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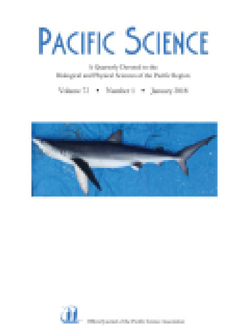

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Trends in Avian Roadside Surveys over a 20-Year Period on Saipan, Commonwealth of the Northern Mariana Islands[1]

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Abstract: We used roadside surveys to examine abundance trends and spatial patterns for 11 terrestrial bird species from 1991 to 2010 on Saipan, Northern Mariana Islands. Relative abundances of the White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Micronesian Starling, and Micronesian Myzomela all increased during the study period. Abundances of the Golden White-eye and Rufous Fantail followed a curvilinear trend that increased during the first half of the survey period (1991–2000) and decreased in the second half (2001–2010). Abundances of the remaining species (Island Collared-Dove, Bridled White-eye, Nightingale Reed-Warbler, and Eurasian Tree Sparrow) showed no significant trends. The most numerous species (over 40 individuals detected per survey), in decreasing order of abundance, were the Bridled White-eye, Rufous Fantail, Golden White-eye, Micronesian Starling, and Micronesian Myzomela. The total abundance of birds increased on average by 0.27 birds per year, per survey station, island-wide. Three stations out of 47 (6.4%) recorded a significant loss of total birds over the time period, and bird numbers increased significantly at only one station (2.1%). Stations at which we detected declines were clustered in the northern, less-populated, region of Saipan. We explored the relationship between typhoon frequency/severity and bird abundance to explain trend patterns but found no significant correlation. We suggest ways to improve roadside surveys as a management tool to aid in detecting avian declines that are of conservation concern.

Keywords: avian monitoring, abundance trends, general linear models, Micronesia

The Commonwealth of the Northern Mariana Islands (CNMI) comprises the 14 northern islands in the Mariana archipelago located in the western tropical Pacific. These islands support a range of endemic bird species. Threats to these species include stochastic events such as typhoons, as well as habitat loss and fragmentation from commercial and residential development, habitat clearing for farmland, destruction of native forest by feral ungulates (U.S. Fish and Wildlife Service 1998*a,b*), overhunting, poaching, and the introduction of invasive exotic plants and animals. Although Saipan has a long history of invasive species introductions and habitat disturbance concomitant with human habitation, the island supports many of the bird species that have gone locally extinct on Guam.

Among the invasive nonnative species that have altered bird habitat on Saipan by smoth-

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ering nesting and foraging trees (Space and Falanruw 1999, PIER 2003) are herbaceous vines that include the scarlet gourd (*Coccinia grandis*), velvet bean (*Mucuna pruriens*), and coral vine (*Antigonon leptopus*). The single greatest potential threat to the CNMI's avifauna, however, is the introduction of the Brown Tree Snake (*Boiga irregularis*) from Guam, where it decimated avian populations several decades ago (Savidge 1987, Wiles et al. 2003). Although sightings of the Brown Tree Snake have been reported on Saipan (Colvin et al. 2005), recent surveys have provided no evidence of a breeding snake population (Rodda and Savidge 2007). These threats, both real and imminent, highlight the tenuous nature of avian populations on the small islands of the CNMI and emphasize the need for monitoring to detect changes in abundance before declines become conservation challenges.

Roadside bird surveys, such as those described here for Saipan, provide an index of population trends over an extended period of time (Sauer et al. 2011). In the 1990s, roadside surveys were established to track abundance trends on the islands of Saipan, Tinian, and Rota in the CNMI. These surveys, similar in procedure to North American Breeding Bird Surveys, are useful in that they do not require a large investment of time and resources, relying on efficient point-count methods (Ralph et al. 1993) to collect data that provide relative measures of bird abundance. Because it is unlikely that the probability of detecting birds remains constant over time and among different vegetation types (an assumption of the method), models for the analysis of count data are generally adjusted for detection probability and often yield reliable population trends (Sauer et al. 2011). On Guam, roadside surveys analogous to those conducted in the CNMI adequately detected declines in bird populations caused by the spread of the Brown Tree Snake between 1970 and 1998 (Wiles et al. 2003). In this analysis, we use a station-by-station, repeated-measures approach to examine spatial differences in avian population trends across Saipan.

The avifauna of the island of Saipan includes 11 resident native land birds (Reichel and Glass 1991), the majority of which are of conservation concern. Three species are federally listed as endangered by the U.S. Fish and Wildlife Service (1984, 1991, 2004): the Nightingale Reed-Warbler (*Acrocephalus luscinia*), Micronesian Megapode (*Megapodius laperouse*), and Mariana Swiftlet (*Aerodramus bartschi*). The IUCN Red List (BirdLife International 2000) also designates the Golden White-eye (*Cleptornis marchei*) as critically endangered, the Mariana Fruit-Dove (*Ptilinopus roseicapilla*) and Bridled White-eye (*Zosterops conspicillatus*) as endangered, and the White-throated Ground-Dove (*Gallicolumba xanthonura*) as near threatened. Four species are widespread on several islands, lessening their vulnerability: the Micronesian Myzomela (*Myzomela rubratra*), Collared Kingfisher (*Todiramphus chloris*), Rufous Fantail (*Rhipidura rufifrons*), and Micronesian Starling (*Aplonis opaca*). The IUCN lists the population status of these four species as unknown or declining.

Frequent typhoons affecting the Marianas can lead to habitat loss and degradation, one of the leading causes of avian imperilment on islands (BirdLife International 2000), and may be a contributing factor to the endangerment of species on Saipan (U.S. Fish and Wildlife Service 1991, 1998*a*). The impacts of cataclysmic storms such as typhoons are likely to include direct effects such as nest destruction and immediate mortality of eggs, nestlings, or fledglings, and also indirect effects such as limited food supply (Lynch 1991), increased competition for limited resources (Hulme 2005), fewer nesting trees and less canopy cover due to storm damage (Cole et al. 1999), or delayed nesting due to vegetation limitations (Lin et al. 2003).

In this article we focus on (1) whether or not trends in total numbers increased or decreased for each of 11 avian species over the 20-yr survey period, (2) spatial patterns of changes in total bird numbers along survey routes on the island, and (3) how those patterns might be related to typhoon frequency and severity. We hypothesized that changes to the forest canopy due to typhoon damage might explain the pattern of changes in total birds during our sampling period. We discuss the application of station-by-station analysis as a useful tool in helping to direct management efforts toward potential trouble spots with an emphasis on interdiction of the Brown Tree Snake. We also recommend changes to the roadside survey method that would provide a more statistically robust program for future data collection.

MATERIALS AND METHODS

Saipan (15° 12′ N, 145° 45′ E) is the largest island in the CNMI and is located in the southern, more volcanically stable region of the archipelago. It measures 120 km² in size, with a central, mountainous spine running along its 22 km length, and rises to 466 m above sea level (Young 1989). Volcanic in origin, the island's substrate is primarily raised limestone reef, most notable in the north where steep escarpments and plateaus surround areas of the eroded volcanic core. In the south, the island slopes down to a brackish lake surrounded by extensive wetlands that drain into a lagoon off the western coast. Most urban and residential development has been in the southern portion of the island, particularly along the coastal plain bordering the lagoon. As the center of the CNMI government, Saipan supports close to 90% of the Commonwealth's residents, with a population of 38,896 in 1990 (U.S. Bureau of the Census 1992), 62,392 in 2000 (U.S. Bureau of the Census 2003), and 48,220 in 2010 (U.S. Bureau of the Census 2011). Its climate is tropical marine with little seasonal variation in temperatures that average between 24° and 27°C (Mueller-Dombois and Fosberg 1998). Average annual rainfall is 200–250 cm (Engbring et al. 1986, Mueller-Dombois and Fosberg 1998), over half of which falls during the wet season from July through November (Young 1989). Located in the primary storm track of the western Pacific, the Mariana Islands are routinely impacted by typhoons between July and December; however, they have been recorded during every month of the year (Young 1989).

Staff from the CNMI's Division of Fish and Wildlife have conducted quarterly roadside surveys on Saipan since 1991 in a manner similar to the Breeding Bird Surveys performed throughout the United States and Canada. Surveys commenced one-half hour before sunrise and were completed by 1030 hours at (an original) 50 permanent stations spaced 0.8 km apart covering the entire island (Figure 1). For consistency, we did not include data from three stations in the analysis because they had been repositioned when urban development eliminated their original locations. Plant communities at stations included native limestone forest; secondary forest often dominated by tangantangan (*Leucaena leucocephala*); a mixture of native, agricultural, and introduced forest species; savanna or grassland; strand or beach vegetation; and mixed vegetation often near residential areas (Raulerson and Rinehart 1991). Wetland plant communities and littoral regions were not sampled by this survey. Observers trained to identify the island avifauna by sight and sound recorded detections of all species seen or heard within an unlimited distance during a 3 min period at each station in January, April, July, and October annually. Cloud cover, rain, and wind conditions were recorded as factors potentially affecting an observer's ability to detect birds (Ralph et al. 1993). Surveys were conducted only under fair-weather conditions when winds were judged to be generally less than 3 as measured on the Beaufort Scale.

Birds identified regularly during surveys but not included in the data analysis due to low detection rates included the Micronesian Megapode, Mariana Swiftlet, Yellow Bittern (*Ixobrychus sinensis*), White Tern (*Gygis alba*), Brown Noddy (*Anous stolidus*), Black Noddy (*Anous minutus*), White-tailed Tropicbird (*Phaethon lepturus*), and Red-tailed Tropicbird (*P. rubricauda*).

We analyzed normally distributed count data for the 11 species listed in Table 1 using general linear models (GLM) in SYSTAT 12. We examined trends in the numbers of each species detected over the 20 yr of the survey as well as changes in the spatial patterns of total bird numbers at each of 47 stations along the survey route. A difference in detectability across seasons was of concern, as it is to any study founded on visual- and audio-based surveys. We were encouraged that Craig (1996) found that detectability was high in the spring, the season of our most complete data set. We

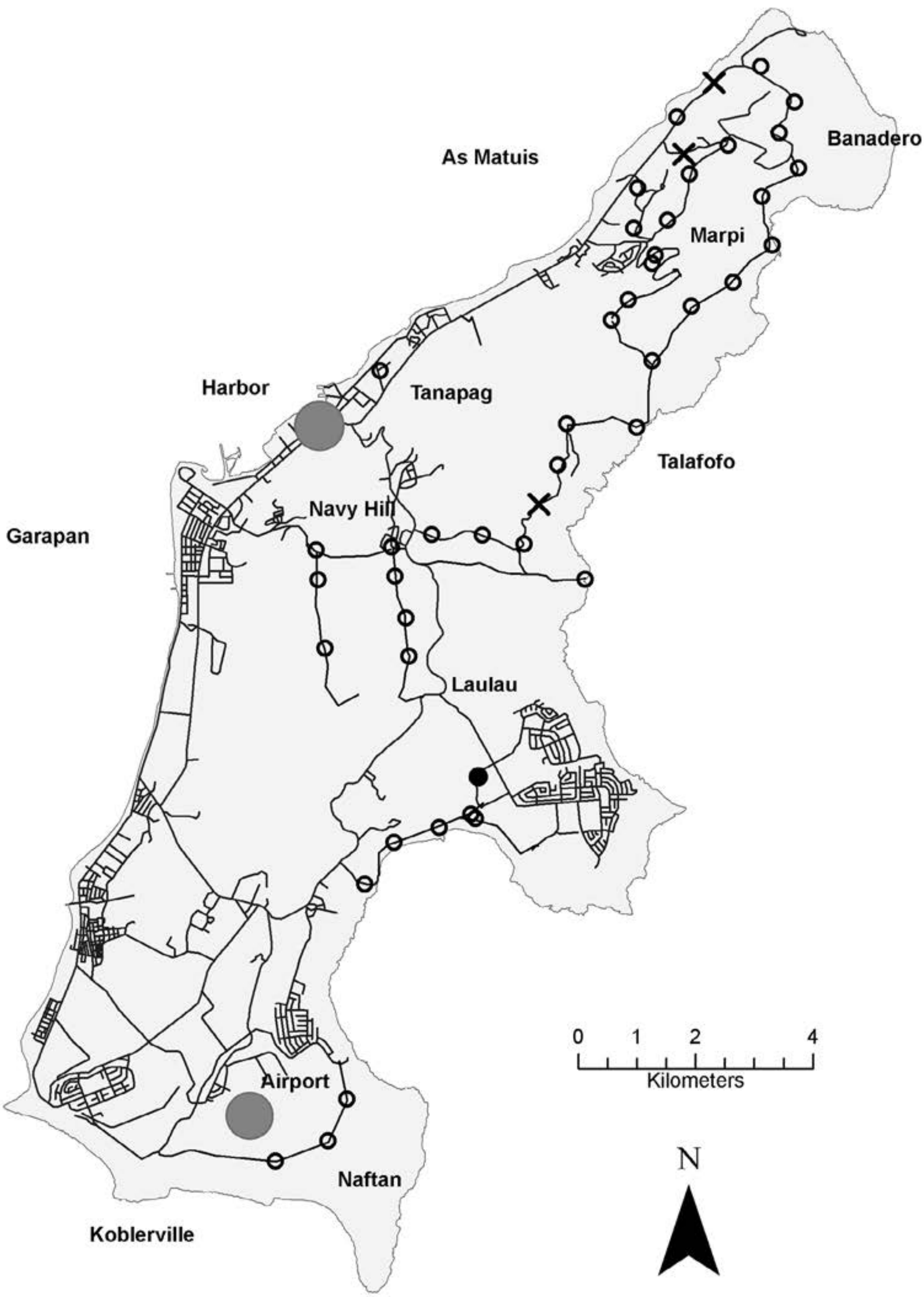

Figure 1. Map of roadside survey routes on Saipan, Commonwealth of the Northern Mariana Islands. Stations where total numbers of birds showed an increasing trend are represented by a black dot (●), and those with decreasing trends are marked with an x (✕). Stations with no change in total number of birds are indicated by open dots (○); large gray circles (●) denote Saipan's seaport and airport.

feel that the seasonality in detectability found by Craig (1996) does not affect the establishment of long-term patterns of abundance given that our preliminary analysis found no seasonal spike in the data and seasonal patterns were similar across years. We therefore present data collected during the spring (April) survey as representative of breeding bird numbers during other times of the year. In our analysis of species trends, year was the predictor variable, and the outcome variable was the number of birds of each species detected across all 47 survey stations in a given year. Because the abundance trend for several species was poorly described by linear models, we also examined quadratic models to explain the relationship of species numbers across years. For temporal patterns, *F* scores, R^2 values, ΔAICc scores, and accompanying Akaike weights (ω) for linear and quadratic models were used to establish the best fit model. In general, all three techniques provided similar conclusions.

To control for detection errors, we restricted our analysis to the spring survey to avoid seasonal effects (the major source of detection variance in preliminary analyses) and minimized the use of multiple observers. Other factors that influence detectability, such as site variation, were incorporated into the model indirectly as random effects influencing variation in the mean count (versus direct parameterization), an approach often taken by others (e.g., Link and Sauer 1997, Royle 2004, Purcell et al. 2005).

For the spatial analysis, we conducted GLM-based regression analyses of total bird numbers across years for each station to measure the trend at each observer location. The results were averaged to obtain a mean trend across stations and included the observed standard deviation. Each station's slope was then compared to this average slope using a Bonferroni-corrected single-sample *t* test to determine which stations exhibited total bird annual gains or losses significantly greater than or less than the population average trend. Significance was accepted at an adjusted $P < .05$. Using this approach, we draw conclusions about route-wide patterns such as changes in total bird numbers over time on Saipan, as well as station-by-station changes across annual patterns.

Data on frequency, distance, strength, and direction of typhoons from 1990 to 2010 were obtained from the Digital Typhoon Database (Kitamoto 2005). We analyzed total bird abundance in relation to the interval between typhoon strikes, the distance to Saipan at closest approach, and the pressure at the center of the typhoon at the time of closest approach (central pressure is inversely related to wind speed or intensity of the storm) for all typhoons approaching within 150 km of Saipan. The typhoon data were analyzed for trends over time using a multivariate general linear model with total number of birds detected as the dependent variable and smoothed values for time between strikes, distance, and pressure as independent variables.

RESULTS

Over the 20 yr that roadside surveys have been conducted on Saipan, 29 avian species were detected. A few, like the Black Kite (*Milvus migrans*) and Great Frigatebird (*Fregata minor*), are only occasional visitors to the island. Of the 12 species of egrets, terns, tropicbirds and other waterfowl detected, eight are resident to the island: Pacific Reef-Heron (*Egretta sacra*), White Tern, Brown Noddy, Black Noddy, White-tailed Tropicbird, Red-tailed Tropicbird, Yellow Bittern, and Marianas Common Moorhen (*Gallinula chloropus guami*). The Pacific Golden Plover (*Pluvialis fulva*), Little Egret (*Egretta garzetta*), Intermediate Egret (*Ardea intermedia*), and Cattle Egret (*Bubulcus ibis*) are regular nonbreeding migrants. Of the 15 species of terrestrial birds recorded, 11 were detected in sufficient numbers for analysis (Table 1); the remaining four were not analyzed. The Red Junglefowl (*Gallus gallus*) and Rock Dove (*Columba livia*), introduced species, were present throughout the survey period. The Orange-cheeked Waxbill (*Estrilda melpoda*), a species native to Africa and common in the pet trade, was noted in the wild on Saipan before 2001 and has been detected in increasing numbers since 2007. The endangered Micronesian Megapode was detected only once or twice per

TABLE 1

Trend Analysis Results for Spring Roadside Bird Surveys on Saipan, 1991–2010

Bird Species	Model	Coefficient (SE)	*F* Value	*P* Value	R^2	ΔAICc	*ω*
Mariana Fruit-Dove	*Lin	1.785 (0.551)	10.486	.005	0.345	0.000	0.778
	Quad	0.064 (0.106)	5.224	.018	0.319	2.838	0.188
	Null					6.279	0.034
White-throated Ground-Dove	*Lin	1.577 (0.508)	9.630	.006	0.324	0.000	0.689
	Quad	0.105 (0.095)	5.484	.015	0.333	1.865	0.271
	Null					5.678	0.040
Collared Kingfisher	*Lin	1.709 (0.419)	16.665	.001	0.465	0.000	0.813
	Quad	0.038 (0.081)	8.061	.004	0.440	2.996	0.182
	Null					10.131	0.005
Micronesian Starling	*Lin	3.416 (0.625)	29.849	.000	0.616	0.000	0.775
	Quad	0.098 (0.119)	14.968	.000	0.608	2.479	0.224
	Null					16.411	0.000
Micronesian Myzomela	Lin	4.733 (0.679)	48.628	.000	0.726	8.774	0.012
	*Quad	0.362 (0.096)	50.175	.000	0.845	0.000	0.988
	Null					31.589	0.000
Golden White-eye	Lin	0.345 (1.365)	0.064	.803	0.000	14.750	0.001
	*Quad	−0.833 (0.166)	12.717	.000	0.566	0.000	0.997
	Null					11.972	0.003
Rufous Fantail	Lin	0.488 (2.724)	0.032	.860	0.000	9.287	0.009
	*Quad	−1.477 (0.382)	7.511	.005	0.420	0.000	0.953
	Null					6.473	0.037
Island Collared-Dove	Lin	1.111 (0.825)	1.812	.196	0.043	0.925	0.326
	Quad	−0.193 (0.153)	1.725	.210	0.075	2.396	0.156
	*Null					0.000	0.518
Eurasian Tree Sparrow	Lin	0.569 (1.279)	0.198	.662	0.000	2.630	0.202
	Quad	0.131 (0.247)	0.280	.235	0.793	5.557	0.047
	*Null					0.000	0.752
Bridled White-eye	Lin	1.205 (6.403)	0.037	.849	0.000	2.808	0.143
	Quad	−2.302 (1.107)	2.183	.145	0.116	1.523	0.273
	*Null					0.000	0.584
Nightingale Reed-Warbler	Lin	−0.136 (0.204)	0.443	.514	0.000	2.360	0.148
	Quad	−0.077 (0.035)	2.735	.095	0.162	0.519	0.371
	*Null					0.000	0.481

Note: The model that best described the data for each species [linear (Lin), quadratic (Quad), or null] was selected based on the significance of the *F* statistic (adjusted $P \leq .05$), the lowest ΔAICc score, and the highest Akaike weight (*ω*); we used R^2 to evaluate how well the selected models fit. The coefficient for each model, which indicates the direction of the trend, is followed by the standard error (SE). An asterisk (*) indicates best-fit models (linear df = 1,17; quadratic df = 2,16).

survey, indicating that the species continues to persist on Saipan, although breeding sites remain to be discovered.

The relative abundance of Saipan's terrestrial birds as surveyed along 47 roadside survey stations in April increased from about 500 birds detected annually in the early 1990s to about 1,000 birds detected annually in recent years. The range in total detections across the island was from a low of 370 in 1994 to a high of 1,253 birds in 2004. On average, 874 birds (SD = 271) were recorded per survey. The most frequently observed species on the island (averaging over 40 individuals recorded per survey) in decreasing detection rates were the Bridled White-eye (range, 267–772 birds), followed by the Rufous Fantail (range, 53–292), Golden White-eye (range, 24–162), Micronesian Starling (range, 21–87), and Micronesian Myzomela (range, 7–136). The Collared Kingfisher (range, 23–81), Eurasian Tree Sparrow (*Passer montanus*) (range, 5–126), Mariana Fruit-Dove (range, 15–79), and Island Collared-Dove (*Streptopelia bitorquata*) (range, 7–71) were common (averaging over 30 individuals per survey). The White-

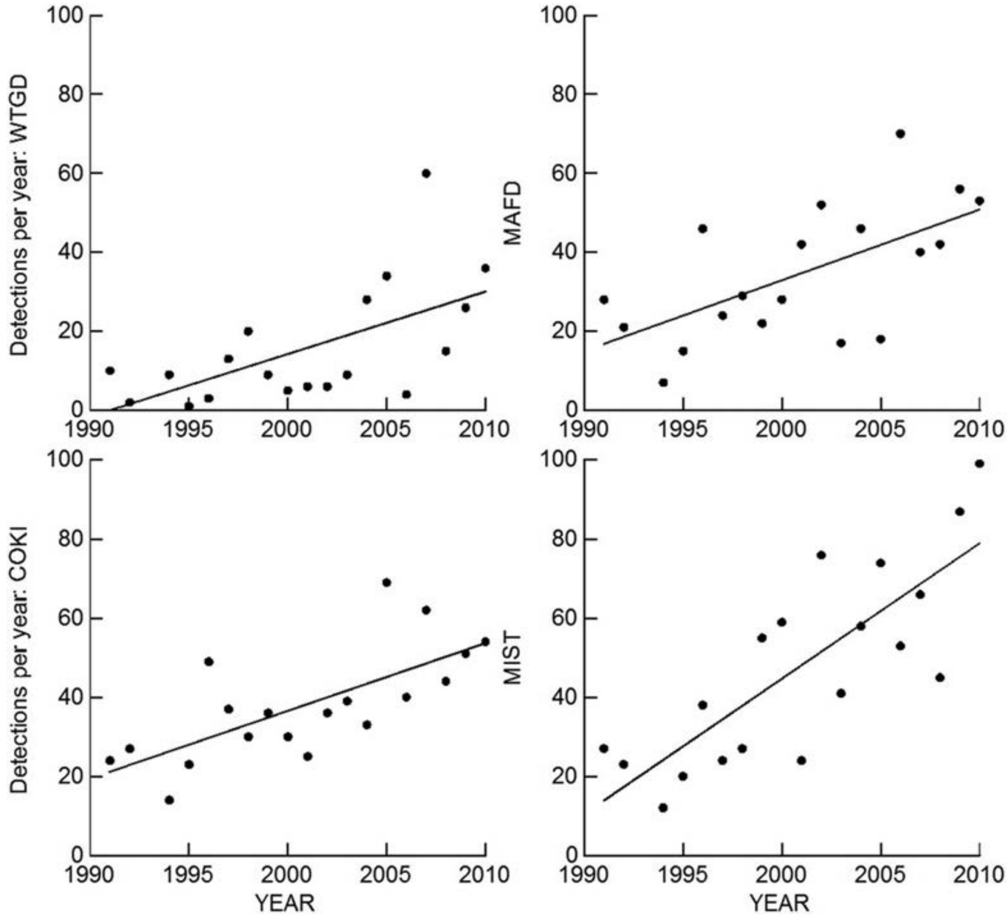

Figure 2. Results from roadside surveys on Saipan from 1991 to 2010 indicated that numbers of White-throated Ground-Dove (WTGD), Mariana Fruit-Dove (MAFD), Collared Kingfisher (COKI), and Micronesian Starling (MIST) counted in each spring survey (the *y*-axis) significantly increased in a linear fashion over the study period.

throated Ground-Dove (range, 1–63) and Nightingale Reed-Warbler (range, 11–24) were the least common species (averaging less than 30 individuals per survey).

Detections of four forest birds, White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, and Micronesian Starling, increased linearly over the survey period (Table 1, Figure 2). The population of Micronesian Myzomela also increased significantly after dipping to a low in the mid-1990s. Populations of Golden White-eye and Rufous Fantail exhibited a dramatic rise in numbers during the first 10 yr of the survey followed by a significant decline during the following decade (Figure 3). Nightingale Reed-Warblers remained at a constant low level during the study. Likewise we could not discern a trend in the remaining species observations (Island Collared-Dove, Bridled White-eye, and Eurasian Tree Sparrow).

A station-by-station analysis of total bird numbers showed that the overall abundance of birds on Saipan increased on average by 0.27 (SD = 0.29) birds per year, per station. One station in the southern portion of Saipan showed a significant increase in number of total birds, relative to the overall increase

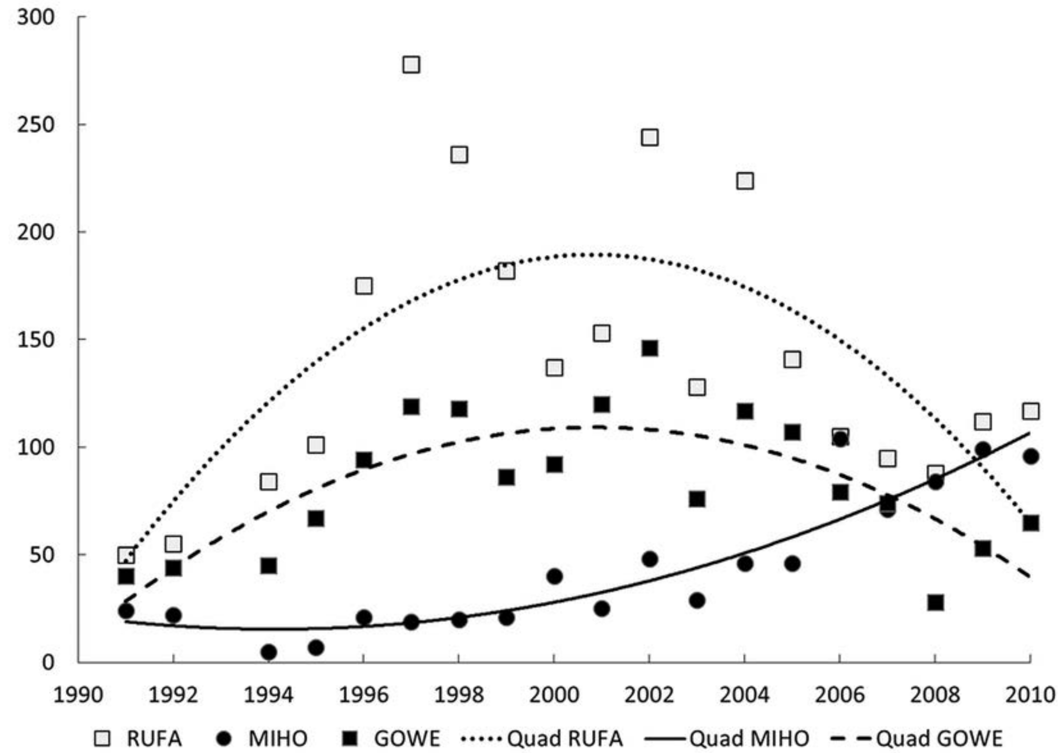

Figure 3. Results from roadside surveys on Saipan from 1991 to 2010 indicated that numbers of Micronesian Myzomela (MIHO) counted in each spring survey (the *y*-axis) increased in a curvilinear fashion over the study period, but numbers of Golden White-eye (GOWE) and Rufous Fantail (RUFA) increased during the first decade of the survey and were in significant decline by the end of the study period.

across the island. Only three stations out of 47 (6.4% of stations) showed a significant loss of total birds over the time period relative to the overall increase in total birds on the island. There was also a decline in bird numbers at another station, although nonsignificant. The stations where significant declines were detected, as well as the station with a nonsignificant decline, were in the As Matuis, Marpi, Banadero, and Talafofo areas in the northern region of the island.

We found no relationship between typhoon variables and total bird numbers across the years of our data set ($F = 0.147$; df = 3,15; $P = .930$).

DISCUSSION

As with the similar North American Breeding Bird Surveys, Saipan's roadside surveys sampled birds that use forest edges (as opposed to, for example, forest interiors or urban centers). Thus, these surveys do not provide accurate absolute island-wide population estimates for focal species; instead they help to illustrate large changes in numbers. The roadside surveys conducted on Saipan from 1991 to 2010 corroborate other studies that found that many native land birds on Saipan are locally common and suggest that the abundances of some species are increasing (Reichel and Glass 1991, Camp et al. 2009). Detections of terrestrial birds increased from an annual average of about 500 birds per survey in the early 1990s to a high of over 1,250 birds in 2004 before leveling off recently at about 1,000 birds per survey.

Roadside surveys indicated that populations of White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Micronesian Myzomela, and Micronesian Starling all increased significantly between 1991 and 2010. Similar to other avian surveys on Saipan (Craig 1996, Camp et al. 2009), we found Bridled White-eyes to be particularly numerous. Analysis in Camp et al. (2009) of point-transect distance sampling conducted on Saipan in 1982, 1997, and 2007 likewise found that densities of White-throated Ground-doves, Micronesian Myzomelas, and Micronesian Starlings had increased; however, they found no change in Collared Kingfisher or Mariana Fruit-Dove densities. In our study, we did not detect any change in the Nightingale Reed-Warbler population, although numbers were consistently low, and it is often difficult to detect variations in small populations. By comparison, Camp et al. (2009) determined that Nightingale Reed-Warblers had declined over time, particularly in vegetation types associated with golf courses, limestone forest, and residential areas deemed less suitable to the species than secondary forest, grasslands, and tangantangan thickets. It is interesting that both our roadside surveys and the off-road distance sampling surveys (Camp et al. 2009) indicated that Rufous Fantails and Golden White-eyes were in decline at the end of the respective study periods.

Although roadside surveys do not yield information on causes of population changes, we explored the relationship between changes in typhoon frequency and severity, often suggested as a factor contributing to the declines of some forest bird species (U.S. Fish and Wildlife Service 1991, 1998*a*, Plentovich et al. 2005), and the trends we discerned in our data. Most of the species with increasing abundance trends foraged for fruit, nectar, or seeds. Species with decreasing trends at the end of the survey interval primarily foraged for insects. We had expected to find that the destructive impacts of typhoons on Saipan's vegetation would negatively affect fruit and nectar eaters and favor species such as the insectivorous Nightingale Reed-Warbler that, partially reliant on grasslands, might be able to take advantage of storm-related open patches. Instead, our analysis of typhoons approaching within 150 km of Saipan suggested that the frequency and intensity of such storms did not explain any of the observed changes in bird populations. Contrary to our expectations, the abundances of frugivores and nectivores increased steadily through a decade of frequent storm activity (1991–2000) and also increased during the following decade of less-frequent storms (2001–2010). Although the abundances of some insectivores increased during the period of frequent storms and decreased during the calmer period, the relationship was not significant. Factors other than the frequency and intensity of typhoons clearly played a more important role in influencing population trends.

Camp et al. (2009) thought that habitat loss and degradation through land clearing for development and agriculture facilitated the observed declines of some species on Saipan. We suggest that an additional factor to consider is the spread of nonnative invasive vines across Saipan in the last decade (Shine et al. 2003, Reddy et al. 2009). The rapid spread of scarlet gourd, for example, has altered the accessibility of nesting and foraging trees as well as potentially benefiting fruit-eating birds through a high production of edible fruit (Berger et al. 2005). Alien introductions often imperil other species, so it would be relevant to understand how the invasive vines are affecting both decreases and increases in avian abundance, nest success, and food availability on Saipan.

The complex ecological consequences of the introduction of invasive species to insular areas have been well documented (e.g., Atkinson 1985, Crooks and Soule 1999, Mooney and Cleland 2001, Simberloff 2001), and this problem presents an important challenge for the Mariana Islands. Of particular concern is the potential for introduction and establishment of the Brown Tree Snake, a devastating avian predator responsible for the rapid decline or extinction of 17 of the 18 native forest bird species on Guam (Wiles et al. 2003). Although extensive efforts have been implemented to interdict the snake in shipments of supplies and materials from Guam, the transportation nexus for the region, the risk of spreading the snake remains high because Guam remains snake infested (Rodda and Savidge 2007). The projected increase in military recreation and training in the CNMI proposed in the Mariana Islands Range Complex EIS/OEIS (Department of the Navy 2009) and the Mariana Islands Training and Testing EIS/OEIS (Department of the Navy 2011) is of concern due to the increase in equipment and materials transported from Guam to the CNMI. The tenuous nature of avian populations on the small islands of the CNMI and the proposed military expansion accentuate the need for monitoring bird populations to detect changes in abundance before they become conservation challenges.

Roadside surveys can serve as an important management tool in identifying changes in bird populations and can be conducted with relatively small expenditures of resources. For those islands threatened by Brown Tree Snake colonization, a station-by-station analysis of survey results can provide assistance to snake interdiction efforts by identifying locations where bird abundance is in decline. Such declines may indicate the presence of snakes, thus helping to focus additional detection efforts. Wildlife managers in the CNMI rightly focus Brown Tree Snake interdiction efforts near Saipan's ports of entry (Engeman and Vice 2001), but, in addition, they may do well to increase detection efforts around survey stations in the As Matuis, Marpi, Banadero, and Talafofo areas of the island, where avian declines were identified. The design of avian roadside surveys could also be altered to aid in this effort. Currently, the number of survey stations located near the airport and shipping docks is insufficient to detect changes in bird abundance without decades of sampling (Purcell et al. 2005). We suggest the establishment of new survey routes and new survey stations along the secondary and tertiary roads through urban areas and around the ports of entry to provide more thorough coverage of the island. Additional survey stations in more rural zones could be established, for added spatial resolution, by halving the distance between stations to one every 0.4 km, a distance that is not likely to increase the chance of counting the same bird at different stations. The new routes would need to be surveyed in the early morning and primary roads should be avoided because traffic noise would likely reduce detections.

Variation in both seasonal and annual detection rates are factors that often have a substantial impact on the number of birds recorded during surveys (Anderson 2001). It is possible that the quarterly sampling regime was not fine-tuned enough for us to detect seasonal variation in the data. Roadside surveys could be improved by testing for temporal variation in detectability, and we recommend that this relatively inexpensive survey be conducted monthly for 1 to 2 yr so that the best season to perform counts can be better ascertained. For native forest birds on Saipan, an optimal period for surveying would be when counts of most species are typically high (near or during the breeding season), variability among observers is low, and weather conditions are apt to be neither windy nor rainy (Simon et al. 2002). Once the best period is established, the consistency of roadside surveys and other more resource-intensive methods (such as distance sampling) would be enhanced.

Although we believe roadside surveys present a consistent reflection of bird numbers on Saipan, we strongly encourage developing a statistically more robust program for future monitoring. One problem with this survey and with point counts in general is that differences among observers often are found to be important sources of variation in detection probabilities (Anderson 2001). An observer training program, reinforced by interobserver reliability exercises before each survey, would reduce variation among observers in the accuracy of counts and identification (Kepler and Scott 1981). Careful assignment of observers (i.e., always the same observers in any specific season) would reduce variability in detection probabilities over time and improve consistency. We also recommend the establishment of interobserver reliability tests using a double-observer approach (Nichols et al. 2000) to improve the precision of avian abundance estimates.

The CNMI government began repeat sampling to improve the robustness of their roadside survey in 2007. Repeat sampling (multiple censuses) within one or two seasons improves within-year estimates of variance and also improves trend estimation by providing data on the amount of variance due to sampling error as separate from interannual variation (Gorreson et al. 2012). Multiple visits to an increased number of stations within a given season will likely improve the power of roadside surveys to detect a decline in species (Purcell et al. 2005), reducing the time needed to verify areas of concern. We urge managers in the CNMI to (1) consider increasing survey coverage by establishing new routes and stations, especially in areas where the Brown Treesnake is likely to make landfall, and to (2) establish a program of multiple observers performing multiple censuses within one or two seasons to provide a standardized basis for future data collection.

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