# GUANA 2009

0



JAMES LAZELL

The Conservation Agency Exploration, Education, and Research

President James D. Lazell, Ph.D. 401-423-2652

14 May 2010

6 Swinburne Street Conanicut Island R.T. 02835 U.S.A.

Dr. Henry Jarecki, Chairman The Falconwood Foundation 10 Timber Trail Rye, NY 10580

Dear Henry,

Herewith my report on our 2009 efforts. It was a notable year because while there were some lovely highs there were also dismal lows. Great progress was made in entomology and herpetology, but the ornithological crew documented all-time low numbers of North American migrants. Densities for some resident birds were also at low ebbs. Bridled Quail Doves, however, were abundant. Here is summary of the contents of this report, with page numbers top right, as usual.

Cover story: Ugh! Yuck! Roaches! -- But wait ...

Clint Boal's Ornithology Report	
Wenhua Lu transitions us from birds to reptiles	L
Fast, agile Ground Lizards are hard to study, but our herp team has made great progress12	2
Razi steps up again, leading documentation of intra-island physiological differentiation1'	7
Guana teams with others to draft a book introduction on exotic herps	5
Gad leads a group drafting a book chapter on BVI herp conservation	r
Soldier Crab pinching? Katharina Gebert explains	L
Barry Valentine's entomological overview	9

A Scientific Non-profit Corporation . Contributions Tax-deductible . IRS 05-0392995

Entomologists team up to expand on our Cover Story: a work in progress
Another group begins investigation of the bizarre Stick Insects (see End Paper)65
A 2007 paper on Longhorn Beetles (I have trimmed it to Guana species)
A big book on tiny moths, culled, with Guana species arrowed: See p. 86
Renee Rondeau and Rudy O'Reilly take on Numi's sheep exclosure plots
Finally, Gerald Henry makes a grass proposal I accept

We are all looking forward to Science Month 2010. With our gratitude and best wishes,

Skip

James Lazell, Ph. D., President

## **COVER STORY**

Roaches! Mating: Making more roaches! Horrible! No, these are Ocellate Golden Roaches (*Eurycotis improcera* Rehn 1930), a forest-dwelling species that never enters human structures. This species was not among the original eight species discussed by Harvard's late Lou Roth in his 1994 paper. It was added by Smithsonian's Daniel Perez and made it into Lazell's 2005 book *Island*..., but misidentified as *E. dicipiens*. At that time we knew of ten species total. Perez has teamed up with Lu and Valentine; they have increased our count to the highest known for any Virgin Island: 16: see p. 61 The Ocellate Golden Roach was the first species described from the Virgin Islands, in 1930. Of our 16 species, only three are pests that enter buildings. The other 13 dwell in natural habitats from the beach berm to deep forest; some are known only from the galleries of termite nests. The native roaches are among the least-known members of our fauna, and now that Roth is gone there are no specialist experts to consult. Getting to know them is an ongoing learning experience.

# ORNITHOLOGICAL MONITORING AND RESEARCH ON GUANA ISLAND, BRITISH VIRGIN ISLANDS

# **PROJECT REPORT 2009**

# Clint W. Boal, Ph.D. USGS Texas Cooperative Fish and Wildlife Research Unit Department of Natural Resources Management Texas Tech University, Lubbock, TX 79409

29 April 2010



Bananaquit

# ORNITHOLOGICAL RESEARCH AND MONITORING ON GUANA ISLAND, BRITISH VIRGIN ISLANDS: PROJECT REPORT 2009

Dr. Clint W. Boal, USGS Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock, TX 79409-2120

#### INTRODUCTION

The Caribbean is an important region for neotropical migrant landbirds during their annual migration from North America to South America. While considerable research has been conducted on migrant ecology in the western Caribbean, comparatively little has been conducted in the Virgin Islands or east Caribbean (Wiley 2000). Thus, ornithological work on Guana Island makes substantive contributions toward a better understanding of the Virgin Islands as stop-over habitat for migrant birds (McNair et al. 2002, Boal et al. 2006, Boal and Estabrook 2007). Avian research on Guana Island is also important in adding to the understanding of the basic ecology of and conservation needs Caribbean birds (e.g., Chipley 1991, Boal et al. 2006, Boal 2008a, Boal 2008b).

Components of avian research on Guana Island are 1) mist-netting and banding neotropical songbirds that migrate through the Caribbean region during the autumn migration, and 2) specific studies focusing on species resident to the island. Progress on all components of the ornithological work was satisfactorily met during the 2009 Science Month. Here I provide data and discussion of the results of the 2009 field season, a review of research productivity stemming from avian research on Guana Island, and plans for the 2010 Science Month.

#### **RESULTS AND DISCUSSION**

#### Mist-Netting and Migrant Ecology

We operated our mist-netting array from 9 to 27 October 2009 for a total of 356 net-hours. This was slightly more net hours than the average of the previous 6 years. Despite this being the average capture effort, we only captured 180 birds of 16 species (Table 1). Since 2003, this was the lowest number of species captured during science month with the single exception of 2007. With 0.51 birds per net hour, it was also the lowest capture rate from 2003 to 2009.

The diversity of neotropical migrants was dramatically lower that in most previous years. As usual, blackpoll warblers were the most common migrant, but only 27 were captured and most were in generally good condition. The only other migrant captured was a single blue grosbeak. All other captures were of resident species. However, a very few black-and-white warblers and ovenbirds were both seen during surveys.

I am currently assessing annual species diversity and richness of neotropical migrant landbirds scaled to mist-netting efforts. I have to examine net locations and mist-netting efforts prior to my involvement in Science Month to insure consistency of net locations used in the data. I will then examine the data for correlations between species diversity and richness to weather patterns in the Caribbean and Atlantic seaboard. This is, however, proving challenging as there is very little high quality weather data for the British Virgin Island. Most data have to be taken from the US Virgin Islands and assumed to be representative of the Virgin Islands as a whole. Furthermore, good data from the USVI is only available since about 2000.

#### Surveys

I conducted an island-wide bird survey that has been repeated annually since 2006. The methodological approach is similar to that used by Arendt (1995) and Wunderle (2001) during

previous surveys on Guana Island. By conducting this survey each Science Month, changes in species abundance and distribution across the island and over time may be detected. I have developed 60 permanent survey points distributed along the Pyramid, Snake Transect, Lao Wei Ping, Long Man Point, Monkey Point, Sugar Loaf, and Palm Ghut trails, Quail Dove Ghut, and in the vicinity of the Hotel and the Flat. I was only able to conduct surveys at 57 of the points in 2009.

Compared to 2007 and 2008, detections were down dramatically for all species. For example, I detected 48 bananquits compared to 65 in 2008 and 89 in 2007. Similarly, I only detected 47 pearly-eyed thrashers compared to 68 in 2008 and 86 in 2007. It would appear the trends of both these species are in decline. However, these two species remain among the most abundant birds on Guana Island. I also suspect the survey data may be misleading. In the dry forest, detections are primarily aural. I suspect that weather conditions the last two years, which have been relatively dry compared to 2007, may have resulted in behaviors not leading to consistent vocalizations and territorial or mating calls. Similar to the interpreting migrant capture results, good weather data would greatly enhance my ability to draw meaningful conclusions from the survey data.

I am in the process of co-authoring a manuscript that analyzes survey data from 1994 (Arendt 1995), 2001 (Wunderle 2001), and 2007-2009 (Boal 2008, 2009, this report). All surveys were conducted in similar fashion. For analysis, I examined detections of resident species for which at least 50 total individuals had been detected. These included Bananaquits (n = 307), Pearly-eyed Thrashers (n = 306), Caribbean Elaenias (n = 70), Zenaida Doves (n = 70), and Black-faced Grassquits (n = 54); no other resident landbird was detected 50 or more times.

Detections of Bananaquits varied among the survey periods (H<sub>4, 293</sub> = 23.36, P = 0.0001) with differences between 1994 and 2009 (P = 0.001) and 2007 and 2009 (P = 0.0015). Mean detections of Bananaquits were similar and highest in 1994 (x = 1.38 ± 0.13) and 2007 (x = 1.34 ± 0.14) but lowest in 2009 (x = 0.56 ± 0.14). Differences among years were more pronounced for the Pearly-eyed Thrasher (H<sub>4, 293</sub> = 102.39, P < 0.0001). he only survey periods between which differences (P < 0.05) did not occur were those of 1994 and 2001, and 2008 and 2009. In general, detections of Pearly-eyed Thrashers were highest in 1994 (x = 1.97 ± 0.12) and progressively decreased to the lowest detection rate in 2009 (x = 0.16 ± 0.12). There were no differences among years in detections of Caribbean Elaenias (H<sub>4, 293</sub> = 8.97, P = 0.062), Zenaida Doves (H<sub>4, 293</sub> = 8.17, P = 0.080), or Black-faced Grassquits (H<sub>4, 293</sub> = 9.19, P = 0.056). This manuscript is in review with co-authors and we hope to have it submitted before years end.

#### Bananaquit Demography

Since 1994, 828 bananaquits have been banded on Guana Island. Over 165 of these birds have been recaptured at least once, and some have been recaptured several times. I have an incredibly robust recapture data set with which I am modeling sex- and age-specific survival rates for the species. I am being held up in trying to get genetic based confirmation of sexes of a sample of bananaquits. If morphological measures are found to accurately reflect sex of adult bird, I will be able to expand the data set to include all adult bananaquits, not just those sexed by their breeding status. I will also attempt to incorporate covariates of weather and climate factors to attempt to understand how global climate change may affect this species. If bananaquits are a suitable surrogate for other Caribbean birds, this may also allow broader predictions of the impact of climate change on Caribbean birds in general.

#### Mangrove Cuckoo Ecology

The lead field investigator for this project is Tracy S. Estabrook (M.S.). The mangrove cuckoo is one of the least-studied North American birds and baseline population estimates and habitat requirements have been identified as among the most important research needs for the species. In 2005 we

3

initiated a standardized call-playback survey along trails on Guana to try to establish baseline information on minimum number of individual cuckoos, pairs, and/or family groups present. A call-playback survey consists of broadcasting the call of the species over a loudspeaker. If an individual of the species is present, it may interpret the broadcast as the vocalization of a territorial intruder, and respond by approaching the surveyor while calling in response.

Between 12 and 26 October 2009, we surveyed 83 points for mangrove cuckoos, using recorded callplayback. Survey points represented nearly complete coverage of the marked trail system on Guana Island. We obtained responses from cuckoos at 20 (24%) of the survey points during 2009, which is the lowest response rate recorded since we initiated surveys in 2005, and substantially lower than the response rates for the same survey routes and points during 2007 (51%) or 2008 (40%). We detected ≥2 cuckoos in close proximity to each other at 4 (20%) of the 20 active territories, indicating the potential presence of pairs or related individuals. This is equal to the percentage of pair/family groups recorded in 2008 (20%) and higher than that recorded in 2007 (7%). As in previous years, we visually observed cuckoos at a few sites (3 sites in 2009) where the survey proper failed to elicit a response or elicited response from a different individual.

Cuckoo responsiveness to call-playback surveys might vary depending on breeding status, as in many bird species (e.g., territoriality associated with breeding behavior, mate-searching, etc.). There might also be differences in response rates of adults and juveniles, regardless of breeding status. Cuckoo vocalizations are not well-understood (Hughes 1997), so we cannot make assumptions about the age or reproductive status of birds that are not seen (the majority of responses). In 2009 we visually identified 2 adult and 4 juvenile cuckoos (using Pyle's orbital-color criterion [1997]) responding to call-playback at 6 of the active territories, and anecdotal evidence across all survey years indicates that both juvenile and adult cuckoos respond to call-playback surveys with a variety of vocalizations.

2009 was notable for our first successful recaptures of mangrove cuckoos. On 19 October, a banded adult bird was visually "recaptured" near the hotel's Garden of Eden within ~15 m of our "Radar" netset, and a different banded adult (presumed to be a breeding F due to presence of a brood patch and lack of cloacal protuberance) was captured in the "Radar" net set. It seems likely that this is a mated pair of adults. Notably, although apparently reproductively active, neither of these birds had responded during the call-playback survey, which raises the question of how breeding phenology might affect responsiveness of this species to the calls of conspecifics.

The relevancy of this study, in addition to acquiring basic biological information for the species, is its utility as a tool for conservation of mangrove cuckoos. The species is suspected of being substantially impacted by habitat loss and degradation due to conversion of low-lying vegetation areas on islands and in coastal regions throughout its range to urbanization, resorts, and agricultural production. Refinement of our survey protocol may enable detection, monitoring, and enhanced conservation of mangrove cuckoos not just in the Caribbean, but in coastal areas of North America.

#### Bridled Quail Doves

During 2009 we observed more bridled quail doves than any other time on Guana Island. In addition to capturing one in a regular mist net, I target trapped individuals by walking behind them to drive them into single nets. In doing this, I was able to capture and individually color band 12 bridled quail doves. We would have been able to at least double the number if I had the appropriate sized nets with me.

As I completed my studies of bananaquits, I will be shifting over to focused population studies of bridled quail doves on Guana Island in 2010 and subsequent years. With the proper sized nets, I 4

anticipate being able to mark numerous individuals and, thereby, develop the first examination of pairing, movement and, most importantly, survival. This would add considerably to the knowledge of the species. Indeed, information is lacking for the genus *Geotrygon* in general, and I hope to pursue funding to expand research on the Geotrygon genus to include sites in other parts of the BVI, the USVI and Puerto Rico.

#### DISCUSSION

A common them during the 2009 field season was low detections of birds on surveys, low capture rates of all species in mist nets, and low responsiveness by cuckoos to playback surveys. In contrast, bridled quail doves were abundant, with at least 4 residing near the laundry facility and regularly foraging in the Garden of Eden area. Additionally, many more individuals than normal were observed near the north beach cottage, the workshop, and the orchard area. It is possible that numbers of this species have increased, conditions at higher elevations have pushed them down to the low lying, moist areas of the island, or both. We suspect the prolonged dry period before science month may have lead to these patterns, but it is as yet unclear how or why. Again, equipment with which to collect reliable, high quality weather data on Guana is important for making interpretations of our data.

## **PROJECT PRODUCTIVITY**

Papers in Development

- 1. Timing and condition of blackpoll warblers arriving on Guana Island.
- 2. Age and sex-specific survival of bananaquits (co-authored with Brent Bibles)
- 3. Autumn monitoring of resident avifauna on Guana Island, BVI (co-authored with Joseph Wunderle and Wayne Arendt)
- 4. Using call-playback to survey and monitor mangrove cuckoos (authored by Tracy Estabrook)

## Papers Published

- Boal, C. W. 2008a. Observations of an Antillean crested hummingbird (*Orthoryhncus cristatus*) attacking saddled anoles (*Anolis stratulus*). *Caribbean Journal of Ornithology* 21:48-49.
- Boal, C. W. 2008b. Predation of a dwarf gecko (Sphaerodactylus macrolepis) by a bridled quail dove (Geotrygon mystacea). Caribbean Journal of Ornithology 21:50-51.
- Boal, C. W., and T. S. Estabrook. 2007. Occurrence and condition of migrant Swainson's thrushes in the British Virgin Islands. *Wilson Journal of Ornithology* 119:716–720.
- Boal, C. W., F. Sibley, T. S. Estabrook, and J. D. Lazell. 2006. Insular migrant species, longevity records, and new species records on Guana Island, British Virgin Islands. *Wilson Journal of Ornithology* 118:218–224.

#### Presentations

- Boal, C. W. 2003. Birds of prey in the British Virgin Islands. H. Levity Stoutt Community College, Roadtown, Tortola, British Virgin Islands.
- Boal, C. W. 2005. Avian research on Guana Island: a decade in review. H. Levity Stoutt Community College, Roadtown, Tortola, British Virgin Islands.
- Boal, C. W. 2006. New bird species in the British Virgin Islands: evidence for migration pattern changes? H. Levity Stoutt Community College, Roadtown, Tortola, British Virgin Islands.
- Boal, C. W. 2009. Timing and condition of autumn migrant Blackpoll Warblers in the British Virgin Islands. Annual Meeting of the Cooper Ornithological Society, Tucson, AZ, USA.
- Estabrook, T. S. 2005. Mangrove cuckoos: where the heck are they and what the heck are they doing? H. Levity Stoutt Community College, Roadtown, Tortola, British Virgin Islands.

## **FUTURE WORK**

Avian studies during Science Month in 2010:

- Continuation of the banding station to study species diversity, abundance, and ecological aspects of neotropical migrant land birds using Guana Island during autumn migration.
  Weather permitting, nets will be operated for at least 350 net hours.
- Continuation and expansion of the mangrove cuckoo study.
- Termination of the island-wide point-counts
- Termination of the color-banding aspect of the bananaquit study
- Initiation of a focused study on ecology of bridled quail doves, including color-banding and annual monitoring of survival, site and pair fidelity.

## ACKNOWLEDGEMENTS

First and foremost, I thank Dr. James Lazell and Dr. Gad Perry for continuing to facilitate avian research activities on Guana Island. I thank Gloria and Henry Jarecki for providing the opportunity for me and other researchers to conduct our studies on Guana Island. I thank the several people who assisted with ornithological studies on Guana Island during the 2008 season. Specifically, these were Brent Bibles, Tracy Estabrook, Catarina Gebert, Susan Valentine, and Tom Willard. Funding for this research was provided by The Conservation Agency through a grant from the Falconwood Foundation and by the U.S. Geological Survey, Texas Cooperative Fish and Wildlife Research Unit.

#### LITERATURE CITED

- Arendt, W. J. 1995. Assessment of avian relative abundance on Guana Island, British Virgin Islands, with emphasis on the Pearly-eyed Thrasher. Project No. IITFW-WJA59140264. Final Report to The Conservation Agency, 10 February 1995.
- Boal, C. W., F. Sibley, T. S. Estabrook, and J. D. Lazell. 2006. Insular migrant species, longevity records, and new species records on Guana Island, British Virgin Islands. *Wilson Journal of Ornithology* 118:218–224.
- Boal, C. W., and T. S. Estabrook. 2007. Occurrence and condition of migrant Swainson's thrushes in the British Virgin Islands. *Wilson Journal of Ornithology* 119: 716–720.
- Chipley, R. M. 1991. Notes on the biology of the bridled quail-dove (*Geotrygon mystacea*). Caribbean Journal of Science 27:180–184.
- Hughes, J. M. 1997. Mangrove cuckoo (*Coccyzus minor*). Account 299 in A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.
- Latta, S.C., and C. Brown. 1999. Autumn stopover ecology of the blackpoll warbler (*Dendroica striata*) in thorn scrub forest of the Dominican Republic. *Canadian Journal of Zoology* 77:1147-1156.
- McNair, D. B., F. Sibley, E. B. Massiah, and M. D. Frost. 2002. Ground-based nearctic-neotropic landbird migration during autumn in the eastern Caribbean. Pages 86–103 in Studies in
- Trinidad and Tobago Ornithology Honouring Richard ffrench (F. E. Hays and S. A. Temple, Eds.). Department of Life Sciences, University of West Indies, St. Augustine, Occasional Paper 11.
- Pyle, P. 1997. Identification guide to North American birds. Part 1. Slate Creek Press, Bolinas, California, USA
- Raffaele, H., J. Wiley, O. Garrido, A. Keith, and J. Raffaele. 1998. A guide to the birds of the West Indies. Princeton University Press, Princeton, New Jersey, USA.
- Wiley, J. W. 2000. A bibliography of ornithology in the West Indies. *Proceedings of the Western* Foundation of Vertebrate Zoology 7.
- Wunderle, J. M., Jr. 2001. Avian surveys on Guana Island, B.V.I. (4–10 October 2001). Final Report to The Conservation Agency, 20 November 2001.

Table 1. Comparison of mist-netting effort and capture rates at the Guana Island field site, British Virgin Islands, 2003–2009. Captures listed include both new birds captured and recaptures of previously banded birds.

Year	Net hrs.	Total Birds Captured <sup>1</sup>	Birds /net hr.	Species <u>Captured</u>
2003	184	185	1.00	25
2004	218	168	0.80	20
2005	403	428	1.10	21
2006	400	284	0.71	24
2007	450	347	0.77	13
2008	460	271	0.59	20
2009	356	180	0.51	16

<sup>1</sup> Table does not include 12 Bridled Quail Doves captured using nets specifically set for their capture.

# **Pictures from Guana Science Month 2009**



Catarina Gebert learns how to not get bitten while banding a pearly-eyed thrasher.



Catarina with a bridled quail dove.



Tracy with a recaptured mangrove cuckoo.



A resident Caribbean yellow warbler.



The 2009 banding crew.



Color-bands on a bridled quail dove.



A bridled quail dove (lower left) and zenaida dove (upper right) for comparison.

### ANOLIS CRISTATELLUS (Crested Anole). AVIAN PREDA-

**TION**. The Pearly-eyed Thrasher (*Margarops fuscatus*) opportunistically feeds on eggs and chicks of parrots and other forest birds (Arendt 2000. Ornithol. Neotropical 11:13–63; Lazell 2005. Island: Fact and Theory in Nature. Univ. California Press, Berkeley), and is an important predator of *Anolis* lizards (Waide and Reagan 1983. Amer. Nat. 121[1]:133–138). In a review of avian predators of West Indian reptiles, Powell and Henderson (2008. Iguana 15[1]:9–11) recorded only two birds taking *A. cristatellus*, both falconiform raptors. Here I report Pearly-eyed Thrasher predation on the Crested Anole on Guana Island, British Virgin Islands (18.46666°N, 64.58333°W; WGS 84).

On 23 Oct 2007 ca. 1800 h, a young male A. cristatellus jumped onto a roof (3 m long, 1 m wide, 2.5 m above ground, and in contact with the vegetation canopy alongside) often used by the species for basking. Unusually, it made a noisy landing. Anoles use flight behavior to deter snake predation (Leal and Rodriguez-Robles 1997. Anim. Behav. 54:1147–1154). This anole quickly ducked under the eve of the roof, followed within 5 sec by the arrival of a thrasher. The bird appeared to be searching for the lizard, located it, but was not able to catch it. In the next few seconds, the bird ran quickly along the roof edge back and forth twice, head looking down, neck cocked sideways, and beak extended below the eve.

Herpetological Review 40(2), 2009

219

It was apparently following the lizard under the eve. It eventually drove the anole out onto the wall. Whether the anole was herded or stopped from escaping by the bird was not clear because I could not see under the eve. Once in the open, the bird caught the lizard in its beak. The lizard struggled and the thrasher took at least 5 min to subdue and swallow it. In addition to falconiform raptors, the snake (*Alsophis portoricensis*) and mongoose (*Herpestes javanicus*) also prey on the Crested Anole (Platenberg and Boulon 2006. J. Appl. Herpetol. 3[3]:215–235; Schwartz and Henderson 1991. Amphibians and Reptiles of the West Indies: Descriptions, Distributions, and Natural History. Univ. Press Florida, Gainesville. 720 pp.).

Submitted by WENHUA LU, The Conservation Agency, 6 Swinburne Street, Jamestown, Rhode Island 02835, USA; e-mail: hq@theconservationagency.org.

## The Ground Lizards (Ameiva exsul) of Guana Island: 2009 Report

12

Matthew E. Gifford Department of Biology, University of Arkansas at Little Rock Little Rock, Arkansas 72204

> Robert Powell Department of Biology, Avila University Kansas City, Missouri 64145



Puerto Rican Ground Lizards (*Ameiva exsul*) are abundant on Guana Island. Large males (top) develop adult coloration, whereas even large females (bottom) frequently retain the striped pattern seen in juveniles.

Puerto Rican Ground Lizards (*Ameiva exsul*) are widely distributed across the Puerto Rico Bank, but are absent or rare on islands with introduced Small Indian Mongooses (*Urva auropunctata*). Primarily associated with dry habitats, smaller individuals are more vulnerable to water loss than large adults, possibly restricting them to moister microhabitats or curtailed activity periods. These diurnal lizards forage actively on insects and other small arthropods, but are facultative omnivores, eating fruits, other vegetable matter, and even small vertebrates. We have observed a large male on Guana Island foraged actively in leaf litter for Puerto Rican Dwarf Geckos (*Sphaerodactylus macrolepis*), a subadult jumping into the air to catch a flying moth, and two other individuals eating red berries of *Cordia polycephala*.

Maximum known snout-vent length (SVL) for males is 201 mm and for females 103 mm, although lizards on Guana to not appear to reach those sizes. These lizards are most active at high temperatures, emerging from dens as temperatures rise in the morning and returning to shelter in late afternoon when temperatures drop. Our data to date suggest a unimodal activity pattern on Guana, although bimodal activity has been observed in populations of other species of West Indian *Ameiva*.

Ground Lizards are not territorial and range widely while foraging, with home ranges of males and females often overlapping. Females lay 4–7 eggs in shallow burrows, with reproduction closely associated with the rainy season in dry habitats of southwestern Puerto Rico, but less seasonal elsewhere in the species' range.

Principal predators include snakes (e.g., Puerto Rican Racers, *Borikenophis portoricensis*), predatory birds (e.g., Red-tailed Hawks, *Buteo jamaicensis*, and American Kestrels, *Falco sparvarius*), feral dogs and cats, and mongooses. On Guana, we observed a Puerto Rican Racer strike unsuccessfully at a juvenile Ground Lizard from ambush along the edge of vegetation along White Bay Beach.

On Guana Island, Ground Lizards exploit most available habitats, including those altered by human activity, but are most abundant in Sea Grape (*Coccoloba uvifera*) leaf litter along beaches and open forests on hillsides essentially islandwide. Population densities have been estimated at 200 lizards/ha in optimal habitat, but preliminary estimates based on encounter rates on Guana Island were lower (34/ha in forest and 52/ha along White Bay Beach).

#### 2009 Activity

Because relatively little is known about life histories of any species of *Ameiva*, the work conducted on Guana has the potential for shedding considerable light on the basic biology of Ground Lizards, which are among the most abundant and certainly most visible components of the herpetofauna on West Indian islands.

#### Capture data:

Total captured = 51. Total marked = 38; total recaptured from previous two years = 13 (all males); 9 of these were recaptures from 2008, 2 were recaptures from 2007, and 2 were recaptured animals captured in both 2007 and 2008. 2009 capture breakdown: 32 adult males, 4 adult females, and 14 juveniles.

2007: 58
2008: 67
<u>2009: 38</u>
TOTAL: 163
2008: 9 2009: 13 (2 animals captured all three years)
17.6% (calculated as total recaptures (22) divided by total number of animals marked in 2007 & 2008 (125)

When broken down between juveniles and adults (males), adults are recaptured at a higher rate than juveniles. This suggests that juvenile mortality exceeds adult mortality, which is not unexpected, but our data will allow quantification of this discrepancy for any species of *Ameiva* for the first time.



An approximate growth curve for Ameiva exsul on Guana using data for animals that have been captured at least twice.

Because we have captured animals in 2009 that were adults when originally captured in 2007, our original hypothesis regarding the longevity of this population was challenged. *Ameiva exsul* on Guana appears to be a fairly long-lived lizard, with a potential life span of at least four or five years. Such longevity is not unknown for lizards, but this is the first study that quantifies longevity in any species of *Ameiva*.

#### Implications for survival:

Phenotypic differences do exist between recaptured juveniles and those that were not recaptured. Animals recaptured are coded as "survivors," those not recaptured are coded as "non-survivors." Surviving juveniles were significantly heavier ( $F_{1,30} = 5.09$ , P = 0.032; survivors mean = 4.85 g, non-survivors mean = 3.21 g) and consistently longer ( $F_{1,30} = 3.86$ , P = 0.059; survivors mean = 55.17 mm, non-survivors mean = 48.92 mm) than non-survivors. These admittedly preliminary data suggest that a potentially significant survival advantage exists for juveniles with large body size. This may be a consequence of an earlier hatching date and/or more efficient foraging and processing of acquired resources — or larger juveniles might be able to avoid predators more effectively than smaller individuals. However, we found no differences between survivors and non-survivors in morphological traits often associated with predator avoidance capacity (e.g., longer hind-limbs for increased sprinting speed). Similarly, no such differences were detected for "surviving" and "non-surviving" adult males.





#### Additional data:

We found no phenotypic differences between the three sampled transects (Transect 1: Anegada House around the eastern side of the Pyramid; Transect 2: Hotel grounds, Iguana Trail, Guanaberry Trail; Transect 3: From base of Guanaberry Trail along White Beach through the dump to the large cistern above the orchard). These data are similar to those from 2008, although the mass:length ratio for animals on the Pyramid was less than for lizards taken in the other transects in 2007. These differences might be attributable to varying resource abundance in different years, which additional years of sampling might be able to resolve (see "future plans").

When all data are combined (2007, 2008, 2009), cloacal temperatures are consistently higher than air and substrate temperatures (combined means for all years: cloacal =  $37.84^{\circ}$ C, air =  $29.7^{\circ}$ C, substrate =  $31.8^{\circ}$ C).

#### **Future Plans**

Based on preliminary estimates of longevity, we would like to continue the study for another 4–5 years in order to develop a life history table for Guana Ground Lizards (no life history tables exist for any West Indian population of *Ameiva*). Development of a life history table requires the continuation of the mark-recapture study along the three transects established during the previous three years. Data over the next few years will also build a survival data set that can be correlated with morphological and habitat variables in

order to test the hypothesis that larger juvenile size (independent of other morphological traits) enhances survival through the first year of life.

In 2010, we will use temperature data loggers to monitor the thermal environments along each transect in order to estimate available operative temperatures. Using these along with estimates of activity temperatures recorded for most new captures, we can evaluate the accuracy of thermoregulation. With adequate data, we should be able to compare the thermal environments in each transect to assess any potential effects on activity. In addition, we also will use 10–15 animals of varying sizes from each transect to measure preferred temperatures in an artificial thermal gradient and to quantify locomotor performance (as an estimate of fitness; i.e., predator avoidance) at temperatures at and slightly above and below preferred temperatures in each transect.



This adult male Puerto Rican Ground Lizard (*Ameiva exsul*) had been foraging in leaf litter near White Bay Beach when he was disturbed by our presence. Note the regenerated tail, possibly the result of a predation attempt or consequence of an occasionally violent male-male conflict. The white mark on the tail indicates that this individual had already been captured.

Complementing the ongoing mark-recapture study, we also propose to collect tissues from animals in other areas on Guana to examine the genetic structure of the island's populations. Recent work on the Ground Lizards of Dominica (*Ameiva fuscata*) suggests that subpopulations exist in close geographic proximity without substantial interaction. If this is true, populations on different parts of Guana should exhibit slightly different genetic profiles. These data also can be compared with those for populations elsewhere in the British Virgin Islands and across the entire Puerto Rico Bank.

During the last year of the study, we propose to collect  $\sim 20$  animals from each transect for dietary analyses. These will shed light on habitat associations and predator-prey relationships that currently rely entirely on anecdotal observations such as those cited in the introduction. Data from years 1–3 suggest that removal of this many animals will have minimal impact on populations capable of rapid recruitment. These specimens also will provide material for skeletochronological analyses that could reveal additional information about longevity, growth, and responses to annual variations in these variables as they respond to varying habitat conditions (e.g., drought or years of abundant rainfall).

#### Addendum: The "Odd" Ground Lizards on Tortola

Since at least 2003, Dr. Gad Perry has observed unusual Ground Lizards in a restricted area on Tortola (animals elsewhere on the island look very much like the lizards on Guana). A single animal was collected and preserved in 2003 (MCZ 183687), another was photographed in 2007, and a third lizard was captured in 2009. Although superficially similar to *Ameiva exsul* in many ways, the lizards in this population are darker in coloration and lack some of the characteristic markings seen on *A. essul* elsewhere in its range and appear to be smaller. The lizard collected in 2009 was a female, but had the blue markings that usually are acquired by male *A. essul* at a much larger size. Although the individual collected last year was



inadvertently released, we did collect tissue (tip of tail) suitable for DNA analysis and comparisons with data for known *A. exsul* collected elsewhere in the Virgin Islands and on Puerto Rico.

Female Ground Lizard (Ameiva sp.) collected on Tortola in 2009.

#### Acknowledgments

We thank the Jarecki family and the Falconwood Foundation for providing the opportunity to conduct research on Guana Island. By maintaining Guana Island as a nature preserve and permitting and actively supporting research, they have rendered a tremendous service to science and to scientists with an interest in the dynamics of West Indian island biotic communities. Drs. James (Skip) Lazell and Gad Perry have encouraged and facilitated our efforts.

Last modified 7 Sep 2009

For Biotropica

3 LRH: Perry, Dmi'el, and Lazell

4 RRH: Water Loss and Altitude

5

1

- 6
- 7 Intra-Island Altitudinal Difference in Reptilian Water Loss Rates
- 8
- 9 Gad Perry<sup>1</sup>
- 10 Department of Natural Resource Management, Box 42125, Texas Tech University,
- 11 Lubbock, Texas 79409, U.S.A.
- 12
- 13 Razi Dmi'el
- 14 Department of Zoology, Tel Aviv University, 69978 Tel Aviv, Israel
- 15
- 16 and
- 17 James Lazell
- 18 The Conservation Agency, 6 Swinburne St., Jamestown, Rhode Island 02835, U.S.A.
- 19
- 20
- 21
- 22 <sup>1</sup> Corresponding author: Gad Perry, email: <u>and reconstruction</u>
- 23
- 24 Received \_\_\_\_\_; revision accepted \_\_\_\_\_.

1 Abstract

2	Conserving water is important for most organisms, and especially for small animals
3	inhabiting exposed habitats. We have previously demonstrated that, in the British Virgin
4	Islands, skin resistance to water loss is positively correlated with the aridity of the island
5	inhabited by the lizard Anolis cristatellus. We also previously found striking differences
6	between lizards at the highest elevation in the Virgin Islands, ca 520 m, and those from sea
7	level. Here we compare water loss rates of three reptile species (the snake Alsophis
8	portoricensis, the anole Anolis cristatellus, and the gecko Sphaerodactylus macrolepis) at
9	different elevations on Guana Island (ca 300 ha; maximum elevation: 246 m). Following
10	MacLean's report of altitudinal differences in water loss of S. macrolepis on Guana, we
11	hypothesized that sea-level populations, being exposed to warmer and drier conditions,
12	would show reduced water loss rates. Our findings partially supported our prediction.
13	Water loss in Alsophis was not correlated with altitude, but both Anolis and
14	Sphaerodactylus had significantly higher water loss rates at higher elevations. These
15	findings may have implications for the impacts of global climate change on animal species.
16	
17	
18	Key words: Alsophis portoricensis; altitude; Anolis cristatellus; British Virgin Islands; body size;
19	evaporative water loss; Sphaerodactylus macrolepis

1	ORGANISMS INHABITING DRY HABITATS RISK EXCESSIVE EVAPORATIVE WATER LOSS (EWL)
2	to their environment. In extreme cases this can result in death, and organisms have therefore
3	evolved mechanisms for avoiding dehydration. Some mechanisms are behavioral, and
4	primarily involve avoidance of undesirable conditions by choosing activity times or
5	microhabitats that are more hospitable. Morphological or physiological mechanisms can
6	help augment behavioral ones. For example, some desert dwellers have evolved elaborate
7	structures that prevent loss of water vapor from exhaled air, whereas others have evolved
8	improved kidney ability to conserve water by greatly concentrating urine. Cutaneous water
9	loss (CWL) is another major avenue of dehydration. In terrestrial reptiles, reducing CWL is
10	a common physiological response to dry conditions (Bentley & Schmidt-Nielsen 1966,
11	Mautz 1982, Dmi'el 1985, Dmi'el et al. 1997, Perry et al. 1999, 2000).
12	Although located in the tropics, the British Virgin Islands (BVI) are relatively dry. There is a
13	pronounced and sometimes severe dry season, and droughts are not uncommon (G. Perry, unpublished
14	data). Anolis cristatellus (Lacertilia: Iguanidae) from the BVI are water limited and show physiological
15	responses to variation in rainfall patterns that encompass genetic and phenotypic changes (Dmi'el et al.
16	1997; Perry et al. 1999, 2000). MacLean and Holt (1979) and MacLean (1985) studied water loss in
17	three species of dwarf geckos of the genus Sphaerodactylus from the Virgin Islands. In a report
18	concentrating on S. parthenopion, MacLean (1985; Table 1) also published his results for S.
19	macrolepis, which he had studied at three sites on Guana Island, BVI: two at sea level and one at ca.
20	240 m. The summary data provided by MacLean (1985), although limited in scope, support the
21	existence of altitudinal differences between populations of S. macrolepis, which he had previously
22	suggested in communication sent to one of us (JL) in 1984. Unfortunately, MacLean never had the

chance to return to this issue, as he indicated he intended (MacLean 1986), and the raw data were lost
following his untimely death.

Other data, obtained on the nearby island of Tortola (55 km<sup>2</sup>) in a different context, support the 3 possibility that within-island, intraspecific altitudinal differences in water loss might be considerable: a 4 5 high-altitude population of Anolis cristatellus (Sage Mountain, ca. 520 m) has repeatedly shown differences in water loss from a sea-level population (Dmi'el et al. 1997; Perry et al. 1999, 2000). 6 However, Guana Island is much smaller (3 km<sup>2</sup>), and its highest point (Guana Peak, 246 m) is much 7 lower than Sage Mountain. Moreover, S. macrolepis can be found at great densities in leaf-litter 8 9 habitats, where it is presumably buffered from dry conditions (Rodda et al. 2001). Finally, the values 10 reported by MacLean (1985) may be biased by altitudinal differences in body size, which was not 11 reported, and the loss of the raw data precludes reevaluating this issue. Our broad goal in the current study was therefore to test MacLean's proposition that there will be altitudinal differences in water loss 12 13 rates within Guana Island. Specifically, we wanted to test three hypotheses: (1) that animals from 14 higher altitudes will have higher water loss rates than those from lower areas. The latter are likely to be 15 more arid because rain more often falls on peaks, and because lower elevations are more exposed to 16 salt spray; (2) that altitude-related differences will be greater for small species, both because of their 17 greater susceptibility to water loss and because of the lower likelihood that they will move widely and 18 thereby sample multiple habitats (Perry & Garland 2002, Jetz et al. 2004); and (3) that differences in water loss rates will be related to body size, with smaller individuals losing more water per unit mass 19 under similar conditions than larger ones. 20

21

22

23

- 1 METHODS
- 2

STUDY ORGANISMS. - We chose three species for this study: (1) Sphaerodactylus macrolepis. MacLean 3 and Holt (1979) and MacLean (1985) studied this small (up to 0.5 g) diurnal gecko, and we therefore 4 5 chose this to be our smallest species. S. macrolepis lives in the leaf-litter and can be found there at extremely high densities (Rodda et al. 2001). Following results in MacLean (1985), we expected to 6 find an altitudinal difference in water loss rates in this species. (2) Anolis cristatellus. This common, 7 medium-sized lizard (up to 9 g) occupies trunk-ground habitats on the Puerto Rico Bank. Water loss in 8 9 this species has been studied extensively (Dmi'el et al. 1997; Perry et al. 1999, 2000), and the variation described previously led us to predict the existence of an altitudinal gradient within Guana as well. (3) 10 11 Alsophis portoricensis. This middle-sized snake (normally up to 100 g, but occasionally >300g) feeds on lizards. It is highly active, moving on the ground and occasionally climbing trees or structures 12 13 (Barun et al. 2007). Because of its active lifestyle and greater size, we predicted that it would 14 experience a variety of conditions, and consequently not show an altitudinal difference in water loss 15 rates. 16 STUDY SITE.- Guana Island is located near Tortola, the main island of the BVI. It has an area of approximately 300 ha (Lazell 1996), has been extensively studied, and is exceptionally diverse for its 17 size (Lazell 2005). We collected study animals at four altitudes: 0, 70, 150, and 240 m. For sea-level 18 19 collection, we used MacLean's (1985) original collection sites, Monkey Point and Muskmelon Bay, 20 and also sampled the White Bay and North Bay areas. At 70 m, we sampled the area immediately 21 around the Guana Island Club. At 150 m, collection was conducted in a forested area on the path 22 leading to the Guana Peak. Finally, we collected in the area just below the peak itself. The vegetation 23 at these sites represents a gradient, becoming increasingly more xerophytic with decreasing altitude.

Thus, agaves (*Agave missionum*) and cacti are common at lower altitudes, whereas plants found only near the peak include *Pepperonia* and several orchids and ferns (G. Proctor in Lazell 2005). Snake populations are less dense than those of the three lizard species studied. Consequently, we also sampled snakes at other locations, rather than attempting to only collect them from the locations given above.

LABORATORY METHODS.- Following capture during normal activity times, study animals were brought 6 7 into the laboratory and housed in plastic containers modified to allow free airflow around the animal. Sphaerodactylus were housed in a cylindrical container (diameter 22 mm, height 50 mm), Anolis in 8 9 commercially bought food boxes (diameter 100 mm, height 50 mm), and Alsophis in slightly larger containers (diameter 105 mm, height 80 mm). We followed MacLean (1985) in measuring total water 10 11 loss, rather than separating cutaneous and respiratory losses as we have previously done for A. cristatellus (Dmi'el et al. 1997, Perry et al. 1999, 2000), for three reasons. First, total water loss is 12 13 arguably the most ecologically relevant measure, since animal survival is a function of overall water 14 retention. Second, separating the two avenues requires testing that is stressful to study animals, and we 15 did not consider that justified given the exploratory nature of this study. Finally, we felt that replicating 16 the methodology used by MacLean (1985) would increase the ability to compare the results of the two 17 studies. We used a Sartorius 1518 balance to weigh each animal to the nearest 1 mg prior to testing. 18 every hour during testing, and at the conclusion of the testing. Changes in mass, representing water 19 loss, were monitored until well after the rate of mass change had stabilized, at least 6 h in each case. Individuals that defecated were re-weighed, and the study restarted. All animals were released at the 20 site of capture at the end of the study. 21

Statistical analyses were performed using SPSS. We used the logarithmic transformation to
linearize mass and water loss data.

1

## 2 **RESULTS and DISCUSSION**

We collected and tested at least 45 individuals of each of our three study species (Table 1). Not 4 surprisingly, the values we obtained for A. cristatellus are similar to those previously reported by us 5 from the BVI (Dmi'el et al. 1997, Perry et al. 1999, 2000). The values we obtained for S. macrolepis 6 were similar to those reported by MacLean (1985), despite methodological differences. MacLean 7 (1985) exposed his animals to continuously flowing air that was first dehumidified by passage through 8 Drierite, whereas we used ambient conditions. The similarity in measured loss rates may thus indicate 9 10 that the values we obtained, which are presumably similar to water loss rates for lizards exposed to normal Guana Island conditions, are close to the maximal values obtainable by this species. Thus, the 11 high humidity within the leaf-litter microhabitat that S. macrolepis inhabit may be essential for survival 12 of these minute geckos. We have not been able to find previous water loss measurements for A. 13 portoricensis or closely related taxa. However, broadly similar values have been reported for other 14 15 colubrids (Gans et al. 1968, Baeyens & Rountree 1983, Dmi'el 1985). Overall, mass was an important predictor of water loss rates in all three species (mg h<sup>-1</sup>: 16 Pearson's r = 0.97, N = 160, P < 0.001; mg/g/h: r = 0.85, N = 160, P < 0.001). Both total water loss 17 18 rates and mass-specific water loss rates differed significantly among species (ANOVA. mg/h:  $F_{2.157} =$ 686, p < 0.001; mg/g/h:  $F_{2,157} = 218$ , p < 0.001). Whereas larger species exhibited greater overall water 19 loss rates (Table 1, Fig. 1A), smaller species had greater mass-specific water loss rates (Fig. 1B). 20 21 Within species, both total water loss and mass-specific water loss were significantly affected by mass (Alsophis: mg/h: r = 0.87, N = 45, P < 0.001; mg/g/h: r = 0.44, N = 45, P = 0.003; Anolis: mg/h: r = 0.44, N = 45, P = 0.003; Anolis: mg/h: r = 0.44, N = 45, P = 0.003; Anolis: mg/h: r = 0.44, N = 0.003; P = 022 0.74, N = 49, P < 0.001; mg/g/h: r = 0.45, N = 49, P = 0.001; Sphaerodactylus: mg/h: r = 0.67, N = 0.001; N23

1	66, $P < 0.001$ ; mg/g/h: $r = 0.40$ , $N = 66$ , $P = 0.001$ ). Thus, our hypothesis is supported. The
2	importance of mass in determining water loss rates at the interspecific level is not surprising, since body
3	size has long been known to be an important determinant of many physiological processes (Schmidt-
4	Nielsen 1984). However, the effect of body size on water loss rates is emerging as an important
5	determinant of ecological traits such as habitat choice and activity pattern (Nicholson et al. 2005).
6	Mass-corrected water loss rates were significantly influenced by altitude in S. macrolepis (Fig.
7	2A, $r = 0.28$ , $N = 66$ , $P = 0.023$ ) and A. cristatellus (Fig. 2B, $r = 0.43$ , $N = 49$ , $P = 0.002$ ), but not in
8	A. portoricensis (Fig. 3. $r = 0.10$ , $N = 45$ , $P = 0.52$ ). These findings confirm the conclusions drawn by
9	W. MacLean (in lit.) from his data (MacLean 1985), and match our predictions: that differences in
10	water loss rates will be related to body size, that animals from higher altitudes will have higher water
11	loss rates than those from lower areas, and that such differences will be larger in small species. Other
12	than MacLean's (1985) data and unpublished findings, this is the first time that intraspecific differences
13	in water loss rates have been demonstrated on such a small geographical and altitudinal scale. We
14	suspect that the difference between our reptile populations is a function of greater exposure to salt
15	spray at sea level and of greater availability of water, and hence higher humidity, at the peak. It would
16	require considerable work to document the actual difference in ambient conditions at these altitudes in
17	a way that captures both the multifaceted nature of the environment and the long-term sampling of
18	conditions reflected in the water loss rates we measured.
19	Our findings are further unique in demonstrating that small species are more strongly affected
20	by altitude than are larger ones. We believe there are two reasons for this. First, smaller species have a

21 greater susceptibility to water loss (present study), and are therefore expected to respond more

22 strongly to small differences in ambient conditions. Second, individuals of the snake *A. portoricensis*,

23 orders of magnitude larger than the other two species we studied, will predictably also have much

larger home ranges (Perry & Garland 2002, Jetz et al. 2004). Unlike the smaller lizards, which could 1 spend their entire lives experiencing a fairly consistent environment, these snakes are likely to span the 2 altitudinal and microclimatic extremes of a small island like Guana within a relatively short period. This 3 could allow smaller species to acclimate to their immediate situation and perhaps even to evolve a 4 genetic difference in physiology. For example, Denno et al. (2001) have shown the existence of 5 significant genetic differences related to ecological differentiation between two populations of Tovia 6 venelia (Insecta: Hemiptera) on Guana Island. In contrast to the two lizard taxa, larger species such as 7 A. portoricensis are likely to sample multiple habitats over relatively short periods, and thus be unable 8 to develop phenotypic and/or genetic differentiation. Jenssen (2002) showed that A. cristatellus will 9 return to their original home range after being displaced, but data on home range size, movement 10 patterns, and population genetic structures are otherwise lacking. 11 As global climate changes, many species are changing their distributions to move pole-wards or 12-13 upwards (Parmesan & Yohe 2003). As they do so, they presumably track desirable local conditions that better match their needs: as the world warms and dries, such conditions are no longer found at traditional 14 15 locations. Our findings help provide a physiological explanation for these movements, although they are 16 unlikely to provide a complete explanation. They also bring up two important questions. First, can species 17 change their requirements, whether via physiological or evolutionary mechanisms, fast enough to meet 18 ongoing changes once they reach a mountain peak or a geographic barrier that prevents further pole-wards 19 moves? And second, will the greater physiological specificity of smaller species, combined with their 20 generally lower vagility, result in greater extinctions among small species compared to large? 21

22

23 Acknowledgments

We thank Henry and Gloria Jarecki for access to Guana Island and the Guana Island staff for technical
assistance. This project was funded by The Conservation Agency through a grant from the Falconwood
Foundation. This is manuscript T-9-1166 of the College of Agricultural Sciences and Natural Resources,
Texas Tech University.

1 Literature cited

2	BAEYENS, D. A., AND R. L. ROUNTREE. 1983. A comparative study of evaporative water
3	loss and epidermal permeability in an arboreal snake, Opheodrys aestivus, and a semi-
4	aquatic snake, Nerodia rhombifera. Comp. Biochem. Physiol. 76A: 301-304.
5	BARUN, A., G. PERRY, R. W. HENDERSON, AND R. POWELL. 2007. Alsophis portoricensis
6	anegadae (Squamata: Colubridae): Morphometric characteristics, activity patterns,
7	and habitat use. Copeia 2007: 93-100.
8	BENTLEY, P. J., AND K. SCHMIDT-NIELSEN. 1966. Cutaneous water loss in reptiles. Science
9	151: 1547-1549.
10	DENNO, R.F., D.J. HAWTHORNE, B.L. THORNE, AND C. GRATTON. 2001. Reduced flight
11	capability in British Virgin Island populations of a wing-dimorphic insect: the role of
12	habitat isolation, persistence, and structure. Ecol. Entomol. 26: 25-36.
13	DMI'EL, R. 1985. Effect of body size and temperature on skin resistance to water loss in a
14	desert snake. J. therm. Biol. 10: 145-149.
15	DMI'EL, R., G. PERRY, AND J. LAZELL. 1997. Evaporative water loss in nine insular
16	populations of the Anolis cristatellus group in the British Virgin Islands. Biotropica
17	29: 111-116.
18	GANS, C., T. KRAKAUER, AND C. V. PAGANELLI. 1968. Water loss in snakes: interspecific
19	and intraspecific variability. Comp. Biochem. Physiol. 27: 747-761.
20	JENSSEN, T. A. 2002. Spatial awareness by the lizard Anolis cristatellus: Why should a non-
21	ranging species demonstrate homing behavior? Herpetologica 58: 364-371.
22	JETZ, W., C. CARBONE, J. FULFORD, AND J.H. BROWN. 2004. The scaling of animal space use. Science 306:
23	266-268.

1	LAZELL, J. 1996. Guana Island: a natural history guide, 3rd edition. The Conservation Agency, Jamestown,
2	Rhode Island, U.S.A.
3	LAZELL, J. 2005. Island: fact and theory in nature. University of California Press, USA.
4	MACLEAN, W. P. 1985. Water-loss rates of Sphaerodactylus parthenopion (Reptilia: Gekkonidae), the
5	smallest amniote vertebrate. Comp. Biochem. Physiol. 82A: 759-761.
6	MACLEAN, W. P. 1986. Seasonal variation in Sphaerodactylus water-loss rates. In Z. Roček (Ed). Studies
7	in Herpetology, pp. 627-629. Charles University and Societas Europaea Herpetologica, Prague,
8	Hungary.
9	MACLEAN, W. P., AND R. D. HOLT. 1979. Distributional patterns in St. Croix Sphaerodactylus lizards: the
10	taxon cycle in action. Biotropica 11: 189-195.
11	MAUTZ, W. J. 1982. Patterns of evaporative water loss. In C. Gans, and F. H. Pough (Eds.).
12	Biology of the Reptilia, Vol. 12, pp. 443-481. Academic Press, London, England.
13	NICHOLSON, K. L., S. M. TORRENCE, D. M. GHIOCA, J. BHATTACHARJEE, A. E. ANDREI, J.
14	OWEN, N. J. A. RADKE, AND G. PERRY. 2005. The influence of temperature and
15	humidity on activity patterns of the lizards Anolis stratulus and Ameiva exsul in the
16	British Virgin Islands. Carib. J. Sci. 41: 870-873.
17	PARMESAN, C., AND G. YOHE. 2003. A globally coherent fingerprint of climate change
18	impacts across natural systems. Nature 421: 37-42.
19	PERRY, G., AND T. GARLAND, JR. 2002. Lizard home ranges revisited: Effects of sex, body
20	size, diet, habitat, and phylogeny. Ecology 83: 1870-1885.
21	PERRY, G., R. DMI'EL, AND J. LAZELL. 1999. Evaporative water loss in insular populations
22	of the Anolis cristatellus group (Reptilia: Sauria) in the British Virgin Islands II: the
23	effects of drought. Biotropica 31: 337-343.

1	PERRY, G., R. DMI'EL, AND J. LAZELL. 2000. Evaporative water loss in insular populations of Anolis
2	cristatellus (Reptilia: Sauria) in the British Virgin Islands III: a common garden experiment. Biotropica
3	32: 722-728.
4	RODDA, G., G. PERRY, R. RONDEAU, AND J. LAZELL. 2001. The densest terrestrial vertebrate. J. Trop.
5	Ecol. 17: 331-338.
6	SCHMIDT-NIELSEN, K. 1984. Scaling: why is animal size so important? Cambridge University Press,
7	Cambridge, England.

TABLE 1. *Mass, water loss rates, and sample sizes of* Sphaerodactylus macrolepis, Anolis cristatellus, *and* Alsophis portoricensis *from Guana Island, British Virgin Islands. Numbers are mean and standard deviation for the total sample for each species.* 

I should apprice when all prover and the start when it was to

22 provention to a second splice shall

in some some some menne som de se anderen i van sin Skale og skale og som state som state som og forste sometere and bieter

5

1

	Sphaerodactylus	Anolis	Alsophis
	macrolepis	cristatellus	portoricensis
Mass (g)	0.27 (0.112)	4.8 (2.06)	55.1 (23.46)
Water loss			
mg/h	0.81 (0.391)	9.2 (3.89)	36.4 (17.32)
mg/g/h	3.34 (1.617)	2.1 (0.73)	0.7 (0.26)
N	66	49	45

6

a ser in sotors to lo )

1.

المراجع والمستري المسترين المتقارع

# Figure legends

2	
3	FIGURE 1. The relationship between mass and evaporative water loss (EWL) rates in
4	Sphaerodactylus macrolepis (squares), Anolis cristatellus (circles), and Alsophis portoricensis
5	(triangles) from Guana Island, British Virgin Islands. Larger species exhibit a greater total water loss
6	(A) but enjoy lower mass-specific water loss rates (B).
7	
8	FIGURE 2. Total evaporative water loss (EWL) rates increase significantly with altitude in
9	Sphaerodactylus macrolepis (A) and Anolis cristatellus (B). Displayed are residuals correcting for
10	mass.
11	
12	
13	FIGURE 3. Total evaporative water loss (EWL) rate is not affected by altitude in Alsophis
14	portoricensis. Displayed are residuals correcting for mass.
15	
16	
17	




Perry et al. Figure 3



# Received 5 May 2010

Non-native amphibians and reptiles in the Greater Caribbean:

#### Patterns of arrival and resulting distributions

Robert Powell<sup>1</sup>, Robert W. Henderson<sup>2</sup>, Michael C. Farmer<sup>3</sup>, Arthur C. Echternacht<sup>4</sup>, Gerard van Buurt<sup>5</sup>, Christina M. Romagosa<sup>6</sup>, and Gad Perry<sup>7,8</sup>

<sup>1</sup>Department of Biology, Avila University, Kansas City, MO 64145, USA

<sup>2</sup>Section of Vertebrate Zoology, Milwaukee Public Museum, Milwaukee, WI 53233, USA

<sup>3</sup>Department of Agricultural and Applied Economics, Texas Tech University, Box 42132, Lubbock, TX 79409, USA

<sup>4</sup>Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996, USA <sup>5</sup>Kaya Oy Sprock 18, Curaçao

<sup>6</sup>Department of Biological Sciences, Auburn University, Auburn, AL 36849, USA

<sup>7</sup>Department of Natural Resource Management, Texas Tech University, Lubbock, TX 79409, USA

<sup>8</sup>Corresponding author; e-mail: Gad.Perry@ttu.edu

#### Abstract.

Non-native species are a growing worldwide problem, and a large number of amphibian and reptilian species are now included in this category. We document the arrival and establishment of alien amphibians and reptiles in the greater Caribbean region and the means by which they arrived. These include over 100 species responsible for over 300 individual introductions, of which about 70 percent resulted in a population established for at least a short period. Primary pathways for introduction include inadvertent arrivals in cargo and ornamental plants and the pet trade. We also review the herpetofauna exported from the Caribbean into the United States (US) and from the US to the Caribbean, a surprisingly large and diverse trade. The extent of such trade and the rates of non-native arrivals continue to increase, and are closely related to indices of regional economic activity.

Key words: Invasive species; Caribbean; reptiles; amphibians; economic activity; vectors; pet trade.

#### Introduction

Natural dispersal is a common phenomenon, although long-distance dispersal is typically infrequent (Nathan et al., 2003; Trakhtenbrot et al., 2005). Human-aided dispersal is increasingly common, however, even over great distances. Globally, human-transported non-native species are among the top three causes of biodiversity loss (Clavero and García-Berthou, 2005; McGeoch et al., 2010). The number of amphibians and reptiles being moved to non-native locations is growing (Lever, 2003; Kraus, 2009), as are reports of their ecological and economic impacts, despite the inadequate attention paid to documenting them (McGeoch et al., 2010).

The greater Caribbean region, with extensive tourism in many areas and limited local production of essential items such as food and building materials, is at especially high risk. Herpetological introductions in the region are not new; 19th-century reports include Schomburgk (1848), Gosse (1851), Fielden (1889), and Boulenger (1891). Modern reports are numerous and highly dispersed, despite efforts of Lever (2003) and Kraus (2009) to collate them. Our goal in this chapter is to summarize what is known about herpetological introductions in the region, the mechanisms that allow them, and their effects in this wide geographical area. By their nature, islands are more isolated than mainland sites, yet over-water dispersal still occurs naturally (e.g., Censky et al., 1998; Calsbeek and Smith, 2003). We exclude such instances from the current analysis, which focuses on human-aided extra-limital dispersal events. We hope that the broad patterns that emerge—in particular, the primacy of a small number of arrival mechanisms and the close relation with economic activity—will encourage a coordinated regional policy response and help reduce negative economic and ecological impacts.

Update on amphibians and reptiles in the British Virgin Islands.doc

Last edited 21 Apr 10

# Conservation of amphibians and reptiles in the British Virgin Islands: an update

Gad Perry<sup>1</sup>, Clive Petrovic<sup>2</sup>, Nancy K. Woodfield<sup>3</sup>, and Glenn P. Gerber<sup>4</sup>

<sup>1</sup> Dept. of Natural Resource Management, Box 42125, Texas Tech University, Lubbock, TX 79409-2125, USA. E-mail: Gad.Perry@ttu.edu

<sup>2</sup> P.O. Box 5648, Road Town, Tortola, British Virgin Islands 00803

<sup>3</sup> BVI National Parks Trust, P.O. Box 860, Road Town, Tortola, British Virgin Islands

<sup>4</sup> San Diego Zoo's Institute for Conservation Research, 15600 San Pasqual Valley Road, Escondido, CA 92027-7000, USA. E-mail: ggerber@sandiegozoo.org

Corresponding author: Gad Perry. E-mail: Gad.Perry@ttu.edu

# Abstract

The herpetofauna of the British Virgin Islands (BVI) was surveyed about five years ago. At the time it contained 34 amphibian and reptile species. Since then, two additional non-native species have been identified from the islands, *Eleutherodactylus lentus* from Jost Van Dyke and *E. johnstonei* from Tortola. In addition, several new records of both native and introduced species have been reported. We summarize those and provide updates on species of concern, especially the critically endangered native iguana, *Cyclura pinguis*. As predicted in our original review, the short-term conservation status of the BVI herpetofauna has not changed, and it remains unlikely to change soon. We remain concerned about the mid- and long-term outlooks, especially as a consequence of ongoing arrival and spread on non-native species and lack of progress on specific remedies previously recommended.

# Introduction

Five years ago, Perry and Gerber (2006) reviewed the herpetofauna of the BVI, identifying 34 species of which the greatest proportion (10 species, 29.5%) were data deficient, eight (23.5%) endangered, six (17.5%) were common, four (12.0%) at risk, four introduced, and two (6.0%) extinct. They provided five specific recommendations: set aside additional areas for conservation; minimize the impacts of development via better enforcement of existing regulations and improved planning; establish baseline population sizes of data-deficient species and a long-term program for monitoring all amphibian and reptile species; support the eradication of existing harmful invasives; and improve public education about the value of conservation in general and herpetofauna in particular. With few

exceptions, the review provided by Perry and Gerber (2006) remains accurate and their recommendations remain appropriate and largely un-implemented. However, some changes have occurred in the ensuing years that are worth noting. Below we do not list species whose status has not changed, do provide updates on those for which new information has expanded our understanding in the intervening years, and list two new species recorded from the islands for the first time. Although some changes have been proposed in scientific names during this period, we retain the original names in order to maximize compatibility between the current contribution and Perry and Gerber (2006).

### SPECIES ACCOUNTS

### Amphibia: Leptodactylidae

Scientific Name	Eleutherodactylus johnstonei None in the BVI; elsewhere, Johnstone's Whistling Frog Tortola: Road Town	
Common name		
Distribution		
Status	Introduced: localized	

Comments: The frogs were noted on August 16, 2008 by amateur herpetologist Alejandro Sanchez (pers. com.), who is very familiar with the regional herpetofauna. His comments: "I found several males singing at night on the grounds of a restaurant at sea level. That very fact seems to point at an introduction in plant produce or the like." The species has been very widely introduced in the region (reviewed in Powell et al., this volume). Given this track record, additional spread seems likely and impacts on native members of the genus are possible (Kaiser, 1997).

Scientific Name

Eleutherodactylus lentus

Common name

None in the BVI; elsewhere, Mute Frog, Virgin Islands robber frog,

Virgin Islands Yellow Frog.

Distribution Jost Van Dyke: Great Harbour

Status Introduced: Locally common

Comments: Until it was reported from Jost Van Dyke (Perry, 2009a), this species was only known from the US Virgin Islands (USVI), where it is at risk because of habitat destruction (Platenberg and Boulon, 2006). The population is most likely the result of a recent introduction, rather than a previously undiscovered native. It appears wellestablished, but impacts are unknown and the appropriate management response is unclear (Perry, 2009a).

# Amphibia: Hylidae

Scientific Name Osteopilus septentrionalis

Common name Cuban treefrog

Distribution Introduced. Established on Tortola, Virgin Gorda, Beef Island, Peter Island. Vagrants found elsewhere.

Status Introduced

Comments: Spread of this ubiquitous, damaging invasive appears to continue (Owen et al., 2006). Despite considerable effort searching (Perry et al., 2006), only a single individual has been captured on Guana Island (Perry, 2009b). In contrast, Cuban treefrogs can now be found all the way to the top of Sage Mountain on Tortola (G. Perry, unpublished data). The 2009 drought appears to have slowed the spread of this

species, which is not yet found in Jost Van Dyke, Great Camanoe, Moskito, or Anegada (G. Perry, C. Petrovic, and G. Gerber, unpublished data).

# **Reptilia: Emydidae**

Scientific Name	Pseudemys nelsoni
Common name	Florida red-bellied turtle
Distribution	Tortola (Owen et al., 2005)
Status	Introduced (possibly extirpated)

Comments: No more of these turtles have been seen since their removal from the botanical garden ponds. However, the species is episodically exported from the US to the Caribbean (Powell et al., this volume) so reinvasion is possible.

Scientific Name	Trachemys scripta elegans
Common name	Red-eared slider
Distribution	Established on Tortola, vagrant on Virgin Gorda and Jost Van Dyke
(Perry et al., 2007b)	

Status Introduced

Comments: No additional individuals have been collected from Virgin Gorda or Jost Van Dyke, but the Tortola population appears to be doing well. Reports of additional turtles in the retention ponds by the Beef Island airport have not been confirmed.

# Reptilia: Iguanidae

Scientific Name Cyclura pinguis

Common name Anegada or Stout iguana

DistributionAnegada; (re?)introduced: Guana, Necker, Norman, Little ThatchStatusNative: Endangered

Comments: Work on both the Anegada and Guana populations continues. Restoration of a self-sustaining population on Anegada remains a priority (IUCN, 2007) and progress toward this goal is being made. In 2006, Island Conservation (islandconservation.org) surveyed Anegada in consultation with the IUCN Iguana Specialist Group and produced a detailed document outlining the steps necessary for feral mammal removal. Funding for this undertaking is being sought. In 2008, a proposed National Park on Anegada that includes the core iguana area cleared a major obstacle by passing the BVI Cabinet. Headstarting efforts continue as well and to date 115 headstarted iguanas have been returned to the wild on Anegada with an encouraging minimum survival rate of 79% (G. Gerber and K. Bradley, unpublished data). A set of polymorphic microsatellite markers has been developed for the species also (Lau et al. 2009) and studies of genetic diversity utilizing these markers are underway. However, despite these accomplishments, many of the objectives identified by the IUCN (2007) or discussed in Perry and Gerber (2006) have yet to be carried out. Perry et al. (2007a) studied reproduction and size, primarily of the Guana population, where animals are in better body condition than those previously reported from Anegada. Anderson et al. (2010) recently reported on the Guana population, which appears to primarily utilize-relatively open areas and avoid the eastern part of the island, perhaps because of the noticeable grazing damage caused by invasive feral sheep. Numbers for that population were estimated in 2009, using mark-recapture and

modern estimation techniques, at about 100 adults and 150 hatchlings (B. Bibles, unpublished data). This estimate is slightly higher than previous estimates of about 100 animals (Perry and Mitchell, 2003), perhaps because of the large difference in methodology and search effort but perhaps showing a slight increase in the population.

Scientific Name	Iguana iguana	
Common name	Green or common iguana	
Distribution	Peter Island (Carey, 1972), Tortola, Virgin Gorda (C. Petr	
unpublished	data)	

Status Introduced: established

Comments: Repeated reports suggest green iguanas are arriving on Tortola via a barge operating between St. Thomas and West End (C. Petrovic, unpublished data). Those reports suggest that at least some of the introductions may be intentional. Unrelated to this population, there are regular reports of them throughout Tortola, including individuals collected from Road Town, Cane Garden Bay, and East End, though in small numbers. These are presumably escaped pr released pets. Green iguanas may now be found on Jost Van Dyke, also as a result of an intentional attempt to establish them there (C. Petrovic, unpublished data). Virgin Gorda populations seem to be thriving, with both adults and juveniles commonly observed at the Bitter End Yacht Club, Biras Creek, Leverick Bay, the Valley, and perhaps other locations. As stated by Perry and Gerber (2006), appropriation of potential *Cyclura pinguis* habitat is the main concern.

# Reptilia: Gekkonidae

Scientific Name	Hemidactylus mabouia	
Common name	Common house gecko, wood slave	
Distribution	All major islands and some smaller ones. A new island record from	
Great Camanoe (G. Perry, unpublished data).		
Status	Probably introduced: Common	
Comments: This new	locality record does not change the outlook for this species.	

# **Reptilia: Boidae**

Scientific Name	Epicrates monensis	
Common name	Virgin Islands boa	
Distribution	Tortola, Great Camanoe (Barker et al., 2009).	
Status	Data deficient	

Comments: Boas are quite common all over Tortola, east to west and sea level to Sage Mountain, often near humans. This new locality record is encouraging in that it suggests the boa may have an even broader, un-reported distribution in the BVI. Studies of BVI population ecology and genetics are highly desirable.

# **Reptilia:** Colubridae

Scientific Name	Elaphe guttata
Common name	Corn snake
Distribution	Tortola (established?); Peter Island (established?)

Introduced: expanding

Status

Comments: This species was not recorded by Perry and Gerber (2006), but several reports and specimens have materialized since then. A snake was killed at the commercial port (18<sup>0</sup> 25' 38.3" N, 64<sup>0</sup> 36' 31.2" W) on May 2006 (C. Petrovic, unpublished data). Two were killed or collected on Peter Island, one in 2008 and one in 2010. As with *I. iguana*, multiple snakes are arriving on Tortola via a barge operating between St. Thomas and West End (C. Petrovic, unpublished data). These join repeated reports of the species from the USVI (Perry and Platenberg, 2007; R. Platenberg, unpublished data) and elsewhere in the Caribbean (Powell et al., this volume). Although the source of the Curaçao population appears to have been pets (Perry et al., 2003), those in the BVI and USVI seem more likely to be related to commerce, given the locations of initial sightings.

# Discussion

Several studies have appeared since the report of Perry and Gerber (2006). Some, such as the study of *Alsophis portoricensis* ecology by Barun et al. (2007), provide little information that is relevant to the conservation concerns discussed here, and so have not been included in this review. There are few enough of those that the lack of knowledge identified by Perry and Gerber (2006) for about a third of the species they reviewed remains virtually unchanged.

Perry and Gerber (2006) characterized about one fourth of BVI species as facing at least some measure of risk. This too remains the case. Although the global economic downturn has slowed or caused cancellation of some "development" plans, projects such as the conversion of Scrub Island into a resort (see <a href="http://scrubisland.com/">http://scrubisland.com/</a>) and Oil Nut Bay on Virgin Gorda (<a href="http://www.oilnutbay.com/home">http://scrubisland.com/</a>) and Oil Nut Bay on Virgin Gorda (<a href="http://www.oilnutbay.com/home">http://scrubisland.com/</a>) and Oil Nut Bay on Virgin Gorda (<a href="http://www.oilnutbay.com/home">http://scrubisland.com/</a>) and Oil Nut Bay on Virgin Gorda (<a href="http://www.oilnutbay.com/home">http://scrubisland.com/</a>) and Oil Nut Bay on amount of dry tropical forest available, and increasing transport of both material and people within the BVI and between them and other locations.

Of the new records we provide, several are minor range extensions or reports of original arrivals of previously documented species, some of them native (e.g., *Epicrates monensis*), others invasive (e.g., *Iguana iguana*), and yet others of unclear origin (*Hemidactylus mabouia*). Other reports are of species not previously recorded in the islands, and these – especially the growing prevalence of *Elaphe guttata* - are of greater concern. The corn snake is a human-tolerant species with broad diet and climatic needs which has the potential of becoming a major predator on native lizards, birds, and mammals. In addition, corn snakes may be able to compete with the native boa, *Epicrates monensis*. Our list is also likely to be incomplete. For example, on a recent trip to the Botanic Gardens in Tortola, one of us (CP) very briefly saw a turtle that was not a red-eared slider but has yet to be re-sighted and identified.

These reports serve to reiterate the concern expressed by Perry and Gerber (2006) over the increasing homogenization of the regional herpetofauna and of the increasing likelihood of impacts on native species. Reports cited here, as well as descriptions of several species dispersing in potted plants transported via cargo (Perry et al., 2006) and able to swim when alarmed (Perry and Powell, 2009) suggest the importance of both intentional and unintentional introduction pathways such as the ornamental plant trade. As Powell et al. (this volume) document, there are many more potential invaders in the region, many of them can cause considerable damage to native species and habitats, and the magnitude of the problem

-

is proportional to economic activity. For example, *Eleutherodactylus coqui* is spreading around the region (and elsewhere) and is likely to be a future addition to the list of invasives in the BVI, especially as much of the material used in "development" projects originates in Puerto Rico, the USVI, and Florida. Arrival or further dispersal of other invasive species, such as the mongoose that is already found on many islands, is also a concern. We therefore recommend additional training to port workers, who acted correctly in killing the BVI and USVI corn snake specimens reported here but are generally poorly trained in control of invasive species. As much cargo is not carefully inspected at the port, training of first handlers is also desired. Similarly, training workers in the nursery industry, the apparent vector for many of the introductions we report, can be highly beneficial. Tightening inspection procedures can go a long way towards reducing the threat of additional individuals and species arriving and establishing.

The pet trade is a common source of invasive species (e.g., Kraus, 2009). However, the situation ion the BVI is more complex than in many places. One of us (CP) conducted an informal survey of all the pet stores regarding their import practices. According to store owners, many people simply bring in their "pets" – often birds or turtles - from Puerto Rico or elsewhere. This makes both control and education efforts especially challenging.

As predicted by Perry and Gerber (2006), broad patterns have not changed much in the few years that have elapsed but the mid- and long-term outlooks suggest increasing impacts from habitat loss and invasive species are likely. Perry and Gerber (2006) recommend the adoption of five strategies to address expected challenges. Like many of the iguana-specific recommendations of the IUCN (2007), most of these are yet to be adopted and appear just as valid now, and we urge their rapid adoption and implementation.

### Acknowledgements

This review is based on many years of field work in the BVI, supported by (in alphabetical order) the American Zoological Association Conservation Endowment Fund, BVI National Parks Trust, The Conservation Agency via a grant from the Falconwood Corporation, the Dallas Zoo, the Fort Worth Zoo, the International Iguana Foundation, the IUCN Sir Peter Scott Fund, the Nando Peretti Foundation, Texas Tech University, the UK Foreign and Commonwealth Office, and the Zoological Society of San Diego. This is manuscript T-9-1193 of the College of Agricultural Sciences and Natural Resources, Texas Tech University.

### References

- Anderson, W.M., Sorensen, G.E., Lloyd-Strovas, J.D., Arroyo, R.J., Sosa, J.A., Wulff, S.J.,
  Bibles, B.D., Boal, C.W., Perry, G. (2010): Distribution and Habitat Use by the Critically
  Endangered Stout Iguana (*Cyclura pinguis*) on Guana Island, British Virgin Islands. In
  Press, Reptiles and Amphibians.
- Barker, B.S., Henderson, R.W., Powell, R. (2009): Geographic distribution. *Epicrates monensis granti*. Herpetol. Rev. 40: 455-456.
- Barun, A., Perry, G., Henderson, R.W., Powell, R. (2007): Alsophis portoricensis anegadae (Squamata: Colubridae): Morphometric characteristics, activity patterns, and habitat use. Copeia 2007: 93-100.

IUCN (2007): Anegada Iguana, Cyclura pinguis, species recovery plan, 2006–2010.
IUCN/SSC Iguana Specialist Group. Available for download at
<u>http://www.iguanafoundation.org</u>.

Kaiser, H. (1997): Origins and introductions of the Caribbean frog, *Eleutherodactylus johnstonei* (Leptodactylidae): Management and conservation concerns. Biodiv. Conserv.
6: 1391-1407.

- Kraus, F. (2009): Alien Reptiles and Amphibians: A Scientific Compendium and Analysis. Invading Nature: Spring Series in Invasion Biology 4. New York, Springer.
- Lau, J., Alberts, A.C., Chemnick, L.G., Gerber, G.P., Jones, K.C., Mitchell, A.A., Ryder,
  O.A. (2009): Isolation and characterization of 23 polymorphic microsatellite loci for a
  West Indian iguana (*Cyclura pinguis*) from the British Virgin Islands. Molec. Ecol.
  Res. 9: 1412-1414.
- Owen, J.L., Perry, G., Lazell, J., Petrovic, C. (2005): Geographic distribution: Pseudemys nelsoni. Herpetol. Rev. **36**: 466.
- Owen, J.L., Perry, G., Lazell, J., Petrovic, C., Egelhoff, J. (2006): Osteopilus septentrionalis: Colonization of the British Virgin Islands. Herpetol. Rev. 37: 74-75.
- Perry, G. (2009a): First record of the frog *Eleutherodactylus lentus* in the British Virgin Islands: Conservation implications of native or introduced status. Appl. Herpetol. 6: 185-187.
- Perry, G. (2009b): First record of Osteopilus septentrionalis on Guana Island, British Virgin Islands. Appl. Herpetol. 6: 191-192.
- Perry, G., Gerber, G.P. (2006): Conservation of amphibians and reptiles in the British Virgin Islands: Status and patterns. Appl. Herpetol. **3**: 237-256.

- Perry, G., Mitchell, N. (2003): Guana and Necker island population assessments 2002. Iguana **10**(2): 49.
- Perry, G., Platenberg, R. (2007): Recent additions to the herpetofauna of Little St. James, US Virgin Islands. Appl. Herpetol. 4: 387-389.
- Perry, G., Powell, R. (2009): The Herpetofauna of Guana Island: an annotated checklist and travelogue. Iguana **16**: 6-17.
- Perry, G., Powell, R., Watson, H. (2006): Keeping invasive species off Guana Island, British Virgin Islands. Iguana 13: 272-277.
- Perry, G., Lazell, J., LeVering, K., Mitchell, N. (2007a): Reproduction and size in the highly endangered stout iguana, *Cyclura pinguis*. Carib. J. Sci. 43: 155-159.
- Perry, G., Owen, J.L., Petrovic, C., Lazell, J., Egelhoff, J. (2007b): The red-eared slider, *Trachemy scripta elegans*, in the British Virgin Islands. Appl. Herpetol. 4: 88-89.
- Perry, G., Pierce, J., Griffin, D., van Buurt, G., Lazell, J. (2003): *Elaphe guttata guttata* (Corn Snake). Distribution. Herp. Rev. 34: 264.
- Platenberg, R.J., Boulon, R.H., Jr. (2006): Conservation status of reptiles and amphibians in the U.S. Virgin Islands. Appl. Herpetol. 3: 215-235.
- Powell, R., Henderson, R.W., Farmer, M.C., Echternacht, A.C., van Buurt, G., Romagosa,
  C.M., Perry, G. (this volume): Non-native amphibians and reptiles in the Greater
  Caribbean: Patterns of arrival and resulting distributions. In: Conservation of Caribbean
  Island Herpetofaunas, p. xxx-xxx. Hailey, A., Wilson, B.S., Horrocks, J.A., Eds.
  Leiden, Brill.

Katharina Gebert Accelerated Biology I Ms. Shoop Period 3/4 May 20<sup>th</sup>, 2009

# <u>The Effect of Soldier Crab's (Coenobita clypeatus) Right Chela Size on Right Chela</u> <u>Pinch Depth</u>

# Introduction:

The circumference of the palm of ten soldier crab's right chela, on Guana Island, will be measured. The pinch depth of their right chela will be measured numerous times. The effect of the size of the crab's right chela on the pinch depth of the crab's right chela will be determined. Handling of soldier crabs, and basic background knowledge of soldier crabs will be obtained. Guana Island, a private island in the British Virgin Islands, is home to at least 50 species of birds, 4 species of bats, more than 14 species of reptiles and amphibians, hundreds of plants and insects, and over 125 species of in-shore fishes (Lazell 1996). There are at least 4 species of land crabs on the island: soldier crabs, ghost crabs, calico rock crabs, and cardisoma crabs. The land crabs which are being tested on in this experiment are known as soldier crabs or Coenobita clypeatus (Perry 2009). They are also known as West Atlantic hermit crabs, Caribbean land crabs, purple pincher crabs, purple claw crabs, and tree crabs (Pavia 2009). These crabs are found in a variety of different colors ranging from purple, to red, to brown. Soldier crabs are crustaceans, and can be found hiding under leaves, wet sand, rocks, or even sitting on trees. They have a pincer, also known as a chela, "in which the dactyl serves as the moveable claw and the propodus serves as the stationary claw", or fixed finger (Cowles 2006). The palm, which is part of the propodus, is the widest part of the chela.



Figure 1 - The anatomy of a crustacean's right and left chelae (Cowles 2006).

Soldier crabs are nocturnal, eating dead plants, animals, overripe fruits, vegetation, feces of other animals, and insects. When eating, the crab holds the food with its right chela, also known as its major chela, and uses its left chela, or minor chela, to pinch the flesh of the fruit (Burggren and McMahon 1988). The left chela is usually used to move food from the right chela to the mouth. Soldier crab claw force production transmission is closely related to the hardness of the crab's diet (Schenk and Wainwright 2000). A study on crayfish has shown females that possessed large chelae were more likely to possess stronger chelae (Bywater, Angilletta, and Wilson 2008). A study on shore crabs has shown weapon size can be used to better predict competitive success (Sneddon 1999). The stronger crabs in these fights had right and left chelae "that exerted a significantly greater force than losing crabs even when claw length was the same". Greater claw height and length to the dactyl in the right chela gives crabs higher mechanical advantage when closing the claw, and exerting a greater force. This experiment will examine the effect of a soldier crab's right chela size on the right chela's pinch depth.

### **Hypothesis:**

It is hypothesized that if a soldier crab has a large right chela, then it will be able to execute a greater pinch depth than a soldier crab with a smaller right chela.

### **Methodology:**

Find 10 soldier crabs. Using the permanent marker, write a number on each soldier crab's shell. Make sure the number is visible. Place all 10 soldier crabs into the cardboard box. Pick up the first soldier crab carefully, using your index finger and thumb to pick the crab up by its shell. Put on the rubber gloves. Lightly tapping the chelas most often causes the soldier crab to recede into its shell. Using the vernier caliper, measure the thickness of the thickest part of the right chela's propodus, also known as the palm. As the measurement may adjust slightly when pulling the vernier caliper away from the soldier crab, it may be best to simply read the measurement off the vernier caliper, while still holding the soldier crab's right chela. Record the thickness of the right chela's palm, and carefully place the soldier crab back into the box.

The various balsa wood thicknesses – 2.5mm, 5mm, 6.5mm – are designed to allow each soldier crab to pinch into the largest piece of balsa wood possible for its right chela size. Using the balsa wood piece best fitted for the soldier crab you will be testing first, label a corner with the number of the soldier crab, using a sharpie. Repeatedly tap at the dactyl, until it seems the fingers have opened the furthest they possibly can. At this point, thrust the balsa wood stick as far back as it will possibly go, between the dactyl and the propodus of the right chela. The soldier crab will immediately pinch close on the balsa wood stick. Using the sharpie, make a circle around the imprint, on both sides of the balsa wood. Each soldier crab has 3 balsa wood sticks into which they may pinch. 3-6 acceptable imprints should be made per soldier crab. Using the vernier caliper, measure the depth of the imprint made by the propodus, and the imprint made by the dactyl. Add these two depth measurements together, to get the total pinch depth of that soldier crab. Once all the total pinch depths for that soldier crab have been found, average them

together, to get the final pinch depth for that soldier crab. Find the thickness of the right chela and the pinch depth for all remaining 9 crabs.

# Data:

Soldier Crab	Right Chela Size (cm)	Right Chela Average Pinch Depth (mm)
#1	0.952	0.168
#2	0.716	0.115
#3	1.138	0.168
#4	1.516	0.249
#5	1.020	0.232
#6	1.082	0.258
#7	1.254	0.271
#8	1.810	0.340
#9	1.832	0.334
#10	1.934	0.384
TP_1.1_1 TPL	1	

Table 1 – The claw size and average pinch depth of 10 soldier crabs, Coenobita clypeatus.





Graph 1 - The effect of soldier crab's claw size on pinch depth.



The Effect of Soldier Crab's (Coenobita Clypeatus) Right Chela Size (cm) on the average Right Chela Pinch Depth (mm)

As seen in Table 1, soldier crab #10 had the largest claw size at 1.934cm. Soldier crab #2 had the smallest claw size at 0.716cm. The mean claw size for the collected soldier crabs was 1.325cm. Soldier crab #10 had the largest average pinch depth at 0.384mm. Soldier crab #2 had the smallest average pinch depth at 0.115mm. The mean average pinch depth for the collected soldier crabs was 0.252mm. Soldier crab #2 had the smallest claw size, closely followed by soldier crab #1, then #5, #6, #3, #7, #4, #8, #9, and lastly, #10. Soldier crab #2 had the smallest average pinch depth, closely followed by #1 and #3, then #5, #4, #6, #7, #9, #8, and lastly #10.

As seen in Graph 1, each soldier crab produced between 3-6 acceptable pinches. The effect of soldier crab claw size on pinch depth was linear. The trendline had an equation of y = 0.1895x. If the soldier crab's claw size increases by 1cm, the average pinch depth increases by .1895mm. The correlation coefficient, or R<sup>2</sup>, is 0.6737, or approximately 67%. The greatest pinch depth was 0.496mm. The smallest pinch depth was 0.078mm.

As seen in Graph 2, the effect of soldier crab claw size on pinch depth was linear. Graph 2 depicts the mean of the pinch depths for each soldier crab claw size, which is depicted in Graph 1. The trendline has an equation of y = 0.1897x. If the soldier crab's claw size increases by 1cm, the average pinch depth increases by .1897mm. The correlation coefficient, or  $R^2$ , is 0.8441, or approximately 84%. The greatest average pinch depth was 0.384mm. The smallest average pinch depth was 0.115mm.

### **Analysis and Conclusion:**

Graphs 1 and 2 have a correlation coefficient of 0.6737 and 0.8441. A correlation coefficient indicates the linear relationship between two random variables. The two random variables, in this case, are right chela size and right chela pinch depth. The correlation coefficient shows how well the trendline describes the data, how well the data points coincide with the trendline. The correlation coefficient, or  $\mathbb{R}^2$ , for the trendline in Graph 1 was approximately 67%. This means, approximately 67% of the data coincides well with the trendline. On the other hand, 33% of the data does not coincide well with the trendline. Seeing as the trendline shows greater claw size causes greater pinch depth, if more data had been collected, this correlation coefficient would surely be greater. The correlation coefficient for the trendline in Graph 2 was approximately 84%. This means, approximately 84% of the data coincides well with the trendline. On the other hand, 16% of the data does not coincide well with the trendline. The correlation coefficient for Graph 2, which is depicting the average pinch depths for various claw sizes, is 17% higher than the correlation coefficient for Graph 1, which is depicting the pinch depths for various claw sizes. This is because less data points are being used. Since only ten data points are being used, the chance of the data points coinciding with the trendline is much greater than the chance of the forty-six data points in Graph 1 coinciding with the trendline. Since the trendline depicts a greater claw size creating a greater pinch depth, and 84% of the data coincides with this trendline, it is highly likely that had more data been collected, it would have followed this trendline also.

As predicted, the soldier crab with the smallest right chela size has the smallest average pinch depth, and the soldier crab with the largest right chela size has the largest average pinch depth. Following soldier crab #2, with the smallest right chela size and average pinch depth, should have been soldier crab #1. Although soldier crab #1 was second smallest, and with that had the second smallest average pinch depth, soldier crab #3 had the same average pinch depth as crab #1 did. This shouldn't have been the case, since it had a larger right chela size than soldier crab #1 did. Following soldier crab #1 should have been soldier crab #5, which was the case. Following soldier crab #5 should have been #6, according to the hypothesis; however, it was soldier crab #4. After soldier crab #6, crab #3 should have been strongest; however, it was the second weakest. Following soldier crab #6 actually was #7, which should have been following soldier crab #3. Soldier crab \*6, and 10 were all close in right chela size and pinch depth. These minimal differences in right chela size versus pinch depth could have been accounted for by various sources of error and variability, or error variance.

The first potential source of error could have occurred by simply misreading the vernier caliper. If the vernier caliper was misread while taking down the claw size of the crab, the soldier crab may seem larger or smaller than it actually is. If the vernier caliper was misread while taking down the top or bottom depth measurement for the crab's pinch depth, the average pinch depth would be a misrepresentation of the crab's actual pinch depth. Each soldier crab's pinch depth was measured multiple times to avoid this potential mistake.

One source of variability is gender. The gender of the soldier crabs was unknown; it wasn't tested for. It is very possible that gender has an effect on the strength of the soldier crab. Some crabs may have been male, some female. With the gender of the crabs unknown, it is not possible to say all crabs were either male or female. If female soldier crabs of the same size as male soldier crabs were able to pinch into balsa wood harder, this would be unknown. Therefore, some crabs which may have appeared stronger or weaker than others may simply have appeared this way because of their gender.

Another source of variability is the hardness of the balsa wood. By the end of the experiment it was observed that some balsa wood was softer or harder than other balsa wood. The soldier crabs which pinched into softer balsa wood pieces could therefore execute a much greater pinch depth than crabs with harder wood. Therefore, some crabs which may have appeared stronger or weaker than others may simply have appeared this way because they received a softer or harder piece of balsa wood.

The health of the soldier crabs is yet another source of variability. Healthier crabs would have been able to execute a far greater pinch depth than unhealthy crabs. If fights had occurred minutes before the soldier crabs were collected, or they were simply in poor health, this would not be known. The unhealthy crabs had a disadvantage, executing their greatest possible pinch depth in their unhealthy condition. Healthy crabs, on the other hand, were able to execute their greatest possible pinch depth in a healthy condition, able to pinch much greater depths than unhealthy crabs would be able to. Therefore, some crabs which may have appeared stronger or weaker than others may simply have appeared this way because they were healthy or unhealthy.

Lastly, another source of variability is the predators the soldier crab had been exposed to. The soldier crab may have been healthy, strong, as it was being tested, however, if it had been exposed to multiple predators, had to fight for its life multiple times, the soldier crab would have pinched much harder during the test. Some crab's pinch depths had much greater variability than others. For example, Graph 1 shows the soldier crab with a right chela size of 1.254cm to have much greater variability in its pinch depth than the soldier crab with a right chela size of 1.516cm does. This variability in pinch depth may be caused by the soldier crab with a right chela size of 1.254cm not being exposed to many predators and near-death circumstances. The crab would then pinch the balsa wood sometimes harder, sometimes softer. The soldier crab with a right chela size of 1.516cm, on the other hand, pinched into the balsa wood consistently. This shows it may have been exposed to various near-death circumstances, causing it to pinch into the balsa wood severely, as hard as it possibly could, each time. Therefore, some crabs which may have appeared stronger or weaker than others may have simply have appeared this way because of past experiences with predators.

The results clearly show the soldier crabs have some sort of a mechanism which allows them to pinch harder or softer. Each soldier crab does not have only one strength at which they always pinch; variability is possible and common. This is because the crabs must pick up food, such as fruits, to eat. If the crabs had only one strength they could execute, they would be picking up overripe, soft fruits with the same force they use to engage in a fight with a predator. This would be impractical causing enormous amounts of fatigue after eating a simple meal, or even loosing the meal because it fell apart because so much pressure was applied. The soldier crabs need strength to use to simply pick up food, and strength to ward off predators. It is very possible that the soldier crabs which offered great variability in this experiment used strengths normally used to ward off predators, *and* strengths used to do simple tasks such as hang on to branches or eat fruits.

In a previous experiment done by L.U. Sneddon of the Animal Welfare Research Group, involving fights between shore crabs, shore crabs were tested to see if weapon size was a better predictor of competitive success than body size. This experiment showed that winners in these fights had "a greater claw height and claw length to the dactyl in the [right chela] giving them a higher mechanical advantage when closing the claw and thus exerting a greater force". Soldier crabs which have a greater claw size had a higher mechanical advantage, allowing them to exert a greater force and have a larger pinch depth. Soldier crabs with smaller claw sizes didn't have these mechanical advantages, producing a lesser force, and a lesser pinch depth.

Further tests on the gender of the crab, the health of the crab, and the crab's predators should be done to fully determine the effect of these variabilities on the soldier crab's strength.

In conclusion, if a soldier crab has a large right chela, it will be able to execute a greater pinch depth than a soldier crab with a smaller right chela.

### **Bibliography:**

- Bywater, C. L., M. J. Angilletta, Jr., and R. S. Wilson. "Weapon size is a reliable indicator of strength and social dominance in female slender crayfish (Cherax dispar)." <u>Functional Ecology</u>. 2008. The University of Queensland, Australia. 22 Mar. 2009 <a href="http://www.uq.edu.au/integrative-ecology/docs/bywateretal2008.pdf">http://www.uq.edu.au/integrative-ecology/docs/bywateretal2008.pdf</a>>.
- Cowles, Dave. "Illustrated Glossary: Chela." <u>Key to Invertebrates Found At or Near The</u> <u>Rosario Beach Marine Laboratory</u>. June 2006. Walla Walla University. 18 May 2009 <http://www.wallawalla.edu/academics/departments/biology/rosario/inverts/ Glossary/Glossary.html>.

"Feeding Behavior." <u>Biology of the Land Crabs</u>. Ed. Warren W. Burggren and Brian R. McMahon. Cambridge: Cambridge University Press, 1988. 104. 25 Mar. 2009 <<u>http://books.google.com/</u> books?id=RR09AAAAIAAJ&pg=PA104&lpg=PA104&dq=coenobita+clypeatus +strength+biology+of+land+crabs&source=bl&ots=moJfM2Ijd6&sig=fjvbK7PD Es2m0a5CLrlCo2kzm4A&hl=en&ei=WsjKSZu0Ns6Ltgeq88ToCQ&sa=X&oi=b ook\_result&resnum=4&ct=result#PPA99,M1>.

Lazell, James. "Other Creatures." <u>Guana Island: A Natural History Guide</u>. 3rd ed. Jamestown, RI: The Conservation Agency, 1996. 12-13.

- Pavia, Audrey. "Coenobita clypeatus." <u>Hermit Crab: Your Happy Healthy Pet</u>. Hoboken: Wiley Publishing, Inc., 2006. 18. 25 Mar. 2009 <a href="http://books.google.com/books?id=FlYGxERCosEC&printsec=copyright&dq=parts+of+a+Coenobita+cly">http://books.google.com/books?id=FlYGxERCosEC&printsec=copyright&dq=parts+of+a+Coenobita+cly</a> peatus#PPA18,M1>.
- Perry, Gad. "FW: Katharina Gebert Biology Questions." E-mail to Katharina Gebert. 23 Mar. 2009.
- Schenk, Steve C., and Peter C. Wainwright. "Dimorphism and the functional basis of claw strength in six brachyuran crabs." <u>Cambridge Journals</u>. 7 Nov. 2000. University of Cambridge. 22 Mar. 2009 <a href="http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=83423">http://journals.cambridge.org/action/ displayAbstract?fromPage=online&aid=83423>.</a>
- Segmentation in Decapod Limbs: Crayfish Chelipeds. Chart. June 2006. Walla Walla University. 18 May 2009 <a href="http://www.wallawalla.edu/academics/departments/biology/rosario/inverts/Glossary/CrayfishCheliped2DLC.jpg">http://www.wallawalla.edu/academics/departments/ biology/rosario/inverts/Glossary/CrayfishCheliped2DLC.jpg</a>>.
- Sneddon, L. U., et al. "Weapon strength and competitive success in the fights of shore crabs (Carcinus maenas)." <u>Cambridge Journals</u>. 19 May 1999. University of Cambridge. 22 Mar. 2009 <a href="http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=40793">http://journals.cambridge.org/action/ displayAbstract?fromPage=online&aid=40793>.</a>

### **Acknowledgements:**

Numerous people made this project possible, and helped me along the way. First, I would like to thank Dr. James "Skip" Lazell, Dr. Gad Perry, and Dr. Lianna Jarecki, for providing me with invaluable information regarding my experiment, for their time and patience, their quick responses to my emails, and for their encouraging words during my project. I would also like to thank Jason Goldberg and the whole staff on Guana for their help. Special thanks to Blender, Corine, La Fleur, Laverne, Megan, Teckla, and Yvonne, for their dedication to the soldier crab population on Guana by avidly feeding them every afternoon. I would like to express my deepest gratitude to Dr. Henry and Gloria Jarecki, for their interest in my project and for their vision to preserve the wildlife and natural beauty of this magical island. Guana Island would not be what it is today, without their constant work and effort in caring for it. Special thanks to Steffanie Shoop, my fabulous Biology teacher, who taught me so much, and whose enthusiasm and passion for Biology infected me. Finally, my parents, Dr. Reinhold and Brigitte Gebert, both former scientists, who enthusiastically supported me during my project through late-night discussions, numerous trips to Home Depot for supplies, and for giving me an opportunity to execute my experiment on Guana Island.

# 2009 report

1 message

Dr & Mrs Barry Valentine <bv@nwcs.com> To: hq@theconservationagency.org Mon, May 3, 2010 at 9:32 AM

Skip, Here are projects and news for the 2009 report:

Collecting was good, with new and/or rare faces, thanks in major part to the nocturnal (and diurnal) efforts of

Dave Dennis, Susan Valentine-Cooper, and Wenhua. Their work with head lamps has added a new dimension

to our survey, and has especially added specimens of many rarer species, plus some previously unknown. These

are being distributed to specialists, and we await reports.

Some projects in progress are:

"Roaches of the British Virgin Islands". Manuscript and illustrations complete. Wenhua and I have 22 species,

16 on Guana, 16 on Tortola, 10 shared, 12 unique to one island; this based on over 600 pinned specimens and

several thousands examined. Most of these are "wild" species which are not associated with humans. Other

BVI islands have from 1 to 9 species, all included in the above. Except for Roth (1994) and Skip's book, the fauna

was unknown. We now have more than doubled it.

Crickets and grasshoppers. The world authority, Dr. Dan Otte, at the Academy of Natural Sciences of Philadelphia,

continues his silence; ignoring the fact that we can now increase the variety and more than double the number of

specimens sent to him previously, and that these would constitute a significant addition to his study of the

West

Indies fauna. Now, Skip has offered to apply pressure to Otte's superiors, so I look forward hopefully to progress.

Earwigs. Despite our best efforts, we still total only 20 specimens representing one species from Guana, Anegada,

Moskito, and St. John, and two different species only from Tortola. The banner year was 2002 with two specimens

from Guana, and three from Tortola. No other year yielded more than two specimens. 2009 was a "very good"

year: one specimen each from Anegada, Moskito, and Tortola. After ten years, the BVI still has only three species.

True bugs. Dr. Thomas Henry of the United States National Museum, an international authority, has been our

house guest and we have just finished identifying our BVI collection: 114 species in 25 families, and many hundreds

of specimens, almost all from Guana. A manuscript is now in progress. Because Tom has been so helpful, I have

donated this group to the National Museum; it is now their legal property, and part of it is already in Washington.

Bees and wasps. Most of our Guana wild bees (15-20 species) are in the American Museum of Natural History in

New York City, under study by Dr. John Archer (a precise count is difficult for me because of sexual dimorphism). I

have e-mailed him for an update, and expect news soon. The 2009 collection, made by David Dennis, is outstanding,

with several species not seen previously, and better male/female representation. Now no other Virgin Island comes

close to Guana in bee species diversity, and final numbers are not yet complete. Wasps remain a problem. About

125 species are on hand, and only a few are identified. Final determinations will require many specialists, some of

whom do not yet exist. We shall keep working on it.

Barry D. Valentine

Professor of Zoology, Emeritus

The Ohio State University

Insecta Mundi

13 May 2010

Wenhua Lu

The Conservation Agency

6 Swinburne Street

Jamestown, RI 02835. wenhua@etal.uri.edu

# Cockroaches (Dictyoptera: Blattaria) from the British Virgin Islands

Wenhua Lu<sup>1</sup>, Barry D. Valentine<sup>2</sup>, and Daniel E. Perez-Gelabert<sup>3</sup>

1. The Conservation Agency, 6 Swinburne Street, Jamestown, RI 02835. wenhua@etal.uri.edu

 Professor of Zoology, Emeritus, The Ohio State University; 5704 Lake Breeze Ct., Sarasota, FL 34233. bv@nwcs.com

 Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0105. perezd@si.edu





Some common cockroaches.

### Abstract

To elucidate the number of species and life history of cockroaches (Dictyoptera: Blattaria) from the British Virgin Islands we conducted a survey from 1999 to 2009 on Guana Island. We have found 23 species of cockroaches on the British Virgin Islands: Cariblatta antiguensis (Saussure & Zehntner), Cariblatta sp. 2, Cariblatta sp. 3, Colapteroblatta sp. 1, Eurycotis improcera Rehn, Eurycotis sp. 2 near E. improcera Rehn, Eurycotis sp. 3 near E. gurneyi Gutiérrez, Eurycotis sp. 4, Euthlastoblatta facies (Walker), Hemiblabera brunneri (Saussure), Nyctibora sp. 1 near N. lutzi Rehn & Hebard, Panchlora sagax Rehn & Hebard, Periplaneta americana (Linnaeus), P. australasiae (Fabricius), P. brunnea Burmeister, Plectoptera rhabdota Rehn & Hebard, Plectoptera sp. 2, Pycnoscelus surinamensis (Linnaeus), Symploce pararuficollis Roth, S. ruficollis (Fabricius), two undetermined species in Blatellidae, and one undetermined species in Polyphagidae; Plectoptera sp. 3, a previously undetermined species in Blatellidae remains unknown. As a result, the number of cockroach species increases from 13 to 24 for the British Virgin Islands, from 2 to 17 for Tortola Island, and from 11 to 18 for Guana Island. A wingless species in Blatellidae, and nymphs of *Euthlastoblatta facies* are reported for the first time as dwellers in termite nests. We also report the first polyphagid adults from the Greater Puerto Rico Bank. Other habitats, multiple new island records, and behaviors of these cockroaches are noted. A key to adult species is provided. This paper lays a foundation for further research on diversity of cockroaches from the Virgin Islands and their relationships with those from the Greater Puerto Rico Bank that were once geologically and biologically connected during the last glacial maximum.

62

Keywords: Blaberidae, Blatellidae, Blattidae, Polyphagidae, season, termite, West Indies, Guana Island.

# Introduction

Geologically and biologically the Virgin Islands (except St. Croix) are part of the Puerto Rico Bank, which connected these islands until about 10,000 years ago. Thus their floras and faunas are expected to have much affinity with those of Puerto Rico (Heatwole et al. 1981). Politically these islands are divided into the British Virgin Islands (BVI) and U. S. Virgin Islands (USVI); Guana Island is a small, privately owned, BVI island located off the northeast end of the BVI capital Tortola at 18°28'N by 64°35'W (Fig. 1). Its rugged topography of 297 hectares features exceptionally well-preserved subtropical dry forest that covers most of the island from sea level to its highest elevation (Sugarloaf Peak at 246 m). Since 1999 we have been systematically studying the diversity and ecology of BVI cockroaches (Dictyoptera: Blattaria), using Guana Island as our base and research station.

There is little information about these cockroaches other than taxonomic species accounts. Rehn and Hebard (1927) recorded the first species from the Virgin Islands, *Nyctibora noctivaga* Rehn, from Loango Island near St. Thomas, USVI, but it is dubious because the identification was based on an immature male, and the species was described from Nicaragua, Panama, Jamaica, and Colombia (Rehn 1902). *Eurycotis improcera* Rehn is the first species originally described in 1930 from the Virgin Islands, but the type locality of St. Croix is geologically not part of the Greater Puerto Rico Bank. The BVI fauna of cockroaches was first systematically investigated when Roth (1994) studied specimens taken by various collectors mostly through the use of Malaise and light traps on Guana Island. Based on that material he recorded 11 species, including a new species, *Symploce pararuficollis* Roth, which is the only species originally described from BVI; it was later also found on Puerto Rico (Gutiérrez & Fisk 1998). Miller (1994) also recorded *Pycnoscelus surinamensis* (Linnaeus) as a "quarantine" pest on a shipment of potted plants being unloaded at Guana Island in 1990s. Eight of the 11 species recorded by Roth were from

Guana Island, as the specimen of *Hemiblabera brunneri* (Saussure) was from the island of Virgin Gorda and the two undetermined *Plectoptera* species were from Tortola. Recently Lazell (2005) provides a list of 10 roach species then known from the Virgin Islands, adding the names *Eurycotis decipiens* (Kirby), *Hemiblabera brunneri* (Saussure), and *Periplaneta americana* (Linnaeus) to the fauna of Guana Island, but omitting the polyphagid nymph recorded by Roth. So before our study, there were 13 species for the British Virgin Islands and 11 for Guana Island.

64

In this paper we correct the earlier identification of *Eurycotis decipiens*, a cockroach species originally described in 1903 from Trinidad, to *E. improcera*, a species originally described in 1930 from USVI. We report for the first time 11 new records for the British Virgin Islands, *Colapteroblatta* sp. 1, *Nyctibora* sp. 1, *Periplaneta australasiae* (Fabricius), possibly *P. brunnea* Burmeister, *Cariblatta* sp. 2, *Cariblatta* sp. 3, *Eurycotis* sp. 2, *Eurycotis* sp. 3, *Eurycotis* sp. 4, and two undetermined species in Blatellidae; these plus a previously found *Plectoptera* sp. 3, totaling 24 species for the British Virgin Islands, 17 for Tortola Island, and 18 for Guana Island. We also provide a key to known adults. This study contributes new information on the ecology and fine mapping of cockroach distribution in the West Indies. We hope to build a data matrix for further diversity study among an array of islands in the Virgin Islands and to understand the biogeographic relationships of the cockroaches from these islands to those from Puerto Rico.

Zootaxa

13 May 2010

Wenhua Lu

The Conservation Agency

6 Swinburne Street

Jamestown, RI 02835

wenhua@etal.uri.edu

# Diversity and Ecology of Stick Insects (Insecta: Phasmida) from the Virgin Islands

Wenhua Lu<sup>1</sup>, Paul D. Brock<sup>2</sup>, Michael Ivie<sup>3</sup>, Rudy G. O'Reilly, Jr.<sup>4</sup>

1. The Conservation Agency, 6 Swinburne Street, Jamestown, RI 02835, USA.

hq@theconservationagency.org

2. The Natural History Museum, London, Cromwell Road, London SW6 5BD, U. K.

pauldbrock@btinternet.com

3. Montana Entomology Collection, Montana State University, Bozeman, MT 59717-3020. mivie@montana.edu

4. USDA Natural Resources Conservation Service, Gallows Bay, U.S. Virgin Islands 00820. rudy.o\_reilly@pr.usda.gov

# Keywords

West Indies, Guana, Diapheromeridae, Phasmatidae, Pseudophasmatidae, host plant, walkingstick, biogeography

# Abstract

Five species of stick insects (Insecta: Phasmida) from the Virgin Islands are systematically studied for the first time: Agamemnon cornutus (Burmeister 1838), Clonistria calamus (Fabricius 1793), C. paramodesta (Otte & Brock 2005) new combination, Haplopus micropterus (St. Fargeau & Serville 1827), and Bacteria yersiniana Saussure 1868. The males of C. calamus and C. paramodesta are described for the first time; the latter is the first report of wings in the genus *Clonistria* Stål 1875. Eggs of all five species are also described for the first time. *Dyme* krugiana Brunner 1907 is a new synonym of Bacteria yersiniana. A. cornutus was omnivorous over >15 species in >10 families of plants with a preference for Colubrina arborescens (Rhamnaceae) in laboratory, but was observed feeding and mating on Cordia polycephala (Boraginaceae) in nature. C. calamus was only found Pithecellobium and Acacia (both Mimosaceae); C. paramodesta was only numerous on Eugenia cordata (Myrtaceae); H. micropterus was only found feeding on Piscidia carthgenensis (Fabaceae) and Pithecellobium unguis-cati (Mimosaceae); all three were tested likely oligovorous in laboratory. Additional notes are provided on life history, defensive warning behavior, oviposition, feeding preference, and distribution among different islands. Low number of species within each genus, sharing mostly the same species with Puerto Rico, and distant relationships among genera indicate that the Virgin Island phasmid fauna is a subset of that of the greater Puerto Rico Bank and only separated from it recently by postglacial sea level rise.

# Introduction

The mainly nocturnal stick insects or walkingsticks (Phasmida = Phasmatodea) are extremely elongate stick-like insects in the order Phasmida. They not only look like twigs but, when disturbed, they mimic the swaying of a twig, perhaps to confuse potential predators. The name is derived from the Greek *phasm*, meaning an apparition or a phantom, and refers to the cryptic appearance and mimetic behavior of these insects. The earliest fossil record of phasmids was from the Triassic (Nel et al. 2004). Stick insects are regarded as an orthopteroid order of about 2957 species (http://phasmida.speciesfile.org, 15 February 2010), related to cockroaches, grasshoppers, and praying mantids; in the early era of classification, they were considered a suborder of Orthoptera. Possession of dorsolateral defensive glands on the prothorax, a vomer in males, which is a ventral modification of abdominal segment 10 to clasp the female during copulation, and a lid-like operculum of eggs (the opening end at hatch), provides support for the current monophyly of the order (Grimaldi and Engel 2005). This order includes the longest insect in the world, measuring up to 356 mm in body length or 567 mm to include the outstretched legs (Hennemann and Conle 2008). Stick insects are important herbivores in tropical or sub-tropical ecosystems, but have been poorly investigated in their natural environment (Blüthgen et al. 2006). Young stick insects are often either green or brown, but may be different from adult coloration; sexual dimorphism is common in size, wing form (if present), and development, where males are usually smaller than females, some winged species have wings that may lack in females, and have fewer nymphal stadia than females. Nymphs of some phasmids are known to browse on a different range of plants than adults.

Geologically the Virgin Islands (except St. Croix) are part of the greater Puerto Rico Bank,

which united these islands until about 10,000 years ago (Lazell 2005). Politically these islands are divided into the British Virgin Islands and the U. S. Virgin Islands. Wolcott (1948) compiled data on stick insects of Puerto Rico including Canuleius cornutus (Burmeister), Bacteria calamus (Fabricius), and Aplopus micropterus (St. Fargeau & Serville). All three species were subsequently transferred to different genera (Otte and Brock 2005). The earliest stick insect recorded from the Virgin Islands is Clonistria calamus (Fabricius) described in 1793 from St. Croix (the largest island of the U. S. Virgin Islands). Recently, multiple papers on ecology and taxonomy of Puerto Rican phasmids have originated from a long-term ecological study (e.g., Tilgner et al. 2000). Langlois et al. (2006), one of a series of publications on phasmids from the West Indies, gave almost complete lists of species from various isles in the West Indies, including seven species from 'Sainte Thomas' and another species from 'Sainte Croix'. However, three of the seven species represent existing or new synonyms reported here, and Ocnophila illegitima Brunner 1907, is from Cuba, not St. Thomas. Langlois et al. (2006) must have presumably listed O. illegitima from St. Thomas, following an unpublished thesis by Moxey (1972) who regarded it as a new synonym of Agamemnon cornutus. Whilst they are similar in appearance, further research is required for the synonymy of O. illegitima with A. cornutus. Otherwise, Moxey (1972) provides the most comprehensive source on phasmids of the West Indies, albeit an unpublished Stick insects are popular pets in addition to their important role as herbivores; as a result, thesis. the biology of many species is well studied. However, there is no published systematic work on the phasmid fauna of the Virgin Islands, and information on host plants and life history is mostly anecdotal.

Guana Island is a small privately owned island in the British Virgin Islands (Fig. 1), located

4
off the north side of the main island Tortola, at 18°28'N by 64°35'W. Its rugged topography of 297 hectares features a well-preserved subtropical dry forest that covers much of the island from sea level to its highest elevation, Sugarloaf Peak at 246 m. Recently we have studied the diversity of phasmids of the Virgin Islands systematically, using Guana Island as the research station. This paper reports on five known species from the Virgin Islands and contributes to the knowledge of their current taxonomy, life history, behavior, host plants, distribution, and biogeography. A key to species is given and eggs are figured where available, to assist field identification. The males of *Clonistria calamus* and *C. paramodesta* are also described for the first time, in addition to the main diagnostic characters for each known species.

See End Paper for an Illustration.

69

Copyright @ 2007 · Magnolia Press

### The *Elaphidion* Audinet-Serville of the Puerto Rican Bank: new species, distributions, taxonomic corrections, and a key to species (Coleoptera: Cerambycidae: Elaphidiini)

### MICHAEL A. IVIE<sup>1</sup> & MICHELLE L. SCHWENGEL-REGALA<sup>2</sup>

<sup>1</sup>Montana Entomology Collection, Montana State University, P.O. Box 173020, Bozeman, MT 59717-3020; corresponding author: mivie@montana.edu

<sup>2</sup>Department of Malacology, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007

#### Abstract

The six species of *Elaphidion* Audinet-Serville occurring in Puerto Rico and the Virgin Islands are keyed, illustrated and diagnosed. *Elaphidion michelii* Ivie NEW SPECIES (Puerto Rico) and *Elaphidion mayesae* Ivie NEW SPECIES (St. Thomas and Puerto Rico) are described. Previous records for *E. pseudonomon* Ivie for Puerto Rico are corrected to *Elaphidion mayesae* Ivie.

Key words: Longhorns, West Indies

### Introduction

In 1985 Ivie published an attempt to clarify the taxonomic status of various West Indian members of the Elaphidiini. One taxonomic innovation of that paper was the unraveling of several names proposed for two cryptic species of *Elaphidion* Audinet-Serville occurring in the Virgin Islands. It was discovered that five available names all referred to *Elaphidion glabratum* (Fabricius) of St. Croix and the Lesser Antilles, while the common species in the northern Virgin Islands (i.e. those lying on the Puerto Rican Bank) actually lacked a valid name. This latter species was named *Elaphidion pseudonomon* Ivie. The type locality was designated as Red Hook, St. Thomas, but paratypes were included from St. John, Tortola, Virgin Gorda, and Anegada. Unfortunately, four specimens from Roosevelt Roads, Puerto Rico, were also included in the paratypes of *E. pseudonomon*.

Discovery of a new but related *Elaphidion* species in a unique pocket of wet forest near the very top of St. Thomas' second highest peak led to a reexamination of *E. pseudonomon*. Clarification of the characters involved led to the discovery that the Puerto Rican specimens included in the type series of *E. pseudonomon* in fact belong to this closely related undescribed species. Additional Puerto Rican specimens have been examined that confirm this conclusion.

We take this opportunity to describe this species, clarify the diagnoses of the three very similar species that occur in Puerto Rico and the Virgin Islands, as well as describe a second, more distantly related new member of the genus from Puerto Rico, and provide a key to the congeners from these Islands.

### Materials and Methods

Distributions are taken from Blackwelder (1946), Villiers (1980), Ivie (1985), Browne et al. (1993), Lingafelter and Micheli (2004), Valentine and Ivie (2005), and Chalumeau and Touroult (2005), except as noted by a citation in the list of islands. Inclusion of a collection coden after an island name indicates a new record not documented by one of the above references, with the voucher to be found in the cited collection. Label data on types are presented exactly as on the label, a change of line indicated by a semicolon (;) and a new label by a slash (/). Length is measured from the front of the antennal tubercles to the tip of the elytral spines.

Material was received from the collections listed below. Repositories for material studied are indicated by the associated codens.

- EAPR Museo de Entomología y Biodiversidad Tropical de la Estación Experimental Agrícola, University of Puerto Rico, Río Piedras, PR. Rosa Franqui.
- ERPL Department of Biology, University of Puerto Rico, Mayagüez, PR. Angel Berríos, Nico Franz.
- FSCA Florida State Collection of Arthropods, Gainesville, FL. Robert. E. Woodruff.
- JAMC Julio A. and Charyn J. Micheli, private collection, Ponce, PR.
- MIZA Museo del Instituto de Zoología Agrícola, Universidad Central de Agricultura, Maracay, VENEZU-ELA. Luis Joly.
- MNRJ Museu Nacional, Rio de Janeiro, BRAZIL. Miguel A. Monné.
- NMNH National Museum of Natural History, Washington, DC. Steven W. Lingafelter.
- WIBF West Indian Beetle Fauna Project, Montana State University, Bozeman, MT. Michael A. Ivie

### Taxonomy

### *Elaphidion conspersum* Newman (Fig. 14)

*Elaphidion conspersum* Newman,1841: 110. Ivie, 1985: 309. Browne et al., 1993: 44. Monné and Giesbert, 1995: 54. Chalumeau and Touroult, 2005: 96. Monné and Hovore, 2005: 65. Valentine & Ivie 2005:280. [For a complete pre-1985 synonymy, see Ivie 1985.]

**DIAGNOSIS:** The bispinose antennae and pronotum with the median callus broadly connected to the base of the pronotum will distinguish this species from all others in the region. Length 18–25 mm.

**DISTRIBUTION:** Bahama Is. (Crooked, Long, Great Exuma, New Providence, Nassau [WIBF] San Salvador [WIBF]); Cuba, Hispaniola, Puerto Rico, St. Thomas, St. John, Guana, St. Croix, Anegada [WIBF], St. Martin, Guadeloupe (Grande-Terre, Basse-Terre, Désirade), Curação, Bonaire.

BIOLOGY: Chalumeau and Touroult (2005) list Hippomane manchinella L. as a host of this species.

*Elaphidion michelii* Ivie, new species (Figs 12–13)

Elaphidion irroratum [not Linnaeus], Wolcott, 1946: 336 [misidentification, part?].

This striking species has been known for many years, but never named. The exceptionally large and oddly patterned specimen that Wolcott (1946) referred to as *E. irroratum* may have belonged to this species. *Elaphidion michelii* is the largest member of the genus found in the United States, and is tied with *Elaphidion* 

this raised area reaching suture between sutural depressed areas; narrow depression laterad of this in basal ½; behind humerus very weakly longitudinally raised, joining other raised areas in median portion of elytron. Length: 9–15 mm. FEMALE. Length: 11–14 mm.

**DISTRIBUTION:** Known only from wet forest on the north side and near the top of St. Peter Mountain, St. Thomas, Virgin Islands and wet forests of Puerto Rico.

**TYPES.** HOLOTYPE MALE : VIRGIN IS: St. Thomas; Est. St. Peter, ca 1450ft; 3-H-4 North Star; 04JAN–30 JUNE 1983; Carol Mayes, u.v.light/ WIBF 021377 (from WIBF, deposited in NMNH).

PARATYPES: 5 MALES, 9 FEMALES-Same data as Holotype, WIBF 021379-82, 84-88, 90-95 (WIBF). ADDITIONAL MATERIAL STUDIED BUT NOT INCULDED IN TYPE SERIES: 3 MALES, 2 FEMALES-PUERTO RICO: El Verde, 250m; 22 SEP 1987; M. A. Ivie, at light; 3 MALES, 5 FEMALESibid., 23 SEP 1987; 1 MALE, 1 FEMALE-ibid., 24 SEP 1987; 1 MALE-ibid., 25 SEP 1987; 1 MALE, 2 FEMALES-ibid., 26 SEP 1987; 4 MALES, 2 FEMALES-ibid., 27 SEP 1987 (WIBF). 2 MALES-PUERTO RICO: Caribbean; National Forest, base of; El Toro trail, 600 meters; 18°16'55"N, 65°51'10"W; tree cut - 26 June 2002; Steven W. Lingafelter (NMNH). 1 MALE, 1 FEMALE --- PUERTO RICO: Caribbean; National Forest, Road 186 at; Km 14.4, Rio Grande bridge; 18°17'50"N, 65°50'33"W; 475 meters, 27 June 2000; dead tree cutting; Steven W. Lingafelter (NMNH). 1 FEMALE-ibid, Charyn J. Micheli (JAMC). 2 FEMALES-PUERTO RICO: Maricao For; Near Cabins, 850-900m; 18°08'45"N, 65°58'52"W; 19 June 2002, Lights; Steven W. Lingafelter (NMNH). 1 FEMALE --- ibid., Norman Woodley (NMNH). 1 FEMALE-ibid., 17-18 June 2002, at lights, Charyn J. Micheli (JAMC). 2 MALES, 1 FEMALE --PUERTO RICO: Bosque Estatal; de Guajataca, along Road 446; 18°25'00"N, 65°58'30"W; 20 June 2003/ Beating veget.; Steven W. Lingafelter (NMNH). 1 FEMALES-PUERTO RICO: Ponce; Rd. 132, km 20; X-22-1976; J. Micheli/ at light (NMNH). 1 MALE-PUERTO RICO: Rd 10 Km 24; VI-8-1977; J. Micheli (NMNH). 1 MALE—PUERTO RICO: Rd 10 Km 24; 5/11-XI-1978; J. Micheli; blacklight trap (JAMC). 1 MALE, 2 FEMALES — PUERTO RICO: Rd 10 Km 24; 1/7-V-1978; J. Micheli; blacklight trap (JAMC). 1 MALE-ibid., 5/11-XI-1978; J. Micheli; (JAMC). 1 FEMALE-Unknown host; Central Rufina; Ponce, P.R.; coll. 11 Dec. '33; R. G. Oakley (NMNH). 1 FEMALE-Mayagüez, P.R.; 190 [sic] (NMNH). 1 MALE-ibid., II-7-1912/ F. W. Hooker collector (NMNH). 1 FEMALE-El Yunque; 800 ft., PR/Feb; 21.00/ C. W. Richmond; collector (NMNH). 1 FEMALE-Bayamon; PR, I-27-34; Lesene &; Anderson/ San Juan; No. 5130. 1 FEMALE-Puerto Rico; Santurce; X-13-'35; Sta. 65; Blackwelder (NMNH). 1 FEMALE-Flight; Ponce, P.R.; D.DeLeon, v.2.'40/ Hopkins US; 33100-A-9 (NMNH). 1 FEMALE-Roosevelt Rds; Puerto Rico; unknown; A.B. Cochran/ 4 March 1963; San Juan, P.R.; [no. symbol] 18392; 63 7416 (NMNH). [The next four specimens were included in error with the paratype series of E. pseudonomon by Ivie (1985). They bear the paratype labels of both species]. 3 MALES, 1 FEMALE Roosevelt Rds; Puerto Rico; unknown; A.B. Cochran/ 4 March 1963; San Juan, P.R.; no.18392; 63 7416 (NMNH).

**ETYMOLOGY:** A noun in the genitive case, named in honor of Dr. Carol H. Mayes, Director, U.S. Virgin Islands Program in The Nature Conservancy's Caribbean Region, who kindly ran the trap that yielded this species under the porch of her house in the wettest forest on St. Thomas.

### Elaphidion irroratum (Linnaeus)

(Fig. 15)

Cerambyx irroratus Linnaeus, 1767: 633.

Elaphidion irroratum: Linsley, 1963: 83. Zayas, 1975: 90. Villiers, 1980: 285. Browne et al., 1993: 45. Lingafelter and Micheli, 2004: 50. Chalumeau and Touroult, 2005: 97. Valentine & Ivie 2005:280. [For more complete synonymy, see Linsley, 1963 and Villiers, 1980.]

**DIAGNOSIS:** The distinct white setose patches on a dark brown background will distinguish this species from other *Elaphidion* in the region. It is also rather large (11–30 mm), and has unispinose antennae.

**DISTRIBUTION:** North America; Bahama Islands (North Bimini, South Bimini, Andros, Mayaguana [WIBF], Fortuna [WIBF], Crooked [WIBF], Acklins [WIBF], Great Exuma [WIBF], New Providence, Eleuthra, Cat, Long, and Nurse and Buena Vista Cays [Rugged Island Group] [WIBF]); Cuba, Isla de la Juventud, Jamaica, Hispaniola, Mona, Puerto Rico, St. Thomas [WIBF], St. John [WIBF], Tortola [WIBF], Guana; Great Camanoe [WIBF], Anegada [WIBF], St. Croix [WIBF], Buck Is. [WIBF], St. Barthelémy, St. Martin, St. Christopher, Guadeloupe (Grande-Terre, Basse-Terre), Curaçao, Bonaire. Chalumeau and Touroult (2004) have begun the process of describing the different island variants of this species as subspecies, placing the Puerto Rican and Virgin Islands populations under the name *E. irroratum debieni* Chalumeau and Touroult.

**BIOLOGY:** This species was reared from a dead log of *Albizia lebbeck* (L.) Benth. at Ponce in 1939 (Martorell 1976). Chalumeau and Touroult (2005) list hosts of *Spondias purpurea* L., *Rhizophora mangle* L., *Hippomane mancinella* L., *Haematoxylon campechianum* L., and *Laguncularia racemosa* (L.) Gaertn.

### Elaphidion glabratum (Fabricius)

(Figs 16, 18 20)

### Stenocorus glabratus Fabricius, 1775: 180.

*Elaphidion glabratum*: Ivie, 1985: 310. Monné and Giesbert, 1995: 54. Chalumeau and Touroult, 2005: 101. Monné and Hovore, 2005: 65. [For a complete pre-1985 synonymy, see Ivie 1985.]

A complete discussion of the tortured nomenclatural history of this species was given by Ivie (1985).

**DIAGNOSIS:** The small size (8–19 mm), cinerous to golden pubescence, and relatively long unispinose antennomere 4 will distinguish this species and *E. pseudonomon* from all other *Elaphidion* in the area. Although long series of these two closely-related species are obviously distinct to the naked eye when placed next to each other, actual diagnoses of *E. glabratum* and *E. pseudonomon* are difficult, and require careful use of details. From *E. glabratum*, *E. pseudonomon*, can be distinguished by the male genitalia (see Ivie 1985), somewhat lighter color, details of the antennal configuration and setation. The antennal characters require detailed measurements. In male *E. glabratum* antennomeres 3 and 4 are subequal (with 4 only rarely more than 1 mm shorter than 3), and 5 is longer (by 1–3 mm) than 3 (*i.e.* antennomere 4 is greater than 30% total length of 3+4+5). In male *E. pseudonomon*, antennomere 3 and 5 are subequal, with 5 no more than 1 mm longer than 3, while 4 is at least 2 mm shorter than 3 (*i.e.* antennomere 4 is less than 30% total length of 3+4+5). In females of both species, antennomere 4 is consistently shorter than 3, and in *E. pseudonomon* it is slightly more so, but the difference is difficult to quantify. In female *E. pseudonomon*, antennomere 4 is usually less that 28% of the total 3+4+5, while in *E. glabratum* it is usually greater than 28%. For unassociated females, the allopatric distribution is helpful, with *E. pseudonomon* occurring on the Virgin Islands that lie on the Puerto Rican Bank, while *E. glabratum* occurs from St. Croix and its satellites into the Lesser Antilles.

The elytral setation and punctation are also different, and helpfully not sexually dimorphic. The setae of *E. pseudonomon* (Figs 17, 19) are more golden and individually larger than in *E. glabratum* (Figs 16, 18), covering the elytra and pronotum more uniformly, but not being dense enough to completely obscure the underlying cuticle. The specimen therefore looks uniformly lighter colored to the unaided eye because of the uniform mix of the color of setae and cuticle. In fresh specimens, the humerus is covered in setae (Fig. 17), and at mid-elytron (at the level of the metacoxa) the setae uniformly cover the entire disc except for 2 narrow, indistinct strial lines (Fig. 19). Older rubbed specimens of *E. pseudonomon* may exhibit bare spots, but never to the extent seen in *E. glabratum*, and the remaining setal patches are always sparse enough to see through to the surface. This characteristic is always distinguishable at a point just mesad the humeral umbone (Fig. 17), and on the mid-point of the elytron at the level of the metacoxa (Fig. 19).

darker, but this is an obvious artifact of preservation. The setae in *E. glabratum* are cinerous and narrower, and form dense patches that at least in part completely obscure the cuticle (Figs 16, 18), leaving other areas bare except for the single seta associated with each puncture. The difference in setal density of these patches relative to the condition in *E. pseudonomon* is always distinguishable at a point just mesad the humeral umbo (Fig. 16), and on the mid-point of the elytron at the level of the metacoxa (Fig. 18). The overall effect of this condition is more areas of unobscured cuticle showing to the naked eye, thus making the fresh specimen look darker.

Lastly, post-humeral punctures of *E. pseudonomon* are usually slightly smaller in diameter, making them seem less dense (Fig. 21). In *E. glabratum* the post-humeral punctures of the elytra are slightly larger (Fig. 20), although there seems to be about the same number of actual elytral punctures in both species.

**DISTRIBUTION:** St. Croix, Buck Is. (near St. Croix, WIBF), Saba (WIBF), St. Martin, St. Barthelémy, St. Eustatius, Nevis, Antigua, Montserrat, and Guadeloupe, and probably St. Christopher, Dominica and St. Lucia

### Elaphidion pseudonomon Ivie

(Figs 1, 2, 11, 17, 19, 21)

Elaphidion pseudonomon Ivie, 1985: 312. Monné and Giesbert, 1995: 55. Monné and Hovore, 2005: 66. Valentine & Ivie 2005:280. [For a complete pre-1985 synonymy, see Ivie 1985.]

Elaphidion glabratum pseudonomon: Chalumeau and Touroult, 2005: 103.

This species has been a problem to distinguish throughout its more-than-100-year history (Ivie 1985). When two unit trays of 50 specimens each are placed side-by-side, the difference between E. pseudonomon and E. glabratum is so obvious that no one would question their distinctiveness. However, when faced with diagnosing these two highly variable species in such a way that every specimen can be identified in isolation, the situation is much more difficult, leading to polite and understandable questions by workers with only small series to work with. This has been aggravated by use of relative and weakly defined characters to diagnose these differences (e.g. Ivie 1985). Recently, Chalumeau and Touroult (2005) went so far at to consider E. pseudonomon a subspecies of E. glabratum. However, the definition of a subspecies generally includes "...and interbreeding successfully where their ranges overlap" (Lincoln et al. 1982), and there is no evidence of these two forms occurring together anywhere in their ranges. Therefore, they cannot be considered subspecies. In the absence of behavioral or genetic data most modern insect systematists consider two allopatric populations that exhibit consistent differences to have divergent evolutionary histories, and place them either as populations of the same taxon or recognize them as full species. After extensive work with these populations for (in the case of Ivie) nearly 30 years, we have found they consistently behave as species, and have identified several, albeit difficult, characters to distinguish them (see diagnosis under E. glabratum above). These differences correspond to a biogeographic boundary (the Anegada Passage), which divides the Greater and Lesser Antillean faunae, further strengthening our argument. We therefore return E. pseudonomon to full specific status.

DIAGNOSIS: See under E. glabratum. Length 9.5-17 mm.

**DISTRIBUTION:** St. Thomas, St. John, Tortola, Guana (Valentine and Ivie, 2005), Virgin Gorda, Anegada. Puerto Rican record removed to *E. mayesea*.

### Key to species of Elaphidion of Puerto Rico and the Virgin Islands

1.	Third and fourth antennomeres spined on both internal and external apical angles2
1'	Third and fourth antennomeres spined only on internal angle

- 2. Prosternal process parallel-sided, rounded apically, with caudad apex at median; length 30 mm or greater; 2' Prosternal process widened and truncate apically, sometimes emarginate medially, median not most caudad point; length 25 mm or less; widespread...... E. conspersum (Newman) 3. Integument dark chocolate brown to black, with patches of white pubescence on head, pronotum and elytra; emargination between apical elytral spines obliquely truncate to weakly bisinuate so that sutural 3' Integument light brown to dark chocolate brown, with ochre to golden pubescence; emargination between apical elytral spines simply arcuate, both spines long, although outer may be longer......4 4. Metafemoral apex spiniform, spine longer than basal metatibial width; antennomere 4 short relative to 5; apical spine of male antennomere 3 greater than  $0.5 \times$  length of antennomere 4; apical spine of female antennomere 3 subequal to or longer than length of antennomere 4; setae of pronotal and elytral disk broader, rounded-blunt at apex ...... E. mayesae Ivie 4' Metafemoral apex dentiform, spine subequal to basal metatibial width; antennomere 4 longer relative to 5; apical spine of male antennomere 3 less than  $0.5 \times$  length of antennomere 4; apical spine of female antennomere 3 distinctly shorter than antennomere 4; setae of pronotal and elytral disk narrow, acutely attenu-5. Lighter in color, setae generally distributed on elytral disc, allowing derm to show through between, always visible just mesad humeral umbone and between striae at level of metacoxa (Figs 15, 17); punctures of basal portion of elytral disc smaller (Fig. 19); Northern Virgin Islands ......E. pseudonomon Ivie 5' Darker in color, setae clumped in dense patches, completely hiding derm, giving a distinct patterned
- 5 Darker in color, setae clumped in dense patches, completely hiding derm, giving a distinct patterned appearance, density always visible just mesad humeral umbone and between striae at level of metacoxa (Figs 14, 16); punctures of basal portion of elytral disc larger (Fig. 18); St. Croix and Lesser Antilles ...... *E. glabratum* (Fabricius)

### Acknowledgements

We would like to thank the curators listed in the Materials section above for the loan of specimens used in this paper. Richard S. Miller, LaDonna L. Ivie, Charyn J. Micheli, Ian Foley, Alistair Ramsdale and Katherine A. Marske helped with many portions of the project with discussions, encouragement and species character testing. Steven W. Lingafelter spent a great deal of time helping by debating the status of the populations of *E. mayesae*, greatly improving the overall conclusions. Carol Mayes was instrumental in running the ultraviolet light trap that provided the specimens critical to understanding the *pseudonomon* species complex. Steven Lingafelter, Frank Hovore and Charyn Micheli reviewed an earlier version of the manuscript. Figure 11 was drawn by Adam Rubenstein, Figures 12, 13 and 15 are by Nikki K. J. Miller. Field work was supported by NSF Grant DEB-93-00766 to Michael A. Ivie and Richard S. Miller. This is a contribution of the Montana Agricultural Experiment Station.

### References

Blackwelder, R.E. (1946) Checklist of the coleopterous insects of Mexico, Central America, the West Indies, and South America, Part 4. United States National Museum Bulletin, 185, 551–763.

Browne, D. J., Peck, S.B., & Ivie, M.A. (1993) Longhorn beetles (Coleoptera Cerambycidae) of Bahama Islands, with an analysis of species-area relationships, distribution patterns, origin of the fauna and annotated species list. *Tropical Zoology*, 6, 27–53.

Chalumeau, F. & Touroult, J. (2004) Nouveaux Elaphidiini des Petites Antilles et notes diverses (Coleoptera, Cerambycidae). Lambillionea, 104, 751–755.

THE ELAPHIDION OF THE PUERTO RICAN BANK

Chalumeau, F. & Touroult, J. (2005) Le Longicornes des Petites Antilles (Coleoptera, Cerambycidae). Taxonomie, Éthologie, Biogéographie. Pensoft Series Faunistica 51: 241.

Fabricius J.C. 1775. Systema Entomologiae. Lipsiae, 30 + 832 pp.

Gilmour, E.F. (1968) The Coleoptera Cerambycidae of Curação, Aruba and Bonaire. *Studies on the Fauna of Curação*, 25, 83–178, 10 pls.

- Ivie, M.A. (1985) Nomenclatural notes on West Indian Elaphidiini (Coleoptera: Cerambycidae). Pan-Pacific Entomologist, 61, 303–314.
- Lincoln, R.J., Boxshall, G.A., & Clark, P.F. (1982) A Dictionary of Ecology, Evolution and Systematics. Cambridge University Press, Cambridge, viii +298 pp.
- Lingafelter, S.W. (1998) The Genera of Elaphidiini Thomson 1864. Memoirs of the Entomological Society of Washington, 20, 1–118.
- Lingafelter, S.W. & Micheli, C.J. (2004) New Species of Cerambycidae (Coleoptera) from Puerto Rico with records and notes for other species. *Journal of the New York Entomological Society*, 112, 37–55.

Linnaeus, C. (1767) Systema naturae, Tome I, Pars II, editio duodecima reformata. Holmiae, 533-1327 pp.

- Linsley, E.G. (1963) The Cerambycidae of North America. Taxonomy and classification of the subfamily Cerambycinae, tribes Elaphidionini through Rhinotragini. *University of California Publications in Entomology*, 21, 1–165.
- Martorell, L.F. (1976) Annotated food plant catalog of the insects of Puerto Rico. Agricultrual Experiment Station, University of Puerto Rico, Mayagez, 303 pp.
- Monn, M.A., & Giesbert, E.F. (1995) Checklist of the Cerambycidae and Disteniidae (Coleoptera) of the Western Hemisphere. Wolfsgarden Books, Burbank, xiv+ 420 pp.
- Monn, M.A. & Hovore, F.T. (2005) Electronic Version. 2005 Checklist of the Cerambycidae of the Western Hemisphere. http://www.hovore.com/pdf/Electronic\_Checklist\_2005.pdf. 393 pp. (accessed 20 June 2006).
- Newman, E. 1841 Entomological notes. Entomologist 7, 110-112.
- Wolcott, G.N. (1951) The insects of Puerto Rico. Coleoptera. Journal of Agriculture of the University of Puerto Rico, 32 [1948], 225–416.
- Valentine, B.D. & Ivie, M.A. (2005) Beetles: Coleoptera. In J. Lazell, Island: Fact and Theory in Nature. University of California Press, Berkeley, pp. 274 282..
- Villiers, A. (1980) Coloptres Cerambycidae des Antilles francaises, II. Cerambycinae. Annales de la Socit Entomologique de France, (N. S.) 16, 265–306.
- Zayas, F.de. 1975 *Revisin de la familia Cerambycidae*. Academia de Ciencias de Cuba, Instituto de Zoologa, La Habana, Cuba, 443 pp.



FIGURES 1–6. Antennae (scale bar = 1mm). 1. *Elaphidion pseudonomon*, male; 2. *E. pseudonomon*, female; 3. *E. may-esae*, male from St. Thomas; 4. *E. mayesae*, female from St. Thomas; 5. *E. mayesae*, male from Puerto Rico; 6. *E. may-esae*, female from Puerto Rico.



FIGURES 7–11. *Elaphidion*. 7. *E. mayesae*, from St. Thomas, aedeagus; 8. *E. mayesae*, from St. Thomas, parameres; 9. *E. mayesae*, from Puerto Rico, aedeagus; 10. *E. mayesae*, male from Puerto Rico, parameres; 11. *E. pseudonomon*, male, habitus.



FIGURES 12–15. *Elaphidion.* 12. *E. michelii*, male; 13. *E. michelii*, female, a = antenna; 14. *E. conspersum*, female; 15. *E. irroratum*, female. Scale bars = 1mm.

THE ELAPHIDION OF THE PUERTO RICAN BANK

SMITHSONIAN CONTRIBUTIONS TO ZOOLOGY • NUMBER 625

The Conservation Agency 6 Swinburne Street Jamestown, RI 02835

# A Revision of the New World Plant-Mining Moths of the Family Opostegidae (Lepidoptera: Nepticuloidea)

Donald R. Davis and Jonas R. Stonis



Smithsonian Institution Scholarly Press WASHINGTON, D.C. 2007

## Contents

· .

1

INTRODUCTION 1 Acknowledgments 2
Materials and Methods 4
BIOLOGY OF THE OPOSTEGIDAE 5 Distribution and Diversity 5 Life History 8
MORPHOLOGY 13
SYSTEMATIC RELATIONSHIPS 18 Characters Used in the Cladistic Analysis 21
OPOSTEGIDAE 22
Key to the Genera of the New World OPOSTEGIDAE 24
Notiopostega Davis 25
Notiopostega atrata Davis 33
Neopostega, new genus 34
Key to the Species of Neopostega 35
Neopostega longispina, new species 36
Neopostega falcata, new species 36
Neopostega asymmetra, new species 37
Neopostega petila, new species 38
Neopostega distola, new species 39
Opostegoides Kozlov 40
Opostegoides scioterma (Meyrick) 42
Pseudopostega Kozlov 46
Key to the Species Groups of Pseudopostega, Based on Characters
of the Male Genitalia 50
The <i>rotunda</i> group 51
Pseudopostega rotunda, new species 51
Pseudopostega ovatula, new species 52
The serrata group 52
Pseudopostega serrata, new species 52
Pseudopostega ferruginea, new species 54

The lateriplicata group 56
Pseudopostega abrupta (Walsingham) 56 🗲
Pseudopostega floridensis, new species 57
Pseudopostega lateriplicata, new species 59
Pseudopostega uncinata, new species 60
The <i>spatulata</i> group 61
Pseudopostega microacris, new species 61
Pseudopostega fumida, new species 62
Pseudopostega gracilis, new species 63
Pseudopostega tucumanae, new species 64
Pseudopostega apotoma, new species 65
Pseudopostega pexa (Meyrick) 66
Pseudopostega diskusi, new species 67
Pseudopostega truncata, new species 67
Pseudopostega monstruosa, new species 68
Pseudopostega microlepta (Meyrick) 69
Pseudopostega spatulata, new species 70
Pseudopostega albogaleriella (Clemens) 70
Pseudopostega denticulata, new species 74
The latisaccula group <b>75</b>
Pseudopostega latisaccula, new species 75 🗲
The triangularis group 76
Pseudopostega attenuata, new species 76
Pseudopostega conicula, new species 78
Pseudopostega triangularis, new species 79
Pseudopostega sacculata (Meyrick) 80
Pseudopostega kempella (Eyer) 81
Pseudopostega paraplicatella, new species 82
Pseudopostega plicatella, new species 82
Pseudopostega cretea (Meyrick) 83
Pseudopostega breviapicula, new species 85
Pseudopostega mignonae, new species 86
Pseudopostega trinidadensis (Busck) 87
Pseudopostega subtila, new species 88
Pseudopostega acuminata, new species 89
Pseudopostega tanygnatha, new species 90
The saltatrix group 90
Pseudopostega colognatha, new species 90
Pseudopostega obtusa, new species 91
Pseudopostega galapagosae, new species 93
Pseudopostega saltatrix (Walsingham) 94
Pseudopostega dorsalis dorsalis, new species 98
Pseudopostega dorsalis dorsalis, new species 98 Pseudopostega dorsalis fasciata, new subspecies 99
Pseudopostega dorsalis dorsalis, new species98Pseudopostega dorsalis fasciata, new subspecies99Pseudopostega parakempella, new species100
Pseudopostega dorsalis dorsalis, new species98Pseudopostega dorsalis fasciata, new subspecies99Pseudopostega parakempella, new species100The longipedicella group101
Pseudopostega dorsalis dorsalis, new species 98 Pseudopostega dorsalis fasciata, new subspecies 99 Pseudopostega parakempella, new species 100 The longipedicella group 101 Pseudopostega adusta (Walsingham) 101
Pseudopostega dorsalis dorsalis, new species98Pseudopostega dorsalis fasciata, new subspecies99Pseudopostega parakempella, new species100The longipedicella group101Pseudopostega adusta (Walsingham)101Pseudopostega longipedicella, new species102
Pseudopostega dorsalis dorsalis, new species98Pseudopostega dorsalis fasciata, new subspecies99Pseudopostega parakempella, new species100The longipedicella group101Pseudopostega adusta (Walsingham)101Pseudopostega longipedicella, new species102The lobata group103
Pseudopostega dorsalis dorsalis, new species98Pseudopostega dorsalis fasciata, new subspecies99Pseudopostega parakempella, new species100The longipedicella group101Pseudopostega adusta (Walsingham)101Pseudopostega longipedicella, new species102The lobata group103Pseudopostega lobata, new species104

NUMBER 625 • V

Pseudopostega sublobata, new species 107 The *duplicata* group 108 Pseudopostega duplicata, new species 108 Pseudopostega didyma, new species 109 Pseudopostega acidata (Meyrick) 110 The tenuifurcata group 112 Pseudopostega tenuifurcata, new species 112 2 Pseudopostega sectila, new species 113 6 115 The divaricata group Pseudopostega texana, new species 115 Pseudopostega curtarama, new species 116 Pseudopostega crassifurcata, new species 117 Pseudopostega turquinoensis, new species 119 Pseudopostega concava, new species 119 Pseudopostega brevifurcata, new species 120 Pseudopostega brevivalva, new species 121 Pseudopostega acrodicra, new species 122 Pseudopostega caulifurcata, new species 123 Pseudopostega resimafurcata, new species 124 Pseudopostega quadristrigella (Chambers) 124 Pseudopostega bidorsalis, new species 127 Pseudopostega divaricata, new species 128 The latifurcata group 129 Pseudopostega contigua, new species 129 Pseudopostega latifurcata latifurcata, new species 130 Pseudopostega latifurcata apoclina, new subspecies 131 The brachybasis group 133 Pseudopostega latiapicula, new species 133 Pseudopostega ecuadoriana, new species 134 Pseudopostega pumila (Walsingham) 135 Pseudopostega beckeri, new species 136 Pseudopostega protomochla (Meyrick) 136 Pseudopostega bicornuta, new species 138 Pseudopostega suffuscula, new species 139 Pseudopostega monosperma (Meyrick) 140 Pseudopostega longifurcata, new species 141 Pseudopostega constricta, new species 141 Pseudopostega brachybasis, new species 142 Pseudopostega venticola (Walsingham) 143 Species unplaced to group 145 Pseudopostega congruens (Walsingham) 145 Pseudopostega elachista (Walsingham) 146 Pseudopostega paromias (Meyrick) 147 Pseudopostega perdigna (Walsingham) 148 Pseudopostega pontifex (Meyrick) 149 REFERENCES 151

FIGURES 127-503 155

INDEX OF INSECT NAMES 211

83

## A Revision of the New World Plant-Mining Moths of the Family Opostegidae (Lepidoptera: Nepticuloidea)

### INTRODUCTION

postegidae are a morphologically distinct family of small, predominantly white moths whose females possess a primitive, monotrysian reproductive system. Together with their sister family, Nepticulidae, the Opostegidae contain some of the smallest Lepidoptera known, with a wingspan ranging from 4 to 16 mm. Although generally global in distribution, evidence now indicates the greatest diversity for Opostegidae occurs in the continental tropical/subtropical regions. One of the more obvious diagnostic features of the family is the greatly expanded antennal scape (Figures 5, 6, 8, 10, 12), which entirely covers the eye at rest and is the origin for the names of the type genus and family [derived from the Greek opos (eye) and stego (cover)]. The Nepticulidae also possess an enlarged scape (but usually developed to a relatively lesser degree), as well as a short, nonpiercing ovipositor superficially similar to that of Opostegidae. Opostegidae are easily distinguished from Nepticulidae by their more specialized larvae, the presence of ascoid antennal sensillae (Figures 14, 58), and the development of a highly modified, pedunculate cucullar lobe on the male valva that bears a prominent pectinifer consisting of a single row of blunt spines (Figure 44).

Since the first reported discovery of a member of this family in 1813 (Pseudopostega auritella (Hübner)) and the family formally recognized as one (Opostegides) of seven groups under Tineidae by Meyrick (1893), the world literature concerning Opostegidae has largely consisted of poorly diagnosed species descriptions without illustrations. Within the past 15 years, notable efforts have appeared to raise this family from obscurity. The first of these was a generic review of the family and world catalogue (Davis, 1989), followed by a revision of the Oriental Opostegidae (Puplesis and Robinson, 1999), and most recently by a review and world catalogue of the Nepticuloidea and Tischerioidea by Puplesis and Diškus (2003). Before 1985, only one generic name, Opostega, had been proposed in this cosmopolitan family. This conservatism was largely a result of the superficial morphological uniformity of these moths apparent to earlier workers as well as the lack of serious morphological examination. In a brief but significant review of a few Asian Opostegidae, Kozlov (1985) proposed the new genus Opostegoides and the subgenus Pseudopostega. Davis (1989) soon afterward proposed three additional genera and recognized Pseudopostega as a distinct genus. The present study continues our investigations on the

Donald R. Davis, Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20013-7012, USA. Jonas R. Stonis (formerly Rimantas Puplesis), Department of Zoology, Vilnius Pedagogical University, Vilnius LT-08106, Lithuania. Manuscript received 18 January 2007; accepted 5 March 2007. diversity and systematics of the Opostegidae with a revision of the New World fauna. Of the 91 species recognized for the New World, nearly 75% (i.e., 68 new species, and 2 new subspecies) are proposed for the first time, in addition to one new genus, bringing the total world's fauna to seven genera, 196 species (including 2 species of *Pseudopostega* and 7 species of *Opostegoides*, which were described but unnamed by Puplesis and Robinson, 1999), and 2 subspecies. In addition, at least three Neotropical species examined during the course of this study are believed to represent new taxa but were not named because of their poor physical condition.

Many factors combine to entitle the Opostegidae as arguably the most difficult family among all Lepidoptera to study. The small size and apparent rarity of most species of Opostegidae, coupled with the great difficulty in locating their usually well concealed, plant-mining larvae, undoubtedly have hindered previous attempts to collect and study this group. The often sparingly marked and similar forewing pattern of most species, together with the possibility for appreciable pattern variation (see Figures 183-190), necessitate that nearly every specimen be dissected for species identification; this is particularly true in areas of high species diversity, such as the Neotropical Region. Furthermore, the one feature of the forewing typically exhibiting the most consistent (and often only) pattern-the subapical strigula-is largely confined to the terminal fringe of the wing, the region most frequently damaged and largely missing in flown adults. Because the forewings are often similar or variable in pattern, the association of males and females within species is frequently difficult and sometimes impossible unless adequate series are available for comparison. The small size of the male genitalia equals that of the Nepticulidae, but the male genitalia of Opostegidae, particularly of the most speciose genus Pseudopostega, are usually more complex and more difficult to prepare and illustrate properly.

Recent collecting over much of the Neotropical Region during the past two decades has provided sufficient material to encourage the first species-level examination of this fauna. Although many problems still persist and remain unanswered, we believe that the present effort has significantly improved our understanding of this family and will greatly facilitate any future work on these moths.

### **ACKNOWLEDGMENTS**

We thank several individuals who have assisted us during the course of this study by providing critical information, loans of specimens under their care, or other special assistance: Vitor O. Becker, Reserva Serra Bonita,

Camacan, Brazil; Richard L. Brown, Mississippi Entomological Museum, Mississippi State, Mississippi; John B. Heppner, Florida State Collection of Arthropods, Gainesville, Florida; Alvaro Herrera and José Montero, Instituto Nacional de Biodiversidad, Santo Domingo, Costa Rica; Edward C. Knudson, Houston, Texas; Bernard Landry, Muséum d'Histoire Naturelle, Genève, Switzerland; Jean-François Landry, Agriculture and Agri-Food Canada, Ottawa, Canada; Kenji Nishida, University of Costa Rica, San José, Costa Rica; Erik J. van Nieukerken, Nationaal Natuurhistorisch Museum, Leiden, The Netherlands; Phillip D. Perkins, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; Jerry A. Powell, University of California, Berkeley, California; John Rawlins, Carnegie Museum, Pittsburgh, Pennsylvania; Gaden S. Robinson and Kevin Tuck, The Natural History Museum, London, United Kingdom; Lazaro Roque, Charles Darwin Research Station, Santa Cruz Island, Ecuador; and Weiping Xie, Natural History Museum of Los Angeles County, Los Angeles, California. We are especially indebted to Vichai Malikul and Young Sohn of the Department of Entomology, Smithsonian Institution, for most of the artwork, as well as George Venable, formerly of the same department. Patricia Gentili Poole, also of the Department of Entomology, contributed greatly to this study by barcoding and recording specimen data and preparing the maps and plates for publication. Marc Epstein (formerly of the Department of Entomology, Smithsonian Institution), California Department of Agriculture, Sacramento, California, also assisted with data capture, and together with Joseph Scheer, Alfred University, Alfred, New York, scanned many of the color illustrations. The color illustrations were drawn principally by Jonas R. Stonis, with some added by Vichai Malikul. We are grateful for the genitalic illustrations provided by Mary Walter and Lina Jasiukonyte, and to Arūnas Diškus, Vilnius Pedagogical University, Vilnius, Lithuania, for his expert assistance with some of the dissections. Susann Braden, formerly of the Smithsonian Scanning Electron Microscope Laboratory, assisted with the SEM photographs. We are particularly thankful to Paul Hebert and his staff at the Biodiversity Institute of Ontario, University of Guelph, Guelph, Ontario, Canada, for providing their DNA sequencing results from several species of Opostegidae provided. The senior author (DRD) especially thanks Vitor Becker and Edward Knudson for the donation of holotype specimens to the National Museum of Natural History.

In addition, DRD also acknowledges the considerable contribution that the ALAS (Arthropods of La Selva) III and IV projects (supported by National Science Foundation

grants DEB-9706976 and DEB-0072702 and by National Geographic Society grant 7751-04) and co-principal investigator John Longino have made to this study, and especially the parataxonomists at La Selva working on this project, Danilo Brenes, Flor Cascante, Nelci Oconitrillo, Maylin Paniagua, and Ronald Vargas. We thank John Longino also for preparing the three diversity graphs (Figures 2-4). The trapping protocol for the 1998-1999 sampling period was designed by Jerry Powell. This procedure was augmented by blacklight collecting at sheets by Powell, John Brown, Eugenie Phillips, David Wagner, and DRD. The Directors and staff of the La Selva Biological Station have also been most helpful. Fieldwork from 1964 through 1966 on the island of Dominica was supported by the Bredin-Archbold Smithsonian Biological Survey of Dominica. Davis (DRD) also expresses gratitude to La Fundación para el Desarrollo de las Ciencias Físicas, Matemáticas y Naturales of Venezuela, and the Scholarly Studies Program of the Smithsonian Institution for their combined support of his fieldwork during 1984 at Cerro de la Neblina, Venezuela, and to the Smithsonian Institution for support of fieldwork in French Guiana through the Research Opportunity Fund. Davis (DRD) also acknowledges the American Philosophical Society for funding his field research in Mexico during the summer of 1963. Fieldwork on Guana and Tortola Islands by Scott Miller, Vitor Becker, and Michael Pogue was supported by the Conservation Agency through a grant from the Mocatta Metals Corporation. The second author (JRS) is particularly grateful to The Royal Society, London, the SYS-RESOURCE (EU-BMNH) program, Prof. M. Hering Memorial Research Fund, the Sladen Memorial Fund (London), and the Lithuanian State Science and Studies Foundation for funding support, and to Simon R. Hill, University of Westminster, UK, and Giovanni Onore, Pontificia Universidad Católica del Ecuador, for their very helpful assistance during expeditions to Belize and Ecuador in 1998, 2000, and 2001. Together we wish to thank the Smithsonian Institution Fellowship Program for a short-term visitors' grant that provided support for J. R. Stonis to study at the National Musem of Natural History during January-February 2002. We are especially thankful to R. Brown, B. Landry, and E. van Nieukerken for their comments on the manuscript. Smithsonian Institution Scholarly Press provided the final editing and prepared the manuscript for publication.

Finally we acknowledge the cooperation of the individuals and institutions listed below and list their acronyms as used in this study.

ANSP Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.  (formerly the British Museum (Natural History)), London, UK.
CAS California Academy of Sciences, San Francisco, California, USA.
CDRS Charles Darwin Research Station, Santa Cruz Island, Galápagos, Ecuador.
CMNH Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, USA.
CNC Canadian National Collections of Insects, Arachnids, and Nematodes,

The Natural History Museum

BMNH

- Insects, Arachnids, and Nematodes, Agriculture and Agri-Food Canada, Ottawa, Canada.
- FSCA Florida State Collection of Arthropods, Gainesville, Florida, USA.
- GSMNP Great Smoky Mountains National Park, Gatlinburg, Tennessee, USA.
- INBIO Instituto Nacional de Biodiversidad, Santo Domingo, Costa Rica.
- LACM Natural History Museum of Los Angeles County, Los Angeles, California, USA.
- MGAB Muzeul de National Istorie Naturala "Grigore Antipa", Bucharest, Romania.
- MEM Mississippi State Entomological Museum, Mississippi State, Mississippi, USA.
- MHNG Muséum d'Histoire Naturelle, Genève, Switzerland.
- NHMV Naturhistorisches Museum Wien, Austria.
- RMNH Nationaal Natuurhistorisch Museum, Leiden, The Netherlands.
- TLS Texas Lepidoptera Survey Collection, Houston, Texas, USA.
- UCB Essig Entomology Museum, University of California, Berkeley, California, USA.
- UNAM Instituto de Biología, Universidad Nacional Autónoma de México, Mexico City, D.F.
- USNM Collections of the former United States National Museum, now deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.

### **Guana Island Sheep Exclosure Study**

### Renée Rondeau, Numi Mitchell, and Rudy O'Reilly

### November 2009

In October 2009, Renée Rondeau and Rudy O'Reilly measured vegetation in the Liao Wei Ping and Harris Ghut sheep exclosures and control plots. These plots were originally set up and read by Numi Mitchell and George Proctor in 1997 and 1998 and re-read in 2004. In 2009 the Harris Ghut fence was **not** intact and sheep dung was found within the fence. The fence had been partially down for at least 2 year (pers. communication with various scientists). We rebuilt the fence after we recorded data.

### Methods

Each site has a 10 x 10 m fenced plot and a nearby control (unfenced) plot. We utilized the same methods that Mitchell used in 1997, 1998, and 2004. Density and size were recorded for all rooted plants (epiphytes were included if growing within 15 cm above the ground), in addition, basal area was recorded for all large (see below for definition) plants within the plot. We used 3 size class categories for all species recorded: small (< 1 m tall), medium ( $\geq$ 1 m tall and < 2 cm in basal diameter), and large ( $\geq$  1 m tall and  $\geq$  2 cm in basal diameter). Basal area was measured just above the boll. In order to assure we counted all plants we divided the plot into 1 m wide belts. Ten leaf litter depth measurements/belt were also collected.

### Results

The following results are for those species that had at least 12 individuals/plot in any given year In general, the medium and tall-sized class individuals did not change much from 1997 and 1998, however the small (or seedling) size class was notably different, especially in the Liao Wei Ping fenced plot. *Amyris elemifera*, *Bursera simaruba*, *Jacquinia berterii*, *Rhyncosia reticulata*, *Tillandsia recurvata*, and *Tragia volubilis* all increased in the fenced plot and declined, or were nearly stable, in the control (Fig. 1). *Centrostema virginianum* was the only species that favored the control over the fenced plot. *Croton asteroites* reacted identical in both fenced and control (Fig. 1). *Guapira fragrans* decreased in both plots in 2004 and increased in the fenced plot in 2009. Nearly 1100 seedlings were growing in the fenced plot versus 289 in the control (Fig. 1).

Harris Ghut does not show the same trend as Liao Wei Ping. The overall seedling count in the control was 635 versus 459 in the fenced plot, a fairly consistent count for all three years (Fig. 2). *Capparis cynophallophora* and *Tragia volubilis* are the only two species that had a noticeable increase in the fenced plot while remaining nearly stable in the control (Fig. 2). *Bursera simaruba, Capparis frondosa, Eugenia spp., Guapira fragrans,* and *Piscidia carthagenensis* either declined or were stable in both the fenced and control plots (Fig. 2).

### Discussion

We believe that the break in the Harris Ghut fence may be the reason we did not see an increase in seedlings. The Liao Wei Ping fenced plot was visibly more vegetated than the surrounding areas (Fig 3.), while the Harris Ghut fenced plot was not. The *Tillandsia recurvata* was abundant in Liao Wei Ping and was quite obvious to the casual observer (Fig 3.). It was also much harder to navigate through this plot than any of the others.

Growth rate of most individuals appear to be slow and most of the large trees had very little recorded growth.

We propose, for October, 2010, to measure the remaining 3 sites that Numi set up in 1997/1998: Harris Ruins 1, Harris Ruins 2, and Monkey Point. If time allows we will also measure the lizard removal plot. In October 2010 we relocated all of these sites and all fences were standing and control plots had their corner stakes. If time allows we may measure seedlings in the Harris Ghut plots. We estimate 8 full days to finish reading all of these plots. Some supplies will be needed.

### Acknowledgements.

We thank Skip Lazell for helping with all the logistics and providing lively conversation. Wenhua Lu assisted with locating, setting up plots, and recording data. Susan Valentine-Cooper and Tom Willards assisted with recording data and rebuilding the Harris Ghut fence. The Guana staff was a terrific help in locating miscellaneous supplies. **Figure 1.** Nunber of seedlings/plot for nine species in the LiaoWei Ping fenced (UTM: NAD 27 333848 east, 2043688 north) and control (UTM: NAD 27 334098 east, 2043101 north) plots. The lower right graph is for all seedlings, regardless of species.

**Figure 2.** Nunber of seedlings/plot for nine species in the Harris Ghut fenced (UTM: NAD 27 333938 east, 2043006 north) and control (UTM: NAD 27 333940 east, 2042978 north) plots. The lower left graph is for all seedlings, regardless of species.

Figure 3. View of Liao Wei Ping fenced plot and surrounding area. The white line indicates the base of the fence. Inside of the fence is on the left.



Figure 1. Nunber of seedlings/plot for nine species in the LiaoWei Ping Site



Figure 2. Number of seedlings plot for nine species in the Harris Ghut site.



Figure 3. View of Liao Wei Ping fenced plot and surrounding area.



Department of Plant and Soil Science M.S. 2122 Lubbock, TX 79409-2122

### Skip,

I am writing you to express interest in going to Guana Island next year to conduct research on Paspalum vaginatum Swartz (seashore paspalum). I would like to determine the distribution of this species on the island with respect to environmental (soil compaction, soil moisture, soil pH, macro- and micronutrients, etc.) and topographical features. Soil compaction and soil moisture data could be obtained onsite, but soil samples will need to be dried and brought back to my lab in the U.S. in order to analyze for pH and nutrient content. In addition, I would like to collect seashore paspalum germplasm (rhizomes) in order to enter them into the turfgrass breeding program here at Texas Tech University. Compared to bermudagrass (Cynodon spp.), seashore paspalum can form a higher quality turf in reduced light conditions, in soils ranging in pH from 3.6 to 10.2, in waterlogged soils, and with fewer nitrogen fertility applications. It tolerates soil salinity levels as high as 54 dSm-1, a level at which most horticultural crops cannot survive. Furthermore, it can sequester heavy metals, and may be a candidate as a buffer or filter strip plant for phytoremediation of such substances. Seashore paspalum is indigenous to tropical and coastal areas worldwide; therefore, the genotype and phenotype of the populations present on the island should be unique. There is a significant amount of diversity within the species: coarse-textured (used for roadsides and forage) and finetextured ecotypes (used for golf courses, athletic fields, and home lawns). Adding more unique germplasm to the existing collections we have here at Texas Tech may significantly enhance our breeding efforts.

Several opportunities exist for the presentation and publication of this research. I will discuss this work (i.e. scientific posters and papers) at several national conferences (Crop Science Society of America, American Society of Agronomy, American Society of Horticultural Science, etc.) and during my annual turfgrass field day at Texas Tech University. A peer-reviewed manuscript will be submitted to an appropriate journal on the distribution of *Paspalum vaginatum* on Guana Island with respect to environmental and topographical features. Popular press articles could be written on these topics as well.

I thank you for entertaining this proposal and would gladly answer any further questions you may have. I am currently investigating the necessary permits required to bring both plant and soil samples back to the U.S.

Thanks,

Judd Her

Gerald Henry, Ph.D. Assistant Professor – Turfgrass Science Texas Tech University Office: (806)742-28 e-mail: gerald.henry@ttu.edu



A Variably Spinose Stick Insect, Agamemnon cornutus (Burmeister 1838). Attaining about three inches, this seems to be the most common of Guana's stick insects, or "walking sticks." Five species of stick insects are known from the Virgin Islands; four of these occur on Guana. Our biologists Lu, Ivie, and O'Reilly have teamed with the world authority at the British Museum, Paul Brock, to chronicle all the species all the way to food plants: see p. 65. But the job is far from done.