Final
Survey Report

Terrestrial Biological Surveys on Tinian in Support of the Commonwealth of the Northern Mariana Islands Joint Military Training Environmental Impact Statement/Overseas Environmental Impact Statement

Prepared for:

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Survey Report
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Acronyms and Abbreviations

ac	acre(s)
CJMT	CNMI Joint Military Training
CNMI	Commonwealth of the Northern Mariana Islands
DFW	Division of Fish and Wildlife
DoN	Department of the Navy
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ft	feet
ha	hectare(s)
km	kilometer(s)
m	meter(s)
MBTA	Migratory Bird Treaty Act
mi	mile(s)
MLA	Military Lease Area
MP#	Megapode transect
NAVFAC	Naval Facilities Engineering Command
NB#	Native Bird transect
OEIS	Overseas Environmental Impact Statement
SWCA	SWCA Environmental Consultants
UHM	University of Hawaii – Manoa
U.S.	United States
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

CHAPTER 1
INTRODUCTION

1.1 OVERVIEW

The purpose of this report is to provide information regarding the the occurrence of terrestrial biological resources on Tinian associated with a proposed action to establish a series of live-fire ranges, training courses, and maneuver areas in the Commonwealth of the Northern Mariana Islands (CNMI) to address the United States (U.S.) Pacific Command Service Components' training deficiencies in the Western Pacific. These live-fire ranges, training courses, and maneuver areas collectively constitute a Range and Training Area. The proposed action would occur on two islands in the CNMI – Tinian and Pagan. The proposed action includes construction, range management, expanded training and operations (to include combined-arms, live-fire, and maneuver training at the unit and combined levels), danger zones, designation of special use airspace, and acquisition and/or lease of land to support simultaneous and integrated training. The CNMI Joint Military Training (CJMT) Environmental Impact Statement (EIS)/Overseas EIS (OEIS) is being prepared to assess the proposed action. Surveys were previously conducted on Pagan (U.S. Fish and Wildlife Service [USFWS] 2010) and are not addressed within this report.

The purpose of the terrestrial biological resource surveys summarized in this report is to document the presence and population status of species on Tinian that are listed and considered candidates for listing under the Endangered Species Act (ESA) and native bird species, including those protected under the Migratory Bird Treaty Act (MBTA). Specific project tasks are as follows:

- Conduct surveys for native birds, including species protected under the MBTA.
- Conduct surveys for the ESA-listed endangered Micronesian megapode (*Megapodius laperouse laperouse*).
- Conduct surveys for the ESA-listed endangered Mariana common moorhen (*Gallinula chloropus guami*).
- Conduct surveys for partulid tree snails (*Partula* spp.) which are candidates for listing under the ESA.

Results of these surveys, as well as data collected on these and other protected species during past surveys, will be incorporated into an EIS/OEIS and Biological Assessment to assess the potential environmental impacts of proposed Joint Military Training in the CNMI and to develop measures to avoid, minimize, or mitigate for potential impacts to these species.

1.2 SURVEY PERSONNEL

The lead personnel involved in performing the project tasks are listed in Table 1. Cardno TEC was the prime contractor managing all survey efforts and report preparation. Subcontractors were SWCA Environmental Consultants (SWCA), University of Hawaii-Manoa (UHM), and U.S. Geological Survey (USGS).

Table 1. Terrestrial Biological Resources Personnel

Role		Name	Organization
Program Director		Peer Amble	Cardno TEC
Project Manager		Rick Spaulding	Cardno TEC
AVIAN SURVEYS			
Principal Investigator		Lainie Zarones, Ph.D.	SWCA/Cardno TEC
Field Biologists	Native birds, megapodes, moorhens	Rick Spaulding Lainie Zarones, Ph.D. Nathan Johnson	Cardno TEC SWCA/Cardno TEC SWCA/Cardno TEC
	Native birds, megapodes	Pete Reynolds	SWCA
Data Analysis		Rick Camp	USGS
TREE SNAIL SURVEYS			
Principal Investigator		Brenden Holland, Ph.D.	UHM
Field Biologists		Brenden Holland, Ph.D. David Sischo	UHM

1.3 LOCATION

Tinian is an island within the CNMI, approximately 177 miles (mi) (285 kilometers [km]) north of Guam. It is the third island from south to north within the CNMI (Figure 1). Tinian is approximately 12 mi (19 km) long and 5 mi (8 km) wide with a total land area of 39.3 square mi (101.8 square km).

In 1983, the United States government, with the Department of the Navy (DoN) as lease manager, entered into a long-term lease with the CNMI government. The DoN now leases 15,400 acres (ac) (6,232 hectares [ha]) of terrestrial lands covering much of northern Tinian to be used for military purposes. This area is known as the Military Lease Area (MLA) (Figure 2) and it contains a variety of terrestrial and wetland habitats that support native wildlife species. The DoN is responsible for the conservation and management of federally listed threatened and endangered species and species protected under the MBTA within the Tinian MLA.

Tinian consists of a series of five low limestone plateaus separated by escarpments and steeply sloping areas with lowland areas between. The primary terrestrial ecosystems identified on Tinian are disturbed lowlands/plateaus, coastal and cliffline forests, and wetland habitats.

Lowlands/plateaus comprise approximately half the total land area on Tinian, and extend between the coastal forests and the island's interior limestone cliffs. The lowlands have been heavily disturbed by historical land uses and violent typhoon weather systems that frequent the Mariana Islands. Lowlands are characterized by secondary forest dominated primarily by non-native tangantangan (*Leucaena leucocephala*), crop and grazing lands, and urban development.

Coastal and cliffline forests consist of isolated areas of native limestone and mixed forest that occur along the coasts or follow the escarpments. Forested areas located at the top of Mount Lasso, around the north escarpment of Maga (Figure 2), and within coastal areas contain native trees such as *Pisonia grandis*, *Ficus* spp., *Cynometra ramiflora*, *Guamia mariannae*, *Pandanus tectorius*, *Cerbera dilatata*, and *Ochrosia mariannensis*.

Potential wetland habitats on Tinian include Lake Hagoi and Lake Makpo, which are permanent small lakes or ponds, and smaller ephemeral potential wetlands at Bateha created by man-made berms. In addition, there are potential wetland sites in naturally low-lying areas and bomb craters within the Mahalang area (Figure 2). More detailed information on the potential wetland habitats of Tinian is provided in Chapter 4, *Mariana Common Moorhen Surveys*.

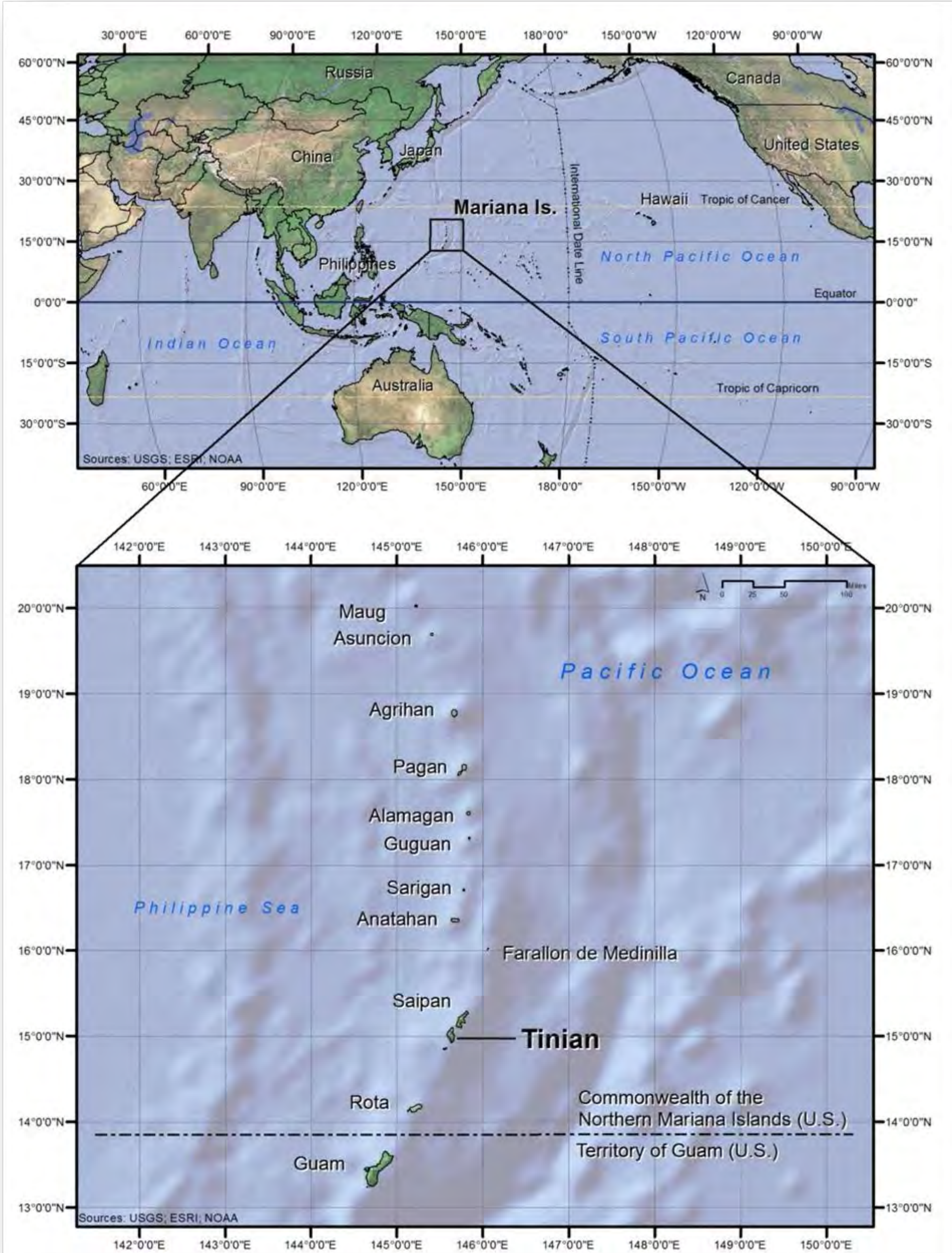

Figure 1. Location of Tinian in the Western Pacific Region and the Mariana Islands

Figure 2. Tinian

CHAPTER 2
NATIVE BIRD SURVEYS

2.1 OVERVIEW OF NATIVE BIRDS

A total of 20 native bird species have been regularly detected during surveys conducted on Tinian between 1982 and 2013, as well as during monthly monitoring by the DoN and periodic monitoring by the CNMI Division of Fish and Wildlife (DFW) (Camp et al. 2009, 2012; DoN 2013a). Species commonly found in native forest include bridled white-eye (*Zosterops conspicillatus saypani*), Tinian monarch (*Monarcha takatsukasae*), Mariana fruit dove (*Ptilinopus roseicapilla*), white-throated ground dove (*Gallicolumba xanthonura*), rufous fantail (*Rhipidura rufifrons*), collared kingfisher (*Todiramphus chloris*), Micronesian honeyeater or myzomela (*Myzomela rubratra*), and Micronesian starling (*Aplonis opaca*). White terns (*Gygis alba*) are also seen in the native forest and yellow bitterns (*Ixobrychus sinensis*) are present in open areas (DoN 2013b).

2.2 SURVEY LOCATIONS AND DESCRIPTION

Point count surveys were conducted between June 11 and 19, and June 26 and 28, 2013. The surveys were conducted along a set of transects originally established and surveyed by the USFWS in 1982. These same transects were surveyed by the USFWS in 1996 and 2008, with four new transects added by the USFWS for the 2008 surveys (USFWS 2009a). Surveying of these standardized transects over time has allowed for analyses of population trends for a subset of the native bird species on Tinian (Camp et al. 2012).

The 2013 native bird surveys used the same survey methods and transects as those used by the USFWS for their 2008 bird surveys on Tinian (USFWS 2009a). The 2008 USFWS surveys were conducted on 14 native bird transects with a total of 254 point count stations (Table 2). In 2013, due to lack of access to private lands and leased public lands for transects south of the MLA, and inaccessibility of some stations on other transects, surveys were conducted on 12 transects at 206 stations (Figures 3, 4, and 5; Table 2). Two transects surveyed in 2008 were not surveyed in 2013 (Native Bird 9 [NB 9] and NB 14); two transects were added in 2013 that were not surveyed in 2008 (NB 15 and NB 16).

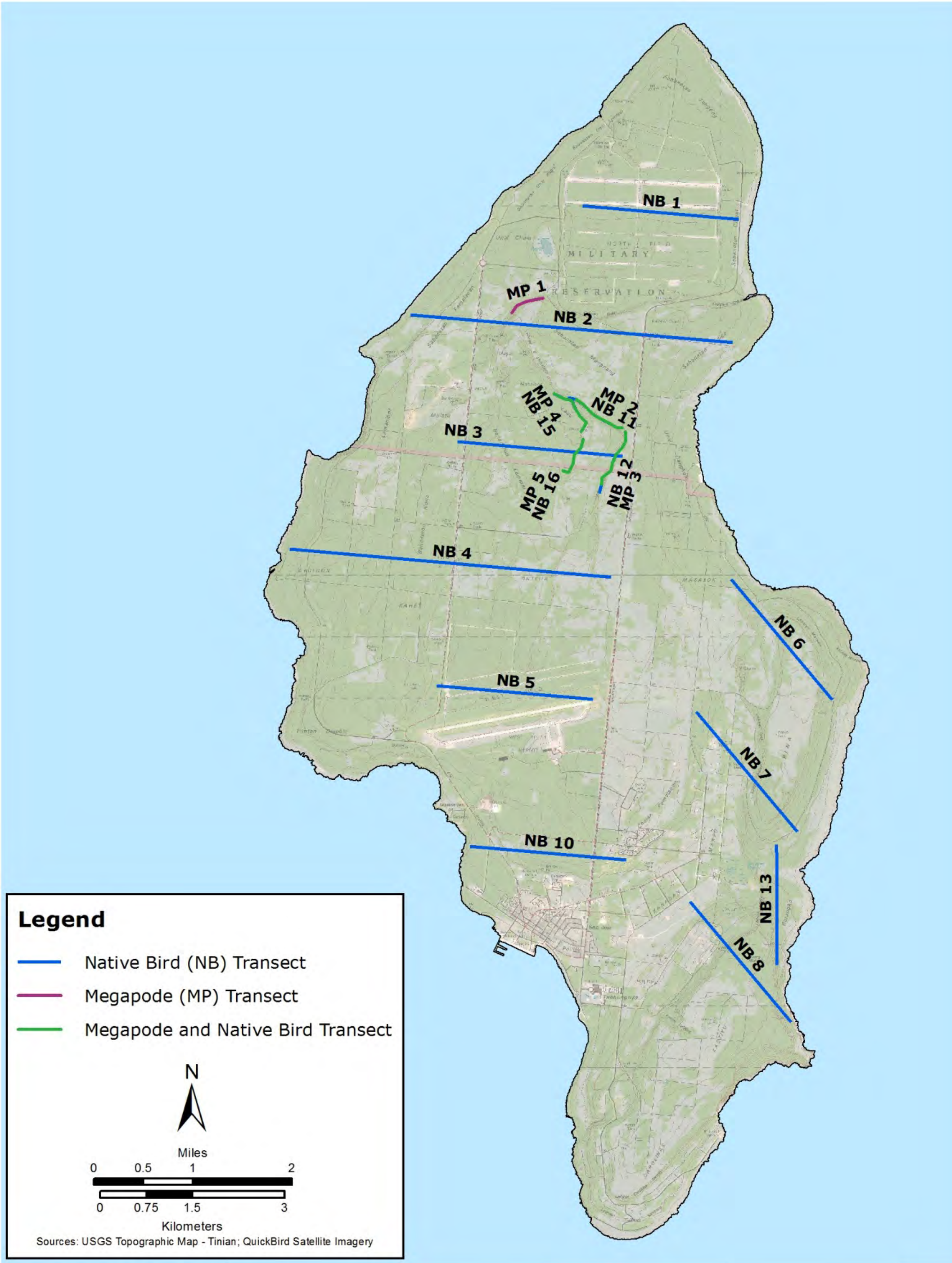

Figure 3. Native Bird and Megapode Survey Transects on Tinian in 2013

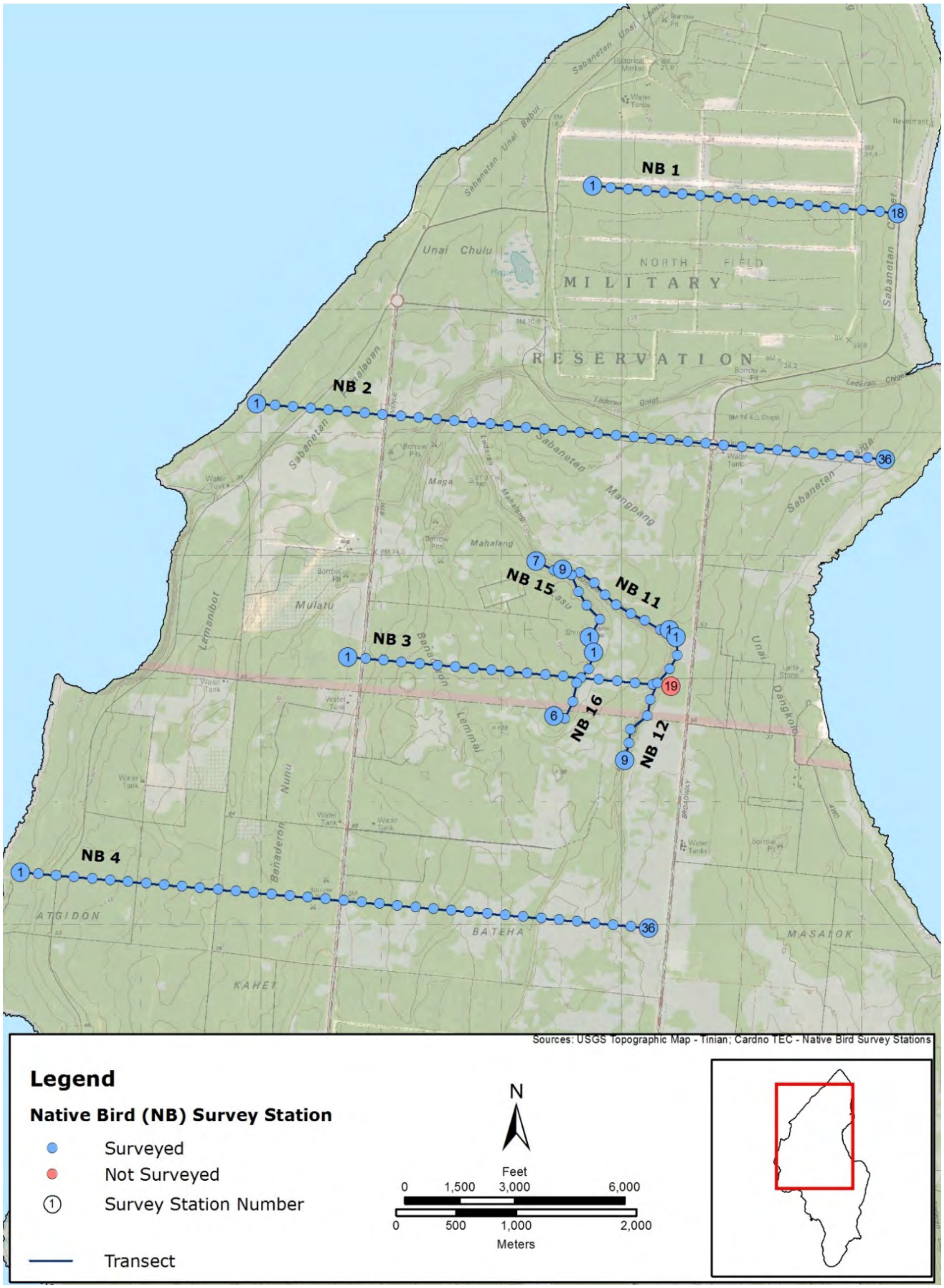

Figure 4. Northern Tinian Native Bird Transects and Survey Stations in 2013

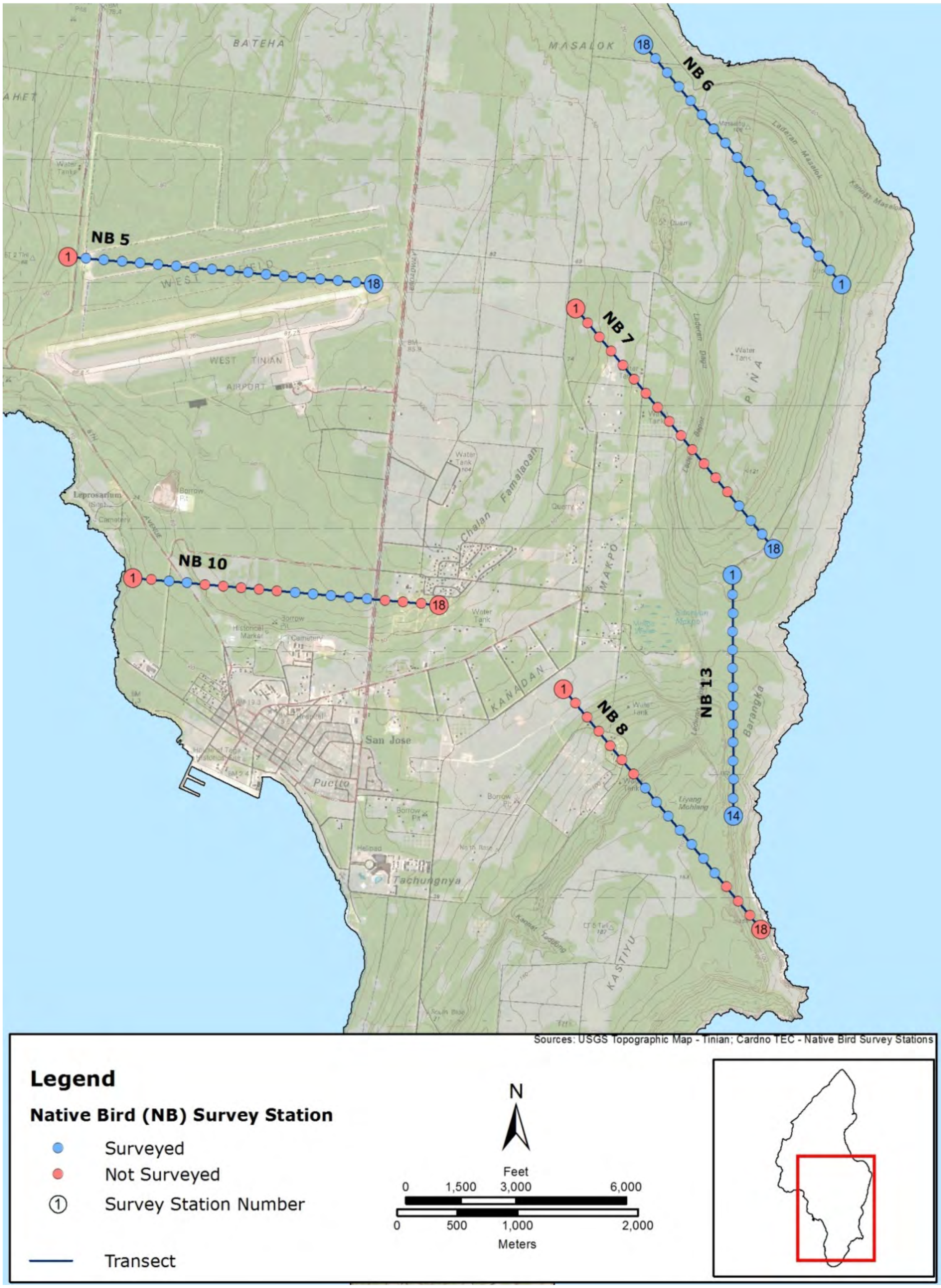

Figure 5. Southern Tinian Native Bird Transects and Survey Stations in 2013

Table 2. Native Bird (NB) Transects and Stations Surveyed on Tinian in 2013

Transect	*2013 Survey Dates*	*Total 2008 Survey Stations*	*Total 2013 Survey Stations*	*Stations Surveyed in 2013*	*Notes*
NB 1	June 12, 13	18	18	1-18	
NB 2	June 26, 27	36	36	1-36	
NB 3	June 15, 16	19	18	1-18	
NB 4	June 26-28	36	36	1-36	
NB 5	June 13, 14	18	17	2-18	1 station on private property – no access.
NB 6	June 11, 12	18	18	1-18	
NB 7	June 11, 13	18	4	15-18	9 stations on private property – no access; stations 10-14 inaccessible.
NB 8	June 16, 17	18	7	8-14	6 stations on private property – no access; stations 7, 15-18 inaccessible.
NB 9	NA	18	0	NA	All stations on private property – no access.
NB 10	June 12, 13	18	7	3-4, 10-14	11 stations on private or leased property – no access.
NB 11	June 16, 17	9	9	1-9	
NB 12	June 18, 19	9	9	1-9	
NB 13	June 16, 17	14	14	1-14	
NB 14	NA	5	0	NA	Not accessible.
NB 15	June 14, 15	NA	7	1-7	New transect
NB 16	June 14, 15	NA	6	1-6	New transect
	Total	**254**	**206**		

Notes: Refer to Figures 3, 4, and 5 for the locations of transects and stations. NA = not applicable.

Descriptions of the habitat types identified during the 2013 native bird surveys on Tinian are listed below. These descriptions are based on habitat names used by Engbring et al. (1986).

- Limestone forest – characterized by native broadleaf species with a variable species composition depending on soil and moisture conditions. Common native tree genera found in this habitat type include *Aglaia, Artocarpus, Cynometra, Elaeocarpus, Eugenia, Ficus, Guamia, Hernandia, Intsia, Mammea, Melanolepis, Neisosperma, Ochrosia, Pandanus, Pisonia,* and *Premna*. Almost all the native forest on Tinian is present along cliffs and nearby steep slopes and on coastal cliffs.
- Secondary forest – forms after the removal of native forest. It is characterized as primarily introduced species of mixed shrubs, small trees, vines, bamboo, and various grass species. Dominant tree species include tangantangan, Formosan koa (*Acacia confusa*), siris tree (*Albizia lebbeck*), coconut palm (*Cocos nucifera*), and flame tree (*Delonix regia*).
- Tangantangan forest – tangantangan often grows in extensive homogeneous stands. The locations of tangantangan stands on Tinian are consistent with former Japanese sugar cane fields. Other tree species associated with tangantangan forest include siris tree, flame tree, Formosan koa, and ironwood (*Casuarina equisetifolia*).
- Open field – characterized by various species of grasses and other herbaceous ground cover, usually found in association with brushy thickets of both native and introduced species. Dominant genera include *Miscanthus*, *Pennisetum*, *Panicum*, *Mimosa*, *Momordica*, *Eupatoruim*, *Dicranopteris*, *Bidens*, *Spathoglottis*, *Nephrolepis*, and *Lantana*.
- Residential – urban and residential areas, along with adjacent fields and openings.

Table 3 provides a summary of the habitat types found along each transect based on observations at each survey station in 2013.

Table 3. Habitat Types on Native Bird (NB) Transects Surveyed in 2013

Transect	*General Habitat*
NB 1	Tangantangan forest adjacent to North Field
NB 2	Tangantangan forest with some secondary forest, and sparse pockets of open field and limestone forest
NB 3	Tangantangan and secondary forest, and bisected two cliff lines containing limestone forest
NB 4	Secondary forest with some tangantangan forest and open field, and a small area of limestone forest near the beginning of the transect
NB 5	Half secondary and tangantangan forest, half open field within the Tinian International Airport property
NB 6	Tangantangan forest with a large area of open field in the middle
NB 7	Tangantangan forest with one station in limestone forest
NB 8*	Half tangantangan forest, half limestone forest
NB 10	Secondary forest
NB 13*	Predominantly limestone forest with two stations in tangantangan forest
NB 11	Limestone forest with sparse pockets of secondary forest
NB 12	Limestone forest
NB 15	Limestone forest with sparse pockets of secondary forest
NB 16	Limestone forest

Note: *Stations 8-14 of Transect 8 and stations 12-14 of Transect 13 are within extensive areas of large *Heritiera longipetiolata* trees, a rare species within the CNMI that is being considered by the USFWS for listing under the ESA.

2.3 METHODS

The surveys followed standard point count methods, consisting of an 8-minute count of all birds seen or heard at each station. Surveys were conducted twice, on different days, at each point count station. Estimated compass direction and horizontal distance to all birds heard and/or seen were recorded during the survey. Data collected at each survey point included habitat type, percent cloud cover, rain and wind conditions, and understory and canopy openness. Birds flying over the station were recorded as fly-overs. Surveys started at sunrise and ended no later than 11 a.m.

2.4 RESULTS

A total of 14 (11 native, 3 introduced) avian species were detected during the point count surveys on Tinian during June 11-19 and 26-28, 2013 (Table 4), including 6 species protected under the MBTA: yellow bittern, brown noddy (*Anous stolidus*), white tern, white-throated ground dove, Mariana fruit dove, and collared kingfisher. The Micronesian megapode, the only ESA-listed bird species on Tinian that occurs in forest habitat, was not detected during these surveys (refer to Chapter 3).

Table 4. Avian Species Detected during Point Count Surveys in 2013

Species[1]	*MBTA Protected*	*Biogeographic Status*[2]	*NB Transects – Species Detections*
Bridled white-eye	No	Native	1-8, 10-13, 15-16
Brown noddy	Yes	Native	1, 6-7, 10
Collared kingfisher	Yes	Native	1-8, 10-13, 15-16
Eurasian tree sparrow (*Passer montanus*)	No	Introduced	1, 5
Island collared-dove (*Streptopelia bitorquata*)	No	Introduced	1-8, 10-13, 15-16
Mariana fruit-dove	Yes	Native	1-8, 10-13, 15-16
Micronesian myzomela/honeyeater	No	Native	1-8, 10-13, 15-16
Micronesian starling	No	Native	1-8, 10-13, 15-16
Orange-cheeked waxbill (*Estrilda melpoda*)	No	Introduced	1, 2
Rufous fantail	No	Native	1-8, 10-13, 15-16
Tinian monarch	No	Native	1-8, 10-13, 15-16
White tern	Yes	Native	1-8, 10-13, 15-16
White-throated ground-dove	Yes	Native	1-8, 10-13, 15-16
Yellow bittern	Yes	Native	1-5, 8, 11, 13

Notes: [1]Nomenclature – Gill and Donsker (2014). [2]Biogeographic status – Reichel and Glass (1991), except orange-cheeked waxbill.

2.4.1 Native Bird Population Density and Abundance Estimates

Analysis of native bird survey data was conducted by the USGS (Camp and Banko 2014; see Appendix A) to allow direct comparison to the data collection and analyses conducted for the 2008 Tinian surveys (Camp et al. 2009), as well as similar analyses for the 1982 and 1996 surveys (Camp et al. 2012). Survey data were used to estimate population densities (birds/ha) within habitat types and population abundance, or total population size. Population density for each species was estimated using the program DISTANCE, version 6.0, release 2 (Thomas et al. 2010) and followed the methods of Camp et al. (2012). Distance analysis uses species-specific detection functions which are fitted with covariates that account for effects of observer, detection type, weather, habitat type, and year. Candidate detection function models were tested, and model selection was based upon the lowest Akaike's Information Criterion corrected (AICc) for small sample size (Buckland et al. 2001; Burnham and Anderson 2002). Population abundance estimates were calculated for each species by multiplying the species density estimates for each habitat type by the total area of the habitat. Methods are described in more detail in Thomas et al. (2010), Camp et al. (2012), and Camp and Banko (2014) (Appendix A). Acreage of habitat types came from Liu and Fischer (2006) and Amidon (2009). The following is a summary of the 2013 native bird survey results. Further details can be found in Appendix A.

Of the 14 avian species detected during the 2013 point count surveys of 14 transects on Tinian (Tables 2 and 4), sufficient numbers of individuals were detected for 9 species to calculate density and abundance estimates: bridled white-eye, collared kingfisher, island collared-dove, Mariana fruit-dove, Micronesian myzomela, Micronesian starling, rufous fantail, Tinian monarch, and white-throated ground-dove (Table 5). Of these, three species are protected under the MBTA: collared kingfisher, Mariana fruit-dove, and white-throated ground-dove (USFWS 2013). Bridled white-eye, rufous fantail, and Tinian monarch were the most abundant birds and exhibited the highest densities, whereas collared kingfisher, island collared-dove, and Mariana fruit dove were the least abundant and exhibited the lowest densities.

Table 5. Estimates of Tinian Forest Bird Species Abundance and Density from All Transects Surveyed in 2013

Species	*Analysis**	*Estimate (95% confidence interval)*
Bridled white-eye	Abundance	442,073 (402,422−481,756)
	Density	45.197 ± 2.069 (41.143−49.254)
Collared kingfisher	Abundance	2,508 (1,898−3,343)
	Density	0.256 ± 0.041 (0.194−0.342)
Island collared-dove	Abundance	3,738 (2,592−5,016)
	Density	0.382 ± 0.066 (0.265−0.513)
Mariana fruit-dove	Abundance	4,042 (3,140−5,321)
	Density	0.413 ± 0.062 (0.321−0.544)
Micronesian myzomela	Abundance	20,660 (16,275−27,045)
	Density	2.112 ± 0.274 (1.664−2.765)
Micronesian starling	Abundance	40,489 (34,391−47,243)
	Density	4.140 ± 0.337 (3.516−4.830)
Rufous fantail	Abundance	125,668 (107,153−144,392)
	Density	12.848 ± 0.936 (10.955−14.763)
Tinian monarch	Abundance	91,420 (74,593−110,822)
	Density	9.347 ± 0.960 (7.626−11.330)
White-throated ground-dove	Abundance	4,879 (3,716−6,209)
	Density	0.499 ± 0.066 (0.380−0.635)

Notes: *Abundance = Density x Area; Density = birds/ha ± standard error.

Bridled white-eye, rufous fantail, and Tinian monarch occurred in higher densities within forested habitats (i.e., limestone forest, secondary forest, tangantangan), whereas the remaining species generally occurred in similar densities across all habitat types (Table 6). However, the white-throated ground-dove was detected in low densities within tangantangan habitat.

Table 6. Estimates of Tinian Forest Bird Species Density by Habitat Type from All Transects Surveyed in 2013

Species	*Habitat Type** *LF*	*HS*	*SF*	*TT*
Bridled white-eye	44.377 ± 2.842 (38.873−50.294)	35.466 ± 5.506 (24.905−45.514)	52.993 ± 2.689 (47.905−58.489)	47.952 ± 2.271 (43.854−52.680)
Collared kingfisher	0.255 ± 0.067 (0.145−0.393)	0.383 ± 0.085 (0.239−0.559)	0.239 ± 0.056 (0.140−0.357)	0.148 ± 0.032 (0.095−0.222)
Island collared-dove	0.307 ± 0.071 (0.183−0.456)	0.355 ± 0.098 (0.183−0.563)	0.563 ± 0.108 (0.377−0.789)	0.304 ± 0.077 (0.181−0.470)
Mariana fruit-dove	0.459 ± 0.072 (0.347−0.613)	0.393 ± 0.086 (0.244−0.599)	0.488 ± 0.080 (0.365−0.669)	0.313 ± 0.054 (0.229−0.428)
Micronesian myzomela	2.658 ± 0.373 (2.051−3.474)	1.761 ± 0.495 (0.899−2.730)	2.415 ± 0.338 (1.853−3.183)	1.615 ± 0.272 (1.128−2.186)
Micronesian starling	4.106 ± 0.444 (3.238−5.005)	4.319 ± 0.718 (2.983−5.719)	4.155 ± 0.390 (3.386−4.907)	3.978 ± 0.453 (3.157−4.867)
Rufous fantail	15.913 ± 1.527 (12.799−18.970)	7.360 ± 1.283 (4.925−9.874)	15.751 ± 1.185 (13.529−18.037)	12.370 ± 1.074 (10.461−14.635)
Tinian monarch	11.188 ± 1.357 (8.786−14.221)	5.047 ± 1.051 (3.085−7.234)	11.005 ± 1.314 (8.657−13.711)	10.147 ± 1.159 (7.984−12.465)
White-throated ground-dove	0.758 ± 0.129 (0.523−1.021)	0.479 ± 0.142 (0.228−0.792)	0.597 ± 0.096 (0.425−0.803)	0.161 ± 0.036 (0.097−0.237)

Notes: *Birds/ha; ± standard error (95% confidence intervals).
LF = limestone forest, HS = herbaceous scrub, SF = secondary forest, TT = tangantangan.

2.5 DISCUSSION

A total of 14 avian species were detected during the surveys, whereas 18 species were recorded during the USFWS's 2008 surveys (Camp et al. 2012). Four species were observed in 2008 that were not recorded in 2013: Pacific golden plover (*Pluvialis fulva*), Pacific reef heron (*Egretta sacra*), ruddy turnstone (*Arenaria interpres*), and white-tailed tropicbird (*Phaethon lepturus*). Red junglefowl (*Gallus gallus*) (chickens) were observed in 2008 and detected, but not recorded, during 2013 surveys. Orange-cheeked waxbills were detected during 2013 surveys, but not in 2008.

Changes in species' population densities over time were assessed using data from the 1982, 1996, 2008, and 2013 surveys. Analyses were conducted using repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, NC) (Table 7 and Appendix A). Survey data used for these analyses were limited to the 10 transects and 161 stations that were surveyed during each of the 1982, 1996, 2008, and 2013 surveys (Table 2 and Appendix A: Supplement 5). Population abundances within habitat types were compared across 2008 and 2013 using two-sample z-tests following methods described in Camp et al. (2012). Comparisons within habitat types were limited to the 2008 and 2013 data because habitat area data for these surveys were collected in 2006, and so wouldn't necessarily apply to the 1982 and 1996 surveys.

Table 7. Results of Repeated Measures Analysis of Variance for Trends in Tinian Forest Bird Densities among Different Time Series

			Differences of Least Squares Means																	
	Fixed Effects		***1982−1996***			***1982−2008***			***1982−2013***			***1996−2008***			***1996−2013***			***2008-2013***		
Species	$F_{3,480}$	***P***	***Est (SE)***	t_{480}	***Adj-P***	***Est (SE)***	t_{480}	***Adj-P***	***Est (SE)***	t_{480}	***Adj-P***	***Est (SE)***	t_{480}	***Adj-P***	***Est (SE)***	t_{480}	***Adj-P***	***Est (SE)***	t_{480}	***Adj-P***
BRWE	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	-0.10 (0.07)	-1.50	0.437	-0.09 (0.07)	-1.40	0.502	0.01 (0.07)	0.11	1.000
COKI	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	-0.35 (0.03)	-10.17	<0.001	0.03 (0.03)	0.84	0.834	0.38 (0.03)	11.02	<0.001
ISCD	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	0.03 (0.03)	1.08	0.700	-0.09 (0.03)	-3.21	0.008	-0.12 (0.03)	-4.29	<0.001
MAFD	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	-0.25 (0.03)	-8.62	<0.001	-0.11 (0.03)	-3.99	<0.001	0.13 (0.03)	4.63	<0.001
MIMY	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	-0.33 (0.03)	-11.25	<0.001	-0.27 (0.03)	-9.13	<0.001	0.06 (0.03)	2.11	0.150
MIST	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	-0.89 (0.08)	-10.73	<0.001	-0.81 (0.08)	-9.66	<0.001	0.09 (0.08)	1.07	0.710
RUFA	19.86	<0.001	-0.27 (0.10)	-2.70	0.036	-0.71 (0.10)	-7.08	<0.001	-0.57 (0.10)	-5.63	<0.001	-0.44 (0.10)	-4.39	<0.001	-0.30 (0.10)	-2.94	0.018	0.15 (0.10)	1.45	0.468
TIMO	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	0.21 (0.12)	1.77	0.289	-0.25 (0.12)	-2.08	0.162	-0.46 (0.12)	-3.85	<0.001
WTGD	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	-0.18 (0.03)	-6.58	<0.001	-0.22 (0.03)	-7.70	<0.001	-0.03 (0.03)	-1.12	0.680

Notes: BRWE = bridled white-eye, COKI = collared kingfisher, ISCD = island collared-dove, MAFD = Mariana fruit-dove, MIMY = Micronesian myzomela, MIST = Micronesian starling, RUFA = rufous fantail, TIMO = Tinian monarch, and WTGD = white-throated ground-dove.
$F_{3,480}$ = F-value with degrees of freedom 3 and 480.
P = p-value.
Est (SE) = comparison estimate and standard error.
t_{480} = t-value with degrees of freedom 480.
Adj-P = multiple comparison adjusted p-value.

2.5.1 Bridled White-eye

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 were relatively similar, with a high of approximately 470,000 birds and a density of 48 birds/ha in 1982 and a low of 402,000 birds and a density of 41 birds/ha in 1996 (Table 8); the 2013 estimate was slightly higher than the 2008 estimate. Density estimates were also similar across all years with a higher estimate in 2013 compared to 2008 (Table 9 and Appendix A: Figure 1a). In terms of density by habitat type, there were significant decreases from 2008 to 2013 in herbaceous scrub and tangantangan habitats (Table 10; Appendix A: Figure 1b). Overall, the trend for bridled white-eye abundance and density since 1982 has been stable (Tables 7, 8, and 9).

2.5.2 Collared Kingfisher

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied greatly, with a high of approximately 7,300 birds and a density of 0.75 birds/ha in 2008, and a low of 842 birds and a density of 0.09 birds/ha in 1982 (Tables 8 and 9; Appendix A: Figure 2a). 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 type, there were significant decreases in density from 2008 to 2013 in limestone forest, secondary forest, and tangantangan habitats (Table 10; Appendix A: Figure 2b). Although there was a decrease in abundance and density from 2008 to 2013, the overall trend for collared kingfisher abundance and density between 1982 and 2013 is increasing (Tables 7, 8, and 9).

2.5.3 Island Collared-dove

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied from a high of approximately 4,500 birds and a density of 0.47 birds/ha in 2013, to a low of 1,250 birds and a density of 0.13 birds/ha in 1982 (Tables 8 and 9; Appendix A: Figure 3a). In terms of density by habitat type, there were significant increases in density from 2008 to 2013 in limestone forest and secondary forest habitats (Table 10; Appendix A: Figure 3b). The overall trend for island collared-dove abundance and density between 1982 and 2013 is increasing (Tables 7, 8 and 9).

2.5.4 Mariana Fruit-dove

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied from a high of approximately 6,600 birds and a density of 0.68 birds/ha in 1982, to a low of 2,445 birds and a density of 0.25 birds/ha in 1996 (Tables 8 and 9; Appendix A: Figure 4a). In terms of density by habitat type, there were significant decreases in density from 2008 to 2013 in herbaceous scrub and tangantangan habitats (Table 10; Appendix A: Figure 4b). The overall trend for Mariana fruit-dove abundance and density between 1982 and 2013 is decreasing (Tables 7, 8, and 9).

2.5.5 Micronesian Myzomela

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied from a high of approximately 16,900 birds and a density of 1.72 birds/ha in 1982, to a low of 5,500 birds and a density of 0.56 birds/ha in 2008 (Tables 8 and 9; Appendix A: Figure 5a). In terms of density by habitat type, there was a significant decrease in density from 2008 to 2013 only in tangantangan habitat (Table 10; Appendix A: Figure 5b). The overall trend for Micronesian myzomela abundance and density between 1982 and 2013 is decreasing (Tables 7, 8, and 9).

Table 8. Estimates of Tinian Forest Bird Species Abundance for 1982, 1996, 2008, and 2013 Surveys Using Data from the 10 Original Transects Surveyed in All Years

Species	*Abundance Estimate**			
	1982	*1996*	*2008*	*2013*
Bridled white-eye	469,621 (437,718−505,745)	402,121 (374,857−432,099)	422,859 (364,671−486,656)	448,493 (404,327−496,508)
Collared kingfisher	842 (516−1,263)	2,746 (1,920−3,815)	7,304 (5,661−9,336)	2,201 (1,605−2,906)
Island collared-dove	1,246 (729−1,875)	3,419 (2,298−4,685)	2,983 (1,892−4,491)	4,555 (3,003−6,441)
Mariana fruit-dove	6,600 (5,203−8,777)	2,445 (1,858−3,274)	5,112 (3,934−6,698)	3,879 (2,970−5,152)
Micronesian myzomela	16,862 (13,473−21,754)	6,675 (4,896−9,247)	5,456 (4,560−6,462)	5,779 (4,768−6,918)
Micronesian starling	18,236 (14,743−21,985)	17,034 (13,375−20,918)	61,957 (50,374−74,221)	40,806 (32,987−49,547)
Rufous fantail	102,677 (86,577−120,007)	123,371 (102,771−142,561)	162,604 (132,469−192,409)	121,331 (104,641−139,837)
Tinian monarch	95,916 (77,491−116,202)	105,352 (84,237−127,758)	56,305 (43,343−70,909)	90,634 (69,311−112,535)
White-throated ground-dove	535 (225−941)	612 (341−941)	2,595 (1,765−3,640)	4,479 (3,077−6,193)

Notes: *Abundance = density x area (95% confidence interval). Estimates are based on the original 10 transects (NB 1 – NB 10, see Table 2) established in 1982 and surveyed across all years.

Table 9. Estimates of Tinian Forest Bird Species Density for 1982, 1996, 2008, and 2013 Surveys Using Data from the 10 Original Transects Surveyed in All Years

Species	*Density Estimate**			
	1982	*1996*	*2008*	*2013*
Bridled white-eye	48.014 ± 1.772 (44.752−51.707)	41.112 ± 1.561 (38.325−44.177)	43.233 ± 3.214 (37.284−49.755)	45.854 ± 2.452 (41.338−50.763)
Collared kingfisher	0.086 ± 0.020 (0.053−0.129)	0.281 ± 0.055 (0.196−0.390)	0.747 ± 0.103 (0.579−0.954)	0.225 ± 0.036 (0.164−0.297)
Island collared-dove	0.127 ± 0.030 (0.075−0.192)	0.350 ± 0.065 (0.235−0.479)	0.305 ± 0.071 (0.193−0.459)	0.466 ± 0.092 (0.307−0.658)
Mariana fruit-dove	0.675 ± 0.102 (0.532−0.897)	0.250 ± 0.040 (0.190−0.335)	0.523 ± 0.078 (0.402−0.685)	0.397 ± 0.061 (0.304−0.527)
Micronesian myzomela	1.724 ± 0.222 (1.377−2.224)	0.682 ± 0.111 (0.501−0.945)	0.558 ± 0.051 (0.466−0.661)	0.591 ± 0.056 (0.487−0.707)
Micronesian starling	1.864 ± 0.189 (1.507−2.248)	1.742 ± 0.192 (1.367−2.139)	6.334 ± 0.635 (5.150−7.588)	4.172 ± 0.426 (3.373−5.066)
Rufous fantail	10.498 ± 0.869 (8.852−12.269)	12.613 ± 1.019 (10.507−14.575)	16.625 ± 1.535 (13.543−19.672)	12.405 ± 0.918 (10.698−14.297)
Tinian monarch	9.806 ± 1.023 (7.923−11.880)	10.771 ± 1.138 (8.612−13.062)	5.757 ± 0.705 (4.431−7.249)	9.266 ± 1.121 (7.086−11.505)
White-throated ground-dove	0.055 ± 0.019 (0.023−0.096)	0.063 ± 0.016 (0.035−0.096)	0.265 ± 0.050 (0.180−0.372)	0.458 ± 0.081 (0.315−0.633)

Notes: *Density = birds/ha ± standard error (95% confidence interval). Estimates are based on the original 10 transects (NB 1 – NB 10, see Table 2) established in 1982 and surveyed across all years.

Table 10. Estimates of Tinian Forest Bird Species Density by Habitat Type for 2008 and 2013 Surveys Using Data from the 10 Original Transects Surveyed in All Years

Species	Year	Habitat Type*			
		LF	HS	SF	TT
Bridled white-eye	2008	38.799 ± 5.710 (28.786−50.738)	**52.039 ± 4.663 (43.374−61.828)**	46.793 ± 3.561 (40.328−54.318)	**56.089 ± 2.968 (50.059−61.812)**
	2013	46.611 ± 4.879 (38.176−56.794)	**35.302 ± 5.724 (24.473−46.134)**	54.146 ± 2.807 (48.759−59.743)	**47.355 ± 2.352 (42.816−52.086)**
		-1.04; 0.30	**-2.27; 0.023**	-1.62; 0.10	**-2.31; 0.021**
Collared kingfisher	2008	**0.656 ± 0.183 (0.336−1.012)**	0.604 ± 0.128 (0.377−0.860)	**0.879 ± 0.130 (0.656−1.179)**	**0.869 ± 0.116 (0.672−1.119)**
	2013	**0.149 ± 0.060 (0.046−0.276)**	0.374 ± 0.082 (0.227−0.550)	**0.230 ± 0.055 (0.133−0.343)**	**0.147 ± 0.032 (0.092−0.215)**
		-2.62; 0.009	-1.52; 0.13	**-4.59; <0.001**	**-5.99; <0.001**
Island collared-dove	2008	**0.121 ± 0.065 (0.027−0.283)**	0.263 ± 0.109 (0.086−0.510)	**0.302 ± 0.078 (0.169−0.470)**	0.312 ± 0.073 (0.189−0.467)
	2013	**0.577 ± 0.212 (0.199−1.010)**	0.363 ± 0.106 (0.188−0.593)	**0.605 ± 0.113 (0.411−0.821)**	0.318 ± 0.081 (0.184−0.498)
		-2.05; 0.040	-0.65; 0.51	**-2.21; 0.027**	-0.05; 0.96
Mariana fruit-dove	2008	0.362 ± 0.096 (0.193−0.576)	**0.812 ± 0.140 (0.580−1.122)**	0.658 ± 0.099 (0.506−0.874)	**0.499 ± 0.081 (0.369−0.675)**
	2013	0.411 ± 0.095 (0.251−0.619)	**0.387 ± 0.083 (0.245−0.565)**	0.481 ± 0.079 (0.354−0.651)	**0.307 ± 0.053 (0.225−0.415)**
		-0.36; 0.72	**-2.61; 0.009**	-1.39; 0.16	**-1.97; 0.048**
Micronesian myzomela	2008	0.409 ± 0.118 (0.197−0.656)	0.930 ± 0.150 (0.650−1.245)	0.975 ± 0.100 (0.789−1.177)	**0.627 ± 0.074 (0.494−0.775)**
	2013	0.573 ± 0.093 (0.395−0.749)	0.615 ± 0.120 (0.408−0.874)	0.740 ± 0.081 (0.588−0.904)	**0.436 ± 0.048 (0.350−0.536)**
		-1.09; 0.28	-1.65; 0.10	-1.83; 0.07	**-2.16; 0.031**
Micronesian starling	2008	5.993 ± 0.839 (4.398−7.583)	5.663 ± 0.947 (3.956−7.466)	5.137 ± 0.513 (4.161−6.189)	4.660 ± 0.428 (3.856−5.520)
	2013	4.230 ± 1.073 (2.257−6.422)	4.303 ± 0.721 (2.961−5.771)	4.169 ± 0.408 (3.391−5.032)	3.986 ± 0.463 (3.080−4.941)
		-1.29; 0.20	-1.14; 0.25	-1.48; 0.14	-1.07; 0.29
Rufous fantail	2008	12.944 ± 2.958 (7.691−19.545)	**14.991 ± 2.655 (10.060−20.367)**	**21.885 ± 2.436 (17.429−26.979)**	**18.681 ± 1.767 (15.310−22.187)**
	2013	14.099 ± 1.736 (10.692−17.473)	**7.430 ± 1.267 (4.977−9.875)**	**15.720 ± 1.198 (13.459−18.216)**	**12.370 ± 1.073 (10.317−14.574)**
		-0.34; 0.74	**-2.57; 0.010**	**-2.27; 0.023**	**-3.05; 0.002**
Tinian monarch	2008	7.361 ± 1.763 (4.284−10.912)	5.001 ± 1.249 (2.793−7.773)	9.510 ± 1.265 (7.084−12.221)	**6.828 ± 0.963 (5.049−8.715)**
	2013	11.049 ± 2.899 (5.506−16.645)	4.994 ± 1.025 (3.136−7.067)	10.902 ± 1.253 (8.578−13.458)	**10.119 ± 1.095 (8.097−12.366)**
		-1.09; 0.28	-0.01; 0.99	-0.78; 0.43	**-2.26; 0.024**
White-throated ground-dove	2008	0.362 ± 0.118 (0.143−0.609)	0.407 ± 0.131 (0.159−0.682)	0.448 ± 0.093 (0.275−0.653)	0.144 ± 0.040 (0.074−0.225)
	2013	0.568 ± 0.247 (0.147−1.108)	0.489 ± 0.136 (0.249−0.778)	0.615 ± 0.097 (0.447−0.831)	0.160 ± 0.036 (0.097−0.240)
		-0.75; 0.45	-0.44; 0.66	-1.23; 0.22	-0.30; 0.77

Notes: Density = birds/ha ± standard error (95% confidence interval). Estimates are based on the original 10 transects (NB 1 – NB 10, see Table 2) and surveyed across both years. Data for 2008 in first two rows; for 2013 in second two rows; results of two-sample z-tests (z-value, p-value) in last row. **Bold** cells are statistically different between years. LF = limestone forest, HS = herbaceous scrub, SF = secondary forest, TT = tangantangan.

Table 11. Estimates of Tinian Forest Bird Species Abundance by Habitat Type for 2008 and 2013 Surveys Using Data from the 10 Original Transects Surveyed in All Years

		*Habitat Type**			
Species	***Year***	***LF***	***HS***	***SF***	***TT***
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)
Collared 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)
Island 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)
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)
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)
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)
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)
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)

Notes: *Abundance = density x area (95% confidence interval). Estimates are based on the original 10 transects (NB 1 – NB 10, see Table 2) and surveyed across both years.
LF = limestone forest, HS = herbaceous scrub, SF = secondary forest, TT = tangantangan.

2.5.6 Micronesian Starling

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied from a high of approximately 62,000 birds and a density of 6.33 birds/ha in 2008, to a low of 17,000 birds and a density of 1.74 birds/ha in 1996 (Tables 8 and 9; Appendix A: Figure 6a). In terms of density by habitat type, there were no significant changes in density from 2008 to 2013 (Table 10; Appendix A: Figure 6b). The overall trend for Micronesian starling abundance and density between 1982 and 2013 is increasing (Tables 7, 8, and 9).

2.5.7 Rufous Fantail

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied greatly, with a high of approximately 162,600 birds and a density of 16.62 birds/ha in 2008, and a low of 102,700 birds and a density of 10.5 birds/ha in 1982 (Tables 8 and 9; Appendix A: Figure 7a). While the 2013 estimates showed a strong decrease in rufous fantail abundance and density compared to 2008, the 2013 estimates were similar to the 1996 estimates. In terms of density by habitat type, there were significant decreases in density from 2008 to 2013 in herbaceous scrub, secondary forest, and tangantangan habitats (Table 10; Appendix A: Figure 7b). Although there was a decrease in abundance and density from 2008 to 2013, the overall trend for rufous fantail abundance and density between 1982 and 2013 is increasing (Tables 7, 8, and 9).

2.5.8 Tinian Monarch

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied greatly, with a high of approximately 105,300 birds and a density of 10.77 birds/ha in 1996, and a low of 56,300 birds and a density of 5.76 birds/ha in 2008 (Tables 8 and 9; Appendix A: Figure 8a). While the 2013 estimates showed a strong increase in Tinian monarch 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 type, there was significant increase in density from 2008 to 2013 in tangantangan habitat (Table 10; Appendix A: Figure 8b). Although there was an increase in abundance and density from 2008 to 2013, the overall trend for Tinian monarch abundance and density between 1982 and 2013 has been stable (Tables 7, 8, and 9).

2.5.9 White-throated Ground-dove

Abundance and density estimates across the four surveys conducted in 1982, 1996, 2008, and 2013 varied greatly and showed an increase across all years, with a high of approximately 4,500 birds and a density of 0.46 birds/ha in 2013, and a low of 535 birds and a density of 0.06 birds/ha in 1982 (Tables 8 and 9; Appendix A: Figure 9a). In terms of density by habitat type, there were no significant changes in density from 2008 to 2013 (Table 10; Appendix A: Figure 9b). Overall, the trend for white-throated ground-dove abundance and density between 1982 and 2013 is increasing (Tables 7, 8, and 9).

2.5.10 MBTA-protected Species

Of the native bird species for which population densities and abundances could be estimated, three are protected under the MBTA: collared kingfisher, Mariana fruit-dove, and white-throated ground-dove. Collared kingfisher and white-throated ground-dove showed increasing population trends between 1982 and 2013 (Tables 7 and 8; Appendix A: Figures 1a and 9a). Mariana fruit dove showed decreasing population trends between 1982 and 2013 (Tables 7 and 8; Appendix A: Figure 4a).

CHAPTER 3
MICRONESIAN MEGAPODE SURVEYS

3.1 OVERVIEW OF THE MICRONESIAN MEGAPODE

The Micronesian megapode (*sasangat* in Chamorro and *sasangal* in Carolinian) is a pigeon-sized bird of the forest floor endemic to the Mariana Islands (CNMI and Guam). It relies primarily on native limestone forest and, to a lesser extent, native and non-native secondary forest as its primary habitat for foraging and shelter. In addition to using its preferred forest habitat for mound-building and burrow-nesting to provide decompositional heat for incubating its eggs, it may also nest at geothermal sites and cinder fields where volcanic activity and the sun provide incubation heat (USFWS 1998; Amidon et al. 2011).

Micronesian Megapode
(Source: S. Vogt)

The Micronesian megapode was listed as endangered by the USFWS in 1970. It was once found throughout the Mariana Islands but no longer occurs on Guam and Rota. Large populations of the Micronesian megapode are still found on (in order of most to least abundant): Asuncion, Sarigan, Guguan, Alamagan, Maug, Saipan, and Pagan. Smaller populations occur on (also in order of most to least abundant) Aguiguan, Farallon de Medinilla, Agrihan, Tinian, and Anatahan (Amidon et al. 2011). The megapode was thought to no longer occur on Anatahan following volcanic eruptions there from 2003 to 2005, but recolonization may have occurred, with observations of Micronesian megapodes on Anatahan in 2010 (Kessler 2011). On Tinian, Micronesian megapode observations have been concentrated along the escarpments associated with Mount Lasso, but the species is thought to be transient on Tinian, as breeding has not been documented and individuals are rarely observed.

Currently the main threats to the megapode are loss and degradation of habitat due to forest clearing, disruption due to feral ungulates, and predation by introduced species such as monitor lizards, dogs, cats, and pigs. The potential introduction of the brown treesnake from Guam to the CNMI is an additional threat (USFWS 1998; Amidon et al. 2011).

3.2 SURVEY LOCATIONS AND DESCRIPTION

Surveys for the Micronesian megapode were conducted using the same survey methods used by the USFWS for their megapode surveys on Tinian in 2008 (USFWS 2009a) and on other islands in the CNMI in 2010 (Amidon et al. 2011). In 2008, the USFWS sampled a total of 21 stations along 3 transects on Tinian (Table 12). In 2013, a total of 34 stations along 5 transects were sampled between June 12 and 17, 2013 (Figure 6, Table 12).

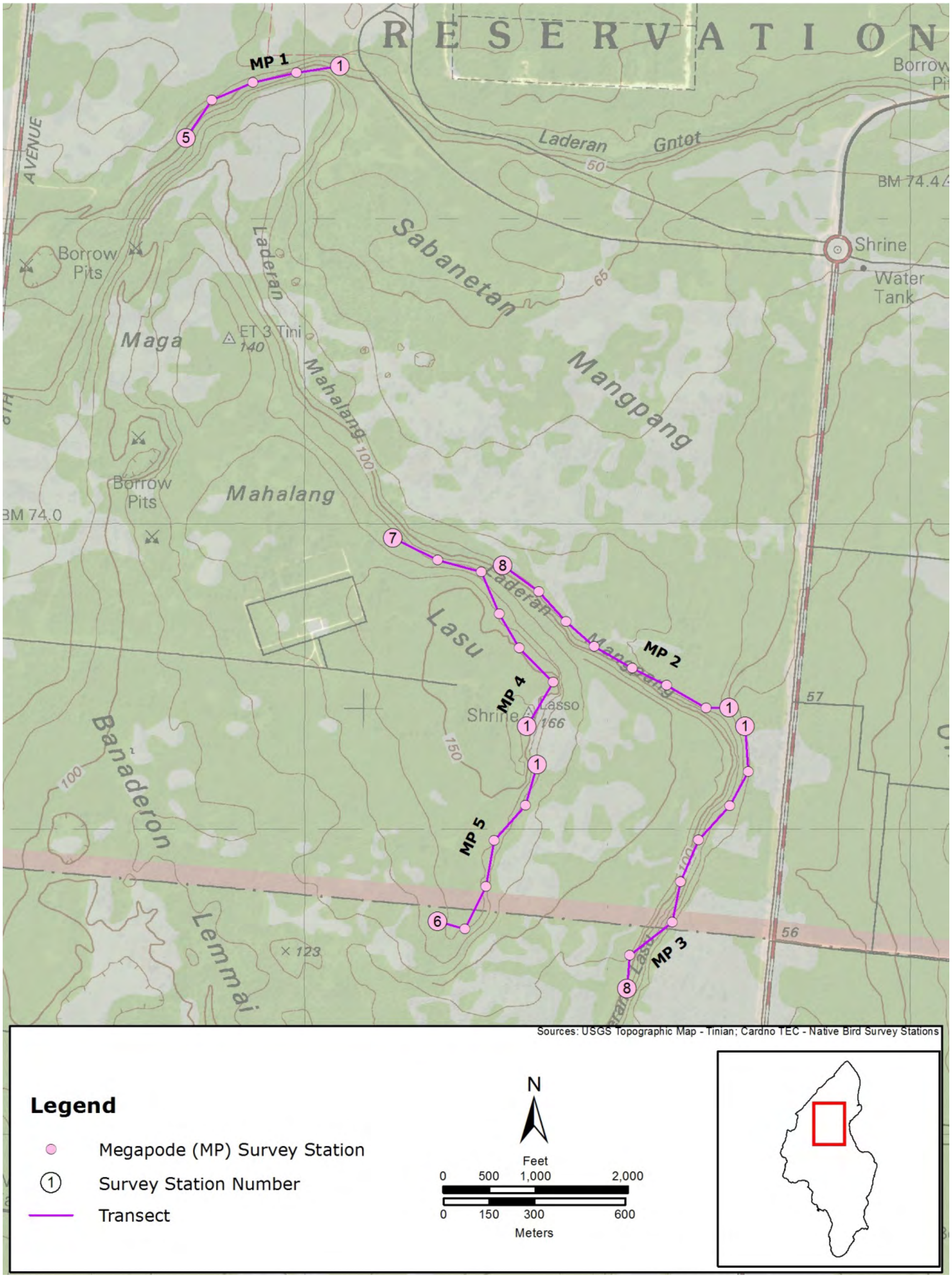

Figure 6. Northern Tinian Micronesian Megapode Transects and Stations in 2013

Table 12. Micronesian Megapode (MP) Transects and Stations Surveyed on Tinian

Transect	*2013 Survey Dates*	*Number of 2008 USFWS Survey Stations*	*Number of 2013 Survey Stations*
MP 1	June 12, 13	5	5
MP 2	June 16, 17	8	8
MP 3	June 16, 17	8	8
MP 4	June 14, 15	NA	7
MP 5	June 14, 15	NA	6
	Total	**21**	**34**

Notes: Refer to Figure 6 for the locations of transects and stations. NA = not applicable.

Descriptions of the habitat types identified during the 2013 megapode surveys on Tinian are listed below. These descriptions are based on habitat names used by Engbring et al. (1986).

- Limestone forest – characterized by native broadleaf species with a variable species composition depending on soil and moisture conditions. Common native tree genera found in this habitat type include *Aglaia, Artocarpus, Cynometra, Elaeocarpus, Eugenia, Ficus, Guamia, Hernandia*, *Intsia, Mammea, Melanolepis, Neisosperma, Ochrosia, Pandanus, Pisonia,* and *Premna*. Almost all the native forest on Tinian is present along cliffs and nearby steep slopes.
- Secondary forest – forms after the removal of native forest. It is characterized as primarily introduced species of mixed shrubs, small trees, vines, bamboo, and various grass species. Dominant tree species include tangantangan, Formosan koa, siris tree, coconut palm, and flame tree.

Table 13 provides a summary of the habitat types found along each transect based on observations at each survey station.

Table 13. Habitat Types on Megapode (MP) Survey Transects

Transects	*General Habitat*
MP 1, MP 3, MP 5	Limestone forest
MP 2, MP 4	Limestone forest with sparse pockets of secondary forest

3.3 METHODS

The survey at each station consisted of a 3-minute survey that included a 30-second broadcast of a taped playback using a USFWS-supplied Micronesian megapode call (using a FOXPRO NX3 or NX4 game caller) followed by 2.5 minutes of observation with no playback. Surveys were conducted twice, on different days, at each station. Estimated horizontal distance to all megapodes heard and/or seen during the survey was recorded. Additional data collected for each observation included direction of the bird from the survey point and time of detection. Data collected at each survey point included habitat type, percent cloud cover, rain and wind conditions, and understory and canopy openness. Surveys were conducted between sunrise and 11 a.m. and between 2 p.m. and 6 p.m. Individuals that conducted playback surveys were authorized to do so under USFWS ESA Permit TE-096741-4, and included Rick Spaulding, Nathan Johnson, and Pete Reynolds.

3.4 RESULTS

No Micronesian megapodes were detected either visually or aurally during the 2013 surveys.

3.5 DISCUSSION

Just as in the USFWS's 2008 surveys, no Micronesian megapodes were detected during the 2013 surveys. Megapodes are rarely recorded on Tinian. Detections of single megapodes were recorded on Tinian in 1985, 1995, 2000, 2001, 2004, 2005, 2009, and 2013 (Wiles et al. 1987; O'Daniel and Krueger 1999; Cruz et al. 2000; Witteman 2001; Vogt 2008; P. Radley, CNMI DFW, pers. comm. 2010; P. Wenninger, Naval Facilities Engineering Command [NAVFAC] Marianas, pers. comm. 2013). These detections of single individuals have consistently occurred within the Maga area (particularly within the area of transects MP 1 and MP 4) (Figure 6) (Wiles et al. 1987; O'Daniel and Krueger 1999; Witteman 2001; Vogt 2008), as well as north of Cross Island Road, just south of Bateha (O'Daniel and Krueger 1999), and south of the MLA along the southeastern cliffline forests near Puntan Kastiyu (Cruz et al. 2000) (Figure 2). These past observations are thought to be of transient megapodes, possibly from Saipan or Aguiguan, as there is not currently a breeding population of Micronesian megapodes on Tinian (Witteman 2001; Vogt 2008).

CHAPTER 4
MARIANA COMMON MOORHEN SURVEYS

4.1 OVERVIEW OF THE MARIANA COMMON MOORHEN

Mariana Common Moorhen
(Source: S. Vogt)

The Mariana common moorhen (*pulattat* in Chamorro and *ghereel bweel* Carolinian) is a bird species endemic to the Mariana Islands (CNMI and Guam) and is a subspecies of the common moorhen. It relies on emergent vegetation of freshwater marshes, ponds, and placid rivers for breeding, foraging, and shelter. Its preferred habitat includes freshwater lakes, marshes, and swamps. Man-made as well as natural wetlands are utilized, and moorhens have been observed at commercial fish ponds, sewage treatment plants, and reservoirs. The key characteristics of optimal moorhen habitat are a combination of deep marshes bordered by robust emergent vegetation, and equal areas of cover and open water. The USFWS recovery plan for the Mariana common moorhen identifies Lake Hagoi as primary habitat for the species (USFWS 1991, 2009b).

The Mariana common moorhen was listed as endangered by the USFWS in 1984. It was originally found on the islands of Guam, Tinian, Saipan, and Pagan, but became extirpated from Pagan when Mount Pagan erupted in 1981. On Rota, moorhen observations are limited to the wastewater treatment ponds operated by Rota Resort. The main threat to the moorhen is loss and degradation of wetland habitat, including filling, alteration of hydrology, invasion of habitat by non-native plants, and unrestricted grazing. The second greatest threat is predation by introduced species (USFWS 1991, 2009b).

4.2 SURVEY LOCATIONS AND DESCRIPTION

Wetland habitats on Tinian are discrete areas of impermeable clay that impound rainwater. There are three potential wetlands areas within the MLA: Lake Hagoi, a permanent wetland and open water complex of approximately 38 ac (15 ha); the Mahalang Complex, an area consisting of a number of potential ephemeral wetlands; and the Bateha sites consisting of two potential wetlands (Figure 7: BD1 and BD2). The Mahalang and Bateha sites were recently mapped and described in detail (DoN 2013c, 2014). Although a wetland delineation has not been conducted for Lake Hagoi, it is considered jurisdictional under Section 404 of the Clean Water Act by the Guam office of the U.S. Army Corps of Engineers.

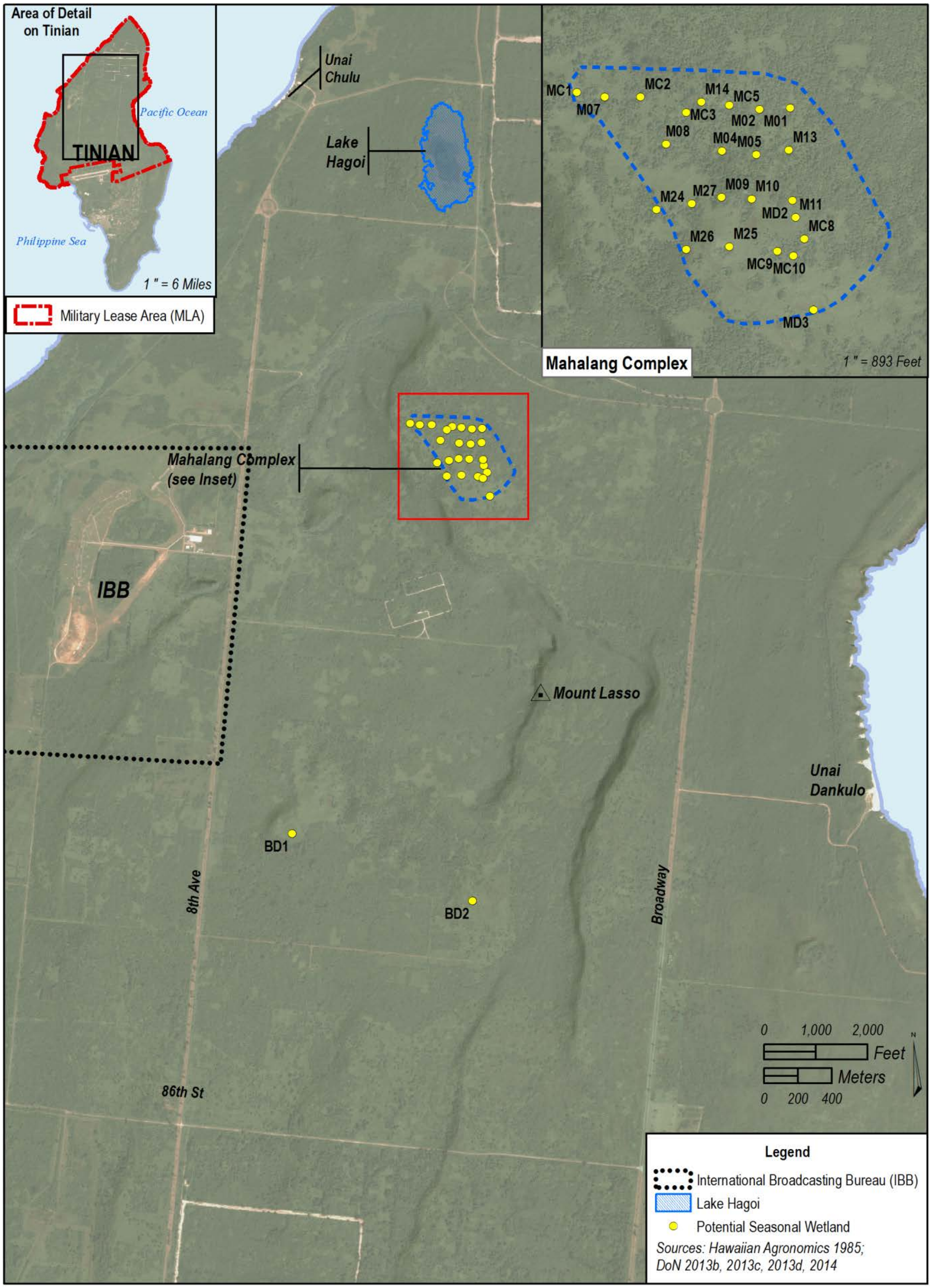

Figure 7. Potential Seasonal Wetlands within the MLA

4.2.1 Lake Hagoi

A 1995 USFWS vegetation map of Lake Hagoi (USFWS 1996) showed a band of the reed *Phragmites karka* and large patches of the bulrush *Schoenoplectus litoralis* around the perimeter of Lake Hagoi. There were also patches of the fern *Acrostichum aureum* and the grass *Paspalum distichum*. All of these species are indigenous to Tinian (Raulerson 2006). As of 2012, vegetation appears to have changed relative to that mapped in 1995 with the occurrence of additional species, such as the indigenous tree *Hibiscus tiliaceus,* and the expansion of existing species into previously open water areas of the lake, particularly *Schoenoplectus litoralis*. In addition, the vegetation has been continually changing over the past 50 years, particularly with the expansion of *Schoenoplectus litoralis* into the perimeter of Lake Hagoi. This expansion of vegetation into the wetland has resulted in a reduction of open water, with particularly rapid changes documented between 2001 and 2013 (DoN 2013a).

4.2.2 Mahalang Complex

The Mahalang Complex is located on a flat area south of Lake Hagoi (Figure 7). More than 20 individual potential wetlands form the complex and are located within a matrix of grasslands, herbaceous scrub, tangantangan, and mixed secondary forest. Although sizes of these sites were not given in previous reports, AECOS and Wil Chee Planning (2009) estimated the two largest features as approximately 1.2 ac (0.5 ha) each. The majority of the potential wetlands are characterized as likely bomb craters resulting from the detonation of stored munitions after World War II (DoN 2014). The introduced grass *Pennisetum polystachion*, mixed with various species of weedy vines, dominates the sides of the craters. Other potential wetlands in the complex consist of shallow depressions with weedy vines and herbs. Two of the potential wetlands contain a dense covering of the introduced, obligate wetland species *Ipomoea aquatica* (DoN 2013c).

4.2.3 Bateha Sites

The Bateha sites consist of two shallow depressional potential wetland areas formed as a result of man-made berms that collect water during wet periods (Figure 7). These areas are approximately 1-2 ac (0.4-0.8 ha) each. Numerous other small areas, previously identified as potential wetlands, did not have the characteristics of seasonal wetlands as of 2012. The larger potential wetland (BD1) is dominated by the introduced, sprawling sub-shrub *Mimosa invisa* during the dry season and also contains the introduced facultative wetland shrub *Cassia alata* along with other weedy species. *Pennisetum polystachion* and *Hibiscus tiliaceus* occur along the perimeter. The other potential wetland (BD2) is a deeper depression surrounded by ridges dominated by an overstory of the introduced Formosan koa and *Pennisetum polystachion*. *Cassia alata* is dispersed throughout this site (DoN 2014).

4.3 METHODS

Taped playback surveys for the Mariana common moorhen were conducted at Lake Hagoi, the Mahalang Complex, and the Bateha sites. A total of 14 survey points (3 at Lake Hagoi, 9 at Mahalang, and 2 at Bateha) were surveyed between November 15 and 16, 2013 to determine the presence of Mariana common moorhens (Figures 8, 9, and 10; Table 14). Selection of the 14 sites to survey was determined based on previous site surveys conducted by NAVFAC Marianas (DoN 2014) and NAVFAC Pacific (DoN 2013c), and the conditions of each site at the time of the survey (i.e., presence of standing water).

Table 14. Sites Surveyed on Tinian (November 2013)

Site	*Survey Date*
M01	November 15, 2013
M02	
MC5	
M07	
MC1	
MD3	
MC9	
MC10	
MD2	
BD2	
BD1	November 16, 2013
Hagoi 1	
Hagoi 2	
Hagoi 3	

Survey points were established at each site at locations that provided the widest possible view of open water while providing maximum cover for observers and were spaced no closer than 328 feet (ft) (100 meters [m]) apart. The survey at each site consisted of a 60-second broadcast of a taped playback using a CNMI DFW-supplied Mariana common moorhen call (using a FOXPRO NX3 or NX4 game caller), followed by 5 minutes of passive listening. Data collected during the passive listening period was recorded at 3 minutes and again at 5 minutes to determine the optimal passive listening time for future studies. The sequence of playback and passive listening was repeated twice for a total of 180 seconds of playback and 15 minutes of passive listening at each survey point. Observers remained hidden during playbacks. Surveys were conducted between 30 minutes before local sunrise and 120 minutes after local sunrise. Individuals that conducted playback surveys were authorized to do so under USFWS ESA Permit TE-096741-4, and included Rick Spaulding, Lainie Zarones, and Nathan Johnson.

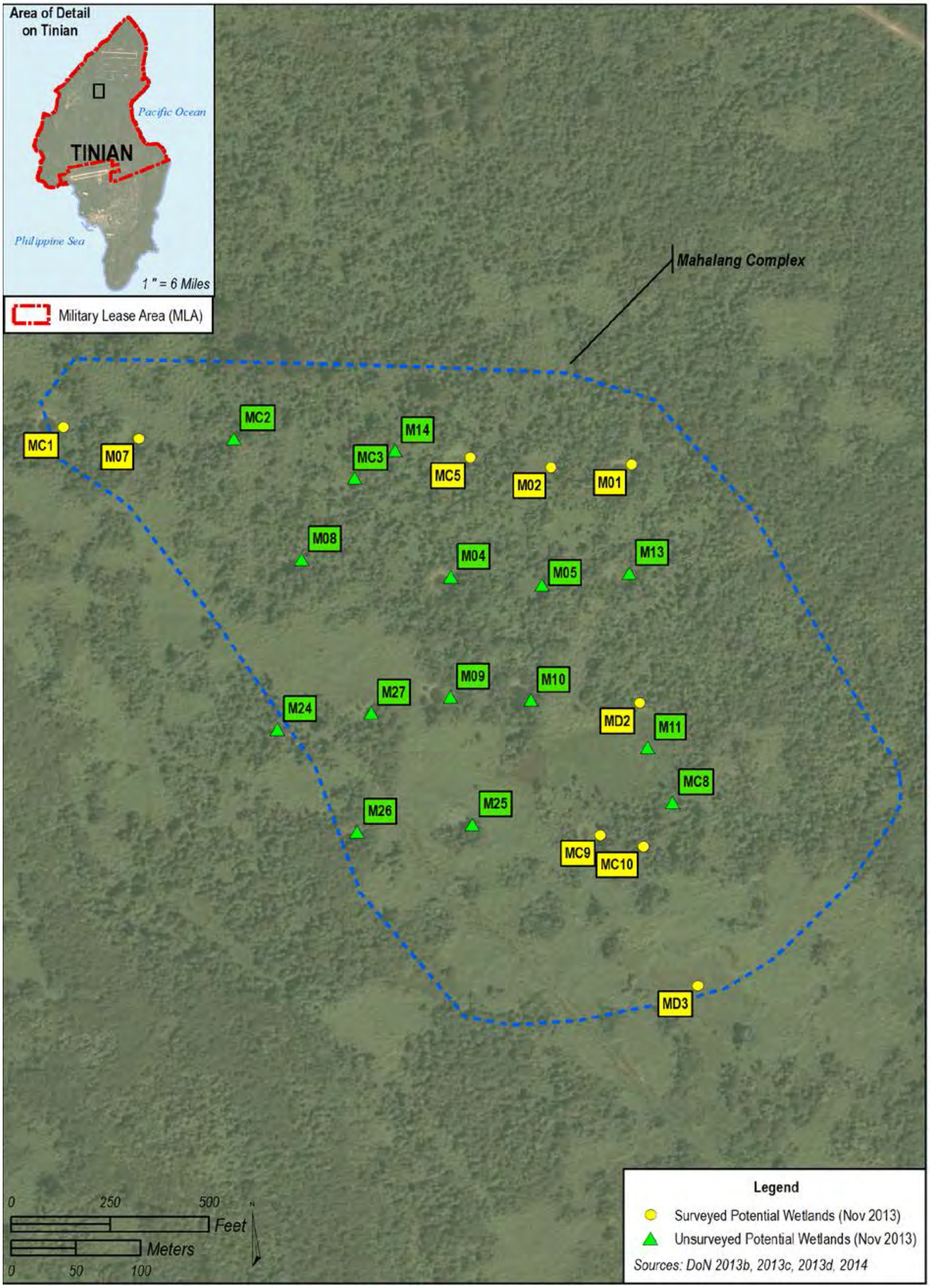

Figure 8. Mariana Common Moorhen Surveys – Mahalang Complex

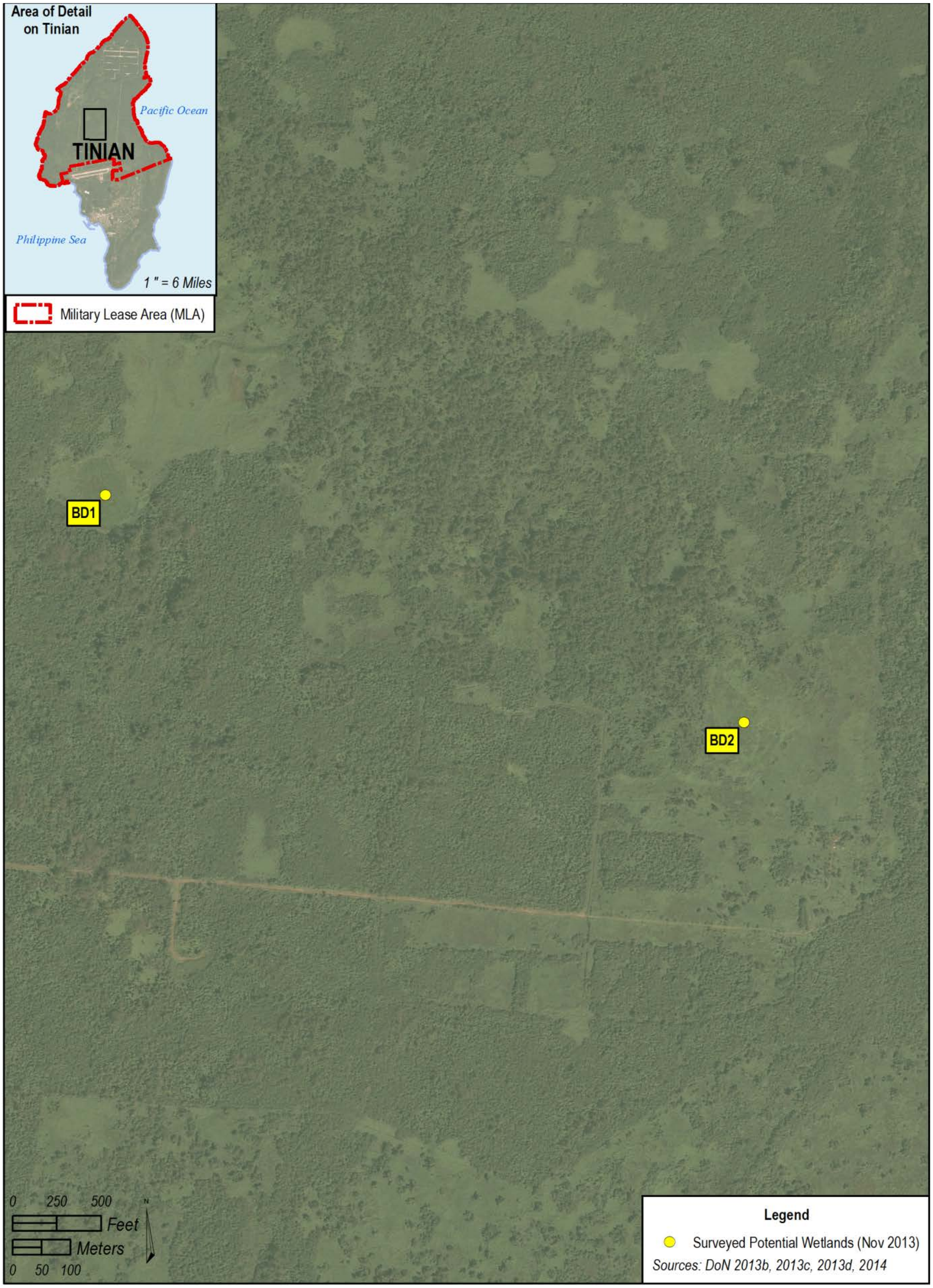

Figure 9. Mariana Common Moorhen Surveys – Bateha Sites

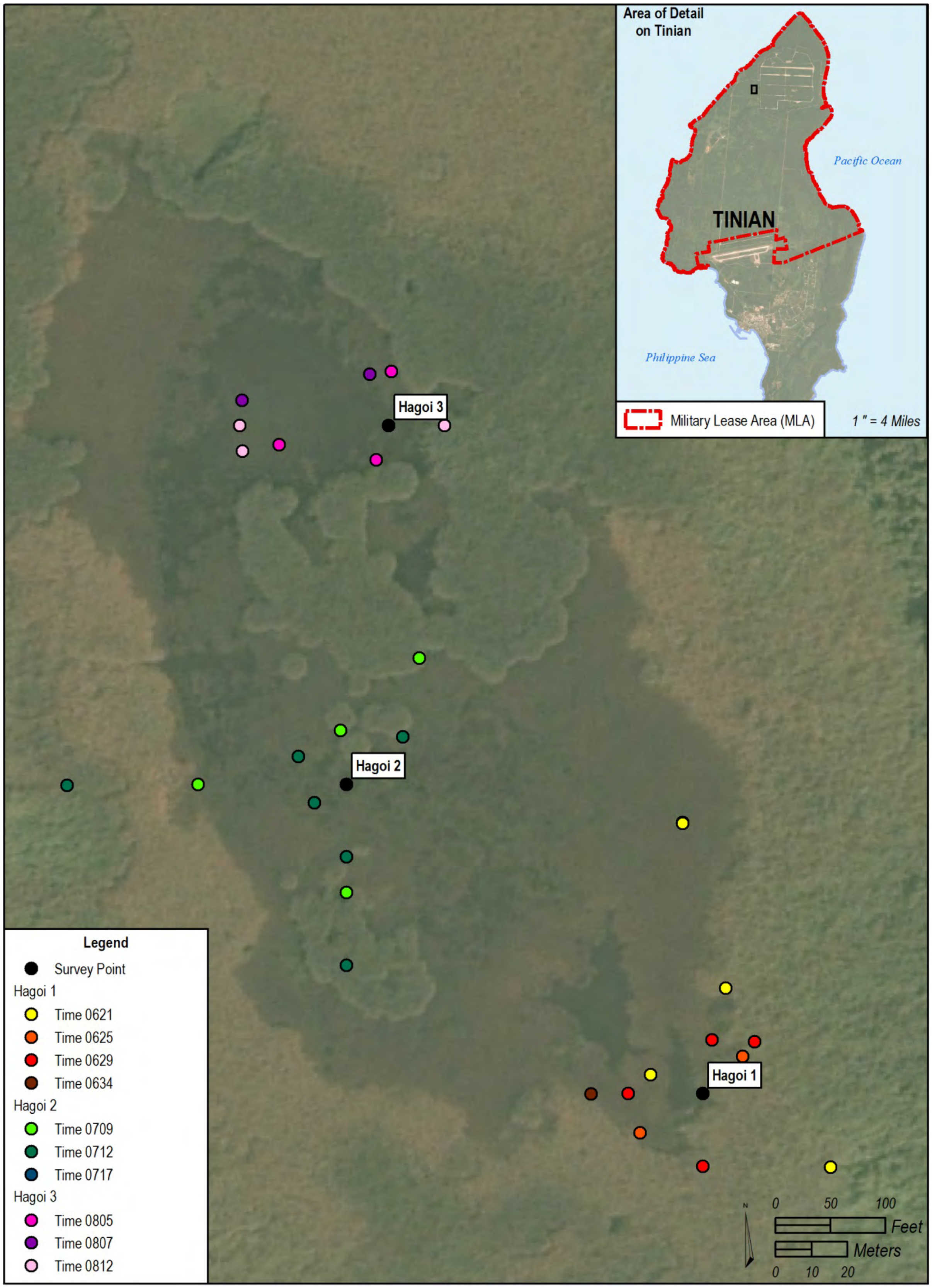

Figure 10. Mariana Common Moorhen Detections – Lake Hagoi

4.4 RESULTS

4.4.1 Lake Hagoi

At Lake Hagoi, 7 – 8 individual moorhens were heard at survey points Hagoi 1 and Hagoi 2, and 6 – 7 individual moorhens were heard at Hagoi 3 (Figure 10, Table 15). Visual observations of moorhens were not possible due to the density of the vegetation (e.g., *Schoenoplectus litoralis*, *Acrostichum aureum*); thus, determining age and behavior of the detected moorhens was not possible. Given the distance between Hagoi 1, 2, and 3, and the estimated locations of each moorhen, it is unlikely that double-counting of moorhens occurred. Therefore, the results of the playback surveys yielded approximately 20 – 23 individual moorhens at Lake Hagoi based on detections from the three survey points.

Table 15. Moorhen Detections during Surveys on Tinian: November 15-16, 2013

Site	*Moorhen Detections (V/A)**
Hagoi 1	7-8 birds – unknown age and behavior (A)
Hagoi 2	7-8 birds – unknown age and behavior (A)
Hagoi 3	6-7 birds – unknown age and behavior (A)
M01	None
M02	None
MC5	None
M07	None
MC1	None
MD3	None
MC9	None
MC10	None
MD2	None
BD2	None
BD1	2 adults, 2 juveniles – all feeding (V)

Notes: *V = visual, A = auditory.

4.4.2 Mahalang and Bateha Sites

Within the Mahalang and Bateha sites, moorhens were only detected at BD1 (Table 14). Two adult and two juvenile moorhens were observed feeding at BD1 on November 16, 2013.

4.4.3 Other Avian Species Detected

Additional avian species detected during the surveys included: Eurasian wigeon (*Anas penelope*) (one at BD1), mallard (*Anas platyrhynchos*) (one at Hagoi 3), yellow bittern (one at BD1, five at BD2, one at MD3, and three at Hagoi 3), and barn swallow (*Hirundo rustica*) (one at Hagoi 3).

4.5 DISCUSSION

Figure 11 presents a summary of moorhen detections at Lake Hagoi and the Mahalang and Bateha sites on Tinian based on previous survey efforts and the current survey effort.

4.5.1 Lake Hagoi

The current surveys resulted in detection of 20 – 23 individual moorhens at 3 survey points on Lake Hagoi. This is within USFWS's range of 21 – 29 moorhens detected per survey during wet season surveys between July 1994 and August 1995 (DoN 2013c). Surveys conducted at Lake Hagoi by the DoN between November 1998 and September 2013 indicate that total moorhen detections have ranged from 0 to 46 birds per survey, with a mean of 15 individuals per survey (DoN 2014).

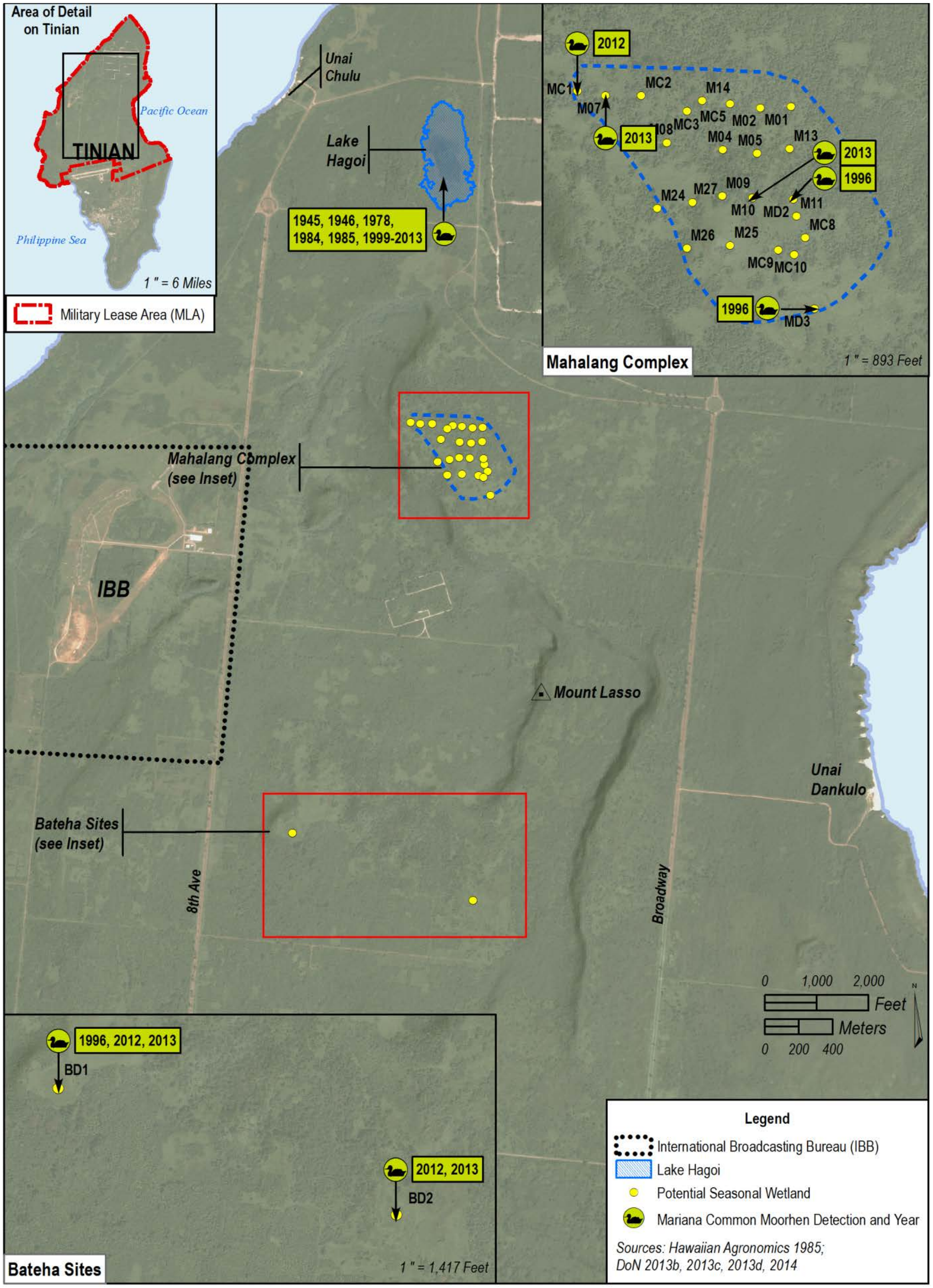

Figure 11. Past and Current Occurrences of Mariana Common Moorhen within the MLA

4.5.2 Mahalang Complex

The current surveys did not detect any moorhens within the Mahalang Complex. However, in conjunction with a separate passive (i.e., taped playback was not used) survey conducted on November 16, 2013, one adult moorhen was observed within M01 (NAVFAC Marianas 2013, unpublished data). Surveys conducted within potential wetland areas of the Mahalang Complex during October 2012 through January 2013 resulted in two detections of adult moorhens within MC1: one in November and one in December. Passive surveys from May through October 2013 detected individual adult moorhens in M07 and M11 (DoN 2014). In addition, a 1996 survey of the complex by the USFWS detected an adult moorhen in MD2 and MD3, but surveys in 2012 and 2013 did not detect any moorhens within these potential wetlands (DoN 2014). As no moorhen nests or chicks have been observed within the potential wetlands of the Mahalang Complex, it is assumed that these potential wetland sites are not used for nesting, but rather as temporary foraging or resting areas by moorhens from either Lake Hagoi or the Bateha sites. Overall, survey data from multiple efforts indicate that up to four individual moorhens may use the Mahalang sites within a single wet season.

4.5.3 Bateha Sites

The current surveys observed two adult and two juvenile moorhens feeding at BD1. Moorhen detections at BD1 are not uncommon: one was observed in October 1994, three were heard during two separate surveys in November 1994, and one subadult was observed in December 1994 (DoN 2013c). Similar to the current survey effort, two adult and two juvenile moorhens were observed feeding at BD1 on October 22, 2012. Between October 2012 and January 2013, a total of 20 moorhen detections were recorded at BD1, including a maximum of 3 visual observations of adults and 4 visual detections of juveniles on both October 22 and November 25, 2012 (DoN 2014).

No moorhens were detected at site BD2 during the current survey effort. However, during a total of 8 surveys conducted at BD2 in 2012 and 2013, a total of 50 moorhen detections were recorded. These included a maximum of 4 visual detections of adults and 3 visual detections of juveniles on November 25, 2012 (DoN 2014).

Overall, survey data from multiple efforts indicate that up to 7 individual moorhens may use each of the Bateha sites within a single wet season, for a total of 14 moorhens at the Bateha sites.

CHAPTER 5
TREE SNAIL SURVEYS

5.1 OVERVIEW OF PARTULID TREE SNAILS

Tree snails (*dendeng* in Chamorro and *denden* in Carolinian) in the family Partulidae inhabit an extraordinarily large area of Oceania from the Austral Islands in the southeastern Pacific, to the Mariana Islands in the central western Pacific. Due to their large distribution and high levels of island endemism, species in the family Partulidae have been considered a scientific center piece for the study of evolution, diversification, and island biogeography (Crampton 1925; Cowie 1992). However, due to environmental sensitivity to a variety of pressures and threats, the family has experienced excessively high levels of extinction and local extirpation (Cowie 1992). Anthropogenic habitat destruction and disturbance from introduced ungulates continue to negatively impact partulid tree snail species. However, perhaps the most insidious threat comes from three intentionally introduced molluscivores that have spread across the Pacific to varying degrees. These include the predatory gastropods wolf snail (*Euglandina rosea*), giant African snail (*Achatina fulica*), and *Gonaxis kibweziensis*; and the predatory Manokwar flatworm (*Platydemus manokwari*) (Murray et al. 1988; Cowie 1992; Miller 1993; Bauman 1996).

Five species of partulid tree snails in two genera are known to occur in the Mariana Islands. Two species, Alifan tree snail (*Partula salifana*) from Guam and Langford's tree snail (*Partula langfordi*) from Aguiguan, have not been seen in recent years and may be extinct. The remaining three species (fragile tree snail [*Samoana fragilis*], Guam tree snail [*Partula radiolata*], and humped tree snail [*Partula gibba*]) have experienced massive range reductions (Hopper and Smith 1992; Smith 2006). Both the Langford's and humped tree snails are candidate species for listing under the ESA (USFWS 2012).

The humped tree snail, the focus of the Tinian surveys, is known to have occurred on Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan (Smith et al. 2008; Kerr 2013). However, due to volcanic activity from 2003 to 2005, this species is possibly extirpated from Anatahan (USFWS 2011a). Tree snail surveys on Tinian and Aguiguan in 2006 and 2008 did not observe any living specimens of the genus *Partula* (Smith 2013). The Langford's tree snail is currently only known to occur on Aguiguan (USFWS 2011b). However, Smith (2013) did not observe any living Langford's tree snails on Aguiguan and suggested that the species may now be extinct. The habitat for both the humped and Langford's tree snails includes most native Mariana forests with high humidity and reduced air movement (USFWS 2011a, 2011b).

5.2 SURVEY LOCATIONS AND DESCRIPTION

No prior distribution details of historical locations of humped tree snails on Tinian were available for these surveys, as little historical data exist. Therefore all survey routes were selected based on the distribution of native limestone forest on Tinian (Figure 12). A total of 15 transects ranging in length from 361 ft (110 m) to 1.1 mi (1.85 km) were surveyed for live individuals of *Partula* species and ground shells (Figure 13).

Figure 12. Native Limestone Forest within the MLA

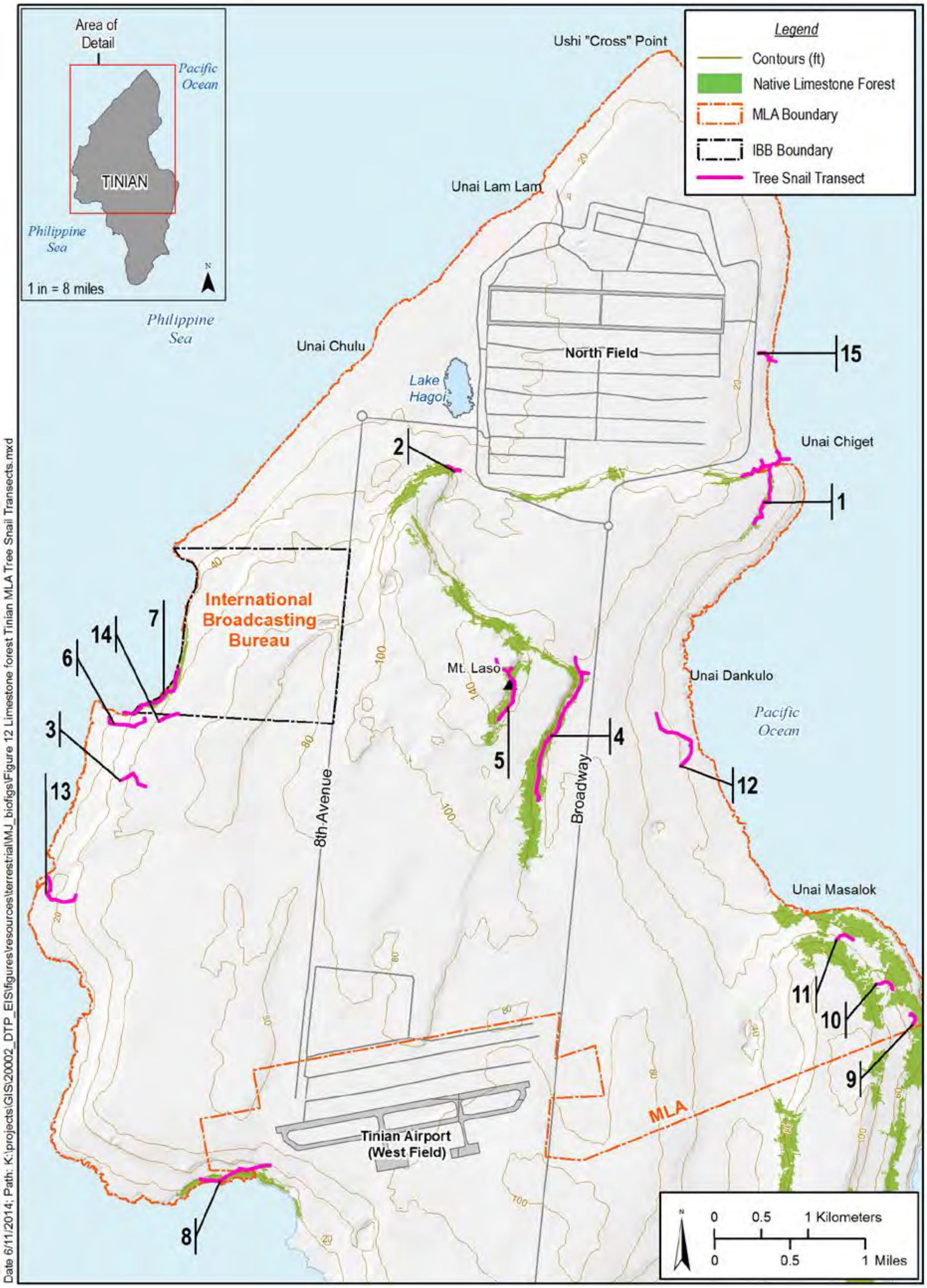

Figure 13. Tree Snail Survey Transects

5.3 METHODS

Partulid tree snail surveys on Tinian were conducted by UHM in June 2013. Tree snail surveys included careful observation and identification of known broad-leafed host plants along survey routes. Plants known to host partulid tree snails on other islands in the Mariana Islands include: *Aglaia mariannensis, Aidia cochichinensis, Alocasia macrorrhiza, Artocarpus mariannensis, Asplenium nidus, Barringtonia asiatica, Carica papaya,* coconut palm, coral tree (*Erythrina variegate*), fig (*Ficus tinctoria*), *Hernandia nymphaeifolia, Mammea odorata, Merrilliodendron megacarpum, Neisosperma oppositifolia, Pandanus dubius,* and *Piper guahamense* (Hopper and Smith 1992; Smith 2006; Hadfield 2010). In addition, the leaf litter at each site was examined closely for the occurrence of empty shells. Gastropod shells tend to persist for many years under certain conditions, and can be an important landmark and indication of both historical distributions, and when fresh intact shells are present, extant populations. Aged, weathered shells appear white and brittle, while fresh shells retain natural color due to remaining periostracum covering the surface of the calcium carbonate shell.

All live snails and ground shells observed along transects were identified to species, genus, or family. Where live *Partula* species were found, detailed demographic data were collected, as well as non-lethal DNA sampling. All observations of Manokwar flatworms, giant African snails, and wolf snails were also noted.

5.4 RESULTS

Of the 14 surveyed transects, live humped tree snails were only observed on 1 transect (Transect 7) and shells of humped tree snails were observed on 7 transects (Table 16).

<u>Transect 1</u>. This site is characterized as native limestone forest with an intact canopy. The forest follows a steep limestone escarpment with many caves. Although no live *Partula* spp. were found, there were abundant native snail shells, including humped tree snails, under a thin layer of dirt and leaf detritus. Shells of giant African snails were present in large quantities often piling up at the base of the limestone escarpment (Figure 14). They were found on top of the native snail shell layer, indicating the giant African snail die-off occurred after the humped tree snail had been extirpated from the area.

Figure 14. Pile of Dead Giant African Snails (*Achatina fulica*)
Note: Observed on Transects 1, 4, and 5.

Table 16. Gastropod Observations on Tinian Survey Transects (2013)

Transect	***Length (ft/m)***	***Live Snails Present***	***Shells Present***
1	3,937/1,200	*Liardetia* sp.	*Partula gibba*
		Elasmias sp	*Omphalotropis* sp.
		Lamellidea sp.	*Succinea* sp.
			Pythia sp.
			Achatina fulica
2	361/110	*Liardetia* sp.	*Partula gibba*
		Elasmias sp	*Omphalotropis* sp.
		Lamellidea sp.	*Succinea* sp.
			Pythia sp.
			Achatina fulica
3 12	1,214/370 3,117/950	None	None
4	6,070/1,850	*Liardetia* sp.	*Partula gibba*
		Elasmias sp	*Omphalotropis* sp.
		Lamellidea sp.	*Pythia* sp.
			Achatina fulica
			Euglandina rosea
			Gastropcopta sp.
			Gonaxis sp.
			Subulinidae
			Charopidae
5	3,117/950	*Liardetia* sp.	*Partula gibba*
		Elasmias sp	*Omphalotropis* sp.
		Lamellidea sp.	*Achatina fulica*
			Subulinidae
6	1,640/500	*Liardetia* sp.	*Achatina fulica*
			Omphalotropis
			Diplomatinidae
			Subulinidae
7	2,953/900	*Partula gibba*	*Partula gibba*
		Liardetia sp.	*Achatina fulica*
		Elasmias sp	*Omphalotropis* sp.
		Lamellidea sp.	*Gastrocopta* sp.
			Subulinidae
8	2,592/790	*Elasmias* sp	*Omphalotropis* sp.
		Lamellidea sp.	*Achatina fulica*
			Pythia scarabaeus
9	492/150	None	*Achatina fulica*
			Euglandina rosea
			Subulinidae
10	722/220	*Liardetia* sp.	*Omphalotropis* sp.
		Elasmias sp.	*Succinea* sp.
			Achatina fulica
			Subulinidae
11	705/215	None	*Partula gibba*
			Omphalotropis sp.
			Achatina fulica
			Subulinidae
13	1,936/590	None	*Achatina fulica*
			Subulinidae
14	492/150	None	*Partula gibba*
			Achatina fulica
			Omphalotropis sp.
			Subulinidae
15	847/258	*Omphalotropis* sp.	None
		Truncatella sp.	
		Gastrocopta sp.	

Transect 2. This site contained mixed native and non-native limestone forest with a closed canopy. No live humped tree snails were found; however, many aged shells were present.

Transect 3. This site contained mostly non-native plant species and appears to have been previously cleared. No shells or live snails were observed.

Transect 4. This area is characterized as native limestone forest. The forest here is narrow and occurs close to or directly on the escarpment. Massive piles of giant African snail shells were observed along the base of the escarpment (Figure 14). These shells were on top of a layer of native shells, including humped tree snail, *Omphalotropis* sp., and Charopidae. This is similar to what was observed along the escarpment on Transect 1.

Transect 5. The area is predominantly native limestone forest with a well-developed canopy and what appears to be recent understory growth. No live humped tree snails were found. However, humped tree snail shells were found and habitat appeared suitable for snails.

Transect 6. The habitat was dry and consisted of mostly non-native plants. Despite the conditions being unsuitable for snails, this trail allowed the assessment of the native forest habitat along the crescent shaped bay between Dump Coke North and Dump Coke South. No live *Partula* or shells were observed.

Transect 7. The habitat along the bay had an intact canopy and understory protected by steep limestone cliffs. The forest was dominated primarily by old growth *Barringtonia asiatica* trees, and to a lesser extent, by *Neisosperma oppositifolia.* Within minutes of starting the survey, several live humped tree snails were located. The survey continued from this entry position northward in habitat bordering the bay. *Partula gibba* individuals were present until a large collapsed limestone feature was encountered, forming an elevated platform approximately 49 ft (15 m) in height. The vegetation here abruptly shifts to *Hibiscus tiliaceus*, coconut palm, and *Pandanus* sp. No humped tree snails were found along this feature. As the survey continued north, the elevated feature came to an abrupt end and the transect continued back downward to an area once again consisting of fairly steep, crumbled, unconsolidated limestone rubble and a forest dominated by *Barringtonia asiatica.* Immediately upon re-entry into this habitat type, humped tree snails were again encountered. Therefore, two discrete humped tree snail populations occur along this bay, separated by approximately 656 ft (200 m) of raised limestone (Figure 15).

Surveys on Transect 7 were conducted on June 24 and 26 for a total of 5 hours. During this limited 5-hour survey effort, 92 live humped tree snails were located (Table 17). Because of the complexity of the habitat it is estimated that many more humped tree snail could be located with additional survey effort.

Table 17. Numbers of Live Humped Tree Snails at Dump Coke Sites 1 and 2

Site	*Age class*			*Total*
	Juvenile	*Subadult*	*Adult*	
1	20	13	19	52
2	15	7	18	40

At both humped tree snail locations, live snails were found almost exclusively in *Barringtonia asiatica* trees which were extremely abundant forming the over story, as well as a well-developed understory (Figures 16 and 17). Other conspicuous plants present at both locations include *Pandanus tectorius*, coconut palm, *Hibiscus tiliaceus,* assorted ferns, and spider lily. *Barringtonia asiatica* was by far the dominant *Partula* host tree; however, snails were also found on coconut palm, *Neisosperma oppositifolia*, and spider lily. Humped tree snails occurred from just above ground level to approximately 20 ft (6 m) high.

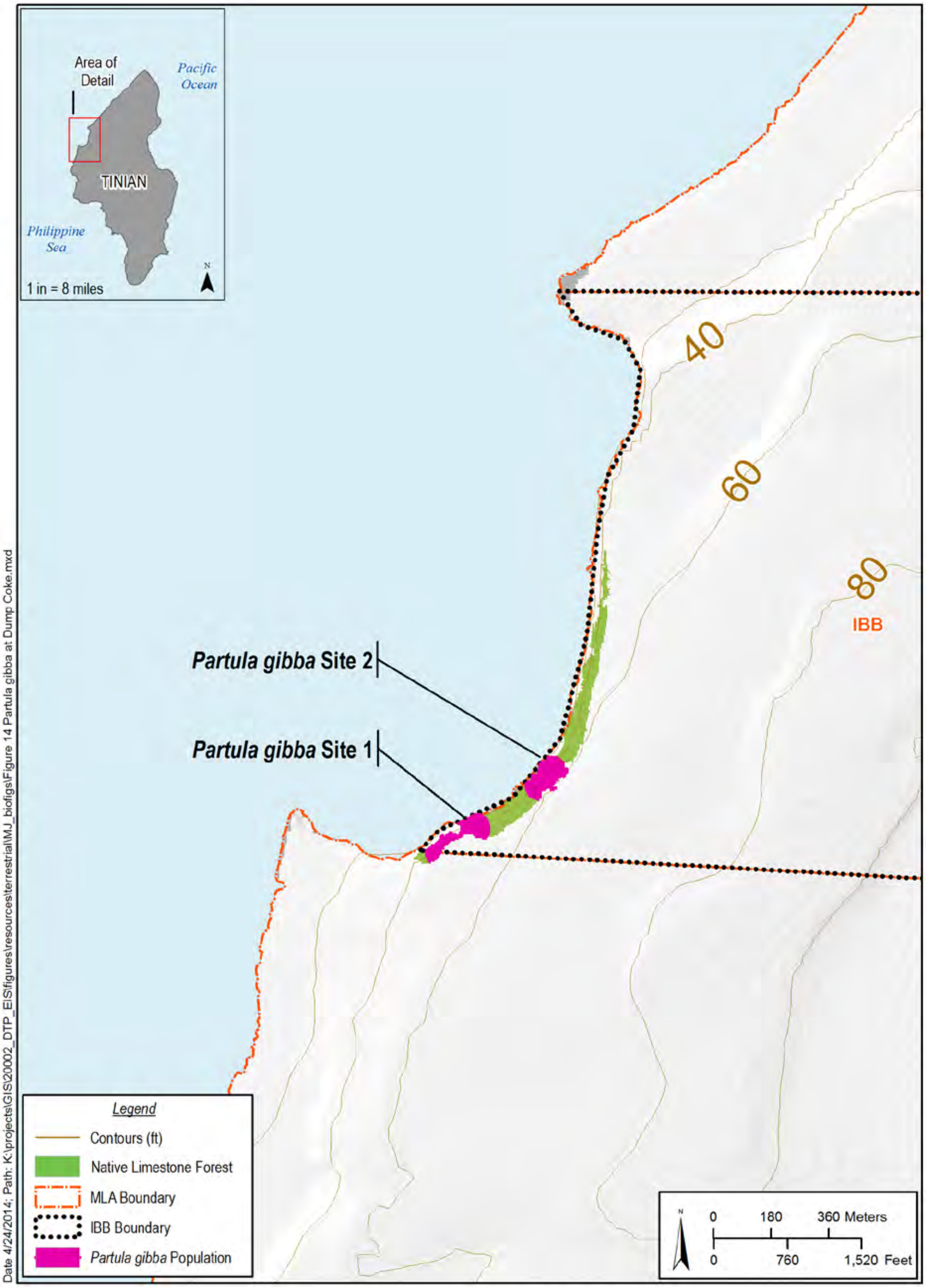

Figure 15. Locations and Ranges of Dump Coke Populations of Humped Tree Snails (*Partula gibba*)

Figure 16. Adult Humped Tree Snails from Dump Coke Site 1 (left) and Site 2 (right)

Figure 17. Humped Tree Snail Habitat at Dump Coke Site 1 (left) and Site 2 (right)

Transect 8. Although this location was initially selected because of its seeming similarity to Dump Coke that is located just to the north of the transect, upon further investigation the limestone cliffs were vertical and had no protected habitat. No live humped tree snails or shells were observed.

Transects 9 and 10. The vegetation in this area consisted of mixed native and non-native plants and was very dry. No live *Partula* or shells were observed.

Transect 11. Vegetation is similar to Transects 9 and 10, consisting of mixed native and non-native plants and was overall very dry. Although no live snails were found, old humped tree snail shells were observed along with giant African snail.

Transect 12. The vegetation along this transect consisted of mixed native and non-native species and was very dry. No live snails or shells were observed.

Transect 13. The vegetation along this transect was mostly non-native tangantangan. No live humped tree snails or shells were observed.

Transect 14. A short transect was surveyed along the road parallel to and above Dump Coke where humped tree snails were observed on Transect 7. The vegetation at this site consisted of mixed native and non-native plants. No live snails of any species were observed; however, aged humped tree snail shells were present.

Transect 15. The vegetation along this transect near the Blow Hole consisted of coastal strand. Although no humped tree snails were observed, other live native snails were present.

5.5 DISCUSSION

Based on the limited snail surveys of Tinian, it appears that although up to 95% of the native limestone forest was historically destroyed, there has been some recovery. There are several areas where patches of existing native forest appear to be of sufficient quality and composition to support native partulid tree snails. However, a number of characteristics of tree snails have likely led to their absence from these areas and the nearly complete extirpation from Tinian. These include tree snails' specific host plant requirements, vulnerability to invasive predators (e.g., *Gonaxis*, Manokwar flatworm, giant African snail, wolf snail, and rats [*Rattus* spp.]), and sedentary life history. In the event of a disturbance, tree snails lack the ability to flee from threats and escape habitat degradation, or move and recolonize to nearby preferred or higher quality, intact habitat.

It is assumed that the humped tree snail populations that were discovered at the Dump Coke site (Transect 7) have persisted in place, along with a narrow strip of native old growth vegetation. The site lies along the lower portion of a sheer cliff of up to 164 ft (50 m) high. During periods of intensive agricultural exploitation, clear cutting, intentional burning, aerial fumigation of pesticides, and artillery barrage, this site seems to have been afforded natural protection due to its position beneath the cliff line.

There is the potential for reintroducing humped tree snails to some of the native limestone forests in other areas of Tinian. This is based on the apparent quality of some of the habitat, as well as the apparent lack of snail predators, such as near the summit of Mount Lasso, and along the ridges extending southwards. Anecdotal information gathered by researchers on Pacific Islands such as Ogasawara, Pohnpei, and Guam (Kerr 2013), strongly suggests that where the invasive gastropod specialist predators Manokwar flatworm, wolf snail, and *Gonaxis* have been released, and where conditions are conducive to long-term persistence of all three, Manokwar flatworm can extirpate the predatory snails. On Tinian, only old, weathered shells of *Gonaxis* and wolf snails were encountered and no live Manokwar flatworms were observed. It is possible that the Manokwar flatworm may have extirpated these two gastropods on Tinian, as it has done elsewhere. While all three predators may have contributed to the apparent extirpation of the invasive giant African snail and humped tree snails, another possibility is that due to very low standing stock of snails of any kind, the snail predators may have ultimately starved. It is recommended that additional surveys and monitoring should be conducted to confirm the absence of snail predators as well as to ensure persistence of the Dump Coke humped tree snail population over the long term. Surveys should also be conducted within suitable habitat within southern Tinian outside the MLA in order to identify additional suitable locations for potential translocation of humped tree snails. It is possible that additional populations may have persisted in this region of the island.

The isolation of this group of snails may have important management implications on two fronts. First, population genetic diversity is frequently used as a general metric for population viability or health (Holland and Hadfield 2002). It is likely that due to the sedentary habits and geographic isolation of the Dump Coke tree snails, genetic diversity may be lower than is expected for large panmictic populations. Thus, if a future management strategy includes plans to translocate humped tree snails from another island and/or release via captive breeding efforts, assuming this is the last remaining Tinian population, a mixture of Dump Coke snails with snails with higher genetic diversity would likely yield positive health effects.

It is possible that the Tinian snails have a unique genetic signature, similar to what preliminary data suggest for *Partula* spp. from numerous other sampling localities throughout the CNMI (Sischo et al. in prep). Non-lethal tissue samples of the Dump Coke humped tree snail population were acquired during the current survey efforts that will provide answers to questions involving genetic diversity of the Dump Coke snails. Loss of the Dump Coke population of humped tree snails, the only known tree snail population on Tinian, would result in the potential extirpation of humped tree snails from Tinian. Potential threats on Tinian include physical forces such as tsunamis, typhoons, land-slides, and fires, and biological threats such as the introduction or expansion of a snail predator or competitor, such as *Drymaeus* or *Satsuma*, or loss of the host trees due to the introduction of a parasitoid wasp, beetle, fungal disease, or ungulate grazing.

CHAPTER 6
REFERENCES

AECOS Inc. and Wil Chee Planning Inc. 2009. Final Guam and Tinian Wetlands Inventory. Honolulu, HI.

Amidon, F.A. 2009. Vegetation Surveys on Tinian and Aguiguan. Pages 8-18 *in* Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008 – Final Report. Prepared by Pacific Islands Fish and Wildlife Office, Honolulu, HI for Marine Forces Pacific (MARFORPAC) and NAVFAC Pacific, Pearl Harbor, HI. December.

Amidon, F.A., A.P. Marshall, and C.C. Kessler. 2011. Status of the Micronesian Megapode in the Commonwealth of the Northern Mariana Islands. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI. *In* Marianas Expedition Wildlife Surveys 2010: Terrestrial Resource Surveys of Pagan, Commonwealth of the Northern Mariana Islands. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI for USMC and NAVFAC Pacific, Pearl Harbor, HI.

Bauman, S. 1996. Diversity and decline of land snails on Rota, Mariana Islands. American Malacological Bulletin 12:13–27.

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 University Press, Oxford, UK.

Burnham, K.P. and D.R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information−Theoretic Approach. Second edition. Springer-Verlag, New York, NY.

Camp, R.J. and P.C. Banko. 2014. Products and Deliverables of the Tinian Forest Bird Data Analysis. Prepared by Hawai'i Cooperative Studies Unit, University of Hawai'i at Hilo, Hawai'i National Park, HI and U.S. Geological Survey, Pacific Island Ecosystems Research Center, Hawai'i National Park, HI for Cardno TEC, Honolulu, HI. April 29.

Camp, R.J., T.K. Pratt, F.A. Amidon, A.P. Marshall, S. Kremer, and M. Laut. 2009. Status and Trends of the Land Bird Avifauna on Tinian and Aguiguan, Mariana Islands. In *Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008 – Final Report. Appendix 3.1*. Prepared by U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI for Marine Forces Pacific and Naval Facilities Engineering Command Pacific Pearl Harbor, HI.

Camp, R.J., F.A. Amidon, A.P. Marshall, and T.K. Pratt. 2012. Bird populations on the island of Tinian: persistence despite wholesale loss of native forests. Pacific Science 66:283-298.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific Island land snails. Philosophical Transactions: Biological Sciences 335:167-191.

Crampton, H.E. 1925. Studies on the Variation, Distribution, and Evolution of the Genus *Partula*: The Species of the Mariana Islands, Guam and Saipan. Carnegie Institution of Washington Publication No. 228A:1-116.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000. Wildlife and Vegetation Surveys in the Tinian Proposed Conservation Area. Technical Report #1. CNMI Division of Fish and Wildlife, Lower Base, Saipan and Tinian Department of Lands and Natural Resources, Fish and Wildlife Conservation Sections, San Jose, Tinian.

DoN. 2013a. Annual Report for Biological Opinion for the Mariana Islands Range Complex (MIRC), Guam and the Commonwealth of the Northern Mariana Islands 2010-2015 (2009-F-0345), 01 October 2012 – 30 September 2013. Prepared by Naval Facilities Engineering Command Pacific, Pearl Harbor, HI and Naval Facilities Engineering Command Marianas, Guam.

DoN. 2013b. Final Integrated Natural Resources Management Plan, Joint Region Marianas. Naval Base Guam. December.

DoN. 2013c. Final Wetlands Management Plan for the Mariana Common Moorhen, Tinian Military Lease Area, Commonwealth of the Northern Mariana Islands. Prepared by NAVFAC Pacific, Pearl Harbor, HI. December 20.

DoN. 2013d. Tinian Natural Resources GIS Data. NAVFAC Pacific, Pearl Harbor, HI.

DoN. 2014. Mariana Common Moorhen Surveys of the Bateha and Mahalang Wetlands, MLA, Tinian. Prepared by PCR Environmental, Inc., Barrigada, Guam for NAVFAC Marianas, Guam. June.

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, Honolulu, HI.

Gill, F. and D. Donsker, editors. 2014. IOC World Bird List. Version 4.1 http://www.worldbirdnames.org/. Accessed March 20.

Hadfield, M.G. 2010. Pagan Island Tree-Snail Surveys: A Report to the U.S. Fish and Wildlife Service. Prepared by Kewalo Marine Laboratory, University of Hawaii at Manoa, Honolulu, HI. *In* Marianas Expedition Wildlife Surveys 2010: Terrestrial Resource Surveys of Pagan, Commonwealth of the Northern Mariana Islands. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI for USMC and NAVFAC Pacific, Pearl Harbor, HI.

Hawaiian Agronomics International, Inc. 1985. Final Report for Flora and Fauna Survey of Tinian, Northern Mariana Islands. 2 Volumes. Prepared for NAVFAC Pacific, Pearl Harbor, HI. December 23.

Holland, B.S. and M.G. Hadfield. Islands within an island: phylogeography and conservation genetics of the endangered Hawaiian tree snail *Achatinella mustelina*. Molecular Ecology 11:365-376.

Hopper, D.R. and B.D. Smith. 1992. Status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H.E. Crampton in 1920. Pacific Science 46:77-85.

Kerr, A.M. 2013. The Partulid Tree Snails (Partulidae: Stylommatophora) of the Mariana Islands, Micronesia. University of Guam Marine Laboratory Technical Report 152.

Kessler, C.C. 2011. Incidental Observations. Marianas Expedition Wildlife Survey 2010. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI. *In* Marianas Expedition Wildlife Surveys 2010: Terrestrial Resource Surveys of Pagan, Commonwealth of the Northern Mariana Islands. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI for USMC and NAVFAC Pacific, Pearl Harbor, HI.

Liu, Z. and L. Fischer. 2006. Commonwealth of the Northern Mariana Islands vegetation mapping using very high spatial resolution imagery: methodology. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Health Protection, McClellan, CA.

Miller, S.E. 1993. Final report on surveys of the arboreal and terrestrial snail fauna of American Samoa. Unpublished report submitted to U.S. Fish and Wildlife Service, Pacific Region, Honolulu, HI.

Murray, J., E. Murray, M.S. Johnson, and B. Clarke. 1988. The extinction of *Partula* on Moorea. Pacific Science 42:150–153.

O'Daniel, D. and S. Krueger. 1999. Recent sightings of the Micronesian megapode on Tinian, Mariana Islands. Micronesica 31:301-307.

Raulerson, L. 2006. Checklist of Plants of the Mariana Islands. University of Guam Herbarium Contribution 37:1-69.

Reichel, J.D. and P.O. Glass. 1991. Checklist of the birds of the Mariana Islands. 'Elepaio 51: 3-10.

Smith, B.D. 2006. Preliminary assessment of the endemic arboreal snails in three forest types in Sarigan, with notes on ground-dwelling species. Pages 8-1 to 8-23 in: Wildlife and vegetation Surveys of Sarigan Island, April 13-25, 2006. G. Martin, editor. CNMI Division of Fish and Wildlife Technical Report 14.

Smith, B.D. 2013. Taxonomic Inventories and Assessments of Terrestrial Snails on the Islands of Tinian and Aguiguan in the Commonwealth of the Northern Mariana islands. University of Guam Marine Laboratory Technical Report 154.

Smith, B.D., R. Cooper-Nurse, and A. Gawel. 2008. Survey of endangered tree snails on Navy-owned lands in Guam. Prepared for U.S. Department of the Navy, Commander Navy Region Marianas, Guam.

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B. Bishop, T.A. Marques, and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5−14.

USFWS. 1991. Recovery Plan for the Mariana Common Moorhen *Gallinula chloropus guami*. Region One, Portland, OR. September.

USFWS. 1996. Characteristics of Mariana Common Moorhens and Wetland Habitats within the U.S. Department of the Navy's Military Lease Area and Exclusive Military Use Area on the Island of Tinian, Commonwealth of the Northern Mariana Islands, July 1994 - August 1995. Prepared by Division of Ecological Services Pacific Islands Ecoregion, Honolulu, HI for Pacific Division, Naval Facilities Engineering Command, Honolulu, HI. February.

USFWS. 1998. Recovery Plan for the Micronesian Megapode (*Megapodius laperouse laperouse*). Region 1, Portland, OR. April.

USFWS. 2009a. Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008. Final Report. Prepared for MARFORPAC and NAVFAC Pacific, Pearl Harbor, HI by USFWS, Pacific Islands Field Office, Honolulu, HI. December.

USFWS. 2009b. Mariana Common Moorhen (*Gallinula chloropus guami*) 5-Year Review Summary and Evaluation. Pacific Islands Fish and Wildlife Office, Honolulu, HI. July 29.

USFWS. 2010. Marianas Expedition Wildlife Surveys 2010: Terrestrial Resource Surveys of Pagan, Commonwealth of the Northern Mariana Islands. Prepared by U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI for U.S. Marine Corps and Naval Facilities Engineering Command, Pacific, Pearl Harbor, HI.

USFWS. 2011a. Species Assessment and Listing Priority Assignment Form – Humped Tree Snail (*Partula gibba*).

USFWS. 2011b. Species Assessment and Listing Priority Assignment Form – Langford's Tree Snail (*Partula langfordi*).

USFWS. 2012. Endangered and Threatened Wildlife and Plants; Review of Native Species That Are Candidates for Listing as Endangered or Threatened; Annual Notice of Findings on Resubmitted Petitions; Annual Description of Progress on Listing Actions. Federal Register 77:69994-70060.

USFWS. 2013. General Provisions; Revised List of Migratory Birds; Final Rule. Federal Register 78:65844-65864.

Vogt, S. 2008. Micronesian megapode (*Megapodius laperouse laperouse*) surveys on Tinian, Commonwealth of the Northern Mariana Islands. United States Navy, Naval Facilities Engineering Command Pacific. Honolulu, HI.

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

Witteman, G.J. 2001. A quantitative survey and inventory of the Micronesian megapode and its habitat on Tinian, CNMI. University of Guam, Division of Natural Resources. Mangilao, Guam.

CHAPTER 7
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APPENDIX A

Products and Deliverables of the Tinian Forest Bird Data Analysis (Camp and Banko 2014)

Products and Deliverables of the Tinian Forest Bird Data Analysis
Prepared for Cardno TEC in Support of the CJMT EIS
April 29, 2014

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Native bird surveys were conducted for the U.S. Department of Navy (Navy) by Cardno TEC on Tinian, Commonwealth of the Northern Mariana Islands (CNMI), in June 2013. The aim of this deliverable is to summarize the land bird detections and to produce updated abundance estimates for native White-throated Ground-Dove (*Gallicolumba xanthonura*), Mariana Fruit-Dove (*Ptilinopus roseicapilla*), Collared Kingfisher (*Todiramphus chloris*), Micronesian Myzomela (*Myzomela rubratra*), Tinian Monarch (*Monarcha takatsukasae*), Rufous Fantail (*Rhipidura rufifrons*), Bridled White-eye (*Zosterops conspicillatus saypani*), and Micronesian Starling (*Aplonis opaca*), and for the non-native Island Collared-Dove (*Streptopelia bitorquata*) based on the 2013 survey of land birds on Tinian. Bird surveys were conducted on Tinian to document current species densities and population estimates, and to compare these estimates to population data from past surveys. Results of these surveys, as well as data collected during past surveys, will be incorporated into an EIS and Biological Assessment to assess the potential environmental impacts of proposed Joint Military Training in the CNMI and to develop measures to avoid, minimize, or mitigate for potential impacts to native bird species. The product of this research will assist the Navy in meeting environmental and biological requirements and provide information critical to conservation efforts.

Methods and Results

Survey data were collected to estimate the density and abundance of avian species on Tinian in different habitats and to determine population trends. Population size was estimated from this data using program DISTANCE following methods described in Thomas *et al*. (2010) and Camp *et al*. (2012). Population trends were determined using repeated measures analysis of variance, and population abundances within habitat types were compared using two-sample z-tests following methods described in Camp *et al*. (2012). The results of these procedures are presented in tabular and graphical formats, and additional materials are included as supplements.

Abundance Estimation

Native bird surveys were conducted on Tinian June 11-28, 2013. Land bird surveys on Tinian followed standard point-transect methods (Buckland *et al*. 2001), consisting of 8-minute counts, where horizontal distances to all birds heard and/or seen were estimated and recorded. A total of four island-wide native bird surveys have been conducted on Tinian since the early 1980s: 1982 (Engbring *et al*. 1986), 1996 (U.S. Fish and Wildlife Service [USFWS] 1996), 2008 (Camp *et al*. 2009; Marshall and Amidon 2010), and 2013 (Navy, unpublished data) (Table 1). A total of 10 permanent transects with 216 stations were surveyed in 1982 and 1996. In 2008, 14 transects with 254 stations were surveyed, and in 2013, 14 transects with 206 stations were surveyed. For all surveys, a total of 10 transects with 161 stations were surveyed in each of the 4 years. A list of bird species observed across surveys is presented in Supplement 1. Indices of bird occurrences and relative abundances for all years are presented in Supplement 2. Distance analysis fits a detection function to estimate the probability of detecting a bird at a given distance from the observer (Supplement 3). This detection function is fitted with covariates, accounting for the effect of the observer, detection type, weather and station conditions, and year. 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 slightly relative to former estimates (Johnson *et al*. 2006).

Density estimates (birds/hectare [ha]) were calculated from point-transect sampling data using program DISTANCE, version 6.0, release 2 (Thomas *et al.* 2010) and followed the procedures described in Camp *et al*. (2012). To test candidate detection function models, the data from the 2013 survey were pooled with detections from the previous three surveys. Candidate models were limited to half-normal and hazard-rate detection functions with expansion series of order two (Buckland *et al.* 2001:361, 365). The uniform detection function was not considered because covariates cannot be modeled.

Following Camp *et al*. (2012), data from only one of the two counts in 1982 were used, while all data from the 1996 and 2008 surveys and from both the 2013 counts were used (Table 2). For the 1982 survey we used detections from only the best counters based on their experience and survey proficiency. Survey-specific effort was adjusted by the number of times the station was counted. To improve model precision, sampling covariates were incorporated in the multiple covariate distance sampling engine of DISTANCE (Thomas *et al.* 2010). Covariates included the weather conditions, time of sampling, type of detection, observer, habitat type, detectability at the station, and year of survey. Models with 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 needed to reliably model the detection function [Buckland *et al*. 2001]).

Right-tail 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 having the lowest Akaike's Information Criterion corrected (AICc) for small sample size (Buckland *et al.* 2001, Burnham and Anderson 2002) (Table 3, Supplement 4). 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 legacy transects and all transects (Tables 4, 5, and 6). The 95% confidence intervals for the annual density estimates were derived from the 2.5th and 97.5th percentiles using bootstrap methods in DISTANCE for 999 iterations (Buckland *et al.* 2001, 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]) (Tables 7, 8, and 9).

Population Trends

Change in bird density among the four annual estimates on Tinian was assessed with repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, NC) (Table 10). Comparisons were conducted on only the original 10 transects and limited to the stations that were sampled on all four surveys (161 stations; Supplement 5). To stabilize the error variance, density-by-station values were ln(density+1) transformed. 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 Type I error (α = 0.05) for multiple-comparison procedures.

Population densities within habitat types during 2008−2013 were compared using a two-sample *z*-test, which is the recommended (L. Thomas, pers. comm.) extension of the method listed in Buckland *et al*. (2001:353) to evaluate for differences between densities (Tables 5, 6, 8, and 9). Comparisons of population densities and species abundance within habitat types were not conducted for the 1982 and 1996 data, because estimates of habitat area were based upon later 2006 U.S. Forest Service and 2008 USFWS data (Liu and Fischer 2006; Amidon 2009).

Literature Cited

Amidon, F.A. 2009. Vegetation Surveys on Tinian and Aguiguan. Pages 8-18 in Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008 – Final Report. Prepared by Pacific Islands Fish and Wildlife Office, Honolulu, HI for Marine Forces Pacific (MARFORPAC) and NAVFAC Pacific, Pearl Harbor, HI. December.

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 University Press, Oxford, UK.

Burnham, K.P., and D.R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information−Theoretic Approach. Second edition. Springer−Verlag, New York, NY.

Camp, R.J., T.K. Pratt, F.A. Amidon, A.P. Marshall, S. Kremer, and M. Laut. 2009. Status and Trends of the Land Bird Avifauna on Tinian and Aguiguan, Mariana Islands. Appendix 3.1 *in* Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008 – Final Report. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI for Marine Forces Pacific (MARFORPAC) and NAVFAC Pacific, Pearl Harbor, HI. December.

Camp, R.J., F.A. Amidon, A.P. Marshall, and T.K. Pratt. 2012. Bird populations on the island of Tinian: Persistence despite wholesale loss of native forests. Pacific Science 66:283-298.

Engbring, J., F.L. Ramsey, and V.J. Wildman. 1986. Micronesian Forest Bird Survey, 1982: Saipan, Tinian, Agiguan, and Rota. U.S. Fish and Wildlife Service Report. Prepared by U.S. Fish and Wildlife Service, Honolulu, HI and Oregon State University, Corvalis, OR in cooperation with Department of Natural Resources, Saipan, CNMI.

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.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS System for Mixed Models. SAS Institute Inc., Cary, NC.

Liu, Z. and L. Fischer. 2006. Commonwealth of the Northern Mariana Islands vegetation mapping using very high spatial resolution imagery: methodology. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Health Protection, McClellan, CA.

Marshall, A.P., and F.A. Amidon. 2010. Status of the Land and Wetland Avifauna of Pagan, Mariana Islands. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI. *In* Marianas Expedition Wildlife Surveys 2010: Terrestrial Resource Surveys of Pagan, Commonwealth of the Northern Mariana Islands. Prepared by USFWS, Pacific Islands Fish and Wildlife Office, Honolulu, HI for USMC and NAVFAC Pacific, Pearl Harbor, HI.

Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B. Bishop, T.A. Marques, and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5−14.

USFWS. 1996. Wildlife Research Report for Navy-leased lands on the Island of Tinian, Commonwealth of the Northern Mariana Islands. Prepared for Department of the Navy, Naval Facilities Engineering Command, Pacific, Pearl Harbor, HI by USFWS, Pacific Islands Ecoregion, Honolulu, HI. April 22.

TABLES

Table 1. Summary of Tinian Survey Attributes and Covariates, Including Period of Sampling and Weather and Station Conditions

Year	*Dates*	*Time*	*Cloud Cover*	*Rain*	*Wind Strength*	*Gust Strength*	*Detectability*	*Habitat**
1982	27 Apr–8 May	5:57–9:56	37 ± 17 (10–70)	0.2 ± 0.4 (0–1)	2.3 ± 0.7 (1–3)	na	na	na
1996	28 Aug–1 Sep	5:58–10:36	36 ± 18 (10–100)	0.1 ± 0.4 (0–2)	0.9 ± 0.7 (0–2)	na	na	na
2008	14–19 Jun	5:40–10:50	27 ± 25 (0–100)	0.1 ± 0.2 (0–3)	0.6 ± 0.7 (0–3)	1.4 ± 1.1 (0–4)	2.1 ± 1.2 (1–5)	AG, HS, LI, SF, TT, UR
2013	11–28 Jun	5:37–10:58	40 ± 26 (0–100)	0.1 ± 0.3 (0–3)	1.5 ± 0.9 (0–3)	2.3 ± 1.2 (0–4)	2.3 ± 1.1 (1–5)	HS, LI, SF, TT

Notes: *AG = agriculture, HS = herbaceous-scrub (also classed as open forest), LI = limestone forest, SF = secondary forest, TT = tangantangan, UR = developed (also classed as urban/residential).

Table 2. Number of Tinian Transects and Stations, and Sampling Effort (Counts) by Survey

Year	*Transects*	*Stations*	*Counts*
1982	10	216	216
1996	10	216	216
2008	14	254	254
2013	14	206	412

Table 3. Attributes of Models Used to Estimate Population Densities of Forest Birds on Tinian

Species abbreviations are Bridled White-eye (BRWE), Collared Kingfisher (COKI), Island Collared-Dove (ISCD), Mariana Fruit-Dove (MAFD), Micronesian Myzomela (MIMY), Micronesian Starling (MIST), Rufous Fantail (RUFA), Tinian Monarch (TIMO), and White-throated Ground-Dove (WTGD). Models are half-normal (H-norm) and hazard-rate (H-rate), with adjustment terms (Key = without adjustment terms), covariates (Obs = observer, DT = detection type), number of parameters, and the negative log-likelihood. AICc is the corrected Akaike information criterion and w_i is the discrete model probability (also called model weights).

Species	*Truncation*	*# Bins*	*Model Type*	*Adjustment Terms*	*Covariates*	*# Parameters*	*Ln(-Likelihood)*	*AICc*	w_i
BRWE	56.0 m	6	H-norm	Key	Obs	12	15194.86	30413.75	1.00000
COKI	91.2 m	6	H-rate	Key	Obs	11	995.61	2013.66	0.95251
ISCD	133.0 m	7	H-rate	Key	DT	4	1116.06	2240.18	0.99992
MAFD	250.0 m	6	H-rate	Key	Year	5	2813.45	5636.93	1.00000
MIMY	100.0 m	6	H-rate	Key	Year	5	1432.66	2875.38	1.00000
MIST	78.3 m	8	H-norm	Key	Obs	11	3698.45	7419.05	0.99991
RUFA	58.7 m	7	H-norm	Key	DT	3	4440.29	8886.59	0.99845
TIMO	68.8 m	6	H-rate	Key	Obs	13	3435.01	6896.19	0.99984
WTGD	115.0 m	7	H-rate	Key	None	2	618.72	1241.48	0.78751

Table 4. Annual Estimates of Tinian Forest Bird Species Density (birds per ha; ± SE) and 95% Confidence Intervals
Estimates for the original 10 transects (Orig) are provided in the first row and for all transects (All) in the second row. See Table 3 for species abbreviations.

		Year			
Species	*Analysis*	*1982*	*1996*	*2008*	*2013*
BRWE	Orig	48.014 ± 1.772 (44.752–51.707)	41.112 ± 1.561 (38.325–44.177)	43.233 ± 3.214 (37.284–49.755)	45.854 ± 2.452 (41.338–50.763)
	All			44.850 ± 3.740 (37.968–52.816)	45.197 ± 2.069 (41.143–49.254)
COKI	Orig	0.086 ± 0.020 (0.053–0.129)	0.281 ± 0.055 (0.196–0.390)	0.747 ± 0.103 (0.579–0.954)	0.225 ± 0.036 (0.164–0.297)
	All			0.745 ± 0.118 (0.566–0.981)	0.256 ± 0.041 (0.194–0.342)
ISCD	Orig	0.127 ± 0.030 (0.075–0.192)	0.350 ± 0.065 (0.235–0.479)	0.305 ± 0.071 (0.193–0.459)	0.466 ± 0.092 (0.307–0.658)
	All			0.294 ± 0.069 (0.179–0.439)	0.382 ± 0.066 (0.265–0.513)
MAFD	Orig	0.675 ± 0.102 (0.532–0.897)	0.250 ± 0.040 (0.190–0.335)	0.523 ± 0.078 (0.402–0.685)	0.397 ± 0.061 (0.304–0.527)
	All			0.530 ± 0.081 (0.405–0.686)	0.413 ± 0.062 (0.321–0.544)
MIMY	Orig	1.724 ± 0.222 (1.377–2.224)	0.682 ± 0.111 (0.501–0.945)	0.558 ± 0.051 (0.466–0.661)	0.591 ± 0.056 (0.487–0.707)
	All			1.322 ± 0.219 (0.979–1.813)	2.112 ± 0.274 (1.664–2.765)
MIST	Orig	1.864 ± 0.189 (1.507–2.248)	1.742 ± 0.192 (1.367–2.139)	6.334 ± 0.635 (5.150–7.588)	4.172 ± 0.426 (3.373–5.066)
	All			6.179 ± 0.646 (4.985–7.475)	4.140 ± 0.337 (3.516–4.830)
RUFA	Orig	10.498 ± 0.869 (8.852–12.269)	12.613 ± 1.019 (10.507–14.575)	16.625 ± 1.535 (13.543–19.672)	12.405 ± 0.918 (10.698–14.297)
	All			17.751 ± 1.721 (14.447–21.133)	12.848 ± 0.936 (10.955–14.763)
TIMO	Orig	9.806 ± 1.023 (7.923–11.880)	10.771 ± 1.138 (8.612–13.062)	5.757 ± 0.705 (4.431–7.249)	9.266 ± 1.121 (7.086–11.505)
	All			7.261 ± 1.226 (5.213–9.899)	9.347 ± 0.960 (7.626–11.330)
WTGD	Orig	0.055 ± 0.019 (0.023–0.096)	0.063 ± 0.016 (0.035–0.096)	0.265 ± 0.050 (0.180–0.372)	0.458 ± 0.081 (0.315–0.633)
	All			0.255 ± 0.048 (0.177–0.359)	0.499 ± 0.066 (0.380–0.635)

Table 5. Estimates of Tinian Forest Bird Species Density (birds/ha; ± SE) and 95% Confidence Intervals by Habitat Type (data from original 10 transects only)

Data for 2008 in first two rows; for 2013 in second two rows; results of two-sample z-tests (z-value, p-value) in last row. See Table 3 for species abbreviations. na – not applicable.

Species	*Year*	*Limestone Forest*	*Herbaceous-Scrub*	*Secondary Forest*	*Tangantangan*	*Agriculture*	*Developed*
BRWE	2008	38.799 ± 5.710 (28.786–50.738)	52.039 ± 4.663 (43.374–61.828)	46.793 ± 3.561 (40.328–54.318)	56.089 ± 2.968 (50.059–61.812)	38.407 ± 12.251 (21.346–57.597)	27.271 ± 11.309 (11.662–52.678)
	2013	46.611 ± 4.879 (38.176–56.794)	35.302 ± 5.724 (24.473–46.134)	54.146 ± 2.807 (48.759–59.743)	47.355 ± 2.352 (42.816–52.086)	na	na
		-1.04, 0.30	-2.27, 0.023	-1.62, 0.10	-2.31, 0.021	na	na
COKI	2008	0.656 ± 0.183 (0.336–1.012)	0.604 ± 0.128 (0.377–0.860)	0.879 ± 0.130 (0.656–1.179)	0.869 ± 0.116 (0.672–1.119)	0.785 ± 0.301 (0.514–1.371)	0.688 ± 0.262 (0.218–1.253)
	2013	0.149 ± 0.060 (0.046–0.276)	0.374 ± 0.082 (0.227–0.550)	0.230 ± 0.055 (0.133–0.343)	0.147 ± 0.032 (0.092–0.215)	na	na
		-2.62, 0.009	-1.52, 0.13	-4.59, <0.001	-5.99, <0.001	na	na
ISCD	2008	0.121 ± 0.065 (0.027–0.283)	0.263 ± 0.109 (0.086–0.510)	0.302 ± 0.078 (0.169–0.470)	0.312 ± 0.073 (0.189–0.467)	0.713 ± 0.285 (0.393–1.336)	0.118 ± 0.065 (0.056–0.281)
	2013	0.577 ± 0.212 (0.199–1.010)	0.363 ± 0.106 (0.188–0.593)	0.605 ± 0.113 (0.411–0.821)	0.318 ± 0.081 (0.184–0.498)	na	na
		-2.05, 0.040	-0.65, 0.51	-2.21, 0.027	-0.05, 0.96	na	na
MAFD	2008	0.362 ± 0.096 (0.193–0.576)	0.812 ± 0.140 (0.580–1.122)	0.658 ± 0.099 (0.506–0.874)	0.499 ± 0.081 (0.369–0.675)	0.409 ± 0.113 (0.233–0.638)	0.397 ± 0.130 (0.154–0.654)
	2013	0.411 ± 0.095 (0.251–0.619)	0.387 ± 0.083 (0.245–0.565)	0.481 ± 0.079 (0.354–0.651)	0.307 ± 0.053 (0.225–0.415)	na	na
		-0.36, 0.72	-2.61, 0.009	-1.39, 0.16	-1.97, 0.048	na	na
MIMY	2008	0.409 ± 0.118 (0.197–0.656)	0.930 ± 0.150 (0.650–1.245)	0.975 ± 0.100 (0.789–1.177)	0.627 ± 0.074 (0.494–0.775)	0.307 ± 0.110 (0.205–0.497)	0.098 ± 0.047 (0.059–0.206)
	2013	0.573 ± 0.093 (0.395–0.749)	0.615 ± 0.120 (0.408–0.874)	0.740 ± 0.081 (0.588–0.904)	0.436 ± 0.048 (0.350–0.536)	na	na
		-1.09, 0.28	-1.65, 0.10	-1.83, 0.07	-2.16, 0.031	na	na
MIST	2008	5.993 ± 0.839 (4.398–7.583)	5.663 ± 0.947 (3.956–7.466)	5.137 ± 0.513 (4.161–6.189)	4.660 ± 0.428 (3.856–5.520)	8.138 ± 2.873 (3.854–12.790)	8.415 ± 1.674 (4.676–11.446)
	2013	4.230 ± 1.073 (2.257–6.422)	4.303 ± 0.721 (2.961–5.771)	4.169 ± 0.408 (3.391–5.032)	3.986 ± 0.463 (3.080–4.941)	na	na
		-1.29, 0.20	-1.14, 0.25	-1.48, 0.14	-1.07, 0.29	na	na

Species	*Year*	*Limestone Forest*	*Herbaceous-Scrub*	*Secondary Forest*	*Tangantangan*	*Agriculture*	*Developed*
RUFA	2008	12.944 ± 2.958 (7.691–19.545)	14.991 ± 2.655 (10.060–20.367)	21.885 ± 2.436 (17.429–26.979)	18.681 ± 1.767 (15.310–22.187)	18.248 ± 4.504 (11.112–25.839)	12.999 ± 1.702 (9.822–16.386)
	2013	14.099 ± 1.736 (10.692–17.473)	7.430 ± 1.267 (4.977–9.875)	15.720 ± 1.198 (13.459–18.216)	12.370 ± 1.073 (10.317–14.574)	na	na
		-0.34, 0.74	-2.57, 0.010	-2.27, 0.023	-3.05, 0.002	na	na
TIMO	2008	7.361 ± 1.763 (4.284–10.912)	5.001 ± 1.249 (2.793–7.773)	9.510 ± 1.265 (7.084–12.221)	6.828 ± 0.963 (5.049–8.715)	3.427 ± 1.251 (2.176–5.735)	2.413 ± 1.283 (0.677–5.326)
	2013	11.049 ± 2.899 (5.506–16.645)	4.994 ± 1.025 (3.136–7.067)	10.902 ± 1.253 (8.578–13.458)	10.119 ± 1.095 (8.097–12.366)	na	na
		-1.09, 0.28	-0.01, 0.99	-0.78, 0.43	-2.26, 0.024	na	na
WTGD	2008	0.362 ± 0.118 (0.143–0.609)	0.407 ± 0.131 (0.159–0.682)	0.448 ± 0.093 (0.275–0.653)	0.144 ± 0.040 (0.074–0.225)	0	0.232 ± 0.224 (0.000–0.756)
	2013	0.568 ± 0.247 (0.147–1.108)	0.489 ± 0.136 (0.249–0.778)	0.615 ± 0.097 (0.447–0.831)	0.160 ± 0.036 (0.097–0.240)	na	na
		-0.75, 0.45	-0.44, 0.66	-1.23, 0.22	-0.30, 0.77	na	na

Table 6. Estimates of Tinian Forest Bird Species Density (birds per ha; ± SE) and 95% Confidence Intervals by Habitat Type (data from all transects)

Data for 2008 in first two rows; data for 2013 in second two rows; results of two-sample z-tests (z-value, p-value) in last row. See Table 3 for species abbreviations. na = not applicable.

Species	*Year*	*Limestone Forest*	*Herbaceous-Scrub*	*Secondary Forest*	*Tangantangan*	*Agriculture*	*Developed*
BRWE	2008	48.299 ± 13.156 (31.163–78.145)	52.020 ± 4.730 (42.966–61.378)	46.731 ± 3.346 (40.523–53.653)	55.898 ± 2.905 (50.158–61.333)	39.154 ± 11.837 (21.495–57.361)	26.996 ± 11.342 (11.462–52.908)
	2013	44.377 ± 2.842 (38.873–50.294)	35.466 ± 5.506 (24.905–45.514)	52.993 ± 2.689 (47.905–58.489)	47.952 ± 2.271 (43.854–52.680)	na	na
		-0.29, 0.77	-2.28, 0.02	-1.46, 0.14	-2.15, 0.03	na	na
COKI	2008	0.641 ± 0.238 (0.299–1.216)	0.610 ± 0.137 (0.379–0.879)	0.886 ± 0.141 (0.652–1.167)	0.852 ± 0.130 (0.639–1.124)	0.796 ± 0.311 (0.521–1.357)	0.687 ± 0.270 (0.227–1.237)
	2013	0.255 ± 0.067 (0.145–0.393)	0.383 ± 0.085 (0.239–0.559)	0.239 ± 0.056 (0.140–0.357)	0.148 ± 0.032 (0.095–0.222)	na	na
		-1.56, 0.12	-1.41, 0.16	-4.26, <0.001	-5.24, <0.001	na	na
ISCD	2008	0.428 ± 0.339 (0.083–1.233)	0.188 ± 0.113 (0.057–0.458)	0.281 ± 0.096 (0.097–0.498)	0.300 ± 0.073 (0.169–0.447)	0.448 ± 0.337 (0.080–1.225)	0.120 ± 0.064 (0.032–0.284)
	2013	0.307 ± 0.071 (0.183–0.456)	0.355 ± 0.098 (0.183–0.563)	0.563 ± 0.108 (0.377–0.789)	0.304 ± 0.077 (0.181–0.470)	na	na
		-0.35, 0.73	-1.12, 0.26	-1.94, 0.052	-0.04, 0.97	na	na
MAFD	2008	0.424 ± 0.119 (0.247–0.696)	0.803 ± 0.139 (0.580–1.088)	0.658 ± 0.096 (0.508–0.864)	0.493 ± 0.082 (0.363–0.677)	0.404 ± 0.111 (0.233–0.638)	0.395 ± 0.139 (0.140–0.712)
	2013	0.459 ± 0.072 (0.347–0.613)	0.393 ± 0.086 (0.244–0.599)	0.488 ± 0.080 (0.365–0.669)	0.313 ± 0.054 (0.229–0.428)	na	na
		-0.25, 0.81	-2.51, 0.01	-1.36, 0.17	-1.84, 0.07	na	na
MIMY	2008	0.362 ± 0.103 (0.188–0.581)	1.344 ± 0.343 (0.707–2.047)	1.566 ± 0.386 (0.890–2.420)	0.800 ± 0.173 (0.489–1.166)	2.343 ± 0.872 (1.536–4.126)	1.517 ± 0.456 (0.641–2.425)
	2013	2.658 ± 0.373 (2.051–3.474)	1.761 ± 0.495 (0.899–2.730)	2.415 ± 0.338 (1.853–3.183)	1.615 ± 0.272 (1.128–2.186)	na	na
		-5.94, <0.001	-0.69, 0.49	-1.65, 0.10	-2.53, 0.01	na	na
MIST	2008	5.159 ± 0.842 (3.770–6.967)	5.700 ± 0.972 (3.904–7.725)	5.141 ± 0.507 (4.193–6.200)	4.561 ± 0.430 (3.779–5.478)	8.117 ± 2.940 (3.825–12.840)	8.394 ± 1.569 (4.919–11.173)
	2013	4.106 ± 0.444 (3.238–5.005)	4.319 ± 0.718 (2.983–5.719)	4.155 ± 0.390 (3.386–4.907)	3.978 ± 0.453 (3.157–4.867)	na	na
		-1.11, 0.27	-1.14, 0.25	-1.54, 0.12	-0.93, 0.35	na	na

Species	*Year*	*Limestone Forest*	*Herbaceous-Scrub*	*Secondary Forest*	*Tangantangan*	*Agriculture*	*Developed*
RUFA	2008	20.429 ± 6.446 (12.162–35.081)	15.062 ± 2.666 (10.261–20.568)	21.800 ± 2.451 (17.314–27.348)	18.481 ± 1.735 (15.232–21.911)	17.863 ± 4.339 (11.146–25.684)	12.870 ± 1.741 (9.440–16.179)
	2013	15.913 ± 1.527 (12.799–18.970)	7.360 ± 1.283 (4.925–9.874)	15.751 ± 1.185 (13.529–18.037)	12.370 ± 1.074 (10.461–14.635)	na	na
		-0.68, 0.50	-2.60, 0.009	-2.22, 0.027	-2.99, 0.003	na	na
TIMO	2008	16.409 ± 6.815 (7.446–32.527)	5.018 ± 1.297 (2.710–7.759)	9.550 ± 1.342 (7.189–12.500)	6.787 ± 0.910 (5.078–8.718)	3.347 ± 1.280 (2.177–5.809)	2.452 ± 1.316 (0.666–5.410)
	2013	11.188 ± 1.357 (8.786–14.221)	5.047 ± 1.051 (3.085–7.234)	11.005 ± 1.314 (8.657–13.711)	10.147 ± 1.159 (7.984–12.465)	na	na
		-0.75, 0.45	-0.02, 0.99	-0.77, 0.44	-2.28, 0.023	na	na
WTGD	2008	0.304 ± 0.074 (0.171–0.458)	0.410 ± 0.133 (0.172–0.673)	0.441 ± 0.093 (0.277–0.635)	0.140 ± 0.039 (0.070–0.220)	0	0.237 ± 0.218 (0.000–0.705)
	2013	0.758 ± 0.129 (0.523–1.021)	0.479 ± 0.142 (0.228–0.792)	0.597 ± 0.096 (0.425–0.803)	0.161 ± 0.036 (0.097–0.237)	na	na
		-3.06, 0.002	-0.35, 0.72	-1.17, 0.24	-0.41, 0.68	na	na

Table 7. Annual Estimates of Tinian Forest Bird Species Abundance (density x area) and 95% Confidence Intervals

Estimates for the original 10 transects (Orig) are provided in the first row and for all transects (All) in the second row. See Table 3 for species abbreviations.

		Year			
Species	*Analysis*	*1982*	*1996*	*2008*	*2013*
BRWE	Orig	469,621 (437,718–505,745)	402,121 (374,857–432,099)	422,859 (364,671–486,656)	448,493 (404,327–496,508)
	All			438,674 (371,361–516,597)	442,073 (402,422–481,756)
COKI	Orig	842 (516–1,263)	2,746 (1,920–3,815)	7,304 (5,661–9,336)	2,201 (1,605–2,906)
	All			7,288 (5,541–9,591)	2,508 (1,898–3,343)
ISCD	Orig	1,246 (729–1,875)	3,419 (2,298–4,685)	2,983 (1,892–4,491)	4,555 (3,003–6,441)
	All			2,876 (1,753–4,290)	3,738 (2,592–5,016)
MAFD	Orig	6,600 (5,203–8,777)	2,445 (1,858–3,274)	5,112 (3,934–6,698)	3,879 (2,970–5,152)
	All			5,181 (3,957–6,711)	4,042 (3,140–5,321)
MIMY	Orig	16,862 (13,473–21,754)	6,675 (4,896–9,247)	5,456 (4,560–6,462)	5,779 (4,768–6,918)
	All			12,930 (9,571–17,728)	20,660 (16,275–27,045)
MIST	Orig	18,236 (14,743–21,985)	17,034 (13,375–20,918)	61,957 (50,374–74,221)	40,806 (32,987–49,547)
	All			60,433 (48,756–73,110)	40,489 (34,391–47,243)
RUFA	Orig	102,677 (86,577–120,007)	123,371 (102,771–142,561)	162,604 (132,469–192,409)	121,331 (104,641–139,837)
	All			173,621 (141,304–206,702)	125,668 (107,153–144,392)
TIMO	Orig	95,916 (77,491–116,202)	105,352 (84,237–127,758)	56,305 (43,343–70,909)	90,634 (69,311–112,535)
	All			71,015 (50,993–96,823)	91,420 (74,593–110,822)
WTGD	Orig	535 (225–941)	612 (341–941)	2,595 (1,765–3,640)	4,479 (3,077–6,193)
	All			2,498 (1,728–3,510)	4,879 (3,716–6,209)

Table 8. Estimates of Tinian Forest Bird Species Abundance (density x area) and 95% Confidence Intervals by Habitat Type (data from original 10 transects only)

See Table 3 for species abbreviations. na = not applicable.

Species	*Year*	*Limestone Forest*	*Herbaceous-Scrub*	*Secondary Forest*	*Tangantangan*	*Agriculture*	*Developed*
BRWE	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)	5,147 (2,860–7,718)	21,135 (9,038–40,825)
	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)	na	na
COKI	2008	360 (185–555)	1,178 (734–1,677)	2,599 (1,939–3,486)	2,969 (2,297–3,824)	105 (69–184)	533 (169–971)
	2013	82 (25–151)	729 (443–1,072)	679 (394–1,014)	504 (314–736)	na	na
ISCD	2008	67 (15–155)	514 (168–995)	893 (499–1,390)	1,068 (647–1,594)	96 (53–179)	91 (43–218)
	2013	317 (109–554)	707 (368–1,155)	1,788 (1,215–2,428)	1,086 (627–1,701)	na	na
MAFD	2008	199 (106–316)	1,582 (1,131–2,188)	1,944 (1,496–2,583)	1,704 (1,260–2,307)	55 (31–85)	308 (119–507)
	2013	226 (138–340)	754 (477–1,102)	1,423 (1,046–1,924)	1,050 (768–1,420)	na	na
MIMY	2008	225 (108–360)	1,814 (1,268–2,428)	2,882 (2,332–3,479)	2,143 (1,689–2,647)	41 (27–67)	76 (46–160)
	2013	314 (217–411)	1,199 (796–1,704)	2,187 (1,739–2,672)	1,489 (1,196–1,832)	na	na
MIST	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)	1,091 (516–1,714)	6,521 (3,624–8,871)
	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)	na	na
RUFA	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)	2,445 (1,489–3,462)	10,074 (7,612–12,699)
	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)	na	na
TIMO	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)	459 (292–768)	1,870 (524–4,128)
	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)	na	na
WTGD	2008	199 (78–334)	793 (311–1,329)	1,323 (814–1,929)	491 (252–769)	0	180 (0–586)
	2013	312 (81–608)	954 (485–1,517)	1,817 (1,323–2,457)	546 (330–819)	na	na

Table 9. Estimates of Tinian Forest Bird Species Abundance (density x area) and 95% Confidence Intervals by Habitat Type (data from all transects)

See Table 3 for species abbreviations. na = not applicable.

Species	*Year*	*Limestone Forest*	*Herbaceous-Scrub*	*Secondary Forest*	*Tangantangan*	*Agriculture*	*Developed*
BRWE	2008	26,516 (17,108–42,901)	101,439 (83,783–119,687)	138,137 (119,786–158,599)	191,003 (171,389–209,574)	5,247 (2,880–7,686)	20,922 (8,883–41,004)
	2013	24,363 (21,341–27,612)	69,159 (48,564–88,753)	156,649 (141,608–172,892)	163,853 (149,848–180,008)	na	na
COKI	2008	352 (164–668)	1,189 (740–1,715)	2,618 (1,929–3,449)	2,911 (2,183–3,841)	107 (70–182)	532 (176–958)
	2013	140 (79–216)	748 (466–1,090)	707 (414–1,054)	506 (326–757)	na	na
ISCD	2008	235 (45–677)	366 (111–892)	832 (288–1,473)	1,027 (577–1,529)	60 (11–164)	93 (24–220)
	2013	168 (100–250)	691 (358–1,098)	1,664 (1,115–2,332)	1,040 (618–1,607)	na	na
MAFD	2008	233 (136–382)	1,566 (1,132–2,122)	1,946 (1,502–2,555)	1,685 (1,241–2,312)	54 (31–86)	306 (109–552)
	2013	252 (191–337)	767 (476–1,169)	1,442 (1,078–1,978)	1,069 (781–1,464)	na	na
MIMY	2008	199 (103–319)	2,621 (1,378–3,992)	4,629 (2,631–7,153)	2,734 (1,671–3,985)	314 (206–553)	1,176 (497–1,880)
	2013	1,460 (1,126–1,907)	3,435 (1,753–5,324)	7,138 (5,477–9,408)	5,517 (3,853–7,469)	na	na
MIST	2008	2,832 (2,070–3,825)	11,115 (7,612–15,064)	15,196 (12,396–18,328)	15,584 (12,913–18,718)	1,088 (513–1,721)	6,505 (3,812–8,659)
	2013	2,254 (1,778–2,748)	8,423 (5,818–11,153)	12,283 (10,010–14,505)	13,592 (10,788–16,631)	na	na
RUFA	2008	11,216 (6,677–19,259)	29,370 (20,010–40,108)	64,442 (51,180–80,840)	63,151 (52,047–74,869)	2,394 (1,494–3,442)	9,974 (7,316–12,539)
	2013	8,736 (7,026–10,415)	14,352 (9,603–19,255)	46,559 (39,991–53,316)	42,267 (35,744–50,006)	na	na
TIMO	2008	9,009 (4,088–17,857)	9,785 (5,284–15,131)	28,230 (21,250–36,950)	23,193 (17,351–29,788)	448 (292–778)	1,900 (516–4,193)
	2013	6,142 (4,824–7,807)	9,841 (6,015–14,106)	32,531 (25,590–40,529)	34,673 (27,283–42,592)	na	na
WTGD	2008	167 (94–251)	800 (335–1,312)	1,304 (818–1,876)	478 (238–751)	0	184 (0–547)
	2013	416 (287–561)	934 (444–1,545)	1,764 (1,256–2,374)	552 (332–810)	na	na

Table 10. Results of Repeated Measures Analysis of Variance for Trends in Tinian Forest Bird Densities among Different Time-Series

$F_{3,480}$ = F-value with degrees of freedom 3 and 480.
P = p-value.
Est (SE) = comparison estimate and standard error.
t_{480} = t-value with degrees of freedom 480.
Adj-P = multiple comparison adjusted p-value.

	Fixed Effects		Differences of Least Squares Means 1982–1996			1982–2008			1982–2013			1996–2008			1996–2013			2008-2013		
Species	$F_{3,480}$	*P*	*Est (SE)*	t_{480}	*Adj-P*	*Est (SE)*	t_{480}	*Adj-P*	*Est (SE)*	t_{480}	*Adj-P*	*Est (SE)*	t_{480}	*Adj-P*	*Est (SE)*	t_{480}	*Adj-P*	*Est (SE)*	t_{480}	*Adj-P*
BRWE	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	-0.10 (0.07)	-1.50	0.437	-0.09 (0.07)	-1.40	0.502	0.01 (0.07)	0.11	1.000
COKI	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	-0.35 (0.03)	-10.17	<0.001	0.03 (0.03)	0.84	0.834	0.38 (0.03)	11.02	<0.001
ISCD	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	0.03 (0.03)	1.08	0.700	-0.09 (0.03)	-3.21	0.008	-0.12 (0.03)	-4.29	<0.001
MAFD	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	-0.25 (0.03)	-8.62	<0.001	-0.11 (0.03)	-3.99	<0.001	0.13 (0.03)	4.63	<0.001
MIMY	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	-0.33 (0.03)	-11.25	<0.001	-0.27 (0.03)	-9.13	<0.001	0.06 (0.03)	2.11	0.150
MIST	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	-0.89 (0.08)	-10.73	<0.001	-0.81 (0.08)	-9.66	<0.001	0.09 (0.08)	1.07	0.710
RUFA	19.86	<0.001	-0.27 (0.10)	-2.70	0.036	-0.71 (0.10)	-7.08	<0.001	-0.57 (0.10)	-5.63	<0.001	-0.44 (0.10)	-4.39	<0.001	-0.30 (0.10)	-2.94	0.018	0.15 (0.10)	1.45	0.468
TIMO	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	0.21 (0.12)	1.77	0.289	-0.25 (0.12)	-2.08	0.162	-0.46 (0.12)	-3.85	<0.001
WTGD	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	-0.18 (0.03)	-6.58	<0.001	-0.22 (0.03)	-7.70	<0.001	-0.03 (0.03)	-1.12	0.680

FIGURES

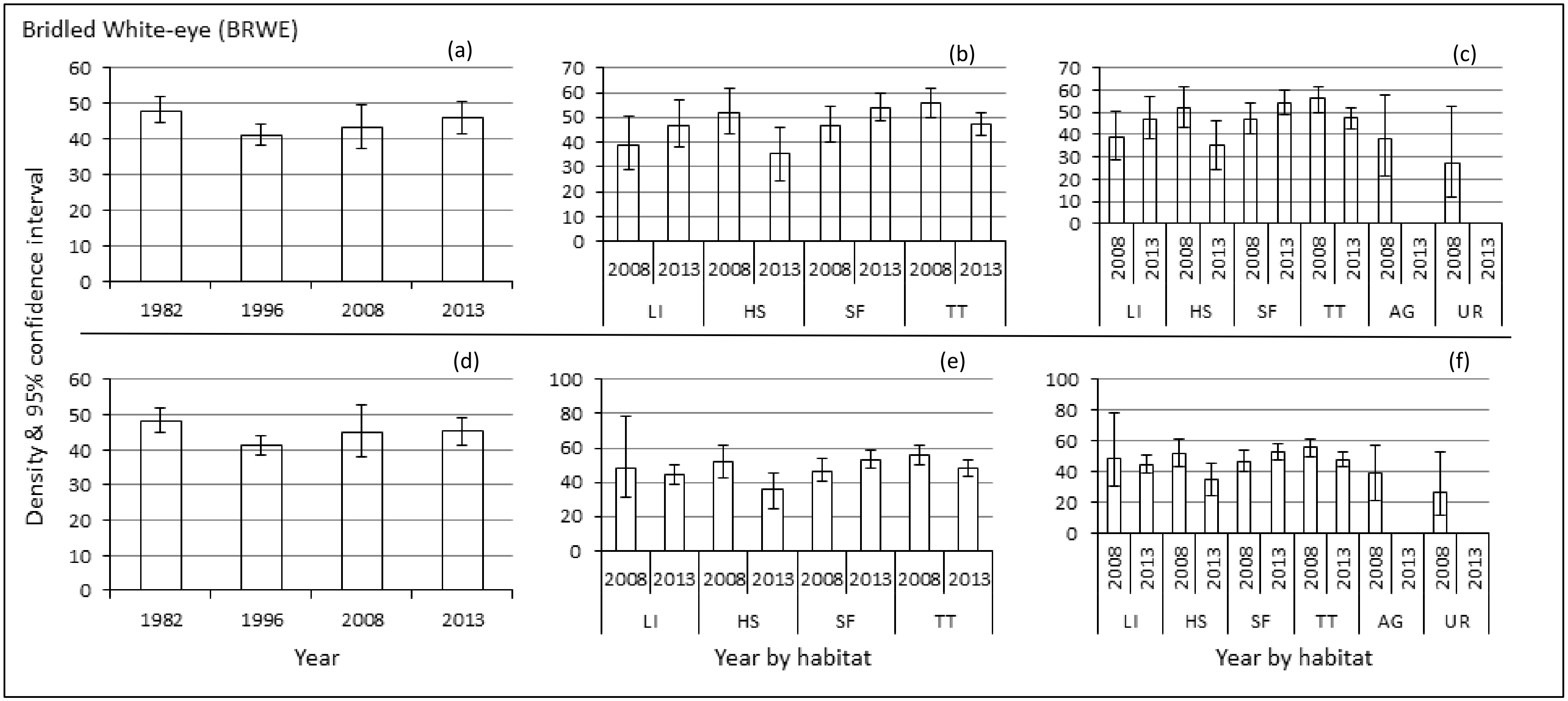


Figure 1. Annual Estimates of Bridled White-Eye Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

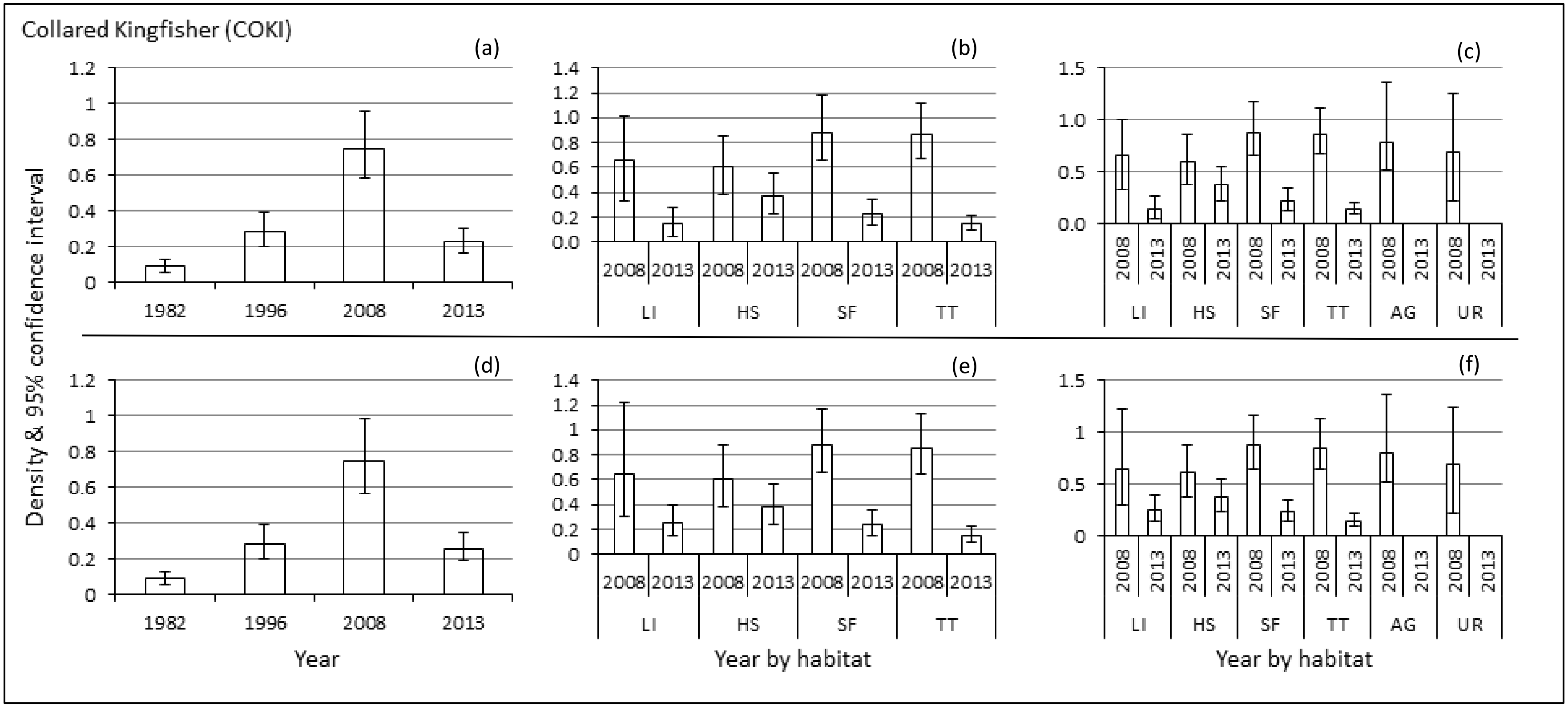


Figure 2. Annual Estimates of Collared Kingfisher Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.
Bottom row: estimates use data from all transects.
Left column: annual, island-wide estimates.
Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.
Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.
Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

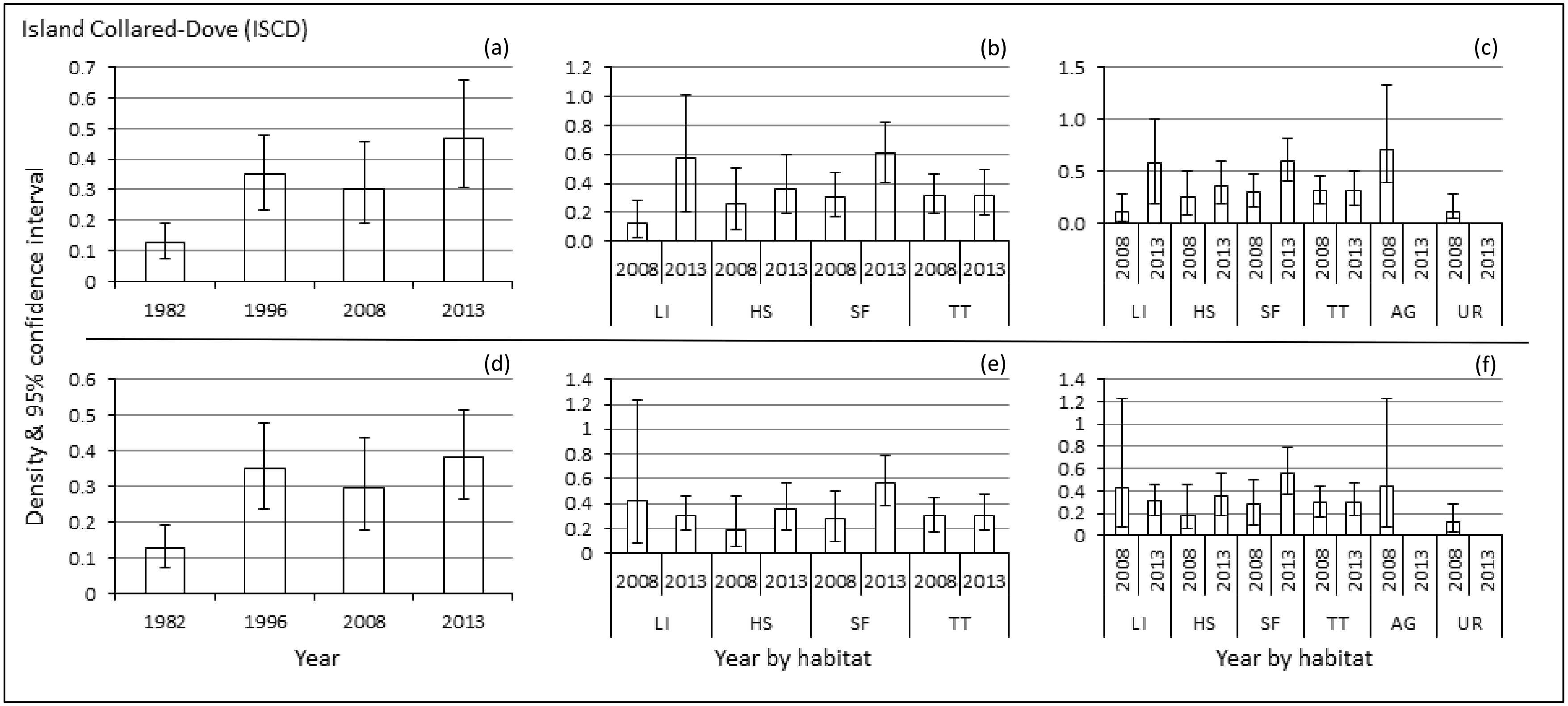


Figure 3. Annual Estimates of Island Collared-Dove Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

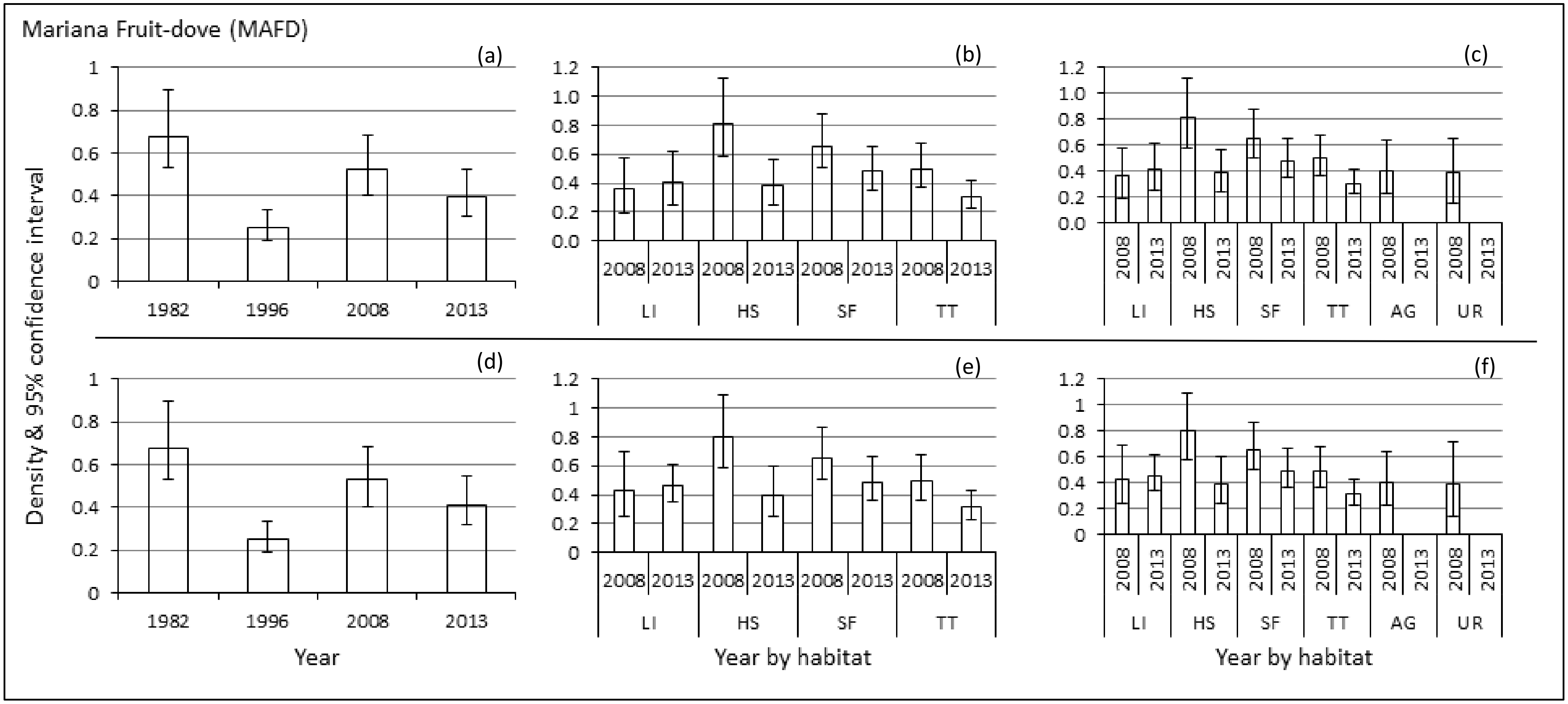


Figure 4. Annual Estimates of Mariana Fruit-Dove Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.
Bottom row: estimates use data from all transects.
Left column: annual, island-wide estimates.
Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.
Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.
Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

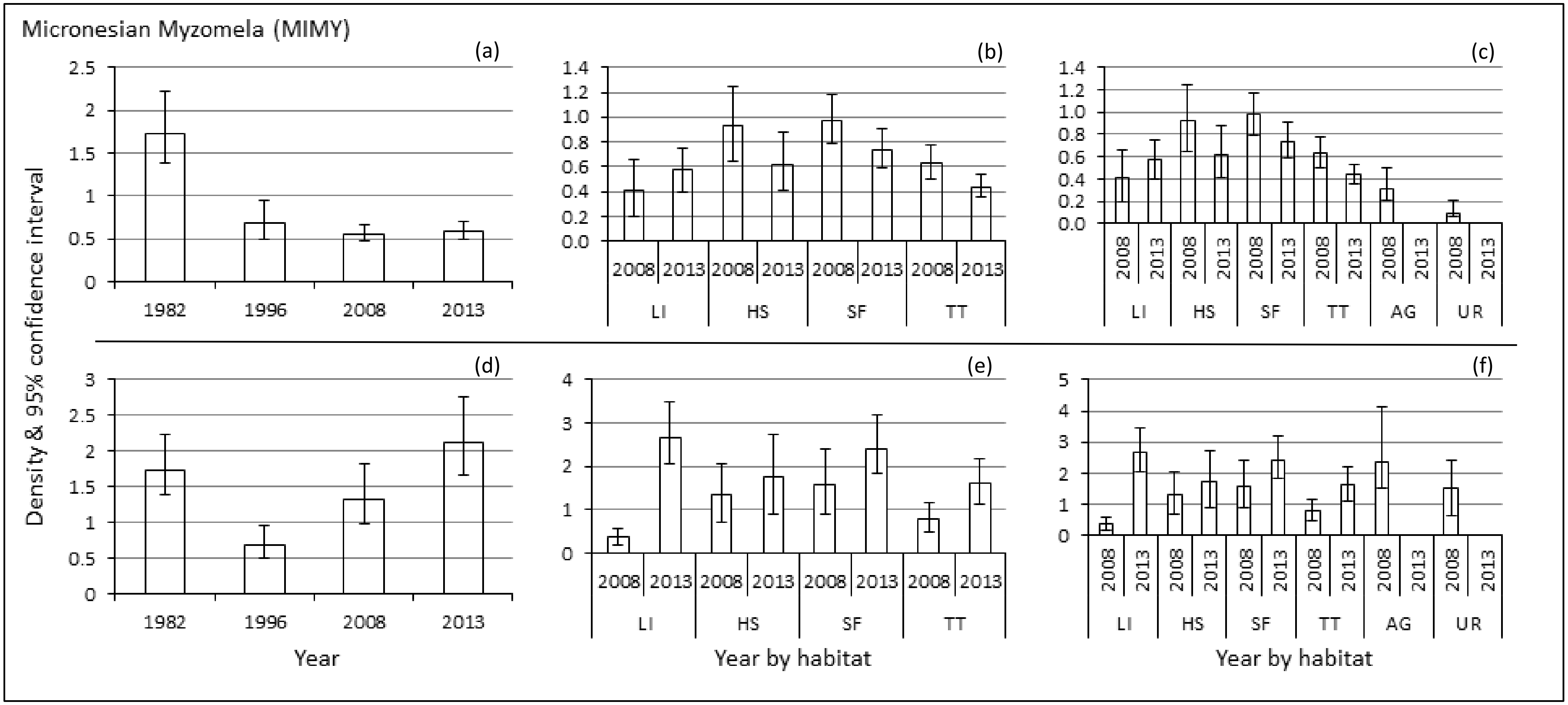


Figure 5. Annual Estimates of Micronesian Myzomela Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

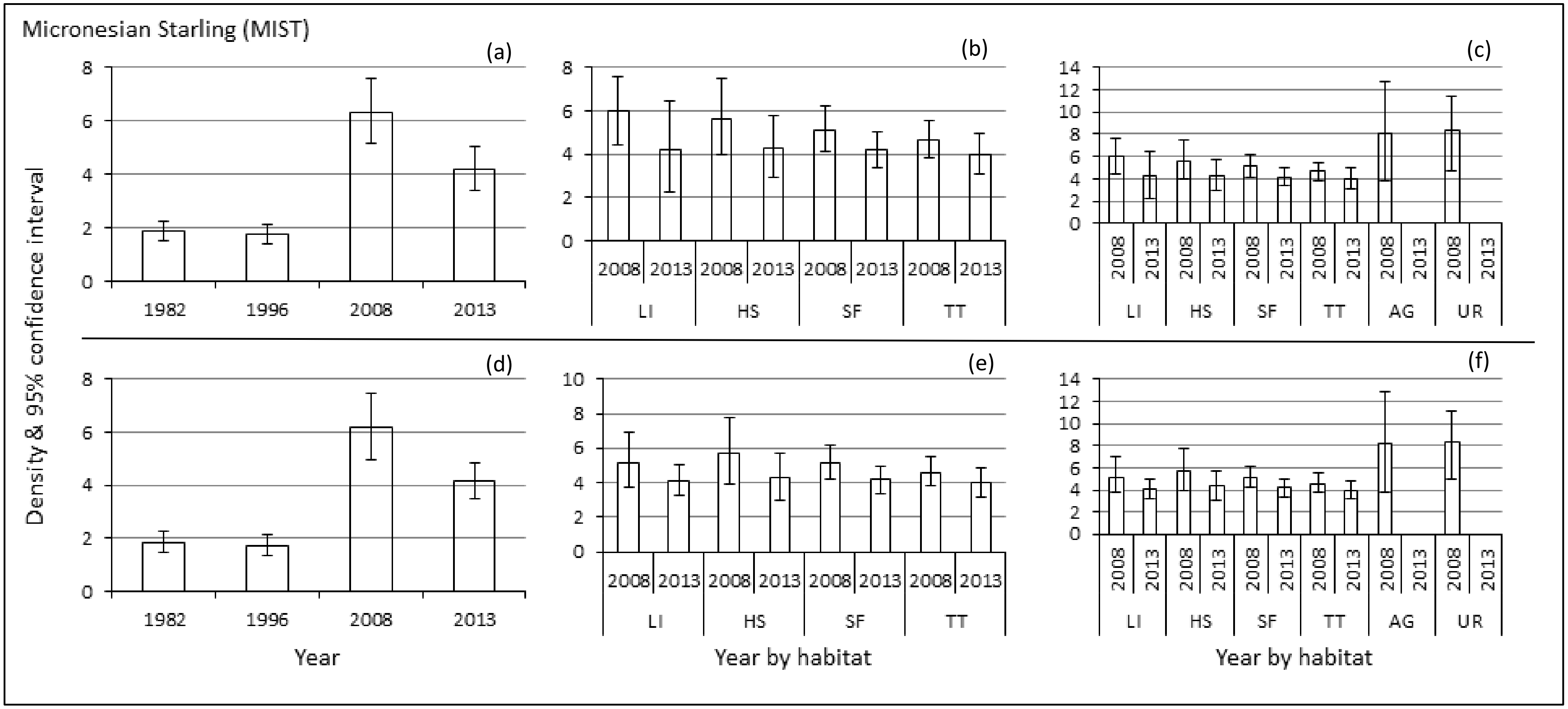


Figure 6. Annual Estimates of Micronesian Starling Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

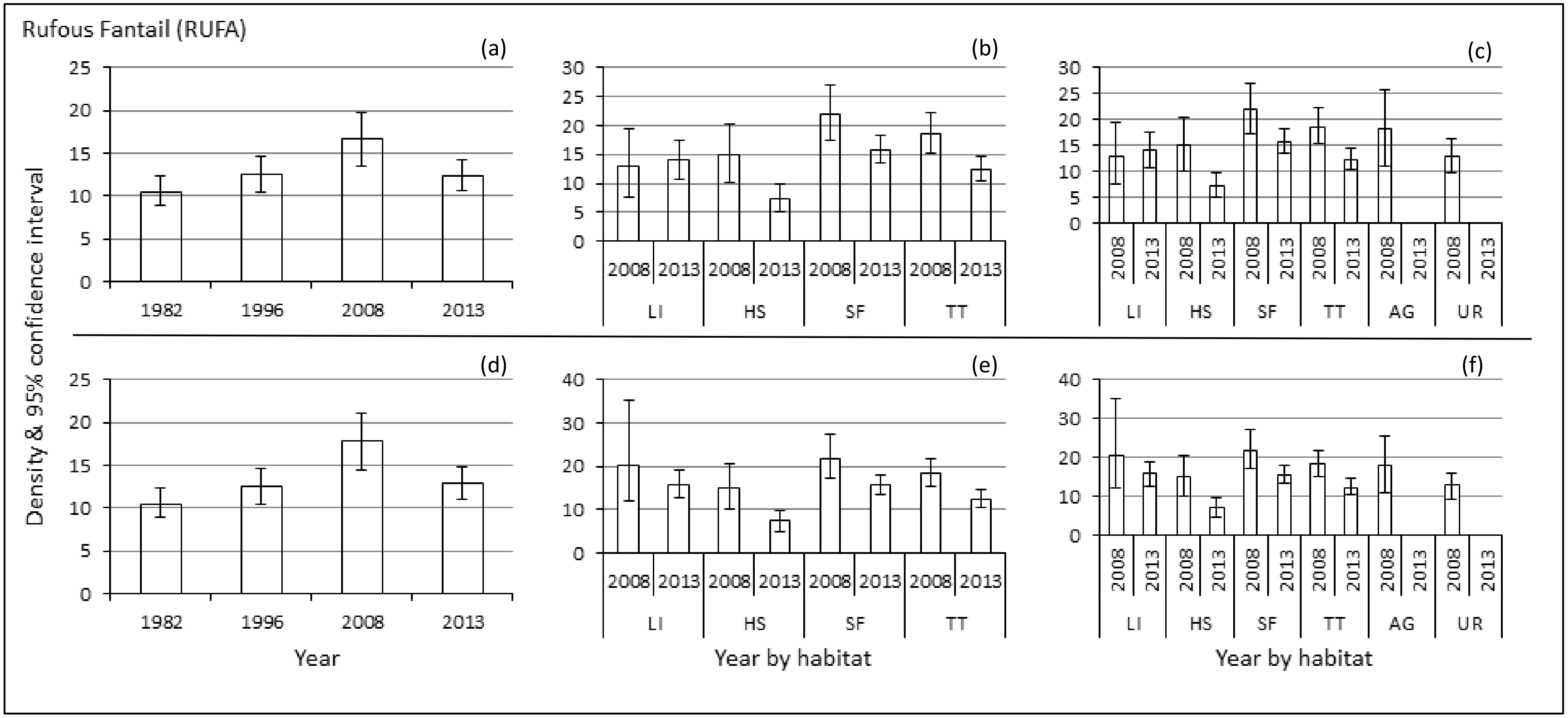


Figure 7. Annual Estimates of Rufous Fantail Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

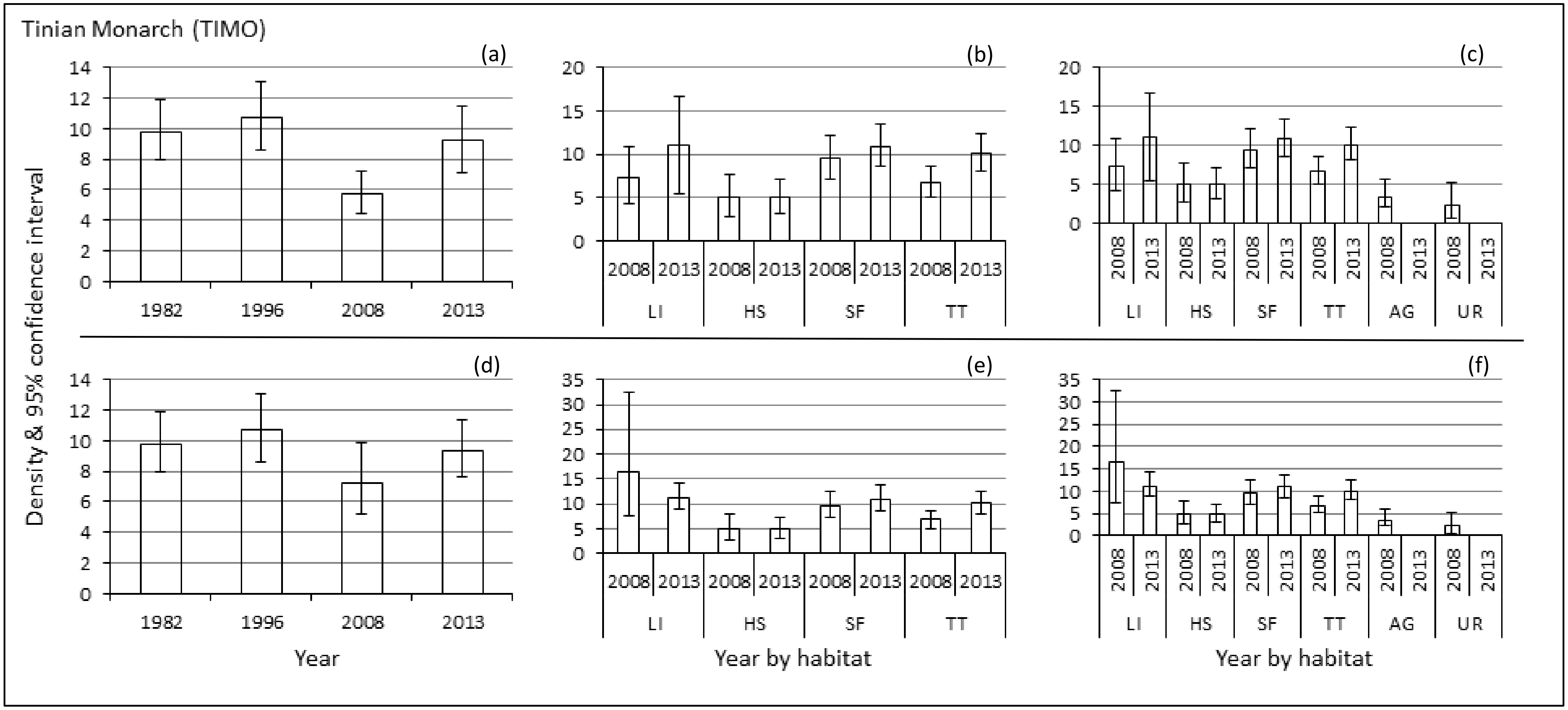


Figure 8. Annual Estimates of Tinian Monarch Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

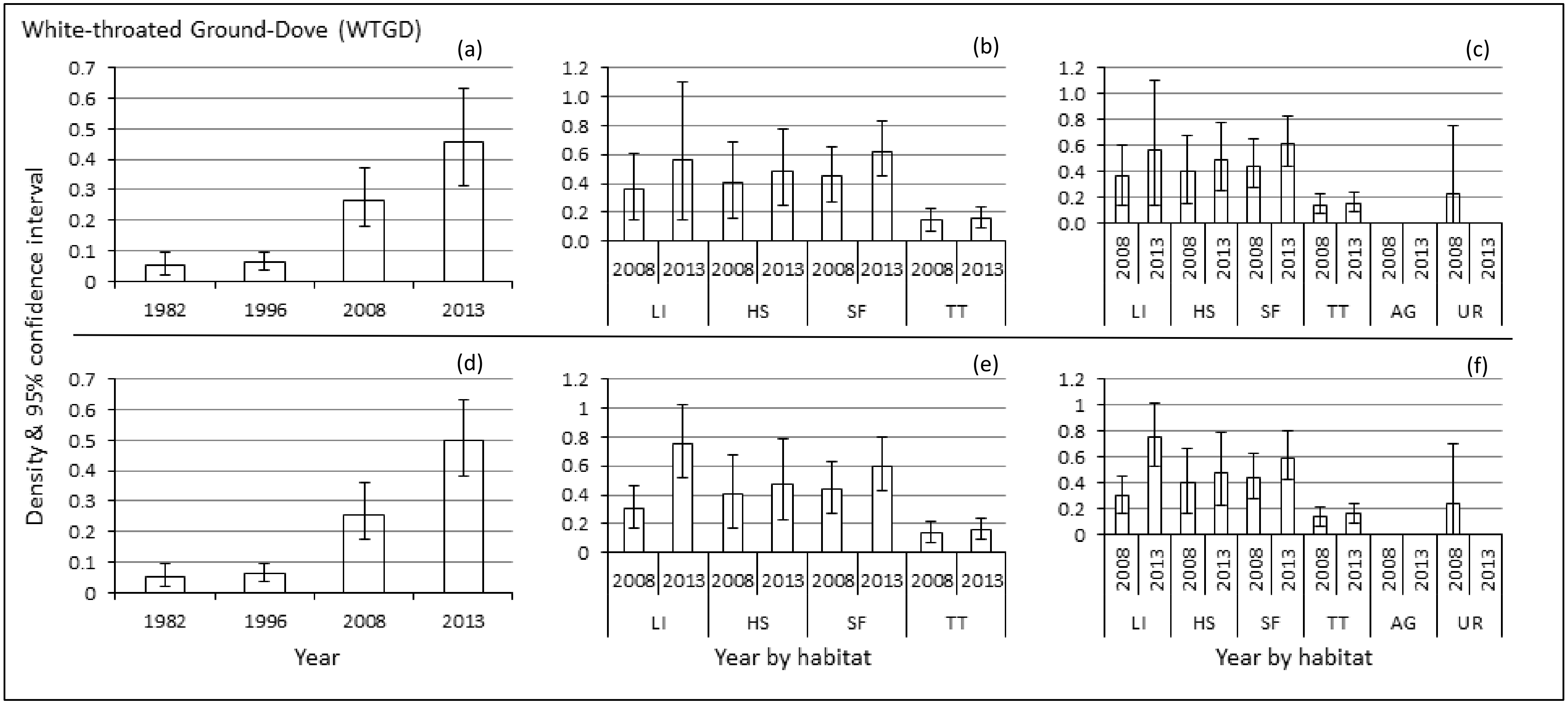


Figure 9. Annual Estimates of White-Throated Ground-Dove Density with 95% Confidence Intervals from Four Point-Transect Surveys

Top row: Estimates use data from the original 10 transects.

Bottom row: estimates use data from all transects.

Left column: annual, island-wide estimates.

Middle column: densities by habitat type (not including human-dominated habitats) from the 2008 and 2013 surveys.

Right column: densities by habitat type (including human-dominated habitats) from the 2008 and 2013 surveys.

Habitat types: limestone forest (LI), herbaceous-scrub (HS), secondary forest (SF), tangantangan (TT), agriculture field (AG), and developed (UR).

SUPPLEMENTS

Supplement 1. List of Species Detected

Species Name	*Scientific Name*	*Species Code*
Brown Noddy	*Anous stolidus*	BRNO
Bridled White-eye	*Zosterops conspicillatus saypani*	BRWE
Collared Kingfisher	*Todiramphus chloris*	COKI
Eurasian Tree sparrow	*Passer montanus*	ETSP
Island Collared Dove	*Streptopelia bitorquata*	ISCD
Mariana Fruit-dove	*Ptilinopus roseicapilla*	MAFD
Micronesian Myzomela	*Myzomela rubratra*	MIMY
Micronesian starling	*Aplonis opaca*	MIST
Orange-cheeked Waxbill	*Estrilda melpoda*	OCWA
Pacific Golden-Plover	*Pluvialis fulva*	PAGP
Pacific Reef Heron	*Egretta sacra*	PARH
Red Junglefowl	*Gallus gallus*	REJU
Rufous Fantail	*Ripidura rufifrons*	RUFA
Tinian Monarch	*Monarcha takatsukasae*	TIMO
White Tern	*Gygis alba rothschildi*	WHTE
White-throated Ground-dove	*Gallicolumba xanthonura*	WTGD
White-tailed Tropicbird	*Phaethon lepturus*	WTTR
Yellow Bittern	*Ixobrychus sinensis*	YEBI

Supplement 2. Indices of Bird Occurrences and Relative Abundances

Stns detect = number of stations with detections

Occ: occurrence = number of stations with one or more detections/number of counts

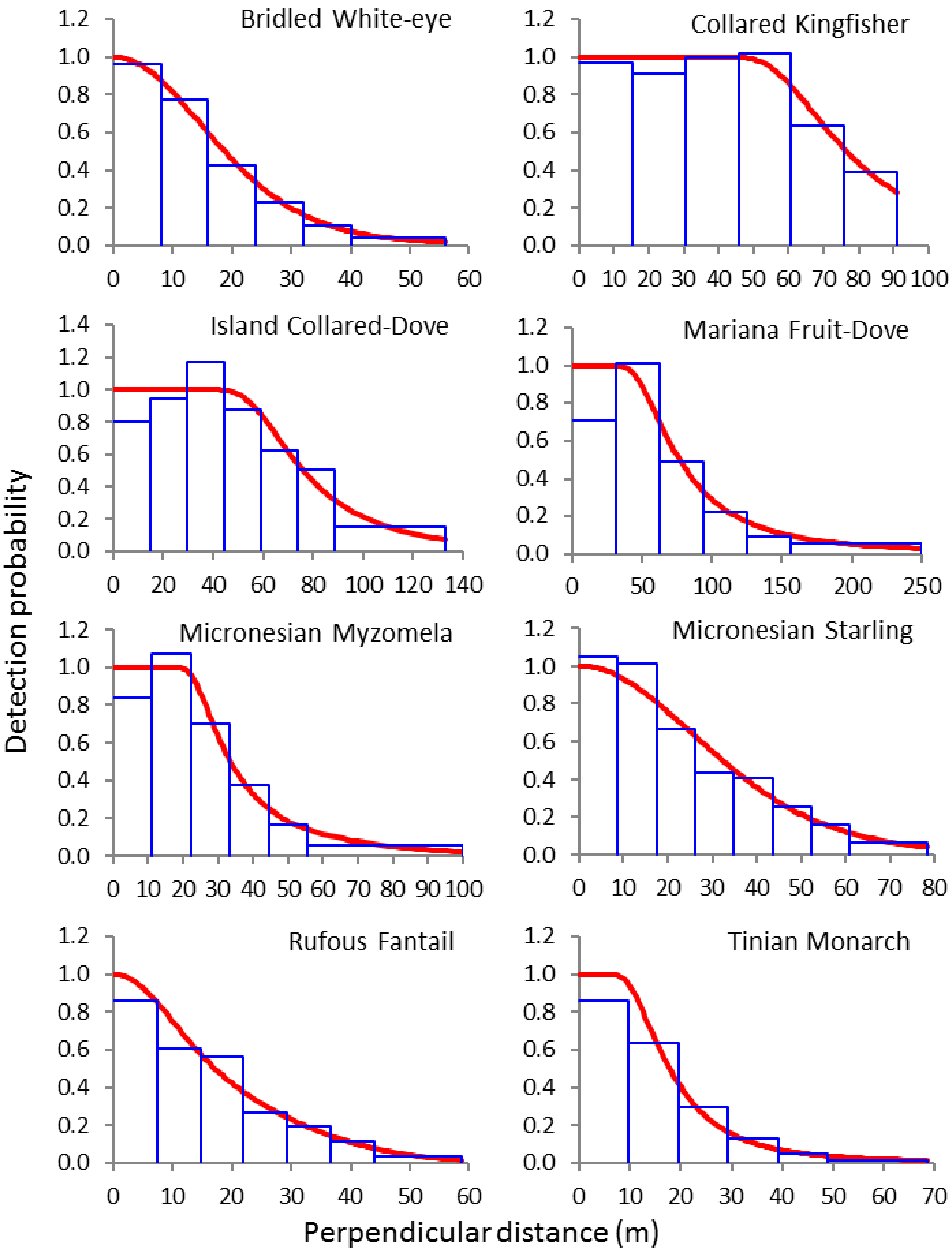
No. detect = number of detections

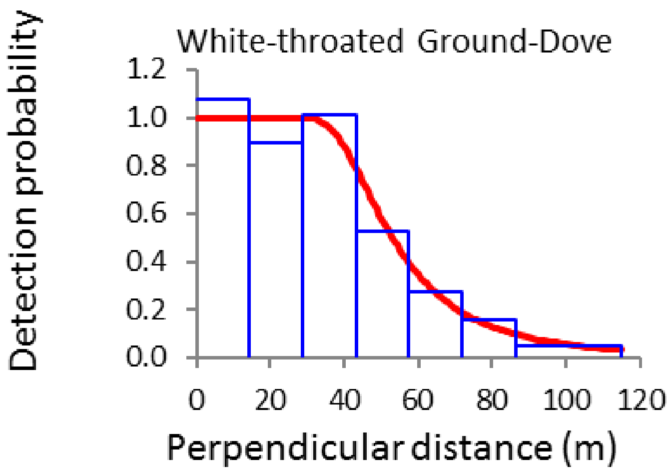
Birds/count: birds per count = number of detections/number of counts

	1982				*1996*				*2008*				*2013*			
Species Code	*Stns detect*	*Occ*	*No. detect*	*Birds/ count*	*Stns detect*	*Occ*	*No. detect*	*Birds/ count*	*Stns detect*	*Occ*	*No. detect*	*Birds/ count*	*Stns detect*	*Occ*	*No. detect*	*Birds/ count*
BRNO	na	na	na	na	na	Na	na	na	1	0.00	1	0.00	8	0.02	25	0.06
BRWE	216	1.00	2222	10.29	216	1.00	1770	8.19	253	1.00	2347	9.24	405	0.98	3592	8.72
COKI	150	0.69	294	1.36	124	0.57	285	1.32	190	0.75	434	1.71	258	0.63	419	1.02
ETSP	1	0.00	1	0.00	3	0.01	13	0.06	13	0.05	74	0.29	5	0.01	6	0.01
ISCD	51	0.24	66	0.31	136	0.63	256	1.19	78	0.31	128	0.50	182	0.44	311	0.75
MAFD	189	0.88	623	2.88	150	0.69	240	1.11	212	0.83	529	2.08	285	0.69	611	1.48
MIMY	131	0.61	236	1.09	59	0.27	94	0.44	87	0.34	151	0.59	244	0.59	493	1.20
MIST	177	0.82	513	2.38	106	0.49	226	1.05	215	0.85	677	2.67	299	0.73	968	2.35
OCWA	na	na	na	na	na	na	na	na	na	na	na	na	3	0.01	6	0.01
PAGP	1	0.00	1	0.00	na	na	na	na	3	0.01	11	0.04	na	na	na	na
PARH	1	0.00	1	0.00	1	0.00	1	0.00	na	na	na	na	na	na	na	na
REJU	45	0.21	105	0.49	na	na	na	na	44	0.17	102	0.40	na	na	na	na
RUFA	202	0.94	786	3.64	188	0.87	502	2.32	234	0.92	829	3.26	369	0.90	981	2.38
TIMO	187	0.87	539	2.50	173	0.80	495	2.29	177	0.70	460	1.81	327	0.79	807	1.96
WHTE	128	0.59	344	1.59	22	0.10	52	0.24	120	0.47	380	1.50	101	0.25	272	0.66
WTGD	13	0.06	16	0.07	23	0.11	23	0.11	64	0.25	90	0.35	163	0.40	255	0.62
WTTR	na	na	na	na	na	na	na	na	3	0.01	5	0.02	na	na	na	na
YEBI	10	0.05	10	0.05	16	0.07	18	0.08	33	0.13	40	0.16	29	0.07	40	0.10

Supplement 3. Histograms of Bird Detections Relative to Distance from Station

Results were used to calculate population estimates on Tinian. The best fit lines for these data were modeled with program DISTANCE.




White-throated Ground-Dove
Detection probability
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Perpendicular distance (m)

Supplement 4. Model Selection and AIC Statistics

AIC statistics and attributes of candidate and selected models used to calculate population estimates of Tinian forest bird species. Within each species analysis, models were sorted by differences in 2nd-order Akaike's information criterion corrected for small sample size (ΔAICc) between each candidate model and the model with the lowest AICc value. Selected models are displayed first.

Species	Model[1]	Adjustment Terms[2]	Covariates[3]	# Parameters[4]	Ln(-Likelihood)[5]	AICc[6]	ΔAICc[7]	wi[8]	Justification
BRWE	H-norm	Key	Obs	12	15194.86	30413.75	0.00	1.00000	
	H-norm	Key	DT14	2	15430.01	30864.03	450.28	0.00000	
	H-norm	Key	Year	4	15430.54	30869.09	455.34	0.00000	
	H-norm	Key	Gust	5	15699.29	31408.59	994.84	0.00000	
	H-norm	Key	DT	3	15710.95	31427.90	1014.15	0.00000	
	H-norm	Key	DT24	2	15721.90	31447.81	1034.06	0.00000	
	H-norm	Key	Detect	5	15756.94	31523.88	1110.13	0.00000	
	H-norm	Key	Habitat	6	15858.25	31728.51	1314.76	0.00000	
	H-norm	Key	Cloud	11	15922.60	31867.22	1453.47	0.00000	
	H-norm	Key	Wind	4	15942.83	31893.67	1479.92	0.00000	
	H-rate	Key		2	15965.37	31934.75	1521.00	0.00000	
	H-norm	Key	Rain	2	16003.85	32011.69	1597.94	0.00000	
	H-norm	Key	Minutes	2	16028.98	32061.96	1648.21	0.00000	
	H-norm	Key		1	16032.50	32066.99	1653.24	0.00000	
	H-norm	Cos							Parameters highly correlated
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Max probability of detection >1
	H-rate	S-poly							Monotonically increasing.
COKI	H-rate	Key	Obs	11	995.61	2013.66	0.00	0.95251	
	H-rate	Key	Rain	3	1007.37	2020.77	7.11	0.02722	
	H-rate	Key	Year	5	1005.64	2021.38	7.72	0.02007	
	H-rate	Key	DT	4	1011.84	2031.74	18.08	0.00011	
	H-rate	Key	DT24	3	1013.20	2032.44	18.78	0.00008	
	H-rate	Key	Gust	5	1014.16	2038.42	24.76	0.00000	
	H-rate	Key	DT14	3	1016.48	2038.99	25.33	0.00000	
	H-rate	Key	Detect	6	1016.24	2044.61	30.95	0.00000	
	H-rate	Key	Wind	5	1017.75	2045.60	31.94	0.00000	
	H-rate	Key	Minutes	3	1019.94	2045.91	32.25	0.00000	
	H-rate	Key		2	1022.20	2048.41	34.75	0.00000	
	H-rate	Key	Cloud	3	1021.55	2049.13	35.47	0.00000	
	H-norm	Key		1	1028.44	2058.89	45.23	0.00000	
	H-norm	Cos							Max probability of detection > 1
	H-norm	H-poly							Max probability of detection > 1
	H-rate	Cos							Key detection function selected
	H-rate	S-poly							Key detection function selected
	H-rate	Key	Habitat						Negative variance estimate for parameter

Species	Model[1]	Adjustment Terms[2]	Covariates[3]	# Parameters[4]	Ln(-Likelihood)[5]	AICc[6]	ΔAICc[7]	wi[8]	Justification
ISCD	H-rate	Key	DT	4	1116.06	2240.18	0.00	0.99992	
	H-rate	Key	Obs	9	1120.40	2259.09	18.91	0.00008	
	H-rate	Key	Year	5	1128.15	2266.40	26.22	0.00000	
	H-rate	Key		2	1148.68	2301.38	61.20	0.00000	
	H-norm	Key		1	1151.01	2304.03	63.85	0.00000	
	H-rate	Key	Rain	3	1149.33	2304.70	64.52	0.00000	
	H-rate	Key	DT24	3	1149.75	2305.54	65.36	0.00000	
	H-rate	Key	Minutes	3	1149.76	2305.55	65.37	0.00000	
	H-rate	Key	DT14	3	1149.77	2305.58	65.40	0.00000	
	H-rate	Key	Cloud	3	1149.78	2305.61	65.43	0.00000	
	H-rate	Key	Gust	5	1149.17	2308.43	68.25	0.00000	
	H-rate	Key	Wind	5	1149.64	2309.38	69.20	0.00000	
	H-rate	Key	Detect	6	1149.49	2311.11	70.93	0.00000	
	H-rate	Key	Habitat	7	1149.36	2312.90	72.72	0.00000	
	H-norm	Cos							Max probability of detection > 1
	H-norm	H-poly							Max probability of detection > 1
	H-rate	Cos							Max probability of detection > 1
	H-rate	S-poly							Max probability of detection > 1
MAFD	H-rate	Key	Year	5	2813.45	5636.93	0.00	1.00000	
	H-rate	Key	Gust	5	3075.07	6160.16	523.23	0.00000	
	H-rate	Key	Wind	5	3100.39	6210.80	573.87	0.00000	
	H-rate	Key	Detect	6	3112.52	6237.09	600.16	0.00000	
	H-norm	Cos		3	3139.93	6285.86	648.93	0.00000	Parameterized model failed bootstrap procedure convergence; therefore, use more parsimonious H-rate Key model with covariates to estimate abundances.
	H-rate	Key		2	3146.25	6296.51	659.58	0.00000	
	H-rate	Key	Cloud	3	3162.65	6331.30	694.37	0.00000	
	H-rate	Key	DT14	3	3162.77	6331.54	694.61	0.00000	
	H-rate	Key	DT24	3	3162.79	6331.60	694.67	0.00000	
	H-rate	Key	Minutes	3	3162.88	6331.77	694.84	0.00000	
	H-rate	Key	DT	4	3163.48	6334.98	698.05	0.00000	
	H-rate	Key	Habitat	7	3162.24	6338.54	701.61	0.00000	
	H-norm	Key		1	3240.06	6482.12	845.19	0.00000	
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Max probability of detection > 1
	H-rate	S-poly							Max probability of detection > 1
	H-rate	Key	Obs						Convergence failure
	H-rate	Key	Rain						Convergence failure
MIMY	H-rate	Key	Year	5	1432.66	2875.38	0.00	1.00000	
	H-rate	Key	Obs	10	1440.65	2901.55	26.17	0.00000	
	H-rate	Key	Rain	3	1472.63	2951.29	75.91	0.00000	

Species	Model[1]	Adjustment Terms[2]	Covariates[3]	# Parameters[4]	Ln(-Likelihood)[5]	AICc[6]	ΔAICc[7]	wi[8]	Justification
	H-rate	Key	DT	4	1531.96	3071.96	196.58	0.00000	
	H-rate	Key	DT24	3	1536.81	3079.65	204.27	0.00000	
	H-rate	Key	DT14	3	1543.18	3092.38	217.00	0.00000	
	H-rate	Key	Gust	5	1541.31	3092.68	217.30	0.00000	
	H-rate	Key	Detect	6	1544.26	3100.61	225.23	0.00000	
	H-rate	Key	Wind	5	1569.50	3149.07	273.69	0.00000	
	H-rate	Key		2	1577.91	3159.83	284.45	0.00000	
	H-rate	Key	Minutes	3	1578.06	3162.14	286.76	0.00000	
	H-rate	Key	Cloud	3	1578.24	3162.51	287.13	0.00000	
	H-norm	Cos		3	1578.59	3163.21	287.83	0.00000	
	H-norm	Key		1	1596.60	3195.20	319.82	0.00000	
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Key detection function selected
	H-rate	S-poly							Key detection function selected
	H-rate	Key	Habitat						Convergence failure
MIST	H-norm	Key	Obs	11	3698.45	7419.05	0.00	0.99991	
	H-norm	Key	DT	3	3715.87	7437.75	18.70	0.00009	
	H-norm	Key	DT24	2	3730.45	7464.92	45.87	0.00000	
	H-norm	Key	Year	4	3733.17	7474.36	55.31	0.00000	
	H-norm	Key	Rain	2	3748.24	7500.49	81.44	0.00000	
	H-norm	Key	Detect	5	3774.56	7559.15	140.10	0.00000	
	H-norm	Key	Habitat	6	3775.50	7563.05	144.00	0.00000	
	H-norm	Key	Gust	4	3780.75	7569.53	150.48	0.00000	
	H-norm	Cos		3	3783.32	7572.65	153.60	0.00000	Parameterized model failed bootstrap procedure convergence; therefore, use more parsimonious key model with covariates to estimate abundances.
	H-norm	Key	DT14	2	3784.60	7573.20	154.15	0.00000	
	H-rate	S-poly		3	3784.80	7575.62	156.57	0.00000	
	H-norm	Key		1	3793.10	7588.20	169.15	0.00000	
	H-norm	Key	Wind	4	3790.43	7588.87	169.82	0.00000	
	H-norm	Key	Minutes	2	3792.78	7589.56	170.51	0.00000	
	H-norm	Key	Cloud	2	3792.98	7589.96	170.91	0.00000	
	H-rate	Key		2	3808.84	7621.70	202.65	0.00000	
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Parameters highly correlated
RUFA	H-norm	Key	DT	3	4440.29	8886.59	0.00	0.99845	
	H-norm	Key	DT24	2	4447.76	8899.53	12.94	0.00155	
	H-norm	Key	DT14	2	4625.56	9255.11	368.52	0.00000	
	H-norm	Key	Obs	12	4746.14	9516.40	629.81	0.00000	
	H-norm	Key	Year	4	4798.09	9604.19	717.60	0.00000	
	H-norm	Key	Detect	5	4815.13	9640.27	753.68	0.00000	

Species	Model[1]	Adjustment Terms[2]	Covariates[3]	# Parameters[4]	Ln(-Likelihood)[5]	AICc[6]	ΔAICc[7]	wi[8]	Justification
	H-norm	Key	Rain	2	4833.42	9670.83	784.24	0.00000	
	H-norm	Key	Habitat	6	4829.46	9670.96	784.37	0.00000	
	H-norm	Key	Gust	4	4834.12	9676.25	789.66	0.00000	
	H-norm	Key	Wind	4	4842.53	9693.07	806.48	0.00000	
	H-norm	Cos		2	4851.51	9707.02	820.43	0.00000	Parameterized model failed bootstrap procedure convergence; therefore, use more parsimonious key model with covariates to estimate abundances.
	H-norm	Key	Minutes	2	4854.36	9712.73	826.14	0.00000	
	H-norm	Key		1	4856.58	9715.17	828.58	0.00000	
	H-norm	Key	Cloud	2	4855.84	9715.69	829.10	0.00000	
	H-rate	Key		2	4868.03	9740.07	853.48	0.00000	
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Max probability of detection > 1
	H-rate	S-poly							Parameters highly correlated
TIMO	H-rate	Key	Obs	13	3435.01	6896.19	0.00	0.99984	
	H-rate	Key	Year	5	3451.80	6913.63	17.44	0.00016	
	H-rate	Key	Gust	5	3465.27	6940.57	44.38	0.00000	
	H-rate	Key	Detect	6	3464.93	6941.91	45.72	0.00000	
	H-rate	Key	Rain	3	3468.93	6943.86	47.67	0.00000	
	H-rate	Key	Habitat	7	3489.25	6992.55	96.36	0.00000	
	H-rate	S-poly		4	3493.50	6995.01	98.82	0.00000	Fully parameterized model, H-rate S-poly, failed to converge during bootstrap procedures. The more parsimonious H-rate Key with covariate OBS model used to estimate abundances.
	H-norm	Cos		3	3494.51	6995.04	98.85	0.00000	
	H-rate	Key		2	3499.80	7003.60	107.41	0.00000	
	H-rate	Key	Cloud	3	3509.68	7025.38	129.19	0.00000	
	H-rate	Key	Minutes	3	3510.22	7026.45	130.26	0.00000	
	H-rate	Key	Wind	5	3510.49	7031.00	134.81	0.00000	
	H-norm	Key		1	3536.92	7075.83	179.64	0.00000	
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Max probability of detection > 1
	H-rate	Key	DT						Convergence failure
	H-rate	Key	DT14						Convergence failure
	H-rate	Key	DT24						Convergence failure

Species	Model[1]	Adjustment Terms[2]	Covariates[3]	# Parameters[4]	Ln(-Likelihood)[5]	AICc[6]	ΔAICc[7]	wi[8]	Justification
WTGD	H-rate	Key		2	618.72	1241.48	0.00	0.78751	
	H-norm	Key		1	621.04	1244.10	2.62	0.21249	
	H-norm	Cos							Key detection function selected
	H-norm	H-poly							Parameters highly correlated
	H-rate	Cos							Key detection function selected
	H-rate	S-poly							Key detection function selected

1 Models examined included half-normal (H-norm) and hazard-rate (H-rate) key detection functions.
2 Adjustment terms include model without adjustment terms (Key), and with cosine (Cos), Hermite polynomial (H-poly), or simple polynomial (S-poly) series expansions.
3 Covariates were incorporated with the most parsimonious model to improve model precision. Covariates included the factor variables cloud cover (Cloud), amount of rain (Rain), Beaufort wind scale (Wind), Beaufort gust scale (Gust), observer (Obs), detection type (DT; pooled auditory detections [DT14]; pooled visual detections [DT24]), understory openness (Detect), habitat (Habitat), survey year (Year), and the continuous variable time of day (Minutes).
4 Number of estimated parameters.
5 Estimate of the log-likelihood.
6 Second-order Akaike's information criterion corrected for small sample sizes (AICc).
7 Difference among AICc.
8 Akaike model weight (*wi*) is the likelihood that each model is the best of the models evaluated.

Supplement 5. List of Stations Sampled by Survey

Data from stations that were sampled during all four surveys were used for repeated measures analysis.

Transect	*Station*	*1982*	*1996*	*2008*	*2013*
1	1	X	X	X	X
1	2	X	X	X	X
1	3	X	X	X	X
1	4	X	X	X	X
1	5	X	X	X	X
1	6	X	X	X	X
1	7	X	X	X	X
1	8	X	X	X	X
1	9	X	X	X	X
1	10	X	X	X	X
1	11	X	X	X	X
1	12	X	X	X	X
1	13	X	X	X	X
1	14	X	X	X	X
1	15	X	X	X	X
1	16	X	X	X	X
1	17	X	X	X	X
1	18	X	X	X	X
2	1	X	X	X	X
2	2	X	X	X	X
2	3	X	X	X	X
2	4	X	X	X	X
2	5	X	X	X	X
2	6	X	X	X	X
2	7	X	X	X	X
2	8	X	X	X	X
2	9	X	X	X	X
2	10	X	X	X	X
2	11	X	X	X	X
2	12	X	X	X	X
2	13	X	X	X	X
2	14	X	X	X	X
2	15	X	X	X	X
2	16	X	X	X	X
2	17	X	X	X	X
2	18	X	X	X	X
2	19	X	X	X	X
2	20	X	X	X	X
2	21	X	X	X	X
2	22	X	X	X	X
2	23	X	X	X	X
2	24	X	X	X	X
2	25	X	X	X	X
2	26	X	X	X	X
2	27	X	X	X	X
2	28	X	X	X	X
2	29	X	X	X	X

Transect	*Station*	*1982*	*1996*	*2008*	*2013*
2	30	X	X	X	X
2	31	X	X	X	X
2	32	X	X	X	X
2	33	X	X	X	X
2	34	X	X	X	X
2	35	X	X	X	X
2	36	X	X	X	X
3	1	X	X	X	X
3	2	X	X	X	X
3	3	X	X	X	X
3	4	X	X	X	X
3	5	X	X	X	X
3	6	X	X	X	X
3	7	X	X	X	X
3	8	X	X	X	X
3	9	X	X	X	X
3	10	X	X	X	X
3	11	X	X	X	X
3	12	X	X	X	X
3	13	X	X	X	X
3	14	X	X	X	X
3	15	X	X	X	X
3	16	X	X	X	X
3	17	X	X	X	X
3	18	X	X	X	X
3	19	X	X	X	
4	1	X	X	X	X
4	2	X	X	X	X
4	3	X	X	X	X
4	4	X	X	X	X
4	5	X	X	X	X
4	6	X	X	X	X
4	7	X	X	X	X
4	8	X	X	X	X
4	9	X	X	X	X
4	10	X	X	X	X
4	11	X	X	X	X
4	12	X	X	X	X
4	13	X	X	X	X
4	14	X	X	X	X
4	15	X	X	X	X
4	16	X	X	X	X
4	17	X	X	X	X
4	18	X	X	X	X
4	19	X	X	X	X
4	20	X	X	X	X
4	21	X	X	X	X
4	22	X	X	X	X
4	23	X	X	X	X
4	24	X	X	X	X
4	25	X	X	X	X

Transect	*Station*	*1982*	*1996*	*2008*	*2013*
4	26	X	X	X	X
4	27	X	X	X	X
4	28	X	X	X	X
4	29	X	X	X	X
4	30	X	X	X	X
4	31	X	X	X	X
4	32	X	X	X	X
4	33	X	X	X	X
4	34	X	X	X	X
4	35	X	X	X	X
4	36	X	X	X	X
5	1	X	X	X	
5	2	X	X	X	X
5	3	X	X	X	X
5	4	X	X	X	X
5	5	X	X	X	X
5	6	X	X	X	X
5	7	X	X	X	X
5	8	X	X	X	X
5	9	X	X	X	X
5	10	X	X	X	X
5	11	X	X	X	X
5	12	X	X	X	X
5	13	X	X	X	X
5	14	X	X	X	X
5	15	X	X	X	X
5	16	X	X	X	X
5	17	X	X	X	X
5	18	X	X	X	X
6	1	X	X	X	X
6	2	X	X	X	X
6	3	X	X	X	X
6	4	X	X	X	X
6	5	X	X	X	X
6	6	X	X	X	X
6	7	X	X	X	X
6	8	X	X	X	X
6	9	X	X	X	X
6	10	X	X	X	X
6	11	X	X	X	X
6	12	X	X	X	X
6	13	X	X	X	X
6	14	X	X	X	X
6	15	X	X	X	X
6	16	X	X	X	X
6	17	X	X	X	X
6	18	X	X	X	X
7	1	X	X	X	
7	2	X	X	X	
7	3	X	X	X	
7	4	X	X	X	

Transect	*Station*	*1982*	*1996*	*2008*	*2013*
7	5	X	X	X	
7	6	X	X	X	
7	7	X	X	X	
7	8	X	X	X	
7	9	X	X	X	
7	10	X	X	X	
7	11	X	X	X	
7	12	X	X	X	
7	13	X	X	X	
7	14	X	X	X	
7	15	X	X	X	X
7	16	X	X	X	X
7	17	X	X	X	X
7	18	X	X	X	X
8	1	X	X	X	
8	2	X	X	X	
8	3	X	X	X	
8	4	X	X	X	
8	5	X	X	X	
8	6	X	X	X	
8	7	X	X	X	
8	8	X	X	X	X
8	9	X	X	X	X
8	10	X	X	X	X
8	11	X	X	X	X
8	12	X	X	X	X
8	13	X	X	X	X
8	14	X	X	X	X
8	15	X	X	X	
8	16	X	X	X	
8	17	X	X	X	
8	18	X	X	X	
9	1	X	X	X	
9	2	X	X	X	
9	3	X	X	X	
9	4	X	X	X	
9	5	X	X	X	
9	6	X	X	X	
9	7	X	X	X	
9	8	X	X	X	
9	9	X	X	X	
9	10	X	X	X	
9	11	X	X	X	
9	12	X	X	X	
9	13	X	X	X	
9	14	X	X	X	
9	15	X	X	X	
9	16	X	X	X	
9	17	X	X	X	
9	18	X	X	X	
10	1	X	X	X	

Transect	*Station*	*1982*	*1996*	*2008*	*2013*
10	2	X	X	X	
10	3	X	X	X	X
10	4	X	X	X	X
10	5	X	X	X	
10	6	X	X	X	
10	7	X	X	X	
10	8	X	X	X	
10	9	X	X	X	
10	10	X	X	X	X
10	11	X	X	X	X
10	12	X	X	X	X
10	13	X	X	X	X
10	14	X	X	X	X
10	15	X	X	X	
10	16	X	X	X	
10	17	X	X	X	
10	18			X	
11	1			X	X
11	2			X	X
11	3			X	X
11	4			X	X
11	5			X	X
11	6			X	X
11	7			X	X
11	8			X	X
11	9			X	X
12	1			X	X
12	2			X	X
12	3			X	X
12	4			X	X
12	5			X	X
12	6			X	X
12	7			X	X
12	8			X	X
12	9			X	X
13	1			X	X
13	2			X	X
13	3			X	X
13	4			X	X
13	5			X	X
13	6			X	X
13	7			X	X
13	8			X	X
13	9			X	X
13	10			X	X
13	11			X	X
13	12			X	X
13	13			X	X
13	14			X	X
14	1			X	
14	2			X	

Transect	*Station*	*1982*	*1996*	*2008*	*2013*
14	3			X	
14	4			X	
14	5			X	
15	1				X
15	2				X
15	3				X
15	4				X
15	5				X
15	6				X
15	7				X
16	1				X
16	2				X
16	3				X
16	4				X
16	5				X
16	6				X