

Terrestrial reptiles of Pagan Island, Commonwealth of the Northern Mariana Islands

Robert N Reed^{1*}
Gordon H Rodda¹
Shane R. Siers²
Elijah Wostl³
Amy A. Yackel Adams³

¹U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Ave, Bldg C, Fort Collins CO 80526

²Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, Colorado 80523, U.S.A.

³ASRC Management Services under contract to USGS, Fort Collins Science Center, 2150 Centre Avenue, Bldg C, Fort Collins, Colorado 80526, USA

* Corresponding author: reedr@usgs.gov, 970-226-9464

Introduction

This work covers the terrestrial herpetofauna of Pagan, including all species encountered via various sampling methods during June and July 2010 within the land environment (including subterranean, terrestrial, and arboreal species).

There is remarkably little available information on the herpetofauna of Pagan. Hasegawa (1993) reported on the results of a Chiba Institute expedition to the northern Mariana Islands, but reported only one specimen collected from Pagan, a *Hemidactylus frenatus* (see Table 1 for a list of scientific and common names mentioned in this report). Scott Vogt collected *Emoia caeruleocauda*, *E. slevini*, *H. frenatus*, *Lepidodactylus lugubris*, and *Varanus indicus* in 1999 as part of a CNMI Division of Fish and Wildlife (DFW) expedition (S. Vogt, pers. comm. 2010). Minimal glueboard sampling (see below) was conducted in 2000 as part of another CNMI DFW research trip, but very few lizards were captured and they were not identified to species.

Originally, the scope of our project included completion of four removal plots, glueboard and visual survey sampling for reptiles across all major habitats, and opportunistic surveys. However, our sampling schedule was greatly abbreviated by a volcano-related evacuation and by the decision by FWS to end biology-related operations on Pagan prior to the scheduled date for completion of our fieldwork. These changes resulted in completion of only two removal plots, although we succeeded in sampling most major habitat types via glueboard and visual.

Table 1. Scientific and common names of species mentioned in this report with taxonomic family and general animal type.

Scientific name	Common name	Family	Animal type
<i>Cryptoblepharus poecilopleurus</i>	Snake-eyed skink	Scincidae	Diurnal lizard
<i>Emoia atrocostata</i>	Tidepool or littoral skink	Scincidae	Diurnal lizard
<i>Emoia caeruleocauda</i>	Blue-tailed skink	Scincidae	Diurnal lizard
<i>Emoia slevini</i>	Slevin's skink	Scincidae	Diurnal lizard
<i>Gehyra mutilata</i>	Mutilating gecko	Gekkonidae	Nocturnal lizard
<i>Gehyra oceanica</i>	Oceanic gecko	Gekkonidae	Nocturnal lizard
<i>Hemidactylus frenatus</i>	Common house gecko	Gekkonidae	Nocturnal lizard
<i>Lepidodactylus lugubris</i>	Mourning gecko	Gekkonidae	Nocturnal lizard
<i>Nactus pelagicus</i>	Pacific slender-toed gecko	Gekkonidae	Nocturnal lizard
<i>Ramphotyphlops braminus</i>	Brahminy blindsnake	Typhlopidae	Fossorial snake
<i>Varanus indicus</i>	Mangrove monitor	Varanidae	Large diurnal lizard

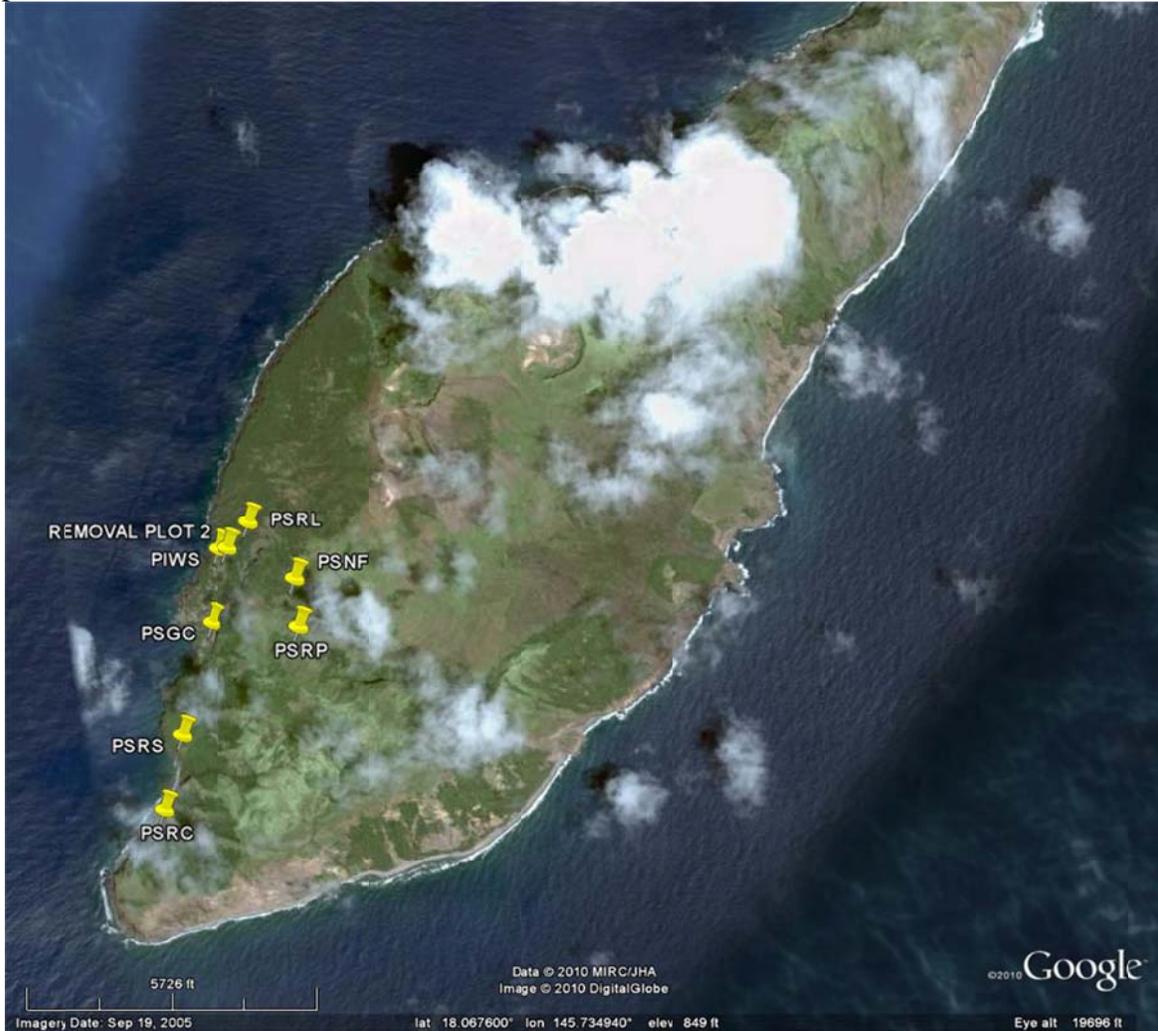
Materials and Methods

Three primary methods were used in 2010 on Pagan: glueboard surveys, nocturnal visual surveys, and total removal plots. All sampling sites are mapped in Fig. 1 (A, B). Habitat names follow Mueller-Dombois and Fosberg (1998), except when departure from these standard names would be helpful or for non-vegetative habitats (e.g., lava flows).

Fig. 1A. Map of sampling sites on northern Pagan. Site codes correspond to information in Tables 2 and 3, below. Note that some site codes refer to general habitat types (e.g., site code PNCN refers to *Casuarina* forest with native understory in northern Pagan); map markers provide just one location for sampling in such a widespread and fairly uniform habitat.



Fig. 1B. Map of sampling sites on southern Pagan. Site codes correspond to codes provided in Tables 2 and 3, below.



Glueboard sampling

Glueboard sampling methods are detailed in Rodda et al. (1993, 2005b). Sampling was conducted using paper mouse glueboards (Victor, Lititz PA). These traps were set individually in straight or slightly curving lines on the ground in shade; a few lines were set at chest height on tree trunks to sample arboreal lizards. Most lines were of 12 traps; deviations from this generality are noted in Table 1. We also placed traps in a ring surrounding total removal plots to gain insight on detection probability, as this allows within-site comparison of glueboard trap capture rates with absolute densities from within removal plots. The traps were checked every 30 min for three morning hours, overnight, or periodically throughout the day for 24 h. Capture rates are expressed as captures per trap-hour.

Table 2. Glueboard sampling of Pagan, 2010. Throughout this document, latitudes and longitudes are given to the precision implied by the number of significant digits and all are in the WGS84 datum.

Site	Latitude	Longitude	Micro-habitat	Time ended	# Traps	Trap-Hrs	Date	Lizard Captures
PURB	N 18.125	145.758	Abandoned buildings	0730	12	24	16-Jun-10	17
PURB	N 18.125	145.758	Abandoned buildings	0730	12	24	16-Jun-10	11
PAEL	N 18.123	E 145.766	Lava field	1215	12	4.25	16-Jun-10	14
PAEL	N 18.123	E 145.766	Lava field	1215	12	4.25	16-Jun-10	15
PNCC	N 18.152	E 145.759	<i>Cocos/Casuarina</i>	730	12	14	17-Jun-10	6
PNCC	N 18.152	E 145.759	<i>Cocos/Casuarina</i>	730	12	14	17-Jun-10	21
MCCL	N 18.118	E 145.764	Miari cliffline	1113	12	3	19-Jun-10	3
MCCO	N 18.120	E 145.761	<i>Cocos</i> forest edge	1120	12	3	19-Jun-10	1
MCJA	N 18.120	E 145.762	<i>Jatropha</i> forest	1130	12	3.5	19-Jun-10	15
SRRF	N 18.121	E 145.7581	Ravine forest	1120	12	3	20-Jun-10	8
MCCL	N 18.118	E 145.764	Miari cliffline	0559	10	11	20-Jun-10	8
SRIN	N 18.122	E 145.757	Intertidal	1135	12	3	20-Jun-10	12
SRCF	N 18.121	E 145.758	<i>Casuarina</i>	1121	12	3	20-Jun-10	1
PURB	N 18.125	145.758	Abandoned buildings	0553	12	11	21-Jun-10	3
PAEL	N 18.123	E 145.766	Lava field	716	13	12.5	21-Jun-10	0
PURB	N 18.125	145.758	Abandoned buildings	642	12	13	22-Jun-10	1
PSRP	N 18.061	E 145.719	Native forest	1137	12	3	25-Jun-10	0
PSNF	N 18.063	E 145.719	Native forest	1146	12	3	25-Jun-10	1
PSNF	N 18.06	E 145.71	Native forest	1146	12	3	25-Jun-10	6
PIWS	N 18.065	E 145.714	<i>Casuarina</i>	0800	12	24	27-Jun-10	5
PIWS	N 18.065	E 145.714	<i>Casuarina</i>	0800	12	24	27-Jun-10	17
PSRL	N 18.064	E 145.715	Ravine forest	0800	12	24	27-Jun-10	5
PSRL	N 18.064	E 145.715	Ravine forest	0800	12	24	27-Jun-10	4
PENF	N 18.112	E 145.793	Native forest	1134	12	17.5	29-Jun-10	7
PENF	N 18.112	E 145.793	Native forest	1134	12	17.5	29-Jun-10	11
PENF	N 18.112	E 145.793	Native forest	1133	12	17.5	29-Jun-10	14
PENF	N 18.112	E 145.793	Native forest	1135	12	17.5	29-Jun-10	4

SRRF	N 18.121	E 145.7581	Ravine forest	1110	12	3	29-Jun-10	7
SRRF	N 18.121	E 145.7581	Ravine forest	1115	12	3	29-Jun-10	8
SRRF	N 18.121	E 145.7581	Ravine forest	1110	12	3	29-Jun-10	8
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	1130	12	17	29-Jun-10	5
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	1130	12	17	29-Jun-10	54
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	1130	12	17	29-Jun-10	31
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	1130	12	17	29-Jun-10	3
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	1130	12	17	29-Jun-10	63
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	1130	12	17	29-Jun-10	69
SRIN	N 18.122	E 145.757	Intertidal	1150	12	4	1-Jul-10	2
SRIN	N 18.122	E 145.757	Intertidal	1150	12	4	1-Jul-10	0
PSNF	N 18.06	E 145.71	Native forest	0600	12	14	2-Jul-10	10
PSNF	N 18.06	E 145.71	Native forest	1200	12	20	2-Jul-10	21
PNBS	N 18.105	E 145.794	<i>Pemphis</i> /intertidal	0647	20	12.1	2-Jul-10	4
PSNF	N 18.06	E 145.71	Native forest	1200	12	4.5	3-Jul-10	11
PSRS	N 18.055	E 145.712	Ravine forest	0600	12	14	3-Jul-10	0
PSRS	N 18.055	E 145.712	Ravine forest	1200	12	20	3-Jul-10	25
PSRS	N 18.055	E 145.712	Ravine forest	1215	12	5	4-Jul-10	3
PSRC	N 18.051	145.711	Ravine/ <i>Cycas</i>	1200	12	18	4-Jul-10	5
PSRC	N 18.051	145.711	Ravine/ <i>Cycas</i>	1200	12	18	4-Jul-10	18
PNCN	N 18.14	E 145.77	<i>Casuarina</i> /native	1130	25	16.5	4-Jul-10	0
PSGC	N 18.06	E 145.713	<i>Casuarina</i> /grass	1200	12	4.5	5-Jul-10	4
PNNF	N 18.156	E 145.79	Native forest	1200	12	18	7-Jul-10	4
PNNF	N 18.156	E 145.79	Native forest	1200	12	18	7-Jul-10	4
PNNF	N 18.156	E 145.79	Native forest	1200	12	18	7-Jul-10	2
PNNF	N 18.156	E 145.79	Native forest	1200	12	18	7-Jul-10	4
PNNF	N 18.156	E 145.79	Native forest	1215	12	4.5	8-Jul-10	1

Fig. 2. Representative image of near-monoculture of *Casuarina* with fern/forb understory, typical of many areas on the northern half of Pagan. This was the location of removal Plot 1.



Fig. 3. Representative image of *Cocos* monoculture with virtually no understory, typical of *Cocos* forest on the east side of Pagan. Sampling site PECO was near this location.



Fig. 4. Representative image of *Casuarina*, scattered native trees, and bunchgrass understory, typical of some areas in southern Pagan. Removal Plot 2 and sampling site PSGC were near this location.



Fig. 5. Representative image of habitat types on southern peninsula plateau, including swordgrass and mixed forest/grass. Native forest sampling site PSRP located at base of slopes.



Fig. 6. Representative image of native forest on southern peninsula plateau; this is the location of sampling site PSRP. Two glueboards in photo depicted by arrows.



Fig. 7. Aerial view of lava field south of active volcano on northern Guam. Sampling site PAEL was in this habitat type. This is the only site on the island where *N. pelagicus* was found.



Visual search methods

Visual search methods are detailed in Rodda et al. (2005a). Briefly, the searchers worked individually, walking at about 0.5 km/h, scanning the vegetation on one side of a trail or road, usually at night with the aid of a headlamp. Each reptile seen was identified to species and characterized by its perch height and perch taxon (plant species on which individual was observed), though the latter data will not be reported here. Relative densities are expressed as captures per unit effort (detections per searcher-hour; Table 3). Searchers used Wilma Pro headlamps (Lupine, Inc.) or Brunton L5 headlamps (Brunton, Inc.), as previous research revealed

that bright headlamps such as these increase effectiveness of visual searching (Lardner et al., 2007, 2010).

Table 3. Nocturnal visual surveys of lands on Pagan, 2010.

Site	Latitude	Longitude	Habitat	Search-Hrs	Date (2010)	Lizard Detections
PSGS	N 18.069	E 145.719	<i>Casuarina</i> forest	4.6	27 JUN	8
PNCN	N 18.14	E 145.77	<i>Casuarina</i> /native	1.7	28 JUN	33
MCCL	N 18.118	E 145.764	Miari cliffline	2.6	28 JUN	5
PECO	N 18.112	E 145.787	<i>Cocos</i> forest	4.5	29 JUN	38
PENF	N 18.112	E 145.793	Native forest	1.5	29 JUN	17
MCCL	N 18.118	E 145.764	Miari cliffline	3.0	29 JUN	11
SRRF	N 18.121	E 145.758	Ravine forest	3.0	30 JUN	15
PAEL	N 18.123	E 145.766	Lava field	2	30 JUN	42
PSNF	N 18.06	E 145.71	Native forest	1.2	02 JUL	3
PNCF	N 18.108	E 145.793	<i>Cocos</i> & grass	1.0	02 JUL	8
PSRS	N 18.055	E 145.712	Ravine forest	2.2	03 JUL	9
PSRS	N 18.054	E 145.712	Ravine forest	1.2	04 JUL	12
PNCN	N 18.1	E 145.8	<i>Casuarina</i> /native	2.6	04 JUL	17
PNNF	N 18.156	E 145.79	Native forest	4.0	07 JUL	14

Total removal methods

Total removal methods are described in detail in Rodda et al. (2001). In brief, our objective was to physically isolate a 10 × 10 m patch of forest such that no lizards (other than large *Varanus indicus*) could leave or enter. Arboreal lizard movement was blocked by canopy separation, and terrestrial movement was prevented by erection of a 0.4 m-tall fence of aluminum flashing which was buried in the ground to block shallow subterranean escape, and sprayed with white lithium automotive grease to discourage climbing. The vegetation was then cut down, carefully inspected, weighed, and removed in small quantities to discover all non-fossorial, non-volant vertebrates present.

To prevent arboreal lizards from fleeing during canopy separation, this process was conducted during the day, when almost all of Pagan's arboreal species are in refugia. To prevent terrestrial lizards from fleeing during erection of the aluminum flashing, fence emplacement occurred at night when the terrestrial species (almost all are diurnal) were in refugia. The Pacific Slender-toed Gecko (*Nactus pelagicus*) could potentially escape because its activity periods are anomalous in this regard: lizards were potentially capable of escaping on the ground because they are terrestrially active at night while the fence was being erected. We do not believe that this species avoided detection on a large scale by these measures, but we were not able to rigorously quantify any leakage of individuals that might have occurred.

The two Pagan plots were chosen to represent the vast areas on the island that are primarily ironwood (*Casuarina*) forest. We did not have time (see Introduction) to sample Pagan's grasslands, coconut (*Cocos*) stands, or lava fields with total removal plots. Table 6 illustrates the attributes of the plots, compares between them, and contrasts their characters with the values of the other 39 total removal plots that have been conducted in a comparable way throughout the large Mariana Islands. One plot, 1PLM, was located at N 18.12753, E 145.76259 in *Casuarina* forest just north of the largely abandoned village and about 2.5 km southwest of the

active volcano. The second plot, PIWS, was located in similar forest at N 18.06506, E 145.71460 near the landing point on the southwestern tip of the island, or about 10 km southwest of the active volcano.

Results and Discussion

We will present results of each sampling method separately, followed by species accounts for each reptile species based on combined results from all survey methods.

Glueboard sampling

Glueboard yields are given in Table 4. We report overall captures per trap hour for each site, in many cases lumping multiple trapping bouts for a single site. We captured five species of skinks and geckos on glueboards, as well as a single *Varanus indicus* and a *Ramphotyphlops braminus*. All of the lizard species were also detected either by visual surveys or in removal plots. Captures per trap hour are not directly comparable among or within sites, as some were set only during the morning (thus biasing results towards morning-active lizards such as skinks), some overnight (biasing results towards nocturnally-active lizards such as geckos), etc.

Table 4. Glueboard capture rates for lizards (captures per trap-hr), with sites grouped by macrohabitat types. Empty cells reflect no captures of a species using this methodology at a site. Missing species (e.g., *G. oceanica*) were not captured on glueboards. See species accounts for details of appropriate conditions. See Table 2 for placement and number of trap-hours at each locality.

Habitat Type	Site	<i>L. lugubris</i>	<i>H. frenatus</i>	<i>G. mutilata</i>	<i>E. caeruleocauda</i>	<i>C. poecilopleurus</i>	Total lizards
Native forest sites							
Native forest	PENF	0.00119		0.00030	0.00089		0.00238
Native forest	PNNF		0.00022	0.00044	0.01264		0.01329
Native forest	PSNF	0.00057		0.00028	0.02749	0.00085	0.02948
Native forest	PSRP				0.22222		0.22222
	Mean	0.00088	0.00022	0.00034	0.06581	0.00085	0.06684
Ravine forest sites							
Ravine forest	PSRL				0.00087	0.00087	0.00174
Ravine forest	PSRS			0.00285	0.09330		0.09615
Ravine forest	SRRF				0.08333		0.08333
Ravine/ <i>Cycas</i>	PSRC				0.00231		0.00231
	Mean			0.00285	0.04496	0.00087	0.04588
Intertidal sites							
<i>Pemphis</i> /intertidal	PNBF	0.01240					0.01240
Intertidal	SRIN				0.04293		0.04293
	Mean	0.01240			0.04293		0.02766
Cocos-dominated sites							
<i>Cocos</i> forest edge	MCCO				0.41667		0.41667
<i>Cocos</i> forest	PECO	0.00177	0.00245	0.00082	0.00136		0.00640
<i>Cocos</i> / <i>Casuarina</i>	PNCC	0.00149		0.01042			0.01190
	Mean	0.00163	0.00245	0.00562	0.20901		0.14499
<i>Casuarina</i>-dominated sites							
<i>Casuarina</i> forest	PIWS	0.00260			0.00521	0.00347	0.01128
<i>Casuarina</i> /Native	PNCN		0.00242		0.00970		0.01212
<i>Casuarina</i> /grass	PSGC				0.12963	0.05556	0.18519
<i>Casuarina</i> forest	SRCF				0.41667		0.41667
	Mean	0.00260	0.00242		0.14030	0.02951	0.15631

Other forested sites

Miari cliffline

MCCL

0.00649

0.00325

0.04545

0.05519

Jatropha forest

MCJA

0.14286

0.14286

Other sites

Lava

PAEL

0.00028

0.00212

0.00099

0.00311

Urban

PURB

0.00087

0.00521

0.00058

0.00434

0.01100

Fig. 8. Example of terrestrial and arboreal placement of glueboards on Pagan (at sampling site PSRP).



Fig. 9. Glueboard on Pagan with two captured *Emoia caeruleocauda*.



Visual surveys

We observed five species of nocturnal lizards (all geckos) during nocturnal visual surveys (Table 5). We also observed a few active or sleeping skinks during surveys, but all of these represented species that were captured on glueboards or from removal plots, and thus are not reported in Table 5. Geckos of undetermined species were regularly observed, but most of these observations came from surveyors with less experience. Among surveyors with extensive experience in the Marianas, there were no observations of geckos suspected to represent any species other than those that were positively identified. Of the five species observed, *Gehyra oceanica* and *Nactus pelagicus* were not detected using glueboards or removal plots.

We also conducted opportunistic diurnal visual surveys during the course of our fieldwork on various parts of the island. These resulted in the capture of one additional *G. oceanica* and observations of several *V. indicus*, but no records of species that were not documented using other field methods.

Table 5. Detection rates (sightings/person-hr) of nocturnal lizards during nocturnal visual surveys on Pagan, 2010. See Table 3 for person-hrs and capture sample sizes. *HF* = *Hemidactylus frenatus*, *LL* = *Lepidodactylus lugubris*, *GO* = *Gehyra oceanica*, *GM* = *Gehyra mutilata*, *NP* = *Nactus pelagicus*, *GE* = *unknown gecko*

General habitat type	Site	<i>HF</i>	<i>LL</i>	<i>GO</i>	<i>GM</i>	<i>NP</i>	<i>GE</i>
<i>Casuarina</i> -dominated	PSGS	0.00	0.43	0.00	1.09	0.00	0.00
	PNCN	7.91	2.09	0.00	1.63	0.00	0.00
<i>Cocos</i> -dominated	PECO	6.00	0.22	0.00	0.22	0.00	2.00
	PNCF	8.00	0.00	0.00	0.00	0.00	0.00
Ravine or native forest	PENF	8.00	0.67	0.00	2.67	0.00	0.00
	SRRF	1.33	2.67	0.00	0.33	0.00	0.67
	PSNF	0.00	0.83	0.00	1.67	0.00	0.00
	PSRS	0.00	0.88	0.29	4.71	0.00	0.00
	PNNF	1.75	0.50	0.00	0.75	0.00	0.50
Cliffline forest	MCCL	1.43	0.18	0.00	0.54	0.00	0.71
Lava	PAEL	5.00	0.00	0.00	9.00	6.00	1.00

Total removal:

Vegetation: Prior to removal of vegetation, the two Pagan plots were covered with dense stands of large trees that had high basal area, tall canopies, and low stem counts (Table 6). Many areas in the Marianas have dense stands (up to > 300 stems/are) of small diameter tangantangan (*Leucaena*), but Pagan was divergent in this regard. Despite the small number of trees, the Pagan plots contained nearly complete canopy coverage and some of the greatest vegetation biomasses that we have recorded, though *Casuarina* is an exceptionally dense wood, which contributed to the high fresh vegetation biomass results. With the exception of a single coconut (*Cocos*) palm in 1PLM, all trees in the plots were either dead or live *Casuarina*. Because dead *Casuarina* constituted an appreciably different substrate for arboreal lizards than did live *Casuarina*, the two forms were catalogued separately. The high proportion of dead trees enhanced “evenness” between the two tree categories, leading to a much higher diversity score with the Shannon-Wiener index, though neither plot would be considered diverse by the standards of tropical forestry. Even compared to the Mariana Islands as a whole, which is often cloaked in monotypic stands (often *Leucaena*), the plots on Pagan were notable for being depauperate. The tough wood and tall canopy of the *Casuarina* forest was responsible for the exceptional labor costs (high person-hours) required to complete these plots.

The other notable attribute of these plots was the paucity of ground-level vegetation of all sorts. Woody seedlings and herbaceous cover were minimal, and herbaceous plant diversity was low. Frequent volcanism has probably contributed to the paucity of plant species, but the paucity of ground cover is at least partly attributable to heavy grazing by feral ungulates. There was little bare soil, due to heavy deposits of shed *Casuarina* needles. We have only limited experience with monotypic stands of *Casuarina* elsewhere in the Marianas, but our impression is that this species does not readily create the moist/shaded microhabitats in the tree or in the leaf litter that are favorable to geckos and most native skinks.

Fig. 10. Time-series photos (n=4) of removal activities at Removal Plot 2 on the southern peninsula of Pagan. A. Initial establishment of plot, depicting preparation for installation of fence. B. Vegetation removal, with most small trees already removed. C. Near-complete vegetation removal. D. Completed plot with above-ground vegetation and leaf litter removed.





Table 6. Characteristics of the Pagan plots. The percentile rankings are based on ranking the values from low to high, with ties given the mean percentile for the ranks that were tied. A percentile (“%-ile”) rank near 50 indicates that the Pagan plots were typical of plots from the four largest Mariana islands (Guam, Rota, Saipan, Tinian), whereas a rank near zero implies an exceptionally low score, and a rank near 100 indicates a high one. Most ranks are based on the full set of 41 plots, but some rankings of tree species composition are based on the 36 plots that had trees present (both Pagan plots had trees). An “are” is a unit of area = 0.01 hectares = 100 m². ‘1PLM’ is the site code for Plot 1, and ‘PIWS’ is the site code for Plot 2.

Character	Mariana Isl. mean	1PLM	1PLM %-ile	PIWS	PIWS %-ile
Tree (>10 mm dbh) basal area	195K mm ²	328K mm ²	83	339K mm ²	85
Stem density	95/are	28/are	22	23/are	24
Fresh vegetation biomass	1954 kg/are	4192 kg/are	93	4027 kg/are	88
Canopy height	5.6 m	14 m	98	12.5 m	95
Canopy coverage	57%	97%	85	94%	78
Herbaceous ground cover	44%	22%	27	1%	7
Vines and forbs cover	13% (non-normal dist.)	0.65%	41	0%	17 (13 tied)
Woody seedlings cover	2.8%	0.5%	27	0%	7 (5 tied)
Graminoid cover	12%	0.5%	59	1%	61
Rock cover	3.5%	0.2%	32	0%	16 (12 tied)
Bare soil cover	6.5%	0%	20 (15 tied)	0%	20 (15 tied)
Litter cover	44%	74%	90	82%	98
Coarse woody debris cover	5.7%	1.2%	20	15.6%	93
Ground cover diversity (Shannon-Wiener index)	1.21	0.78	15	0.56	10
Tree diversity (S-W index)	0.76	0.43	36	0.56	42
Large tree (> 100 mm dbh) density	4.4/are	13/are	90	16/are	93
Leucaena dominance (% of basal area)	43.5% (bimodal)	0%	14 (9 tied)	0%	14 (9 tied)
Effort required to remove and inspect all vegetation	69 person-h	230 person-h	100	183 person-h	98

Fig. 11. Plant biomass removed from Removal Plot 2 on southern Pagan.



Reptiles: The yields of reptiles from the total removal plots are tabulated in Table 7. In comparison to the mean densities in the Marianas, these values reflect low densities in Pagan *Casuarina* forests of *E. caeruleocauda*, *Gehyra oceanica*, *H. frenatus*, *L. lugubris*, and *Nactus pelagicus*. Densities of *Cryptoblepharus poecilopleurus* and *Ramphotyphlops braminus* appeared slightly elevated and that of *Gehyra mutilata* was about average. Too little information is available to assess the density of the extremely rare *E. slevini*. The observed densities of *R. braminus* should not be taken at face value, insofar as this species is subterranean and is inadequately sampled (on all islands) by our method. Although there was ample evidence of ongoing reproduction in all populations observed with an adequate sample size, the adults were generally undersized, in keeping with their general scarcity. Presumably the grazing-induced shortage of ground-level vegetation, and the lack of tree diversity limit the demographic success of many species.

Because lizards may achieve different sizes on different islands, comparisons among islands are best executed using measurements of each population's biomass rather than counts of individuals (which are vulnerable to seasonal bursts of hatchlings). Table 3 reports the mean biomass densities for each of these species in relation to similar values from the large southern Mariana Islands. These comparisons support the conclusions reached in the preceding paragraph.

Table 7. Reptile densities observed in two 10 x 10 m total removal plots in *Casuarina* forest on Pagan. All density values in number/ha. ‘1PLM’ is the site code for Plot 1, and ‘PIWS’ is the site code for Plot 2.

Species	Observed size distribution	1PLM	PIWS	Mariana Isl. mean
Skinks				
<i>Cryptoblepharus poecilopleurus</i>	Small adults; many hatchlings	0	600	17
<i>Emoia caeruleocauda</i>	Small adults; intermediate-sized young	600	0	1978
<i>Emoia slevini</i>	Not observed	0	0	0
Geckos				
<i>Gehyra mutilata</i>	High proportion of juveniles	800	500	780
<i>Gehyra oceanica</i>	Not observed	0	0	271
<i>Hemidactylus frenatus</i>	Many small hatchlings	700	0	745
<i>Lepidodactylus lugubris</i>	Recent reproduction	1500	800	1971
<i>Nactus pelagicus</i>	Not observed	0	0	18
Snakes				
<i>Ramphotyphlops braminus</i>	Mostly big juveniles	300	300	199

Table 8. Mean biomass densities of reptiles found on Pagan, in comparison to values obtained from the four large southern Mariana Islands. All values are in kg/ha.

Species	Pagan	Guam	Rota	Saipan	Tinian	Marianas
Skinks						
<i>C. poecilopleurus</i>	0.238	0	0	0	0.300	0.055
<i>E. caeruleocauda</i>	0.430	4.273	6.113	0.068	0.161	3.214
<i>E. slevini</i>	0	0	0	0	0	0
Geckos						
<i>G. mutilata</i>	0.840	0.705	3.114	1.212	0.907	1.204
<i>G. oceanica</i>	0	0	7.332	3.690	1.928	1.953
<i>H. frenatus</i>	0.587	2.986	0.197	0.302	0.507	1.676
<i>L. lugubris</i>	1.001	1.555	4.297	2.267	1.283	2.046
<i>N. pelagicus</i>	0	0	0.228	0	0	0.038
Snakes						
<i>R. braminus</i>	0.088	0.220	0.069	0.018	0.032	0.134

Herpetofaunal species accounts

Native species

Oceanic Snake-eyed Skink, *Cryptoblepharus poecilopleurus*

Body length¹: 22 - 47 mm Mass: 0.2 - 1.8 g, Fig. 12

Fig. 12. The Oceanic Snake-eyed Skink, *Cryptoblepharus poecilopleurus*.



Previous studies – Note that the nominal species is under revision and is likely to contain a number of island endemics in the South Pacific (Horner 2007, G. Zug, 2008 pers. comm.), but the form in the Mariana Islands is relatively widespread in the northwestern Pacific. Because this littoral clade has extensively speciated on islands (reflecting an evolutionarily long residence in the area of speciation), and because this particular species is endemic to the northern Pacific, it is assumed that this species reached many islands on its own (i.e., it was not introduced by man). Because it is very small and its skeleton is fragile, it is not a good candidate for preservation as a subfossil in pre-human remains. Thus we assume it is likely native despite the absence of reported subfossils in pre-human strata (Pregill 1998).

This species is found in a variety of microhabitats, including *Casuarina* (Australian pine) groves, rocky and sandy areas, grass, leaf litter around *Cocos* (coconut) palms, etc. (McCoid et al. 1995). However the bulk of the existing literature suggests that the unifying factor in this range of habitat types is that these microhabitats must be closely associated with the littoral zone. For example, *C. poecilopleurus* has been collected on and around *Casuarina*, but only when the trees are immediately adjacent to the shore. Vogt and Williams (2004) report occasional specimens from upland situations (limestone forest implied but not explicitly stated) on Saipan and the northern Mariana Islands, though these may be associated with cliffs (also found around upland cliffs on Rota [Rodda, pers. obs.]). One notable exception is on Guguan, where this species occurs throughout the island as a sand swimmer in ash fields (McCoid et al. 1995). Vogt (2008) comments that its former abundance on Sarigan (northern Mariana Islands) may have been attributable to soil disturbance associated with dense populations of goats. It is possible that goat-churned soil could provide a loose soil niche similar to that found in ash fields on Guguan.

¹ Sizes given above photographs are ranges for specimens from the Mariana Islands (G.H. Rodda, unpubl. data).

On Tinian in 2008, we found a specimen nearly 1 km inland, in North Field's characteristic monotypic stands of *Leucaena*. To the best of our knowledge, this was the first record for this species anywhere in *Leucaena* habitat or at a great distance from cliff or strand habitat.

This study (2010) – We found the Snake-eyed Skink (*Cryptoblepharus poecilopleurus*) in five sampling sites encompassing native forest, ravine forest, *Casuarina* forest, *Casuarina*/grass savannah, and lava fields. Interestingly, we found the species in abundance in various habitats in southern Pagan, but only in a few sites on northern Pagan (lava flows, near the old village, and on one of the eastern beaches); we have no obvious hypotheses to explain this disparity.

Observations from Pagan further up-end previous assumptions (see above) that in the Marianas this species is limited to the vicinity of littoral habitats. We discovered numerous individuals of *C. poecilopleurus* in Removal Plot 2 in southern Pagan, but none in Removal Plot 1 in northern Pagan; this situation was exactly reversed for *Emoia caeruleocauda* (see below). Plot 2 had relatively thin canopy cover and a bunchgrass understory, while Plot 1 was more shaded and had a sparse fern understory. It is our impression that, on Pagan, *C. poecilopleurus* was more likely to be found in warmer and/or more arid microclimates than was *E. caeruleocauda*, potentially implicating physiological tolerances as one driver of microhabitat use. Results of glueboard sampling also suggested that *C. poecilopleurus* remains active as temperatures rise in the morning, while activity of *E. caeruleocauda* decreases. As a supporting anecdote, one of us (Reed) observed a *C. poecilopleurus* active in sparse grass on the Pagan landing strip, >25 m from the nearest shade, at 0920h on a hot morning in June; we would never expect to see a *E. caeruleocauda* in such a microhabitat.

Conservation and management implications - The nominal species has an extensive distribution throughout the northwestern Pacific, though some of these localities may be of closely-related species. It is found along the coast of virtually all of the Mariana Islands, including the far northern islands (Vogt and Williams 2004). As presently understood the species is not considered to be at risk of endangerment or in need of special management. As with all of Pagan's native species, the most important protection is prevention of new introductions. It is notable that Hawley (2008) and Vogt (2008) observed a recent apparent decline of this species on Sarigan; Vogt (2008) suggested that the species may benefit from soil disturbance by ungulates, but this notion was not strongly supported by our results from Pagan, as we found the species in fewer habitats in an area with more species of introduced ungulates.

Pacific Blue-tailed Skink, *Emoia caeruleocauda*

Body length: 21 – 56 mm Mass: 0.1 – 3.7 g, Fig. 14

Fig. 13. The Pacific Blue-tailed Skink, *Emoia caeruleocauda*.



Previous studies – The colorful and conspicuous Pacific Blue-tailed Skink (*Emoia caeruleocauda*) is found from Borneo to Vanuatu and throughout the western Pacific on the ground and low in vegetation in forested areas (Brown 1991). Pregill (1998) found it in early prehistoric subfossil material, but did not record it in pre-human strata. However, it is endemic to western Oceania and therefore is presumably native to at least some of the islands therein. For that reason we treat it as native to the Mariana Islands.

In the Marianas it is the only common native skink still found throughout most islands (Rodda et al. 1991), although it appears to have been replaced or suppressed by the introduced Curious Skink (*Carlia ailanpalai*) in many habitats on the human-inhabited southern islands (Wiles et al. 1989). It is not known if this replacement has been due to direct interaction between the species or an indirect interaction, such as a reciprocal response to a habitat feature (e.g., one species prefers drier areas; the other prefers wetter areas). Previous studies have found the blue-tailed skink to be largely missing from the extensive *Leucaena* stands on military lease lands of Tinian (Wiles et al. 1989, Rodda et al. 2008).

This study (2010) – We found *E. caeruleocauda* in all but three sampling sites on Pagan, and in most habitats this species was the most predictable and conspicuous member of the diurnal herpetofauna of the island. In general, on Pagan the species appears to prefer forest with near-complete canopy closure, especially as compared to *C. poecilopleurus* (above). However, even in apparently good habitat on Pagan (e.g., Removal Plot 1), densities of this species appear to be lower than on Rota or Guam, and more similar to low densities observed in most habitats on Tinian and Saipan. The disparity between Rota/Guam as opposed to Tinian/Saipan has previously (Rodda et al. 2008) been hypothesized to be due to predation on *E. caeruleocauda* by *Suncus murinus* on Tinian and Saipan (the shrew is absent or rare on the other two islands). However, we observed relatively low densities of *E. caeruleocauda* on Pagan in the apparent absence of *S. murinus*, suggesting that some other factor may be in play. It could be that the sparse understory on Pagan resultant from high ungulate grazing pressure destroys some of the

understory vegetative structure that would otherwise allow *E. caeruleocauda* to escape detection by kingfishers, megapodes, and other predators.

Conservation and management implications – This species is not globally rare (due to its extensive geographic range) and populations appear to be fairly secure on Pagan. Blue-tailed skinks may benefit from vegetative recovery after removal of ungulates. Because anecdotal evidence suggests that *E. caeruleocauda* may be replaced by exotic *C. ailanpalai* elsewhere in the Marianas, prevention of new species introductions should remain a priority. Management activities that benefit *E. caeruleocauda* may in turn benefit other species; Slifka et al (2004) found that this skink represents a highly nutritious food item for kingfishers. Presumably it provides the same benefits to other saurophagous (lizard-eating) birds such as Micronesian megapodes.

Mariana Skink, *Emoia slevini*

Body length: 20 – 77 mm Mass: 0.4 – 10.4 g, Fig. 15

Fig. 14. The Mariana Skink, *Emoia slevini*.



Previous studies – The Mariana Skink, *Emoia slevini*, is found only in the Mariana Islands. Pregill (1998) did not detect this species in pre-human strata, but did find it to dominate skink remains in all prehistoric strata. We assume it is therefore native to all of the Mariana Islands. This species has disappeared from the large southern Mariana Islands in the last 50 years, for no obvious reason (McCoid et al. 1995). Whatever the reason, it may apply to all four large Mariana Islands. In the northern islands, specimens have been taken from Alamagan, Asuncion, Guguan, Sarigan, and Pagan; the most recent specimen from Pagan was collected on the southern peninsula in 1999 (S. Vogt, pers. comm. 2010).

This study (2010) – We did not detect this species despite considerable sampling effort on the southern peninsula where the last known specimen was collected; this specimen was collected near sampling site PSNF. We are confident that this failure was not due to mis-identification of skinks that were captured on glueboards, and the larger size and divergent color pattern of *E. slevini* should have allowed us to identify the lizard had it been encountered during visual surveys. The lizard may still be present on Pagan, but if so it appears to have been greatly reduced in numbers.

Conservation and management implications – This species is endemic to the Mariana Islands and has been extirpated from the bulk of its historic range, and yet has never been the subject of thorough ecological study. Additional sampling on Pagan would help answer the question of whether the species is extirpated or merely greatly reduced in numbers on the island, and field studies on other islands where it is still numerous would inform any future management plans for the species.

Mourning Gecko, *Lepidodactylus lugubris*

Body length: 19 – 49 mm Mass: 0.1 – 2.7 g, Fig. 16

Fig. 15. The Mourning Gecko, *Lepidodactylus lugubris*.



Previous studies – As currently understood, the triploid species *Lepidodactylus lugubris* is a parthenogenetic hybrid derived from diploid *Lepidodactylus moestus* and an undescribed species (Radtkey et al. 1995). Because the present distributions of the parental stocks overlap only in Micronesia, the presumption is that the species arose in Micronesia, or at least somewhere in Oceania. Thus even though no pre-human fossils of this very delicate species have yet been detected in the fossil record (Pregill 1998) we presume this species to be native. This species has been found to be widely distributed in Oceania and reasonably common throughout the Mariana Islands, including Tinian (Wiles et al. 1989, Table 9).

This study (2010) – We found evidence of this species in most habitats and sampling sites. It was numerically the most abundant lizard in both removal plots and was responsible for the greatest portion of biomass in both sites. However, the observed biomasses on Pagan were considerably lower than those from the four large inhabited Mariana islands. The Mourning Gecko is known to occur from intertidal habitats to undisturbed upland forest (Sabath 1981), and the evidence from Tinian supports the general conclusion that this species may be found in most habitats on the island. Based on the perches occupied by the *Lepidodactylus* during surveys throughout the Marianas, the species appears to have a preference for twig-end or foliage perches. This may reduce detection rates via both nocturnal visual surveys and glueboarding in many habitats on Pagan, as the dominant trees (*Cocos*, *Casuarina*) tend to bear foliage high above the ground. However, the low densities revealed by removal plots suggest that low detection rates by other sampling methods are not simply the product of microhabitat-based detection biases.

Conservation and management implications – As the species concept is presently applied, the Mourning Gecko is broadly distributed throughout the world (having been introduced in both Africa and the New World), ubiquitous in all habitats on Tinian, and common in all habitats. If

what we perceive to be a single Mourning Gecko species turns out to include several cryptic species, some of them rare or highly localized, we would need to reevaluate the assumption that the conservation of this species is assured. The latter scenario is possible, as the species concept is difficult to apply to this parthenogenetic (clonally reproducing) form, and there are many identified strains or clones of this nominal species (Ineich 1988). The clonal representation on Tinian has not been investigated or quantified as it has for some Japanese islands (Yamashiro et al. 2000). Even if the current conception of the species concept is correct, an introduced insectivorous lizard occupying the same nocturnal twig-end niche could potentially displace it in the Mariana Islands. The most likely competitive displacement of the Mourning Gecko would be by other clones of the same superspecies, as has been suggested by Yamashiro et al. (2000). Clarification of clonal composition on Tinian would be of value in understanding the species' apparent population decline. In the southern Marianas, densities of *L. lugubris* appear to have declined in recent years while densities of *Hemidactylus frenatus* (below) have increased (Rodda et al. 2008). Future monitoring of these species on Pagan may help to assess the generality of this trend.

Brahminy Blindsnake, *Ramphotyphlops braminus*

Body length: 59 – 151 mm Mass: 0.1 – 1.2 g, Fig. 17

Fig. 16. The Brahminy Blindsnake, *Ramphotyphlops braminus*.



Previous studies – Pregill (1998) found the blind snake to be present in the Mariana Islands since at least early pre-human times; thus is unquestionably native. The snake is known from the southern Marianas (Wiles et al. 1989), but we are unaware of any specimens from Pagan.

This study (2010) – We found *Ramphotyphlops braminus* in both removal plots, despite the presence of fairly thin soils and only moderate amounts of leaf litter. Biomass from the two plots on Pagan (0.088 kg/ha) was within the range of biomasses from the four southern inhabited Mariana Islands (0.018 – 0.22 kg/ha). The total removal method is poorly suited to enumeration of this fossorial species, suggesting that we underestimated its abundance. We did not actively search for *R. braminus* in any other sampling sites, but there is no reason not to expect its presence in any area of the island with sufficient soil and ground cover.

Conservation and management implications – This parthenogenetic snake presently has a pan-tropical distribution, probably due to the ability of single individuals (they are all females) to found a new population, and the propensity of this species to stow-away in plants, soil, and other protective materials. No biodiversity concerns have been suggested regarding this species.

Potentially native species

Indo-Pacific House Gecko, *Hemidactylus frenatus*

Body length: 20 – 59 mm Mass: 0.1 – 3.9 g, Fig. 18

Fig. 17. The Indo-Pacific House Gecko, *Hemidactylus frenatus*.



Previous studies – The Indo-Pacific House Gecko (*Hemidactylus frenatus*) may be a complex of several species (N. Arnold, 2007 pers. comm.; A. Bauer 2007 pers. comm.), but as presently recognized it is one of the world's most widespread geckos, introduced throughout the New and Old World tropics and sub-tropics. For this reason, many authors assume that this species was carried to Oceania only through human agency, but Pregill (1998) found it in prehistoric strata that predate the arrival of all other introduced vertebrates, including rats. Thus it may be native to the western part of Micronesia, though evidence from eastern Micronesia suggests it was a human introduction there and in Polynesian sites further east (Pregill 1998).

This study (2010) – We found this species in Removal Plot 1 in *Casuarina* forest on northern Pagan, but not in Removal Plot 2 in the south. Biomass of *H. frenatus* on Pagan was 0.587 kg/ha, placing it within the range calculated for the four southern islands (0.197 – 2.99 kg/ha). Glueboard sampling and visual surveys yielded specimens in most of the major habitat types on the island, including *Casuarina* forest, mixed *Casuarina*/native forest, *Cocos* forest, ravine forest, and lava fields. However, all of these sites were on northern Pagan, and we failed to document *H. frenatus* on the southern peninsula by any sampling technique.

Conservation and management implications – This increasing pan-tropical species presents no obvious biodiversity concerns, unless the nominal species turns out to be composed of a variety of species, some of which are rare. The form in the Marianas appears to be of a widespread genotype however (Moritz et al. 1993).

Pacific Slender-toed Gecko, *Nactus pelagicus*

Body length: 23 – 68 mm Mass: 0.1 – 7.0 g, Fig. 19

Fig. 18. The Pacific Slender-toed Gecko, *Nactus pelagicus*.



Previous studies – *Nactus pelagicus* is widespread in the northwestern Pacific, apparently derived from a species complex in Melanesia (Zug and Moon 1995). As an all-female species (parthenogenetic), it would be an excellent candidate for natural dispersal. However, the uniformity of this species in Micronesia suggests an evolutionarily recent and human-aided dispersal. Pregill (1998) found some prehistoric but no pre-human remains; thus there remains some question as to whether this species was introduced by prehistoric settlers. We are unaware of any previous specimens from Pagan, but the species is known from elsewhere in the far northern Marianas (i.e., Alamagan, Anatahan, Sarigan).

This study (2010) – We detected this species only on the lava flow at the east end of the airstrip (sampling site PAEL). Within this habitat, sightings averaged six individuals per hour, suggesting moderately high abundance. We have no convincing hypothesis to explain the apparent absence of pelagic geckos in forested habitats on Pagan. This gecko's cryptic pattern and terrestrial habits render it difficult to see during nocturnal visual surveys – it may be that detection is maximized when the lizard is on a black lava substrate, and that we missed it during visual surveys elsewhere.

Conservation and management implications – The nominal species is widespread in Oceania (Zug and Moon 1995) and the species is not at risk of range-wide endangerment. However, it is now rare or extirpated from large portions of the southern Marianas, and several authors suggest that *N. pelagicus* is highly vulnerable to predation by *S. murinus* (Rodda 1992, Rodda and Fritts 1992, Fritts and Rodda 1998). Biosecurity measures to prevent the establishment of *S. murinus* on Pagan may therefore be the best conservation measure for *N. pelagicus*. If the shrew is eradicated from any of the southern islands, Pagan might serve as a source of pelagic geckos for re-introduction to these islands.

Introduced species

Mutilating Gecko, *Gehyra mutilata*

Body length: 19 – 56 mm Mass: 0.1 – 4.3 g, Fig. 20

Fig. 19. The Mutilating Gecko, *Gehyra mutilata*.



Previous studies – There is some uncertainty about the status of the mutilating gecko in the Marianas. Pregill (1998) stated that the species was introduced to the Marianas after contact with Europeans, and we (e.g., Rodda et al. 2008) previously based our conclusion that the species was a recent introduction on Pregill’s 1998 findings. However, a more recent paper (Pregill and Steadman 2009) found subfossil remains of *G. mutilata* on Guam in strata dating from 890 to 1160 AD, suggesting that the gecko is either native or was introduced by ancient seafarers. Pending additional paleontological work in the far northern Marianas, we tentatively still consider this species to be a human introduction, although it is likely that the introduction was prehistoric.

This study (2010) – We found this species in both removal plots, and densities (500 and 800/ha in plots 1 and 2, respectively) are consistent with the Marianas-wide mean of 780/ha. At 0.84 kg/ha, biomass on Pagan was near the low end of the range recorded from the four southern islands (range 0.705 – 3.114 kg/ha), but still represented the second-highest (after *L. lugubris*) biomass recorded from Pagan plots. Visual surveys yielded observations in most major habitat types, although detection rates tended to be higher in ravine forest and native forest as compared to *Casuarina* or *Cocos* forests. Detection rates were highest (9.0 lizards/hr) on lava flows, but as with *N. pelagicus* this may be biased upward by increased detectability on a dark substrate. Interestingly, all geckos observed on lava at night were very dark in coloration. This is in contrast with the typical ‘blanching’ seen in geckos in the Marianas at night, and suggests that geckos may engage in opportunistic background-matching.

Conservation and management implications – Management of this species is largely dependent on a better understanding of its history in the Marianas. If native, it should be conserved, and the

species appears to be relatively secure on islands lacking novel snake predators. If introduced, it may eat smaller native geckos (i.e., *Lepidodactylus lugubris* or juveniles of other species), and compete with similar-sized lizards, but there is no evidence that it is having an adverse impact on any island in the Marianas archipelago. Judgments on its status as a native or introduced species should be re-evaluated in light of new findings when they become available.

Oceanic Gecko, *Gehyra oceanica*

Body length: 29 – 86 mm Mass: 0.7 – 14.2 g, Fig. 21

Fig. 20. The Oceanic Gecko, *Gehyra oceanica*.



Previous studies – This species appears to be a historic introduction to the Marianas (Pregill 1998, Pregill and Steadman 2009), likely coincident with the arrival of Europeans about 500 years ago. Oceanic geckos have declined on Guam in the face of predation by Brown Treesnakes (Rodda and Fritts 1992), but populations elsewhere in the Marianas appear to be stable. The species is known from most islands in the Marianas, but we are unaware of previous records from Pagan. Pregill (1998) suggested that the introduction of this large gecko may have negatively influenced the survival of the native gecko *Perochirus ateles*.

This study (2010): We found only two individuals of this species, and it appears to be much less abundant on Pagan than on snake-free islands in the southern Marianas (i.e., Tinian, Rota, Saipan). Too few data on sighting rates are available for other islands in the far northern Marianas to assess the generality of our results for Pagan. One individual was found opportunistically during daylight hours on the southern peninsula (it fell from a tree into Reed's shirt while he was walking through ravine forest at sampling site PSRP) and another was found in native forest during a nocturnal visual survey a few hundred meters away at site PSRS. The two sightings of this species were in moderately close proximity to each other on the southern peninsula. If the lizard is limited to this part of the island, its relative rarity could be because it has only been recently introduced to Pagan, or because some unknown factor has eliminated it elsewhere and our findings reflect a relict population.

Conservation and management implications – Because this species is non-native and potentially hazardous to native geckos such as the Micronesian Gecko, *Perochirus ateles*, conservation of this species is neither necessary nor desirable. As it may be a recent introduction to Pagan, monitoring would be useful in documenting its potential rate of spread in the future.

Mangrove Monitor, *Varanus indicus*

Body length: 99 - 540 mm Mass: 10 – 3650 g, Fig. 22

Fig. 21. The Mangrove Monitor, *Varanus indicus*.



Previous studies – Pregill (1998) established that monitor lizards on Tinian were likely introduced during the western period (less than 500 years ago); the earliest written observation was by De la Corte (mid 1800s: Wiles et al. 1989). However, Pregill and Steadman (2009) found subfossils from *V. indicus* that extended well into prehistoric strata (dating to 390-550 AD), suggesting that the species was either introduced prehistorically or is native. In the Marianas, mangrove monitors are known scavengers around trash piles, so it is possible that monitor remains in deep strata could be the remnants of individuals that were buried while digging. Pending additional paleontological work in the far northern Marianas, we tentatively consider this species to be a human introduction, although it is likely that the introduction was prehistoric. Scott Vogt (pers. comm. 2010) had sighted *V. indicus* on Pagan prior to this trip.

This study (2010) – Removal plots, glueboards, and nocturnal visual surveys are of low utility for this species. We captured one monitor on a glueboard, but otherwise all of our observations were opportunistic. It was our impression that monitor lizards on Pagan were present in relatively low numbers as compared to the other Mariana islands, and this was corroborated by diurnal transect surveys conducted in July 2010 by Scott Vogt (pers. comm. 2010). In contrast, Chris Eggleston (U.S. Fish and Wildlife Service) observed four monitors foraging within 10 m of him at one time along a trail in the southernmost part of Pagan; this could indicate scattered patches of higher density or simply remarkably good luck. Overall, monitors appeared to be more common on the southern peninsula.

Conservation and management implications – As with *Gehyra mutilata*, management of *V. indicus* hinges on whether it is native or introduced. The monitor is the largest terrestrial predator on most islands in the Marianas, and may exert top-down pressure on other vertebrates, but the importance of this pressure is poorly understood. Endangered species such as the Micronesian megapode, which is rare on Pagan and vulnerable to monitor predation on its eggs, may be affected adversely (U.S. Fish and Wildlife Service 1997). Monitor control may be warranted to conserve megapodes regardless of whether the lizard is introduced. Previous work on Sarigan (S. Vogt, pers. comm.) suggests that *V. indicus* populations may increase after ungulate eradication, as monitors are able to gorge themselves on dead ungulates. This potential outcome of ungulate control should be considered if ungulates are targeted on

Pagan for conservation reasons. For example, Micronesian megapodes may initially benefit from control of goats, pigs, and cattle, only to suffer increased egg mortality if monitor lizards then become more prevalent.

Acknowledgments

Funding for reptile and terrestrial mammals surveys was provided to the U.S. Geological Survey by the U.S Fish and Wildlife Service, which in turn received overall project funding from the Department of Defense, U.S. Marine Corps, through the Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawaii. We appreciate the efforts of Earl Campbell, Curt Kessler, and Craig Clark to ensure success of our project. For assistance with logistics, background information, boat handling, etc, we thank Lea' Bonewell, Scott Vogt, Paul Reyes, Sandy Castro, Jess Omar, and many others. We are grateful to Ann Gawel, Eric Cook, Jude Martinez, Jose Quan, Francisco Villagomez, and Maria Kottermair for field assistance. Improvements to an earlier draft of the manuscript were suggested by Neal Evenhuis, Ernie Garcia, and Lea' Bonewell. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Literature Cited

- Fritts, T. H., and G. H. Rodda. 1998. The role of introduced species in the degradation of island ecosystems: a case history of Guam. *Ann. Rev. Ecol. Syst.* 29:113-140.
- Hawley, N. B. 2008. Herpetological surveys and small mammal surveys, Sarigan 2006. In G. Martin, L. L. Williams, J. B. de Cruz, N. B. Hawley, S. Vogt, B. D. Smith, O. Bourquin, S. Kremer, and C. Kessler (eds.), *Wildlife and Vegetation Surveys of Sarigan Island April 13-25, 2006*, pp. 4-1 to 4-4. Northern Mariana Islands, Div. of Fish and Wildlife, Saipan MP.
- Ineich, I. 1988. Mise en évidence d'un complexe unisexué-bisexué chez le gecko *Lepidodactylus lugubris* (Sauria, Lacertilia) en Polynésie française. *C. R. Acad. Sci. Paris* 307:271-277.
- Lardner, B., J. A. Savidge, and G. H. Rodda. 2007. Spotting cryptic animals in the dark: what light properties should a good headlamp have? In G. W. Witmer, W. C. Pitt, and K. A. Fagerstone (eds.), *Managing Vertebrate Invasive Species: Proceedings of an International Symposium*, pp. 234-245. USDA-APHIS Wildlife Services National Wildlife Research Center, Fort Collins, CO.
- Lardner, B. M., J. A. Savidge, G. H. Rodda, R. N. Reed, and A. A. Yackel Adams. 2010. The results of nocturnal visual survey are influenced by lamp properties. *Applied Herpetology* 6:391-396.
- McCoid, M. J., G. H. Rodda, and T. H. Fritts. 1995. Distribution and abundance of *Emoia slevini* (Scincidae) in the Mariana Islands. *Herpetol. Rev.* 26:70-72.
- Moritz, C., T. J. Case, D. T. Bolger, and S. C. Donnellan. 1993. Genetic diversity and the history of Pacific island house geckos (*Hemidactylus* and *Lepidodactylus*). *Biol. J. Linn. Soc.* 48:113-133.
- Mueller-Dombois, D. and F. R. Fosberg. 1998. *Vegetation of the tropical Pacific islands*. Springer, New York, New York, USA.
- Pregill, G. K. 1998. Squamate reptiles from prehistoric sites in the Mariana Islands, Micronesia. *Copeia* 1998:64-75.
- Pregill, G. K., and D. W. Steadman. 2009. The prehistory and biogeography of terrestrial vertebrates on Guam, Mariana Islands. *Diversity and Distributions* 15:983-996.
- Radtkey, R. R., S. C. Donnellan, R. N. Fisher, C. Moritz, K. A. Hanley, and T. J. Case. 1995. When species collide: the origin and spread of an asexual species of gecko. *Proc. Roy. Soc. Lond. B Biol. Sci.* 259:145-152.
- Rodda, G. H. 1992. Loss of native reptiles associated with introductions of exotics in the Mariana Islands. *Pac. Sci.* 46:399-400.
- Rodda, G. H., E. W. Campbell, III, and T. H. Fritts. 2001. A high validity census technique for herpetofaunal assemblages. *Herpetol. Rev.* 32:24-30.
- Rodda, G. H., E. W. Campbell, III, T. H. Fritts, and C. S. Clark. 2005a. The predictive power of visual searching. *Herpetol. Rev.* 36:259-264.
- Rodda, G. H., K. Dean-Bradley, and T. H. Fritts. 2005b. Glueboards for estimating lizard abundance. *Herpetol. Rev.* 36:252-259.
- Rodda, G. H., and T. H. Fritts. 1992. The impact of the introduction of the Brown Tree Snake, *Boiga irregularis*, on Guam's lizards. *J. Herpetol.* 26:166-174.
- Rodda, G. H., T. H. Fritts, and J. D. Reichel. 1991. The distributional patterns of reptiles and amphibians in the Mariana Islands. *Micronesica* 24:195-210.
- Rodda, G. H., M. J. McCoid, and T. H. Fritts. 1993. Adhesive trapping II. *Herpetol. Rev.* 24:99-

- Rodda, G. H., R. N. Reed, S. R. Siers, T. J. Hinkle, T. H. Fritts, and R. P. Reynolds. 2008. The land reptiles and amphibians of Tinian. U.S. Geological Survey Administrative Report. 52 pp.
- Sabath, M. D. 1981. Gekkonid lizards of Guam, Mariana Islands: reproduction and habitat preference. *J. Herpetol.* 15:71-75.
- Slifka, K., P. McGill, A. Oiler, and D. Kesler. 2004. Nutrient composition of lizards consumed by Micronesian Kingfishers (*Todirhamphus cinnamomina reichenbachii*) on Pohnpei. Proceedings of the Fifth Comparative Nutrition Society Symposium.
- U.S. Fish and Wildlife Service. 1997 Technical/agency draft recovery plan for the Micronesian Megapode (*Megapodius laperouse laperouse*). US Fish and Wildlife Service, Portland, OR.
- Vogt, S. R. 2008. Ground skink surveys on Sarigan Island, Commonwealth of the Northern Mariana Islands. In G. Martin, L. L. Williams, J. B. de Cruz, N. B. Hawley, S. Vogt, B. D. Smith, O. Bourquin, S. Kremer, and C. Kessler (eds.), *Wildlife and Vegetation Surveys of Sarigan Island April 13-25, 2006*, pp. 5-1 to 5-6. Northern Mariana Islands, Div. of Fish and Wildlife, Saipan MP.
- Vogt, S. R. and L. L. Williams. 2004. *Common flora and fauna of the Mariana Islands*. Published by authors. 158 pp.
- Wiles, G. J., A. B. Amerson, Jr., and R. E. Beck, Jr. 1989. Notes on the herpetofauna of Tinian, Mariana Islands. *Micronesica* 22:107-118.
- Yamashiro, S., M. Toda, and H. Ota. 2000. Clonal composition of the parthenogenetic gecko, *Lepidodactylus lugubris*, at the northernmost extremity of its range. *Zool. Sci.* 17:1013-1020.
- Zug, G. R., and B. R. Moon. 1995. Systematics of the Pacific slender-toed geckos, *Nactus pelagicus* complex: Oceania, Vanuatu, and Solomon Islands populations. *Herpetologica* 51:77-90.