–1,832)
Rufous Fantail	2008	7,106 (4,222–10,730)	29,233 (19,617–39,715)	64,691 (51,519–79,751)	63,832 (52,313–75,811)
	2013	7,741 (5,870–9,593)	14,489 (9,704–19,256)	46,467 (39,785–53,848)	42,268 (35,254–49,799)
Tinian Monarch	2008	4,041 (2,352–5,991)	9,752 (5,446–15,158)	28,111 (20,940–36,124)	23,330 (17,251–29,780)
	2013	6,066 (3,023–9,138)	9,741 (6,116–13,780)	32,225 (25,356–39,781)	34,577 (27,668–42,255)
Bridled White-eye	2008	21,300 (15,803–27,855)	101,475 (84,580–120,565)	138,319 (119,209–160,564)	191,655 (171,050–211,211)
	2013	25,589 (20,959–31,180)	68,839 (47,723–89,962)	160,054 (144,130–176,601)	161,814 (146,302–177,979)
Micronesian Starling	2008	3,290 (2,414–4,163)	11,044 (7,714–14,558)	15,186 (12,301–18,295)	15,924 (13,178–18,863)
	2013	2,322 (1,239–3,526)	8,391 (5,773–11,254)	12,325 (10,025–14,874)	13,620 (10,526–16,884)

Notes: Data from only the original 10 transects.

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TABLE 5

Estimates of Tinian Forest Bird Species Density (birds/ha; ±SE) and 95% Confidence Intervals by Habitat Cover Type for the 2008 and 2013 Surveys

Species	Year	Limestone Forest	Btw Yr Change	Herbaceous-Scrub	Btw Yr Change	Secondary Forest	Btw Yr Change	Tangantangan	Btw Yr Change
Philippine Collared Dove	2008	**0.12 ± 0.06 (0.03–0.28)**	▲	0.26 ± 0.11 (0.09–0.51)	—	**0.30 ± 0.08 (0.17–0.47)**	▲	0.31 ± 0.07 (0.19–0.47)	—
	2013	**0.58 ± 0.21 (0.20–1.01)**	0.36 ± 0.11 (0.19–0.59)	**0.60 ± 0.11 (0.41–0.82)**	0.32 ± 0.08 (0.18–0.50)				
	z-test	**−2.05, 0.040**	−0.65, 0.51	**−2.21, 0.027**	−0.05, 0.96				
White-throated Ground Dove	2008	0.36 ± 0.12 (0.14–0.61)	—	0.41 ± 0.13 (0.16–0.68)	—	0.45 ± 0.09 (0.27–0.65)	—	0.14 ± 0.04 (0.07–0.22)	—
	2013	0.57 ± 0.25 (0.15–1.11)	0.49 ± 0.14 (0.25–0.78)	0.61 ± 0.10 (0.45–0.83)	0.16 ± 0.04 (0.10–0.24)				
	z-test	−0.75, 0.45	−0.44, 0.66	−1.23, 0.22	−0.30, 0.77				
Mariana Fruit Dove	2008	0.36 ± 0.10 (0.19–0.58)	—	**0.81 ± 0.14 (0.58–1.12)**	▼	0.66 ± 0.10 (0.51–0.87)	—	**0.50 ± 0.08 (0.37–0.67)**	▼
	2013	0.41 ± 0.09 (0.25–0.62)	**0.39 ± 0.08 (0.24–0.56)**	0.48 ± 0.08 (0.35–0.65)	**0.31 ± 0.05 (0.22–0.41)**				
	z-test	−0.36, 0.72	**−2.61, 0.009**	−1.39, 0.16	**−1.97, 0.048**				
Mariana Kingfisher	2008	**0.66 ± 0.18 (0.34–1.01)**	▼	0.60 ± 0.13 (0.38–0.86)	—	**0.88 ± 0.13 (0.66–1.18)**	▼	**0.87 ± 0.12 (0.67–1.12)**	▼
	2013	**0.15 ± 0.06 (0.05–0.28)**	0.37 ± 0.08 (0.23–0.55)	**0.23 ± 0.05 (0.13–0.34)**	**0.15 ± 0.03 (0.09–0.21)**				
	z-test	**−2.62, 0.009**	−1.52, 0.13	**−4.59, <0.001**	**−5.99, <0.001**				
Micronesian Myzomela	2008	0.41 ± 0.12 (0.20–0.66)	—	0.93 ± 0.15 (0.65–1.24)	—	0.97 ± 0.10 (0.79–1.18)	—	**0.63 ± 0.07 (0.49–0.77)**	▼
	2013	0.57 ± 0.09 (0.39–0.75)	0.61 ± 0.12 (0.41–0.87)	0.74 ± 0.08 (0.59–0.90)	**0.44 ± 0.05 (0.35–0.54)**				
	z-test	−1.09, 0.28	−1.65, 0.10	−1.83, 0.07	**−2.16, 0.031**				
Rufous Fantail	2008	12.94 ± 2.96 (7.69–19.54)	—	**14.99 ± 2.65 (10.06–20.37)**	▼	**21.88 ± 2.44 (17.43–26.98)**	▼	**18.68 ± 1.77 (15.31–22.19)**	▼
	2013	14.10 ± 1.74 (10.69–17.47)	**7.43 ± 1.27 (4.98–9.87)**	**15.72 ± 1.20 (13.46–18.22)**	**12.37 ± 1.07 (10.32–14.57)**				
	z-test	−0.34, 0.74	**−2.57, 0.010**	**−2.27, 0.023**	**−3.05, 0.002**				
Tinian Monarch	2008	7.36 ± 1.76 (4.28–10.91)	—	5.00 ± 1.25 (2.79–7.77)	—	9.51 ± 1.26 (7.08–12.22)	—	**6.83 ± 0.96 (5.05–8.71)**	▲
	2013	11.05 ± 2.90 (5.51–16.64)	4.99 ± 1.02 (3.14–7.07)	10.90 ± 1.25 (8.58–13.46)	**10.12 ± 1.09 (8.10–12.37)**				
	z-test	−1.09, 0.28	−0.01, 0.99	−0.78, 0.43	**−2.26, 0.024**				
Bridled White-eye	2008	38.80 ± 5.71 (28.79–50.74)	—	**52.04 ± 4.66 (43.37–61.83)**	▼	46.79 ± 3.56 (40.33–54.32)	—	**56.09 ± 2.97 (50.06–61.81)**	▼
	2013	46.61 ± 4.88 (38.18–56.79)	**35.30 ± 5.72 (24.47–46.13)**	54.15 ± 2.81 (48.76 – 59.74)	**47.35 ± 2.35 (42.82–52.09)**				
	z-test	−1.04, 0.30	**−2.27, 0.023**	−1.62, 0.10	**−2.31, 0.021**				
Micronesian Starling	2008	5.99 ± 0.84 (4.40–7.58)	—	5.66 ± 0.95 (3.96–7.47)	—	5.14 ± 0.51 (4.16–6.19)	—	4.66 ± 0.43 (3.86–5.52)	—
	2013	4.23 ± 1.07 (2.26–6.42)	4.30 ± 0.72 (2.96–5.77)	4.17 ± 0.41 (3.39–5.03)	3.99 ± 0.46 (3.08–4.94)				
	z-test	−1.29, 0.20	−1.14, 0.25	−1.48, 0.14	−1.07, 0.29				

Notes: Data from only original 10 transects.
Results of two-sample *z*-tests (*z*-value, *P*-value) in last row for each species. Bold cells are statistically different between years.
Btw Yr Change = between year change: increase (▲), decrease (▼), and no change (—).

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density from 2008 to 2013 were significant in herbaceous-scrub, secondary forest, and tangantangan (Table 5 and Figure 2). Although abundance and density decreased from 2008 to 2013, the overall trend for Rufous Fantail density between 1982 and 2013 was upward (Table 3).

Tinian Monarch

Abundance and density estimates varied greatly across the surveys, with a high of 105,352 birds and a density of 10.77 birds/ha in 1996, and a low of 56,305 birds and a density of 5.76 birds/ha in 2008 (Table 2 and Figure 1). While the 2013 estimates showed a strong increase in abundance and density compared to 2008, the 2013 estimates were similar to the 1982 and 1996 estimates, albeit slightly lower. In terms of density by habitat cover type, density increased significantly from 2008 to 2013 in tangantangan (Table 5 and Figure 2). Although abundance and density increased from 2008 to 2013, the overall trend for Tinian Monarch density between 1982 and 2013 has been stable (Table 3).

Bridled White-eye

Abundance and density estimates were relatively similar across the surveys, with a high of 469,621 birds and a density of 48.01 birds/ha in 1982 and a low of 402,121 birds and a density of 41.11 birds/ha in 1996 (Table 2 and Figure 1). In terms of density by habitat cover type, decreases from 2008 to 2013 were significant in herbaceous-scrub and tangantangan (Table 5 and Figure 2). Overall, the trend for Bridled White-eye density since 1982 has been stable (Table 3).

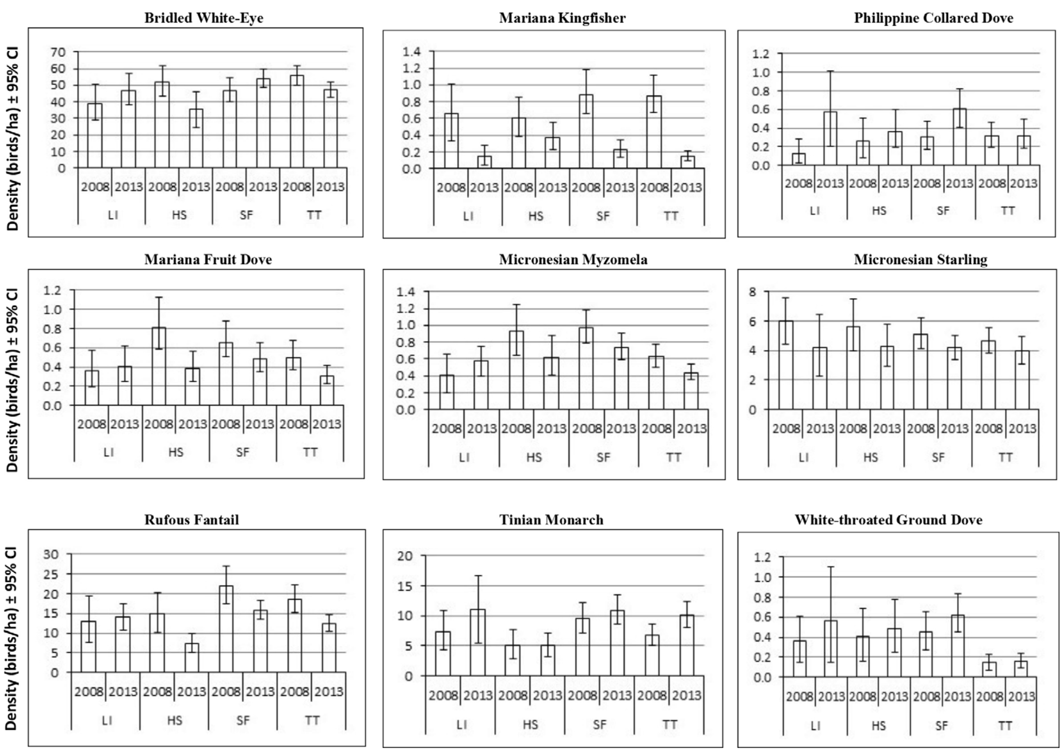

FIGURE 2. Density estimates by habitat cover types with 95% CI for native and non-native Tinian birds from 2018 and 2013 point-transect distance surveys. Data only from the original 10 transects. Habitat cover types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), and tangantangan (TT).

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Micronesian Starling

Abundance and density estimates varied across the surveys from a high of 61,957 birds and a density of 6.33 birds/ha in 2008, to a low of 17,034 birds and a density of 1.74 birds/ha in 1996 (Table 2 and Figure 1). In terms of density by habitat cover type, no changes in density were significant from 2008 to 2013 (Table 5 and Figure 2). The overall trend for Micronesian Starling density between 1982 and 2013 was upward (Table 3).

DISCUSSION

Trends in Species Abundance: 1982–2013

Based on the 2013 surveys, the abundances of four native species (White-throated Ground Dove, Mariana Kingfisher, Rufous Fantail, and Micronesian Starling) and the non-native Philippine Collared Dove have increased on Tinian since the 1982 survey. The overall trends in abundance of the Tinian Monarch and Bridled White-eye have remained stable from 1982 through 2013, and both species, along with the Rufous Fantail, were the most abundant native forest bird species on the island in 2013.

Only two species have shown significant declines in abundance since 1982: Mariana Fruit Dove and Micronesian Myzomela. The numbers of Mariana Fruit Dove vary among surveys, which may be due to periodic environmental fluctuations. However, the decline in Micronesian Myzomela numbers is noteworthy, with a significant drop from approximately 16,900 individuals in 1982 to approximately 6,700 individuals in 1996, and then a leveling off at around 5,500 individuals in 2008 and 2013. Based on the dominant habitat cover type recorded at each survey station during the 2008 and 2013 surveys, there have been no significant habitat changes on Tinian that would have resulted in the loss of areas that support fruit-bearing trees, shrubs, and vines for the fruit dove, and flowering trees, shrubs, and vines that provide nectar for the myzomela. The Micronesian Myzomela also feeds on insects (Engbring et al. 1986), but there is no indication that insects were declining or absent given that other insectivores, such as the Rufous Fantail, Tinian Monarch, and Bridled White-eye, did not show similar population declines but were instead increasing or stable. Nevertheless, the extent to which the myzomela is a vigorous defender of territory and resources may incur energetic costs that put them at risk when resources decline (Pimm and Pimm 1982, Jenkins 1983).

Our 1982 myzomela density estimate was 32% greater than what Engbring et al. (1986) reported (1.72 and 1.14 birds/ha, respectively); however, the 95% CI limits bracketed the point estimates (Engbring et al. [1986] CV = 102%).

Changes in Abundance by Habitat Cover Type: 2008 vs 2013

Two species showed a significant increase in density within habitat cover types (Philippine Collared Dove in limestone forest and secondary forest, and Tinian Monarch in tangantangan), and two species showed no significant change in densities across any cover type (Micronesian Starling and White-throated Ground Dove) between 2008 and 2013 (Table 5). The Philippine Collared Dove increased in secondary forest, which provides suitable habitat with nesting and prey/food resources required to sustain abundant populations (Engbring et al. 1986).

The post-delisting monitoring plan for the Tinian Monarch identified limestone and secondary forest and tangantangan thickets as important habitat cover types for the Tinian Monarch (USFWS 2005). Although monarch densities increased in limestone and secondary forest and were nearly identical in herbaceous-scrub from 2008 to 2013, significant increases in monarch densities occurred in tangantangan over that time. Micronesian Starling and White-throated Ground Dove densities did not differ significantly among any of the habitat cover types from 2008 to 2013. This is likely due to small differences in densities and not a lack of statistical power to detect a difference, as the density estimates were relatively precise (mean CV 0.14 ± SD 0.05 and 0.27 ± 0.08, respectively).

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In summary, of the nine species assessed, densities of only two (Philippine Collared Dove and Mariana Fruit Dove) differed consistently within habitat cover types and population-wide trends from 1982 through 2013. All other species showed varying differences in density by habitat cover types and population-wide trends in 1982, 1996, 2008, and 2013 (Tables 3 and 5). Overall, it appears that 2008 was an anomalous year, with most species assessed showing significant differences between previous years and 2013, while the 2013 data aligned better with the 1982 and 1996 data (Figure 1 and Table 2). This may be due to population variation in response to either fluctuating environmental conditions or an unknown factor(s) unique to 2008 or to changes in the sampling conditions and species detectability. The Mariana Islands are frequently affected by typhoons, which cause mortality and nest destruction. In addition, damage to forest from typhoons results in large areas stripped of foliage and covered with downed trees, leading to loss of forage and nesting habitat for avian species (USFWS 2018*a*). The only storm event that affected Tinian in the years immediately prior to the 2008 surveys was a tropical depression in June 2004. No other major storm events affected Tinian prior to the 2008 surveys that might explain the decrease in avian populations in 2008. In addition, although changes in military activities, cattle grazing, and other land development activities may result in habitat changes, there were no major changes in those activities on Tinian between 2008 and 2013 that would have resulted in significant changes in habitat. Likewise, we did not detect changes in dominant habitat cover types across survey stations.

MCDS methods allowed us to evaluate whether sampling conditions affected detectability, but the best approximating models did not include sampling condition covariates. This is not unexpected because potential differences due to sampling conditions were minimized by sampling only under prescribed conditions and observers followed standard point-transect distance sampling procedures including participating in pre-survey training and calibration exercises. These efforts minimized any annual effects. Given the importance of understanding changes in density within habitat cover types and that the current dataset for this analysis is only for two survey years (2008 and 2013), conservation and management efforts would benefit if future surveys collected habitat data that could be used to evaluate changes in density by habitat cover type.

Status of the Tinian Monarch: 2013

The Tinian Monarch is endemic to Tinian, where it nests in native limestone, secondary, and tangantangan forest communities and forages for insects in the middle to lower canopy (USFWS 1996, 2018*a*). Native tree species are preferred by Tinian Monarchs for nesting, and native limestone forest appears to provide higher-quality habitat cover for the species, as evidenced by higher monarch densities, nesting rates, and reproductive success in this cover type compared to secondary and tangantangan forest communities (USFWS 1996, 2018*a*).

In June 1970, the Tinian Monarch was federally listed as endangered under the Endangered Species Conservation Act of 1969 (superseded by the ESA of 1973) because its population was thought to be critically low owing to the destruction of 95% of native forest cover on Tinian by pre-WWII agricultural practices and by military activities during and after WWII (USFWS 2004). Based on forest bird surveys in 1982, which resulted in a population estimate of 39,338 individuals (Engbring et al. 1986), the Tinian Monarch was downlisted to threatened status in April 1987 (USFWS 2005). Further population studies in 1994 and 1995 resulted in a population estimate of approximately 52,904 birds (USFWS 1996). In 1996, surveys conducted along the same transects and using the same methods used in 1982 yielded a population estimate of 55,721 birds (Lusk et al. 2000). The 1996 survey also found a significant increase in forest vegetation density relative to 1982, indicating an improvement in monarch habitat. The USFWS proposed delisting the Tinian Monarch from the Federal List of Endangered and

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Threatened Wildlife in February 1999, and the species was federally delisted in 2004 (USFWS 2005). The Tinian Monarch was subsequently delisted by the CNMI government in 2009 (Commonwealth Register Volume 31, page 29532).

After delisting of the Tinian Monarch in 2004, the species was monitored for 5 years under the *Post-Delisting Monitoring Plan for the Tinian Monarch* to verify that the species remained secure from the risk of extinction (USFWS 2005). In 2008, surveys indicated a population of approximately 33,310 Tinian Monarchs, a decline of approximately 40% since 1996. Tinian Monarch densities in high-quality habitat cover types calculated from the 2008 surveys also declined significantly from densities reported by USFWS (2005).

Based on the 2008 survey results, the USFWS received a petition in December 2013 to relist the Tinian Monarch as a threatened or endangered species under the ESA (Center for Biological Diversity 2013). The USFWS determined that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted and, in 2015, initiated a status review of the Tinian Monarch (USFWS 2015).

The USFWS status review did not identify a cause for the reported drop in population size between 1996 and 2008. Given that weather conditions, including cloud cover, rain, wind strength, and time of year (June) were similar between surveys, the detectability of Tinian Monarchs during both surveys was considered consistent. However, variation in estimated population size among years could be caused by true changes in population size or by errors associated with imperfect sampling and modeling of the population (USFWS 2018*a*). Separating the sources of variation in the population estimates between years is difficult without a more regular and continuous series of surveys over time, ideally annually. USFWS (2018*a*) did investigate whether some biologically meaningful factors may have caused the drop in the Tinian Monarch population, including, but not limited to, changes in rainfall and other weather conditions, avian pox (*Avipoxvirus* spp.) incidence, and insect prey availability. Rainfall was generally higher in the 5 years preceding the 2008 survey, which could have caused an increase in pox-transmitting mosquito populations. Although some monarchs were observed with pox lesions during the period between 1996 and 2008, data were insufficient to support this theory, including data regarding mosquito populations on Tinian (USFWS 2018*a*).

Although weather phenomena or reduced insect prey abundance could potentially have caused a decrease in the Tinian Monarch population from 1996 to 2008, supporting data are lacking. Indeed, the higher rainfall during the 5 years prior to the 2008 decline would likely have increased insect prey due to increased plant growth (Saracco et al. 2016). The strongest evidence against a habitat-caused explanation for the decline in the Tinian Monarch in 2008 was the concurrent increase of the insectivorous, forest-dwelling species Rufous Fantail (USFWS 2018*a*). In addition, the 2013 estimates for both the Rufous Fantail and Tinian Monarch were similar to the 1996 estimates (Figure 1 and Table 2). Camp et al. (2012) hypothesized that the overall Tinian Monarch population decline between 1982 and 2008 was associated with reduced density in quality habitats, particularly limestone forest. However, the 2008 and 2013 data indicate that Tinian Monarch densities did not significantly change in limestone forest (a quality habitat), herbaceous-scrub, or secondary forest, indicating that the return to abundances observed in 1982 and 1996 was likely driven by increasing densities of the species in tangantangan (Tables 4 and 5).

Island-wide surveys in 2013 using the original 10 transects established by the USFWS in 1982 resulted in a Tinian Monarch population estimate of approximately 90,600 birds. Because analytical methods have changed slightly over time, the 1982, 1996, and 2008 survey data were re-analyzed using the same methods used for the 2013 data. Results of these analyses provided population estimates of approximately 95,900 monarchs in 1982, 105,300 monarchs in 1996, and 56,300 monarchs in 2008

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(Table 2). When data are pooled across surveys to estimate detection probabilities, the recommended modeling approach (Buckland et al. 2015) that we have used here, small differences in the density estimates are expected. These changes diminish with increasing numbers of surveys, and MCDS methods can be applied to model survey-specific detection probabilities if detectability varies markedly among surveys (Buckland et al. 2015).

CNMI Division of Fish and Wildlife (DFW) Breeding Bird Survey data from quarterly roadside counts also indicated a stable or moderately increasing Tinian Monarch population for the 1999–2017 survey period, although surveys were not conducted in all years (USFWS 2018*a*, Kohler 2019). Moreover, the roadside count data also showed a reduction in Tinian Monarch detections during the 2005, 2009, and 2010 surveys, with a subsequent significant increase in detections in 2011, 2012, and 2013 (USFWS 2018*a*). These patterns mirror the decrease in the Tinian Monarch densities seen in the 2008 forest-based point-transect distance sampling survey and the increase seen in the 2013 forest-based survey.

Overall, despite an unexplained and approximate 50% drop in the estimated population size between 1996 and 2008, the general trend in Tinian Monarch abundance and density from 1982 through 2013 appears stable, and the species maintains a wide distribution across the island. Based on the Species Status Assessment (USFWS 2018*a*) and utilizing the 2013 survey data, the USFWS issued a determination in December 2018 that listing the Tinian Monarch as an endangered species or threatened species was not warranted (USFWS 2018*b*).

Population trends of the Tinian Monarch can be tracked with frequent surveys (e.g., annually or bi-annually), but assessing changes in environmental conditions, habitat quality, demography, predation, and prey base can help to determine causative factors driving population changes. This is especially important because the species faces ongoing and future threats from the potential invasion of the brown treesnake, predation by introduced mammals such as rats (*Rattus* spp.) and cats (*Felis catus*), infection from avian pox and other diseases, and habitat degradation and loss due to typhoons, introduction of non-native plants, and human activities (USFWS 2005).

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Appendix A

TABLE A1

Truncation Distance in Meters (Trunc (m)), Number of Bins (# Bins), and Final Models Used to Estimate Population Densities of Forest Birds on Tinian Island

Species	Trunc (m)	# Bins	Model	Covariates	# Par	−LogLike	AICc	w
Bridled White-eye (*Zosterops conspicillatus*)	56.0	6 bins	H-norm	Obs	12	15194.86	30413.75	1.00000
Mariana Kingfisher (*Todiramphus chloris*)	91.2	6 bins	H-rate	Obs	11	995.61	2013.66	0.95251
Mariana Fruit Dove (*Ptilinopus roseicapilla*)	250.0	6 bins	H-rate	Year	5	2813.45	5636.93	1.00000
Micronesian Myzomela (*Myzomela rubratra*)	100.0	6 bins	H-rate	Year	5	1432.66	2875.38	1.00000
Micronesian Starling (*Aplonis opaca*)	78.3	8 bins	H-norm	Obs	11	3698.45	7419.05	0.99991
Philippine Collared Dove (*Streptopelia dusumieri*)	133.0	7 bins	H-rate	DT	4	1116.06	2240.18	0.99992
Rufous Fantail (*Rhipidura rufifrons*)	58.7	7 bins	H-norm	DT	3	4440.29	8886.59	0.99845
Tinian Monarch (*Monarcha takatsukasae*)	68.8	6 bins	H-rate	Obs	13	3435.01	6896.19	0.99984
White-throated Ground Dove (*Pampusana xanthonura*)	115.0	7 bins	H-rate	None	2	618.72	1241.48	0.78751

Detection function models include half-normal (H-norm) and hazard-rate (H-rate), covariates (Obs = observer and DT = detection type), number of parameters (# Par), negative log-likelihood (−LogLike), Akaike's Information Criterion corrected for small size (AICc), and AICc weights (w). No adjustment terms were selected for any species.

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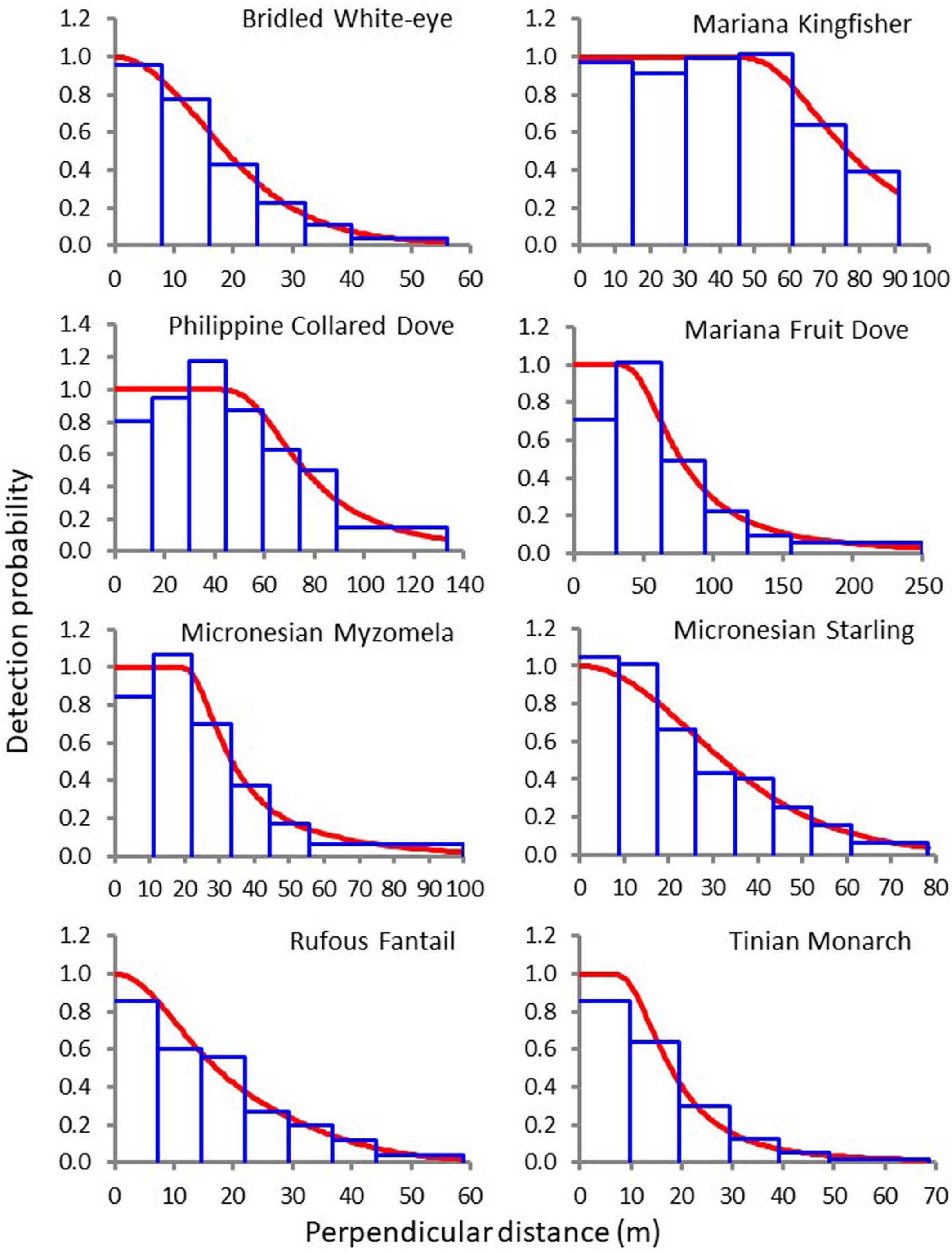

FIGURE A1. Histogram of detection distances, bin intervals, and fitted detection function for forest birds on Tinian.

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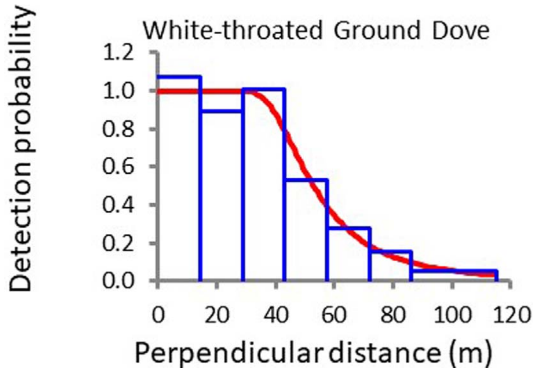

FIGURE A1. (*Continued*).

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