GUANA

2010

The Conservation Agency
Exploration, Education, and Research

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

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

14 June 2011

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

Dear Henry,

I am running late this year, but it's been a big one in terms of production, as you can see. Page numbers are top right in the text, as follows:

1. Cover Story: Blackpoll Warbler.

2-45. Here is Clint Boal's ornithological report, with three draft texts of papers in progress, including one on the Blackpolls.

46-56. The famous Mealybug paper by Al Wheeler et al. This came out after the BVI Ag. Dept. had sent a team to Guana to look for the Mealybugs. They found none, but how did they know to look? Mystery still unsolved....

57-58. Two butterflies are new to Guana. Richard Lutman caught them; he and Scott Miller wrote them up. These are the first additions to our butterfly fauna in a quarter century.

59-65. Two species of little "tortricid" moths (no common name) are added to our insect fauna by Vitor Becker (remember him? From Brazil) and a colleague.

66-70. Scott Miller found this 2007 paper with just one Guana species in 212 pages. Scott and Vitor collected others elsewhere in the VI and we got a nice acknowledgement, even if far out-of-date.

71-93. Gad Perry and Glenn Gerber produced a 2011 book chapter on BVI amphibians and reptiles with lots relevant to Guana.

94-96. Bob Powell, Bob Henderson, Gad Perry, and five more produced another 2011 ponderous book chapter, but only three pages are relevant to Guana.

97-100. Gad and his TTU students produced a dandy paper on Guana's 'guanas.

101-106. And Katharina Gebert contributes again; this time filling in the iguana gap with a published paper on the hatchlings -- hot off the press.

107-116. Our most ambitious boat day ever: to the nether isle of Sombrero, written up by grad student Lizzie Wright. I had been there in 1963 and found three species of lizards, two of dubious identity. Other herpetologists had been back since and failed to find all three, calling my data into question. I didn't go this time, but surely was gratified that they got all three and DNA samples to really identify them. This article ties back to our Cover Story because they also found lots of Blackpoll Warblers -- even farther East!

117-148. Finally, Deborah Davis, University of Leicester, had only our literature to go by but wrote a lot about Guana archeology. I find her stuff very interesting and encouraged her to write a proposal to come to Guana in 2012. Sadly, Holly Righter has Lewy body syndrome and I do not believe that she can lead this work. I have culled Deborah's thesis and end this report with her proposal.

2011 should be a great October on Guana, with a concentration on more iguana data collection and lots of entomology. I look forward to seeing you and Gloria (and CA Nadia) there!

All the Best,

Skip

COVER STORY

The Blackpoll Warbler is a classic Neotropical migrant. It nests and summers in the boreal forests of North America. Come autumn, Blackpolls flock up and depart the East coast; they fly out over the Atlantic all the way to the tropics. Typically, they used to land in the eastern Bahamas, hop to the Greater Antilles, refuel, and cross the Caribbean to South America for the winter. They were never recorded as far East as the BVI by our original ornithologists: Jonnie Fiske, D. N. Mirecki, or Rowan Roy. The first BVI Blackpolls were recorded in October, 1994, on Guana by Wayne Arendt. Since then they have become regular and numerous. Blackpolls are now our most abundant Neotropical migrant species: see Clint Boal's report. In 2010 they were abundant as far East as the Northeast extreme of the Lesser Antilles: Sombrero. See the story by Lizzie Wright in my report.

What can account for this shift? Well, if they stay in the boreal forests longer into the autumn and then depart from farther North, then they must also depart from farther East. For example, from Cape Cod or Nova Scotia instead of Cape May. Does this mean that Blackpoll Warblers, with bird brains, believe in global warming? Dr. Boal will not go quite this far, but I suggest it. At least they are not republicans.

2

ORNITHOLOGICAL MONITORING AND RESEARCH ON GUANA ISLAND, BRITISH VIRGIN ISLANDS

PROJECT REPORT 2010

Color-banded Bananaquit

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

15 May 2011

ORNITHOLOGICAL RESEARCH AND MONITORING ON GUANA ISLAND, BRITISH VIRGIN ISLANDS: PROJECT REPORT 2010

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 British 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 and conservation needs of Caribbean birds (e.g., Chipley 1991, Boal et al. 2006, Boal 2008a, Boal 2008b). This may be especially important as other islands undergo development and habitat loss, and as climate change affect the Caribbean region as a whole.

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 2010 Science Month. Here I provide data and discussion of the results of the 2010 field season, a review of research productivity stemming from avian research on Guana Island, and plans for the 2011 Science Month.

RESULTS AND DISCUSSION

Mist-Netting and Migrant Ecology

I operated a mist-netting array from 10 to 23 October 2010 for a total of 405 net-hours. During this mist-netting effort, I had a total capture rate of 0.92 birds/hour. This includes only new captures of birds (*n* = 287) and recaptures of previously banded birds (*n* = 87). Not included are captures of 44 birds that escaped from the net while being removed, or those for which we do not have bands (e.g., hummingbirds). Our capture rate of 0.92 birds/hour is the third highest achieved during the 2003 – 2010 science months, being only slightly exceeded in 2003 (1.0/hr) and 2005 (1.1/hr), and is almost double the lowest rate (0.51/hr) we experienced in 2009.

Among the resident birds captured, as usual, bananquits and pearly-eyed thrashers were the most commonly captured. We obtained new captures of 34 bananaquits and 37 recaptures of 23 individuals; territory residents were frequently recaptured more than once. Among the pearly-eyed thrashers, we captured 28 new individuals and had 24 recaptures of 21 individuals. We also had a good year in terms of black-faced grassquits, with 13 new captures and 15 recaptures of 10 individuals. More unique for Guana, we captured and banded 2 lesser Antillean bullfinches, a species not seen on Guana Island for several years. Numerous bullfinches were also observed foraging in open grassy areas along the trail between the Club and the Crab Cove Trail trailhead.

One of the reasons our capture rate was high in 2010 was due to a banner year in blackpoll warbler migration. We captured 185 migrating blackpoll warblers, breaking the record of 176 we set in 2005. To our knowledge, this is also the most blackpoll warblers ever captured at a single banding station in the Caribbean during one migration, and more migrating blackpolls have been captured and banded on Guana Island than any other island in the Caribbean. This emphasizes the importance and value of maintaining a migrant bird banding station on Guana Island.

The en route ecology of many neotropical migrant landbirds is poorly understood, and this is especially intriguing for Blackpoll Warblers in that they undertake the longest open water migration of any wood warbler species, departing from northeastern North America and making landfall in the Caribbean or South America. This migration requires substantial energy reserves and subjects blackpolls to unpredictable weather events which may influence survival. Few studies, however, have examined Blackpoll Warbler age ratios or condition while en route through the British Virgin Islands. Upon analysis of data over the last 8 migrations I found ratios of hatch-year birds to adults were 5 – 15% less than that reported at presumed continental departure locations. Average mass of all blackpolls was less than that reported at departure locations or at two other locations in the Caribbean, and hatch-year birds were consistently in poorer condition than adults. Poorer condition of blackpolls arriving in the British Virgin Islands is likely due to the islands being the first landfall after the transatlantic crossing, whereas blackpolls may have had opportunities for stopover prior to arrival at other Caribbean study locations. However, this suggests that the British Virgin Islands likely provide important stopover habitat as the first landfall location for some blackpolls arriving from the transatlantic migration route. A manuscript detailing the analysis is currently undergoing revision and will be submitted to a peer-reviewed journal in summer 2011.

Other migrant birds captured included 5 barn swallows, 3 indigo buntings, 3 northern parulas, an ovenbird, a rose-breasted grosbeak, and a yellow-billed cuckoo. Although some barn swallows are usually seen over Guana Island during migration, they are normally quite high over the island. In 2010 they were particularly abundant and frequently flying low over the club area and cottages, which allowed some to be captured in our nets.

Surveys

I did not conduct island wide surveys in 2010 as I had done in 2007 – 2009. That component of research has been completed I co-authored a manuscript that analyzes survey data from 1994 (Arendt 1995), 2001 (Wunderle 2001), and 2007-2009 (Boal 2008, 2009, this report). The manuscript is currently in review with the Journal of Caribbean Ornithology.

Bananaquit Demography

I have been color-banding bananaquits since 2005 to monitor pair bond fidelity and site fidelity. More importantly, I have been examining sex and age-specific survival and assessing this in context of weather patterns. This will allow predictions of Caribbean bird response to anticipated climate change patterns. My analysis is ongoing, but I have collaborated with Dr. Brent Bibles at Unity College to develop a model based on morphometrics (e.g., body measurements) that will allow us to determine sex of bananaquits. This is an important component of the study, in that we need to be able to differentiate the sexes for analysis. A draft manuscript is being prepared for submission. This will be a precursor to my manuscript documenting sex- and age-specific survival.

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, despite have nets of the wrong size. In 2010, I captured 2 quail-doves and recaptured one banded in 2009. Due to logistical constraints, I was not able to spend as much time attempting to capture quail-doves as I wanted. I anticipate putting a substantially greater amount of effort toward this in 2011 in order to get a large sample of individuals with which to model 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.

PROJECT PRODUCTIVITY

Papers in Development

Title: Autumn Monitoring of Resident Avifauna on Guana Island, B.V.I.
Authors: Clint Boal, Joseph Wunderle and Wayne Arendt
Status: Submitted to Caribbean Journal of Science
Attached as Appendix I

Title: Timing and Condition of Blackpoll Warblers Migrating Through the British Virgin Islands
Author: Clint Boal
Status: In final revision for submittal
Attached as Appendix II

Title: Morphometric-Based Sexual Determination of Bananaquits (*Coereba flaveola*)
Authors: Brent Bibles and Clint Boal
Status: In final revision for submittal
Attached as Appendix III

FUTURE WORK

Avian studies during Science Month in 2011:

- 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 400 net hours.
- Continuation of the demography study of bananaquits.
- Increased focus on 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 2010 season. Specifically, these were Tracy Estabrook, Erin Estabrook, Tom Willard, and Susan Valentine. 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.

7

Pictures from Guana Science Month 2010

Lesser Antillean Bullfinch (resident)

Ovenbird (migrant)

7a

Yellow-billed Cuckoo (migrant)

Northern Palula (migrant)

Blackpoll Warbler (migrant)

Clint Boal banding a blackpoll warbler with visiting class

Autumn Monitoring of Resident Avifauna on Guana Island, B.V.I.

Clint W. Boal, U. S. Geological Survey, Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock, TX 79409, Email: clint.boal@ttu.edu

Joseph M. Wunderle, Jr., International Institute of Tropical Forestry, USDA Forest Service, Sabana Field Research Station, HC 02 Box 6205, Luquillo, Puerto Rico 00773

Wayne J. Arendt, International Institute of Tropical Forestry, USDA Forest Service, Sabana Field Research Station, HC 02 Box 6205, Luquillo, Puerto Rico 00773

Suggested Running Head: Long term avifauna monitoring in the B.V.I.

APPENDIX I

Abstract.--Although the Caribbean region is considered a biodiversity hotspot and a priority for ecological conservation efforts, there is little information on population trends of West Indian landbirds. Such data may be especially important given unknown influences of anticipated climate change. We combined data collected from 3 studies spanning a 16-year period on a small island with a minimal human presence in the British Virgin Islands. Taken together the studies present a view of temporal patterns in avifaunal abundances and how environmental conditions may influence detectability. Our data indicate a stable avifaunal composition. Although abundances varied among surveys, the same species were detected with rare exceptions. Despite stability in species composition, the resident landbirds were variable in their individual detectabilities. Survey detections relatively mirrored net captures for some species, but are quite different for others. We suspect that this is likely due to differences in detectability due to species-specific behaviors mediated by environmental conditions, such as rainfall, during the month or months prior to our surveys. It is difficult to assess the influence of timing or amount of precipitation on bird detections rates among our surveys due to a lack of consistent collection of location-specific weather data in the British Virgin Islands. Our study suggests monitoring efforts conducted in concert with collection of site-specific climate data would facilitate improved interpretation of survey data and a better understanding of avian species response to climate mediated changes.

Key Words.-- bananaquit, birds, climate, monitoring, pearly-eyed thrasher, surveys, weather

INTRODUCTION

The Puerto Rican Bank, consisting of Puerto Rico, the US Virgin Islands, and the British Virgin Islands, is one of ten Endemic Bird Areas of the Caribbean (BirdLife International 2010). Within the Puerto Rican Bank, substantial research and monitoring attention have been directed at resident bird communities (Dugger et al. 2000, Faaborg and Arendt 1992, Faaborg et al. 1997) and the nearctic/neotropical migrant landbirds wintering in dry forest within the Guánica Biosphere Reserve, Puerto Rico (Dugger et al. 2004, Faaborg et al. 2007). In contrast, there is a paucity of data for the British Virgin Islands (Mayer and Chipley 1992, Boal et al. 2006, McGowan et al. 2007). Indeed, there is a well recognized need for avian monitoring programs among the Caribbean islands in general (Latta 2005, Haynes-Sutton and Wood 2008). Monitoring of avifaunal communities is important to identify the impact of environmental changes, and to facilitate assessments of the loss, habituation, recovery or expansion of highly vulnerable, often endemic species (Arendt et al. 1997, Hilton et al. 2003, Dalsgaard et al. 2007). Monitoring may be especially important given likely environmental changes that are anticipated to occur in association with changing climate. For example, hurricanes are known to have negative influences on migrant and resident landbirds (Wiley and Wunderle 1993, Wunderle 2005). Hurricane events have increased over the last century (Martin and Weech 2001) and the prognosis is for an increased frequency and intensity of hurricanes due to warmer sea surface temperatures associated with climate change (Emanuel 2005).

APPENDIX I

Most islands in the Caribbean are not without some human presence and the influences of anthropogenic activities (e.g., landscape conversion, introduction of non-native species) on avifaunal trends are important factors. However, islands with little human disturbance would allow assessment of environmental influences while keeping the confounding factors of local anthropogenic activities to a minimum. Under this guiding concept, we combined data collected from 3 different studies spanning a 16-year period on a small Caribbean island with a minimal human presence. The studies were conducted at different times by different researchers so there are some slight inconsistencies in methodological approaches. However, taken together the studies present a view of temporal patterns in avifaunal abundances and, perhaps more importantly, how environmental conditions may influence detectability.

MATERIALS AND METHODS

We conducted bird surveys on Guana Island (18° 30′ N, 64° 30′ W), a small (3.1 km^2) island located approximately 0.5 km immediately north of Tortola, British Virgin Islands (BVI). The BVI are located approximately 150 km east of Puerto Rico. Temperature in the BVI normally ranges from 28–33 °C, with relative humidity fairly constant at about 78% (Lazell 2005). Annual mean rainfall for Guana Island is estimated at 92 cm, but data are limited and the long-term average may be lower (Lazell 2005).

Guana Island is privately owned and has undergone little development or fragmentation. A small resort area occupies approximately 3% of the island; the remainder of the island is a nature preserve covered by subtropical vegetation, the majority of which is subtropical dry forest (90%) and mesic ghaut forest (5%) (Lazell 2005). The primary native vegetation on Guana Island is *Tabebuia heterophylla*, *Bursera simaruba*, *Pisonia subcordata*, *Conocarpus erectus*, *Plumeria alba*, *Acacia muricata*, and *Coccoloba uvifera*. *Leucaena leucocephela* is common in disturbed areas. Other introduced species include *Cocos nucifera*, *Tamarinda indica*, and *Delonix regia* (Lazell 2005).

We used fixed-radius points (Hutto et al. 1986) to survey landbirds on Guana Island during the month of October in 1994 (Arendt 1995), 2001 (Wunderle 2001), and 2007, 2008, and 2009 (Boal 2010). Surveyors recorded all birds detected by sight and or sound and classified distance as less than or greater than 25-m from the survey point. Birds in flight were not included in the analyses. Surveys were conducted for 10 min at each point during the 1994 and 2001 surveys, and for 7 min during the 2007–2009 surveys.

We used a hip-chain and biodegradable string to locate survey points at 100-m intervals along parallel transects placed 100 m across the entire island in 1994. In 2001 and 2007-2009 we took advantage of a network of trails across Guana Island. The trail system allows access to all vegetation communities and areas on the island and made surveys more logistically feasible given the rugged topography and thick vegetation. A hip-chain was also used in 2001 to locate survey points at 100-m intervals along the trails. In 2007, survey points were paced at 150 pace intervals which, based on GPS coordinates, resulted in survey points located approximately 120 to 150 m apart. Survey-point coordinates were recorded with a handheld GPS unit in 2007 and used in 2008 and 2009. Ultimately, the same sections of trail and, hence, the same areas, were sampled in all surveys, which facilitates comparison of data among survey years.

Caribbean birds can be counted during any season, but surveys should be conducted at the same time annually using the same protocol to monitor population changes (Wunderle 1994, Faaborg et al. 2000). Surveys of bird populations also need to take into account species-specific detection rates. Distance sampling (Buckland et al. 2001) has become a method of choice for estimating avian abundance, density and population size in context of different detectabilities. However, meeting assumptions for distance sampling can be challenging. A minimum of 75–100 detections per species within a cover type is necessary for estimation of valid detection functions when using point counts (Buckland et al. 2001). Furthermore, a critical component of distance sampling is accurate estimation of distance (Buckland et al. 2001). Auditory detections can comprise over 80% of songbird detections in tropical forests (Scott et al. 1981). Based on trials with song simulation, Alldredge et al. (2007a) estimated observers detected only 19%–65% of the true bird population, and suggested a lack of control under normal field survey conditions likely makes estimates even more variable. Furthermore, trials have revealed substantial uncertainty in distance estimation based on aural detections and that point count estimates based on distance methods are likely biased (Alldredge et al. 2007b).

Failure to meet criteria of distance sampling methodology, such as adequate sample size, and suspicion of bias due to the majority of detections of forest birds being derived from aural cues, compromise use of the method under some conditions and in certain habitat types. Project constraints that limit the number of species whose numbers can be reliably estimated by detectability methods dictate that indices be used as an alternative (Thompson et al. 1998). Therefore, we present our data as an index of relative abundance, not actual density. Indices do not allow for precise estimates of population densities, but they do allow for comparisons between years within the same study area (Hutto and Young 2002).

Based on our survey data, we calculated mean number of detections within 25-m fixed-radius points. We used Kruskal–Wallis tests to compare median number of detections within 25 m among years. We conducted these analyses for two variables, the number of individuals and species detected, for resident landbird species only. We used multiple comparisons of mean rank to examine differences among years (Siegel and Castellan 1988). We then examined species-specific patterns of detection for those species that were detected ≥50 times. During each October of 2007–2009, CWB operated a banding station on Guana Island. This provided us the opportunity to compare survey detection rates to capture rates. Nets were located in the same locations along a northeast–southwest ridge on the west side of the island at ca. 70 m elevation each year. All nets were placed in subtropical dry forest and in human altered areas of the island hotel. As many as 12, 32-mm mesh nets were opened for an average of 422 (± 57 SE) h each year (Boal 2010). The banding station occupied only a small area of the island, whereas surveys were island wide. However, net captures provide a measure of relative abundance independent of surveys based on aural/visual detections (Faaborg et al. 2004). Therefore, for the 2007–2009 data, we compared survey data to net capture rates to assess common patterns in numerical trends. To examine similarities or differences between net captures and surveys, for each method we ranked the relative abundance of each species captured or detected, depending on method, over the three study periods in 2007–2009. This resulted in a ranking of 1–15 (3 years x 5 species) for each method. We then took the absolute values of the difference of the ranks of the two methods for each species within a given year and calculated the 95% Confidence Interval on these numbers. If the two methods are equivalent the interval would be expected to include zero. Failure of inclusion of zero may indicate detection probabilities varied between methods, among years and species, the methods are equivalent but sampled different populations due to restricted area sampled by the mist-netting, or a combination of these factors. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

RESULTS

We analyzed October avian survey data collected at 60 points in 1994, 65 points in 2001, and at 58, 53, and 57 points in 2007–2009, respectively (Table 1). The surveys in 2007–2009 were at the same points each year, but differed in number due to weather or other factors preventing complete surveys of all 58 points.

There was a significant difference among surveys in terms of total individuals of resident species detected ($H_{4,\,293} = 101.87$, $P < 0.0001$) and number of resident species detected ($H_{4,\,293} = 89.97$, $P < 0.0001$). Pairwise comparisons of total detections indicated significant differences ($P < 0.05$) between 1994 and all other years, and between 2001 and 2007, 2007 and 2009, and 2008 and 2009. A pairwise comparison of species detected indicated significant differences ($P < 0.05$) between 1994 and 2007, 2008, and 2009; detections in 2001, 2007 and 2008 were all significantly different from those in 2009. Essentially, 2009 was consistently lower in detections of both total individuals and total resident species compared to all other survey years (Table 2).

Because we restricted our analysis to only those species for which we had at least 50 detections, our analysis included Bananaquit (*Coereba flaveola*; $n = 307$), Pearly-eyed Thrasher (*Magarops fuscatus*; $n = 306$), Caribbean Elaenia (*Elaenia martinica*; $n = 70$), Zenaida Dove (*Zenaida aurita*; $n = 70$), and Black-faced Grassquit (*Tiaris bicolor*; $n = 54$); no other resident landbird was detected 50 or more times (Table 1).

Detections of Bananaquit varied among the survey periods ($H_{4,\,293} = 23.36$, $P = 0.0001$) with differences between 1994 and 2009 ($P = 0.001$) and 2007 and 2009 ($P = 0.0015$). Mean detections of Bananaquit were similar and highest in 1994 ($\bar{x} = 1.38 \pm 0.13$) and 2007 ($\bar{x} = 1.34 \pm 0.14$) but lowest in 2009 ($\bar{x} = 0.56 \pm 0.14$) (Table 2). Differences among years were more pronounced for the Pearly-eyed Thrasher ($H_{4,\,293} = 102.39$, $P < 0.0001$). The only survey periods between which differences ($P < 0.05$) were not detected among thrashers were those of 1994 and 2001, and 2008 and 2009. In general, detections of Pearly-eyed Thrasher were highest in 1994 ($\bar{x} = 1.97 \pm 0.12$) and progressively decreased to the lowest detection rate in 2009 ($\bar{x} = 0.16 \pm 0.12$) (Table 2).

There were no statistical differences among years in detections of Caribbean Elaenia ($H_{4,\,293} = 8.97$, $P = 0.062$), Zenaida Dove ($H_{4,\,293} = 8.17$, $P = 0.080$), or Black-faced Grassquit ($H_{4,\,293} = 9.19$, $P = 0.056$). However, we suspect this is likely due to sample sizes. Detections for Black-faced Grassquit in 2009 was only 34 % of that in 2007 and 32% of that in 2008 (Table 2, Fig. 1). Similarly, detections for Zenaida Dove in 2009 were only 33% of that in 2007 and 26% of that in 2008 (Table 2, Fig. 1). Differences among years for elaenias were not as dramatic, but did suggest a consistent declining trend from 1994 to 2009 (Table 2, Fig. 1).

Mist net captures were not consistent among years for most resident species (Fig. 2). Bananaquit was the most frequently captured resident species in all years, with 19.8/100 net-h in 2007, a dip to 13.7/100 net-h in 2008, then up to 16.3/100 net-h in 2009. Pearly-eyed Thrasher, the second most frequently captured resident species, demonstrated a similar pattern with 11.5 captures/100 net-h in 2007, a drop to only 4.1/100 net-hin 2008, then 9.5/100 net-h in 2009. Mist-net captures were relatively consistent, if low, for Zenaida Dove (2.2–3.3/100 net-h). Captures of Black-faced Grassquit were similar in 2007 and 2009 (2.9 and 3.4/100 net-h), but almost double in 2009, with 6.3 birds per 100 net-h. Caribbean Elaenia was the only resident species that demonstrated a consistent decrease in captures, with 2.2, 0.9, and 0.6/100 net-h, in 2007, 2008, and 2009, respectively. In general, Bananaquit and Pearly-eyed Thrasher were captured in greater numbers in 2007 and 2009, with lows in 2008 (Fig. 2). In contrast, Zenaida Dove and Black-faced Grassquit were captured in similar numbers in 2007 and 2009, but in higher numbers in 2008 (Fig. 2).

We found evidence that the methods of surveys and net captures are not equitable in assessing population trends. The mean rank was 2.27 (± 1.89) with a 95% Confidence Interval (1.22, 3.31) that did not include zero. This suggests net captures and surveys were not consistent in detecting the five most commonly detected species.

DISCUSSION

Our combined survey data indicate Guana Island appears to be stable in terms of avifaunal composition. Although abundance varied among surveys, the same species were detected with rare exception. Typically, these discrepancies were of low density species, such as American Kestrel (*Falco sparverius*) and Red-tailed Hawk (*Buteo jamaicensis*) and, as such, are not unexpected. However, Arendt (1995) observed an Antillean Mango (*Anthracothorax dominicus*) which has not been detected during surveys since; and based on prior captures and subspecies verification, Boal (2010) detected the presumably resident Caribbean form of Yellow Warbler (*Dendroica petechia cruziana*).

Despite stability in species composition, Caribbean resident landbirds are variable in their individual detectabilities. For example, Mangrove Cuckoo, known for being secretive, had high detectability ratios in 1994 due to calling associate with breeding (Arendt 1995). In contrast Wunderle (2001) did not detect the species on surveys, and Boal (2010) detected very few, and in only two of three years. However, based on call-playback surveys during the same 3-yr period, the species was considered abundant on the island (T.S. Estabrook, pers. com.). As Wunderle (2001) suggested, some of these differences may be associated with differences in rainfall prior to the surveys or seasonal hurricane events. The 1994 survey was conducted at the end of a wet period that, presumably, resulted in more species breeding during the survey period (Arendt 1995, Wunderle 2001). The high detection rates Arendt (1995) found for Zenaida Dove and Common Ground-Dove, due largely to their calling associated with breeding, have not been approached in systematic surveys since. When making qualitative comparisons between surveys and net captures in 2007–2009, survey detections relatively mirror net captures for Zenaida Dove, Caribbean Elaenia, and Black-faced Grassquit (Fig. 1, Fig. 2). However, survey data for Bananaquit and Pearly-eyed Thrasher are quite different from net capture data (Fig. 1, Fig. 2). We suspect that this is likely due to species-specific differences in detectability, possibly as a result of behaviors mediated by, as yet uncertain, environmental conditions.

It is difficult to assess the influence of timing or amount of precipitation on bird detection rates among our surveys due to a lack of consistent collection of location-specific weather data in the British Virgin Islands. The closest weather station to Guana Island is located 40 km to the southeast at Charlotte Amalie on Saint Thomas. Thus, rainfall conditions on Guana Island are derived more from onsite assessments by the researchers during October than by actual measures. The survey in 1994 was conducted during what was considered a wet year, whereas the 2001 survey was conducted at the end of a long dry period (Wunderle 2001). Surveys in 2007, 2008, and 2009 were considered normal, wet and dry.

APPENDIX I

The Caribbean region has experienced an increase in average annual temperatures over the last century, and is anticipated to experience a further increase of over 2 °C this century (U.S. Department of Interior 2010). In addition to increased temperature, a decades old drying trend is also expected to continue in the Caribbean, resulting in less summer precipitation (Neelin et al. 2006, U.S. Department of Interior 2010). Added to this is the expected increase in frequency and severity of tropical storm events due to warming sea waters. These environmental changes may have consequences for birds resident to the Caribbean islands. Even though monitoring is primarily a passive means of identifying population change, and often fails to provide insight as to causes of those changes, it is an important tool for initiating and evaluating conservation plans. As Latta (2005) and Haynes-Sutton and Wood (2008) have stated, monitoring of Caribbean avifauna is sorely lacking. Because environmental conditions are likely to have a substantial influence on both detection and population size of resident landbirds, survey methods need to be suitable for addressing these issues. Our study suggests monitoring efforts conducted in concert with collection of site-specific climate data would facilitate improved interpretation of survey data and a better understanding of avian species response to environmental and climate mediated changes. This would enable robust modeling of time-specific influences of climate conditions on behavior and, therefore, detectability of resident bird species. Such modeling efforts would allow more confidence in interpretation of monitoring data and identification of factors driving population trends.

Acknowledgments.--Our thanks to the Jarecki family, the Falconwood Foundation, and The Conservation Agency for their continued access to Guana Island and support for this research, and to the USGS Cooperative Research Units for facilitating this research. Special thanks to J.D. Lazell and G. Perry for coordinating research opportunities on Guana Island, and to the many volunteers that have assisted in the ornithological research program on the island. This manuscript benefitted from the thoughtful reviews and suggestions of B. Bibles and G. Perry. The 1994 and 2001 research was conducted in cooperation with the University of Puerto Rico.

LITERATURE CITED

Alldredge, M. W., T. R. Simons, and K. H. Pollock. 2007a. Factors affecting aural detections of songbirds. *Ecol. Appl.* 17:948-955.

Alldredge, M. W., T. R. Simons, and K. H. Pollock. 2007b. A field evaluation of distance measurement error in auditory avian point count surveys. *J. Wildl. Manage.* 71:2759-2766.

Arendt, W. J. 1995. Assessment of avian relative abundance on Guana Island, British Virgin Islands, with emphasis on the pearly-eyed thrasher. *Final Rept. The Conservation Agency*, 10 February 1995.

Arendt, W. J., D. W. Gibbons, and G. Gray. 1997. Status of the Volcanically Threatened Montserrat Oriole, *Icterus oberi*. *Bird Conserv. Int.* 9:351-372.

BirdLife International. 2003. BirdLife international data zone. Cambridge, UK: BirdLife International. http://www.birdlife.org/datazone/home.

Boal, C. W. 2010. Ornithological monitoring and research on Guana Island, British Virgin Islands. *Proj. Rept. 2009 The Conservation Agency*, 29 April 2010.

Boal, C. W., F. C. Sibley, T. S. Estabrook, and J. Lazell. 2006. Insular and migrant species, longevity records, and new species records on Guana Island, British Virgin Islands. *Wilson J. Ornithol.* 118:218-224.

APPENDIX I

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, L. Thomas. 2001. *Introduction to distance sampling: estimating abundance of biological populations*. Oxford University Press, New York, New York, USA.

Dalsgaard, B., G. M. Hilton, G. A. L. Gray, L. Aymer, J. Boatswain, J. Daley, C. Fenton, J. Martin, L. Martin, P. Murrain, W. J. Arendt, D. W. Gibbons and J. M. Olesen. 2007. Impacts of a volcanic eruption on the forest bird community of Montserrat, Lesser Antilles. *Ibis* 149:298-312

Dugger, K. M., J. Faaborg, and W. J. Arendt. 2000. Rainfall correlates of bird populations and survival rates in a Puerto Rican dry forest. *Bird Popul.* 5:11-27.

Dugger, K. M., J. Faaborg, W. J. Arendt, and K. A. Hobson. 2004. Understanding survival and abundance of overwintering warblers: does rainfall matter? *Condor* 106:744-760.

Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 436:686-688.

Faaborg, J., and W. J. Arendt. 1992. Rainfall correlates of bird population fluctuations in a Puerto Rican dry forest: a 15-year study. *Ornitología Caribeña* 3:10-19.

Faaborg, J., W. J. Arendt, and K. M. Dugger. 2000. The Guánica, Puerto Rico, bird monitoring project. *Bird Popul.* 5:102-111.

Faaborg, J., W. J. Arendt, and K. M. Dugger. 2004. Bird population studies in Puerto Rico using mist nets: General patterns and comparisons with point counts. *Stud. Avian Biol.* 29:144-150.

Faaborg, J., K. M. Dugger, and W. J. Arendt. 2007. Long-term variations in the winter resident bird community of Guánica Forest, Puerto Rico: lessons for measuring and monitoring species richness. *J. Field Ornithol.* 78:270-278.

Faaborg, J., K. Dugger, W. J. Arendt, B. Woodworth, and M. Baltz. 1997. Population declines of the Puerto Rican Vireo in Guánica Forest. *Wilson Bull.* 109:195-202.

Haynes-Sutton, A. and C. Wood. 2008. Report of the monitoring working group. *J. Caribb. Ornithol.* 21:95-96.

Hilton, G. M., P. W. Atkinson, G. A. L. Gray, W. J. Arendt, and D. W. Gibbons. 2003. Rapid decline of the volcanically threatened Montserrat Oriole. *Biol. Conserv.* 111:79-89.

Hutto, R. L., S. M. Pletschet, and P. Hendricks. 1986. A fixed–radius point count method for non-breeding and breeding season use. *Auk* 103:593-602.

Hutto, R. L. and J. S. Young. 2002. Regional landbird monitoring: perspectives from the Northern Rocky Mountains. *Wildl. Soc. Bull.* 30:738-750.

Latta, S. 2005. Bird monitoring working group of the SCSCB: towards all-species monitoring and expanded training opportunities in the Caribbean. *J. Caribb. Ornithol.* 18:109-114.

Lazell, J. D. 2005. *Island: fact and theory in nature*. University of California Press, Berkeley, California, USA.

Martin, H. C. and P. S. Weech. 2001. Climate change in the Bahamas? Evidence in the meteorological records. *Bahamas J. Sci.* 5:22-32.

Mayer, G. C. and R. M. Chipley. 1992. Turnover in the avifauna of Guana Island, British Virgin Islands. *J. Anim. Ecol.* 61:561-566.

McGowan, A., N. K. Woodfield, G. Hilton, A. C. Broderick, and B. J. Godley. 2007. A rigorous assessment of the avifauna of a small Caribbean island: a case study in Andegada, British Virgin Islands. *Caribb. J. Sci.* 43:99-116.

Neelin, J. D., M. Münnich, H. Su, J. E. Meyerson, and C. E. Holloway. 2006. Tropical drying trends in global warming models and observations. *Proc. Natl. Acad. Sci. USA* 103:6110-6115.

Scott, J. M., F. L. Ramsey, and C. B. Kepler. 1981. Distance estimation as a variable in estimating bird numbers from vocalizations. *Stud. Avian Biol.* 6:334-340.

Siegel, S., and N. J. Castellan. 1988. *Nonparametric statistics for the behavioral sciences* (2nd ed.) McGraw-Hill, New York, New York, USA.

Thompson, W. L., G. C.White, and C. Gowan. 1998. *Monitoring vertebrate populations.* Academic Press, San Diego, California, USA.

U.S. Department of Interior. 2010. *The state of the birds 2010 report on climate change, United States of America.* North American Bird Conservation Initiative, U.S. Committee, U.S. Department of the Interior, Washington, DC., USA.

Wiley, J. W. and J. M. Wunderle, Jr. 1993. The effects of hurricanes on birds with special reference to Caribbean islands. *Bird Conserv. Int.* 3:319-349.

Wunderle, J. M., Jr. 1994. Census methods for Caribbean land birds. U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, New Orleans, LA. *Gen. Tech. Rep. SO-98.* 26 p.

Wunderle, J.M., Jr. 2001. Avian surveys on Guana Island, B.V.I. (4-10 October 2001). *Final Rept. The Conservation Agency*, 20 November 2001.

Wunderle, J.M., Jr. 2005. Hurricanes and the fate of Caribbean birds. *J. Caribb. Ornithol.* 18:94-96.

Wunderle, J.M. Jr. and W.J. Arendt. 2010. Avian studies and research opportunities in the Luquillo Experimental Forest: a tropical rain forest in Puerto Rico. *Forest Ecology*: In press.

18

APPENDIX I

Table 1. Mean detections within 25-m radius survey points for surveys conducted during October surveys on Guana Island, 1994, 2001, and 2007–2009.

Species	1994	2001	2007	2008	2009
American Kestrel	0	0	0.03	0	0
Mangrove Cuckoo	0.12	0	0.02	0	0
Smooth-billed Ani	0.02	0	0	0	0.02
Scaly-naped Pigeon	0.08	0.11	0.09	0.08	0.04
Zenaida Dove	0.43	0.17	0.12	0.09	0.05
Common Ground-Dove	0.15	0	0	0.04	0
Bridled Quail-Dove	0.03	0.11	0.05	0.04	0
Green-throated Carib	0.22	0.23	0.03	0.06	0.05
Antillean Crested Hummingbird	0.17	0.05	0.1	0.09	0
Antillean Mango	0.02	0	0	0	0
Gray Kingbird	0.13	0.08	0.03	0.08	0.02
Caribbean Elaenia	0.3	0.18	0.22	0.15	0.11
Pearly-eyed Thrasher	0.87	0.85	0.47	0.38	0.16
Northern Mockingbird	0	0	0	0	0
Bananaquit	0.75	0.57	0.74	0.64	0.46
Yellow Warbler	0	0	0	0	0.02
Black-faced Grassquit	0.12	0.15	0.17	0.19	0.02

19

APPENDIX I

Table 2. Average and SE for detections of common resident landbirds within 25-m radius plots during October surveys, 1994, 2001, 2007–2009 on Guana Island, British Virgin Islands.

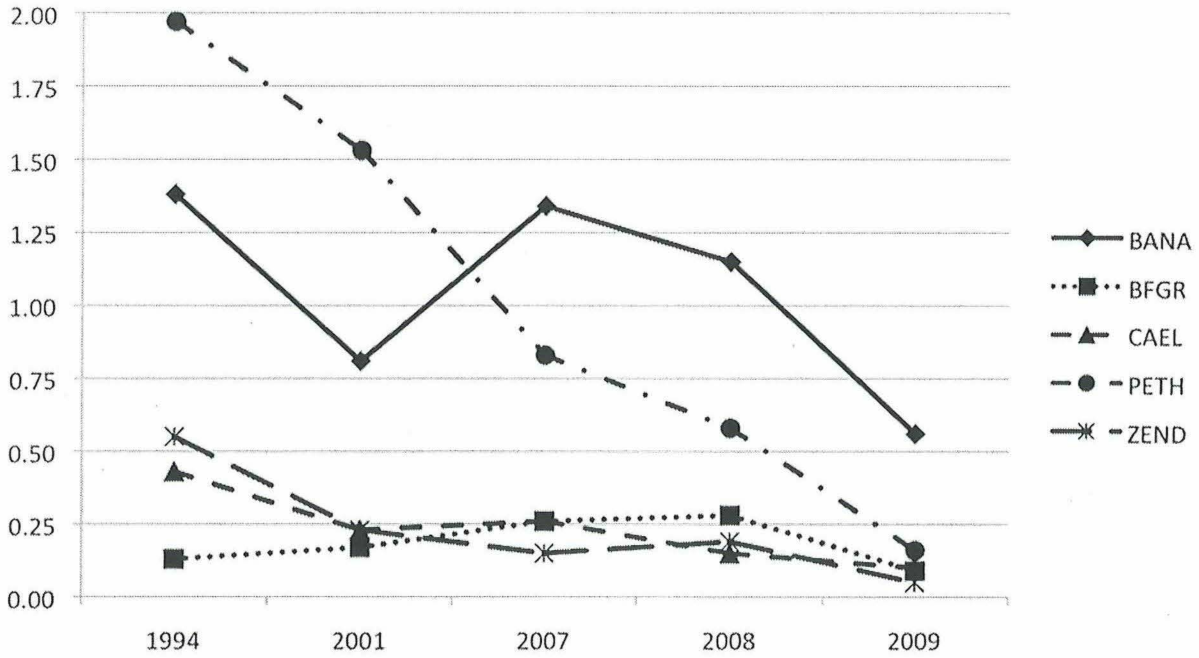
	Bananaquit	Black-faced Grassquit	Caribbean Elaenia	Pearly-eyed Thrasher	Zenaida Dove
1994	1.38 ± 0.13	0.13 ± 0.07	0.43 ± 0.07	1.97 ± 0.12	0.55 ± 0.07
2001	0.81 ± 0.13	0.17 ± 0.07	0.23 ± 0.07	1.53 ± 0.12	0.23 ± 0.07
2007	1.34 ± 0.14	0.26 ± 0.07	0.26 ± 0.07	0.83 ± 0.12	0.15 ± 0.07
2008	1.15 ± 0.14	0.28 ± 0.08	0.15 ± 0.07	0.58 ± 0.13	0.19 ± 0.07
2009	0.56 ± 0.14	0.09 ± 0.07	0.10 ± 0.07	0.16 ± 0.12	0.05 ± 0.07

APPENDIX I

Figure 1. Mean detections for Bananaquit (BANA), Black-faced Grassquit (BFGR), Caribbean Elaenia (CAEL), Pearly-eyed Thrasher (PETH), and Zenaida Dove (ZEND) per 25-m fixed-radius point-counts in October on Guana Island, BVI.

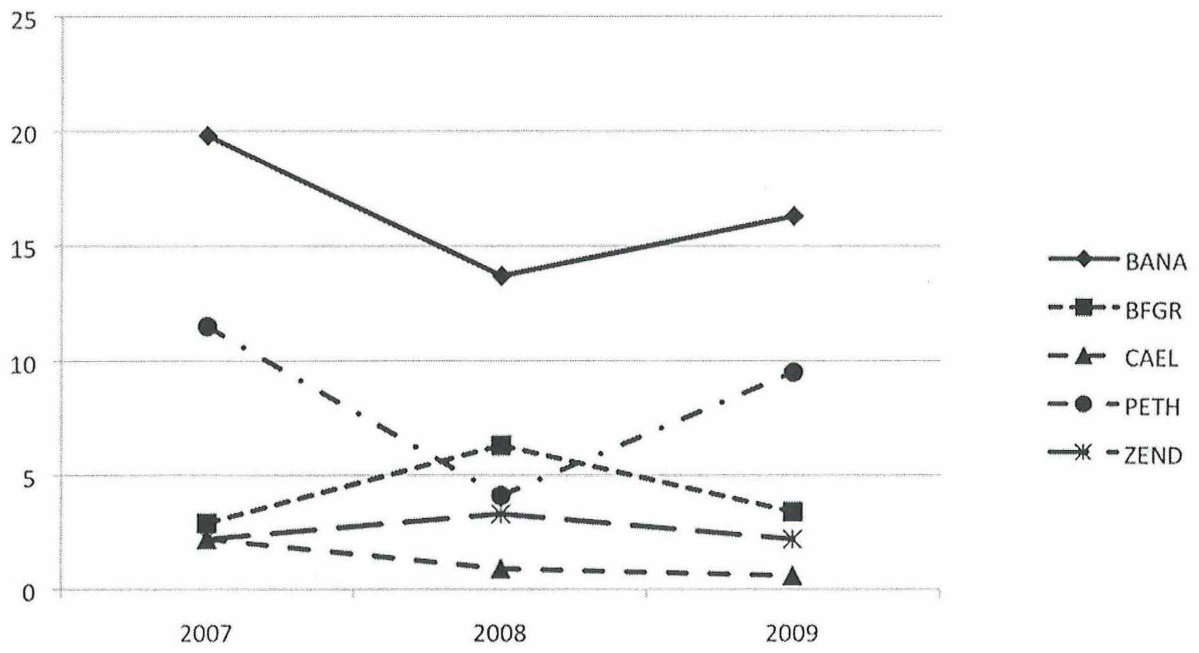
Figure 2. Net [NO HYPHEN] captures per 100 h for Bananaquit (BANA), Black-faced Grassquit (BFGR), Caribbean Elaenia (CAEL), Pearly-eyed Thrasher (PETH), and Zenaida Dove (ZEND) in October (2007–2009) on Guana Island, BVI. Values do not include recaptures within the same year.

APPENDIX I


2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1994
2001
2007
2008
2009
BANA
BFGR
CAEL
PETH
ZEND

22

APPENDIX I



APPENDIX II

Timing and Condition of Blackpoll Warblers Migrating Through the British Virgin Islands

Clint W. Boal, U. S. Geological Survey, Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock, TX 79409

Abstract: The en route ecology of many neotropical migrant landbirds is poorly understood. The en route ecology of Blackpoll Warblers is especially intriguing in that they undertake the longest open water migration of any wood warbler species, departing from northeastern North America and making landfall in the Caribbean or South America. This migration requires substantial energy reserves and subjects blackpolls to unpredictable weather events which may influence survival. Studies assessing migrating blackpolls have largely been limited to banding stations across the North American continent. Few studies, however, have examined Blackpoll Warbler age ratios or condition while en route through the Caribbean region. Over 8 autumn migrations I found ratios of hatch-year to adult Blackpoll Warblers passing through the British Virgin Islands were 5 – 15% less than that reported at presumed continental departure locations. Average mass of all blackpolls was less than that reported at continental departure locations or at two other locations in the Caribbean, and hatch-year birds were consistently in poorer condition than adults. Poorer condition of blackpolls arriving in the British Virgin Islands is likely due to the islands being the first landfall after the transatlantic crossing, whereas blackpolls may have had opportunities for stopover prior to arrival at other Caribbean study locations. However, this suggests that the British Virgin Islands likely provide important stopover habitat as a first landfall location for blackpolls arriving from the transatlantic migration route.

The breeding ecology of many neotropical migrant land birds is relatively well studied, but there is a substantive lack of information for their en route ecology during migration (Rappole 1995, Latta et al. 2003, Heglund and Skagen 2005). Understanding en route ecology of migrant land birds is foundational to developing a more complete understanding of life histories and critical to developing sound conservation strategies (Rappole 1995, Heglund and Skagen 2005). Long-distance migration requires both the physiological ability to store large energy reserves and the availability of suitable stopover habitat to replenish expended energy stores, all while crossing broad spatial scales over relatively short temporal periods (Heglund and Skagen 2005, Kelly and Hutto 2005). Sex, age, and physiological condition may all relate to migration timing, success, and survival (Rappole 1995, Butler 2000, Kelly and Hutto 2005). Unfavorable weather may force migrants to expend their energy reserves more quickly, change direction, or seek stopover locations (McNair et al. 2002). Such situations may be particularly influential on migrants during long-distance over-water flights that afford few opportunities to land if necessitated by weather or energy depletion. For example, breeding abundances of 3 migrant species were negatively correlated with previous autumn storm frequency in the Caribbean (Butler 2000).

APPENDIX II

Several studies have examined various aspects of neotropical migrant land bird ecology during spring (Moore et al. 1990, Kuenzi et al. 1991, Rodewald and Brittingham 2007) and autumn (Morris et al. 1996, Woodrey and Moore 1997, Davis 2001) on mainland and near shore islands of North America. Additionally, there are numerous studies of over-wintering neotropical migrant land birds in the Caribbean (e.g., Ewert and Askins 1991, Wunderle 1995, Dugger et al. 2004), but studies are lacking for en route migrants through the region (Latta et al. 2003).

Each autumn, Blackpoll Warblers (*Dendroica striata*) undertake the longest migration (up to 8,000 km) of any North American warbler (Hunt and Eliason 1999). Blackpolls distributed across the coniferous forests of northern North America first migrate eastward to congregate along the northeastern seaboard (Morse 1989, Hunt and Eliason 1999). From the northeastern seaboard, blackpolls depart on an approximately 2,500 – 3,500 km transatlantic flight , making landfall among the Caribbean islands (Williams et al. 1978, Nisbet et al. 1995, Hunt and Eliason 1999) and continuing on to their wintering grounds in South America (Hunt and Eliason 1999). During migration through the Caribbean region, blackpolls are considered a common transient (i.e., present in moderate numbers) in the Bahamas and the large islands of the Western Antilles (e.g., Cuba, Puerto Rico) (Arendt 1992, Raffaele et al. 1998). In contrast, they were reported as casual to uncommon (e.g., few to small numbers) transients among most of the small islands making up the north – south laying Lesser Antilles (e.g, Antigua, Dominica, St. Lucia) chain of the eastern Caribbean (Arendt 1992, Raffaele et al. 1998). At the northern most extent of the Lesser Antilles, Blackpoll Warblers were considered uncommon transients in the U.S. Virgin Islands with no data available for the nearby British Virgin Islands or for many of the Lesser Antilles (Arendt 1992).

Latta and Brown (1999) point out that, despite the importance of understanding stopover habitat and other factors of migration (Moore et al. 1990, Hagan and Johnston 1992), the majority of papers addressing Blackpoll Warbler migration have focused on the migratory route used (see Murray 1989, Nisbet et al. 1995). Hunt and Eliason (1999), Latta et al. (2003) and McNair et al. (2002) have called for a more systematic sampling of blackpolls and other warblers in the West Indies, including a focus on migration timing, movements, and physiological condition. However, little additional information has been compiled since McNair et al. (2002). Herein I report annual variation in numbers captured, timing of migration, age ratios, and physiological conditions of migrant Blackpoll Warblers during autumn migrations from 2003 – 2010 in the British Virgin Islands.

Methods

My study site was on Guana Island (18° 30′ N, 64° 30′ W), a small (3 km^2) island located approximately 0.5 km north of Tortola, British Virgin Islands. The British Virgin Islands, along with the U. S. Virgin Islands, are a chain of approximately 76 islands and cays located roughly 150 km east of Puerto Rico that, combined with Puerto Rico, constitute the Puerto Rican Bank (Lazell 2005). Temperature in the British Virgin Islands normally ranges from 28–33°C, with annual mean rainfall for Guana Island estimated at 92 cm (Lazell 2005).

Guana Island is topographically rugged with an elevation range from sea level to 246 m. It is privately owned and has undergone little development or habitat fragmentation. A resort area occupies approximately 3% of the island; the remainder of the island is a *de facto* nature preserve. The majority of the island is vegetated with approximately 90% subtropical dry forest and 5% mesic forest. The primary native vegetation on Guana Island is *Tabebuia heterophylla*, *Bursera simaruba*, *Pisonia subcordata*, *Conocarpus erectus*, *Plumeria alba*, *Acacia muricata*, and *Coccoloba uvifera*. *Leucaena leucocephela* is common in disturbed areas. Other introduced species include *Cocos nucifera*, *Tamarinda indica*, and *Delonix regia* (Lazell 2005).

I have operated a banding station on Guana Island each October of 2003 - 2010. As many as 12, 32-mm mesh nets were opened for an average of 422 (± 57 SE) h each year (Boal 2010). Nets were open from 0630 - 1100 hrs; nets were open all daylight hours during fallouts. The duration of netting and number of nets opened were contingent upon local meteorological conditions and the number of individuals to assist with net monitoring. Nets were located in the same locations along a northeast–southwest ridge on the west side of the island at ca. 70 m elevation each year. Exceptions occurred when vegetation changes or operations of the island staff necessitated slight shifts of location. The location takes advantage of south and south-east bound migrants crossing a north-west facing saddle of the island.

All captured birds were placed in cotton holding bags and transported to a central banding station for processing. I determined species identification, age and sex to the extent possible based on Pyle (1997) and Raffaele et al. (1998). I recorded unflattened wing chord with a stopped wing ruler. In 2003 I weighed birds with Pesola spring scales, but measured mass with an electronic scale accurate to 0.1 g (Ohaus Model CS200) from 2004 – 2010. Because of a lack of precision with the spring scale, I only used data from 2004 onward for analysis of mass and other physiological characteristics. I estimated fat using the five categories presented by the North American Banding Council (2001). I also categorized the condition of breast muscle as emaciated, poor, fair, and good. An aluminum leg band provided by the U. S. Geological Survey Bird Banding Laboratory was attached to each bird prior to release. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U. S. Government.

I refer to all adult Blackpoll Warblers (i.e., after-hatch-year) as AHY and all young-of-the-year (i.e., hatch-year) as HY. Due to variance in size among individuals of a species, it is common to calculate an adjusted mass (mass/wing length) for analysis of condition (Latta and Brown 1999, Dunn 2000). However, Francis and Wood (1989) reported young wood – warblers have shorter wing chords due solely to shorter feathers. Jones et al. (2002) surmised that calculations of adjusted mass may lead to interpreting HY individuals of a mass similar to AHY individuals as being in better relative condition. Therefore, I conducted analysis on age-specific differences in wing chord, mass, and adjusted mass with *t*-tests. I used Mann-Whitney *U* tests to assess age-specific differences in fat scores and condition scores. Tests indicated strong differences between the age classes, so I examined within age class differences in mass among the years with analysis of variance (ANOVA) tests, and used Tukey HSD post-hoc tests to identify where differences occurred among the years. Similarly, I examined within age class differences in fat and condition scores among the years with a Kruskal-Wallis analysis of variance on ranks test.

Two leap years occurred during our study so I transformed dates to Julian dates for analysis. I used an ANOVA to examine passage dates among years for all blackpolls pooled, and used Tukey HSD post-hoc tests to identify which years differed. I then looked at age-specific differences in mean passage date within each year with *t*-tests.

Migrants typically depart on southbound migration following passage of low pressure systems (Williams et al. 1977). Weather systems and winds they encounter en route would presumably influence when they arrived at our field station or passed to the east or west. Thus, identifying the meteorological conditions that result in stopover is challenging. Williams (1985) found that birds migrating over Antigua flew at an average of 2100 – 3090 m above sea level, but did not necessarily fly with favorable wind conditions. The wind speed and direction data available for my study area were at sea level, suggesting analysis of wind and arrival of migrants was not promising. Temperature in the tropics is fairly static and unlikely to be predictive of warbler migration. However, Latta and Brown (1999) reported a Blackpoll Warbler fallout on the Dominican Republic was associated with a drop in barometric pressure (hereafter, BP). I accessed BP records for each October of 2003 – 2010 from the weather stations at Lameshur Bay, St. John and Charlotte Amalie, St. Thomas, U. S. Virgin Islands (http://www.co-ops.nos.noaa.gov/index.shtml; last accessed 21 March 2011). These stations are operated by the National Oceanographic and Atmospheric Administration, are located approximately 23 km and 40 km away, respectively, from the study site, and are the closest weather stations to the study area that collect these data. I used hourly BP readings to calculate an average for each day of each October, then used Pearson's product-moment correlation to explore patterns between BP and arrival of blackpolls.

Results

I captured and banded 645 Blackpoll Warblers during the Octobers of 2003 – 2010. Annual number captured ranged from 7 to 185 individuals (mean = 8 ± 70/year) at a rate of 0.03 to 0.46/net hr (mean = 0.20 ± 0.16). Mean date of passage was 16.2 October (± 2.3 days), but was variable ($F_{7, 637} = 69.797$, $P < 0.0001$). Tukey HSD tests ($P < 0.05$) indicated that passage was significantly later in 2008 compared to all other years, and significantly earlier in 2009 compared to all other years (Fig. 1). Passage in 2005 and 2006 also occurred significantly later than in 2007 and 2010 (Fig. 1).

I was unable to age 7 of the Blackpoll Warblers captured, and omitted those individuals from all age-specific analyses (Table 1). HY birds accounted for 62.2% of the 638 aged blackpolls, but proportions were highly variable among years (Table 1). The only age-specific differences in arrival day occurred in 2005, 2007, and 2010 (Table 1, Fig. 1). Even though AHY blackpolls arrived statistically earlier (day 290.6 ± 0.8 days) than HY blackpolls (day 290.9 ± 0.3 days) in 2005 ($t_{173} = 3.074$, $P = 0.0024$), a biological relevance is elusive. In 2007, AHYs arrived 1.4 days earlier (day 287.8 ± 1.4 days) than HY warblers (day 289.2 ± 2.4 days) ($t_{109} = 3.037$, $P = 0.0027$). In contrast, HY blackpolls arrived 1.4 days earlier (day 288.1 ± 2.8 days) than AHYs (day 289.5 ± 3.3 days) in 2010 ($t_{183} = -2.836$, $P = 0.0051$). There was no correlation between blackpoll arrival and BP ($r = 0.033$, $P = 0.610$). To visually verify this, I plotted median passage day against daily mean BP for each year in which at least 50 blackpolls were captured; there was no apparent pattern of association between the two measures. Blackpolls arrived in 2006 during a down swing in BP, in 2005, 2007 and 2008 during high points in BP, and in 2010 when BP was holding generally steady.

I initially pooled all years to compare condition between AHY and HY Blackpoll Warblers. AHY birds had greater mass ($P < 0.0001$), longer wing chords ($P < 0.0001$) and greater adjusted mass ($P = 0.025$) than HY birds (Table 2). However, there were strong correlations between

27

wing length and age class ($r = 0.166$, $P < 0.001$) and wing length and mass ($r = 0.112$, $P = 0.005$), but mass and age class were not correlated. When all blackpolls were pooled by age, the difference in weights between AHY and HY birds was 0.5 g. The overall averages of 11.3 g for AHY and 10.8 g for HY birds were, respectively, 9.2% and 4.1% greater than the estimated fat-free mass of Blackpoll Warblers (Odum in Dunning 1993). Although the average mass of AHY Blackpoll Warblers was consistently above the fat-free mass estimation, average mass of HY birds was lower in 2004 and was only tenths of a gram greater in 2006, 2008, and 2010. Across the 8 years, 35.9% and 75.1% of AHY and HY blackpolls, respectively, were at or below the estimated fat-free mass of the species (Fig. 2). Additionally, it was not uncommon to capture individuals that were emaciated and as much as 19.7% below the estimated fat-free mass for the species. As would be suggested by age-specific differences in mass, AHY blackpolls scored higher than HY blackpolls in both fat scores ($U = 36490.5$, $P = 0.01$; Table 3) and condition scores ($U = 25572.0$, $P = 0.043$).

There were significant differences in mass of AHY blackpolls among the years of the study ($F_{6, 219} = 4.713$, $P = 0.0002$), but post-hoc analysis revealed the difference was due to mass in 2006 being significantly ($P < 0.05$) lower than that in 2005, 2007, or 2009. There was also a difference in mass among years for HY blackpolls ($F_{6, 375} = 7.543$, $P < 0.0001$). HY blackpolls weighed more in 2007 than 2006, 2008, or 2010 ($P < 0.05$); HY blackpolls in 2009 also weighed less than those in 2010 ($P < 0.05$).

Only 3 individuals were recaptured in subsequent days. Mass gain from day of capture to last recapture was significant ($r = 0.7604$, $P < 0.05$). Bird 1 gained 0.2 g in one day, bird 2 gained 1.1 g in 2 days and bird 3 gained 2.1 g in 4 days and another 1.2 g at 7 days (total 3.3 g). The warblers appeared to gain about 1.0 g per 2 days.

Discussion

Studies assessing migrant of Blackpoll Warblers have largely been limited to banding stations across the North American continent, with an emphasis on the northeastern region of the continent (Hunt and Eliason 1999). Condition of autumn migrant Blackpoll Warblers has been examined via mist-netting in Massachusetts (Nisbet et al. 1963), Maine (Morris et al. 1996) and Nova Scotia (Davis 2001), and on Bermuda (Nisbet et al. 1963). Compared to the robust samples from most of these studies, the few mist-netting studies conducted of blackpolls en route through the Caribbean have been limited to only 1 migration and typically of small (<100 birds) samples (Latta and Brown 1999, McNair et al. 2002). In contrast, I have been able to assess aspects of timing, age ratios, and condition of a comparatively large number of blackpoll warblers through the previously unsampled British Virgin Islands. Numbers captured were variable among years, ranging from substantially lower to double that reported elsewhere (Latta and Brown 1999, McNair et al. 2002). Thus, I do not believe my study location necessarily received more blackpolls on migration, but only that I was fortunate in being able to sample across 8 autumn migrations and detect the variability.

Prior to southbound migration from their presumed coastal departure points, HY blackpolls typically outnumber AHY birds (Nisbet et al. 1963, Ralph 1981). HY birds accounted for 72.4% of blackpolls captured on Bon Portage Island, Nova Scotia (Davis 2001), 76.5% of blackpolls captured on Appledore Island, Maine (Morris et al. 1996), and 90.4% of blackpolls captured on Island Beach, New Jersey (Murray 1966). Thus, age ratios of blackpolls at en route stopover locations may be indicative of age-specific success of transatlantic passage.

Unfortunately, the data with which to assess this are sparse. Mist-netting activities on Bermuda, midway between the presumed migration departure region of the NE North America and the Caribbean islands, revealed only 56% of blackpolls were HY (Ralph 1981). However, similar to age ratios reported in New England and Nova Scotia, 73% of blackpolls arriving on the Dominican Republic were HY birds (Latta and Brown 1999). My data are interesting in that HY birds accounted for 62% of 638 aged blackpolls arriving in the British Virgin Island, a ratio roughly midway between that reported on Bermuda and the Dominican Republic. However, there was substantial variability among years, with HY accounting for 35 to 71% of blackpolls (Table 1). Although the ratios in 2003 and 2004 are suspect due to small samples, the annual variability in age ratios suggest first, that studies from only one year may be misleading and second, that in most years HY birds accounted for about 5 – 15% fewer blackpolls than observed at continental departure points.

One explanation for lower proportions of HY blackpolls arriving in the Caribbean is lower success in open water crossing regardless of the departure point. This would be consistent with my findings of HY blackpolls being consistently lower in mass, lower in fat scores, and in poorer condition that AHY birds (Tables 2, 3, Fig. 2). Indeed, average mass across years was lower for both AHY and HY birds than averages reported on the continent at Florida (Murray 1989), Main (Morris et al. 1996), and Nova Scotia (Davis 2001), and at the transatlantic midway point Bermuda (Nisbet et al. 1963). However, blackpolls captured in the Dominican Republic (Latta and Brown 1999) and on Barbados (McNair et al. 2002) also averaged greater mass than those in the British Virgin Islands.

This may be explained by Latta and Brown (1999) and McNair et al. (2002) presenting data from only one migration and thus not capturing annual variability. Alternatively, the relatively better condition of blackpolls on the Dominican Republic could have been a result of migration from a more southerly departure point and less open ocean to cross, or migration across the Bahamas where the opportunity for stopover was available if needed. Similarly, blackpolls arriving on Barbados could have made earlier landfall anywhere north among the islands of the Lesser Antilles.

In contrast to the Dominican Republic and Barbados, there is nothing between the British Virgin Island and departure points in northeastern North America that would provide blackpolls a stopover except for 53.2 km^2 Bermuda, a virtual needle in a haystack. Thus, the Virgin Islands was probably the first landfall for arriving blackpolls since leaving the continent. Variance in weather encountered in different years over a long open-water crossing may explain the annual variability in the number and condition, and the overall poorer condition of blackpoll captured at my station.

If there is typically no difference in condition among AHY and HY blackpolls departing on migration (Morris et al. 1996, Davis 2002), some aspect of en route flight behavior may lead to the differences among those making landfall. McNair et al. (2002) found AHY blackpolls preceded HY by a median of 12 – 13 days in Barbados. In contrast, I found age-specific difference in time of passage during only 3 of 8 years, but the differences were less than 2 days, and HY birds were earlier in one year (Table 1). This may be explained by flocks of blackpolls arriving at first landfall during similar time periods but HY birds, being in comparatively poorer condition, may take longer to replenish their reserves before continuing on migration.

Acknowledgements

APPENDIX II

I thank the Jarecki family, the Falconwood Foundation, and The Conservation Agency for their continued access to Guana Island and support for this research, and to the USGS Cooperative Research Units for facilitating this research. Special thanks to J.D. Lazell and G. Perry for coordinating research opportunities on Guana Island. Mist-netting efforts could not have been accomplished without the assistance of many volunteers, especially T.S. Estabrook, T. Willard, S. Valentine-Cooper, B.D. Bibles, and E.P. Estabrook.

Literature Cited

Arendt, W. J. 1992. Status of North American migrant landbirds in the Caribbean region: a summary. Pages 143 – 171 in Ecology and conservation of neotropical migrant landbirds (J. M. Hagen, III and D. W. Johnston, eds.). Smithsonian Press, Washington, D.C.

Boal, C. W., and T. S. Estabrook. 2007. Occurrence and condition of migrating 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 and migrant species, longevity records, and new species records on Guana Island, British Virgin Islands. Wilson Journal of Ornithology 118:218-224.

Davis, A. K. 2001. Blackpoll Warbler (*Dendroica striata*) fat deposition in southern Nova Scotia during autumn migration. Northeastern Naturalist 8:149-162

Dugger, K. M., J. Faaborg, W. J. Arendt, and K. A. Hobson. 2004. Understanding survival and abundance of overwintering warblers: does rainfall matter?

Dunning, J. B., Jr. 1993. CRC handbook of avian body masses. CRC Press, Boca Raton, FL.

Ewert, D. N., and R. A. Askins. 1991. Flocking behavior of migratory warblers in winter in the Virgin Islands. Condor 93:864-868.

Francis, C. M., and D. S. Wood. 1989. Effects of age and wear on wing length of wood-warblers. Journal of Field Ornithology 52:97-111.

Heglund, P. J., and S. K. Skagen. 2005. Ecology and physiology of en route nearctic-neotropical migratory birds: a call for collaboration. Condor 107:193-196.

Hunt, P. D., and B. C. Eliason. 1999. Blackpoll Warbler (*Dendroica striata*). In The Birds of North America, No. 431 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Jones, J., C. M. Francis, M. Drew, S. Fuller, and M. W. S. Ng. 2002. Age-related differences in body mass and rates of mass gain of passerines during autumn migratory stopover. Condor 104:49-58.

Kelly, J. F., and R. L. Hutto. 2005. An east-west comparison of migration in North American wood warblers. Condor 107:197-211.

Kuenzi, A. J., F. R. Moore, and T. R. Simons. 1991. Stopover of neotropical landbird migrants on East Ship Island following trans-gulf migration. Condor 93:869-883.

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.

Latta, S. C., A. Tossas, A. Sutton, H. Gonzalez, P. B. Hamel, and D. DeSante. 2003. Research, monitoring, and conservation of neotropical migratory land birds in the West Indies. Journal of Caribbean Ornithology 16:1-19.

APPENDIX II

Lazell, J. 2005. Island: fact and theory in nature. University of California Press, Berkeley, California, USA.

McNair, D. B., E. B. Massiah, and M. D. Frost. 2002. Ground-based migration of Blackpoll Warblers at Harrison Point, Barbados. Caribbean Journal of Science 38:239-248.

Moore, F. R., P. Kerlinger, and T. R. Simons. 1990. Stopover on a Gulf Coast barrier island by spring trans-gulf migrants. Wilson Bulletin 102:487-500.

Morse, D. H. 1989. American warblers: an ecological and behavioral perspective. Harvard University Press, Cambridge, MA.

Murray, B. G., Jr. 1989. A critical review of the transoceanic migration of the Blackpoll Warbler. Auk 106:8-17.

Nisbet, I. G. T., D. B. McNair, W. Post, and T. C. Williams. 1995. Transoceanic migration of the Blackpoll Warbler: summary of scientific evidence and response to criticisms by Murray. Journal of Field Ornithology 66:612-622.

Pyle, P. 1997. Identification guide to North American birds: Part I Columbidae to Ploceidae. Slate Creek Press, Bolinas, CA.

Raffaele, H., J. Wiley, O. H. Garrido, A. Keith, and J. I. Raffaele. 1998. A guide to the birds of the West Indies. Princeton University Press, Princeton, NJ

Rappole, J. H. 1995. The ecology of migrant birds: a neotropical perspective. Smithsonian Institution Press, Washington D.C.

Rodewald, P. G., and M. C. Brittingham. 2007. Stopover habitat use by spring migrant landbirds: the roles of habitat structure, leaf development, and food availability. Auk 124:1063-1074.

Williams, T. C., J. M. Williams, L. C. Ireland, and J. M. Teal. 1977. Autumnal bird migration over the western North Atlantic Ocean. American Birds 31:251-267.

Williams, T. C. 1985. Autumnal bird migration over the Windward Caribbean Islands. Auk 102:163-167.

Woodrey, M. S., and F. R Moore. 1997. Age-related differences in the stopover of fall landbird migrants on the coast of Alabama. Auk 114:695-707.

Wunderle, J. M., Jr. 1995. Population characteristics of Black-throated Blue Warblers wintering in three sites on Puerto Rico. Auk 112:931-946.

APPENDIX II

Table 1. Mean Julian date, standard deviations, *t*-test results for day of passage, and proportion of hatching-year (HY) birds for after-hatching-year (AHY) and HY Blackpoll Warblers captured on Guana Island, British Virgin Islands, during October migrations of 2003 – 2010.

	AHY			HY						
YEAR	*n*	Mean	SD	*n*	Mean	SD	*t*	*df*	*P*	% HY
2003	9	289.3	1.2	5	289.6	1.1	0.3993	12	0.6967	35
2004	2	289.5	0.7	5	289.8	0.4	0.7032	5	0.5133	71
2005	78	290.6	0.8	97	290.9	0.3	3.0742	173	0.0025	55
2006	38	290.7	0.9	25	291.4	2.4	1.6738	61	0.0993	40
2007	33	287.8	1.5	78	289.2	2.4	3.0739	109	0.0027	70
2008	18	292.8	4.9	37	294.7	3.7	1.5926	53	0.1172	67
2009	10	284.3	4.5	18	282.9	0.2	-1.3025	26	0.2042	64
2010	53	289.5	3.3	132	288.1	2.8	-2.8367	183	0.0051	71

Table 2. Comparison of mass (MASS), wing chord (WING), and adjusted mass (ADJM) between after-hatch-year (AHY) and hatch-year (HY) Blackpoll Warblers captured on Guana Island, British Virgin Islands, Octobers 2004 – 2010.

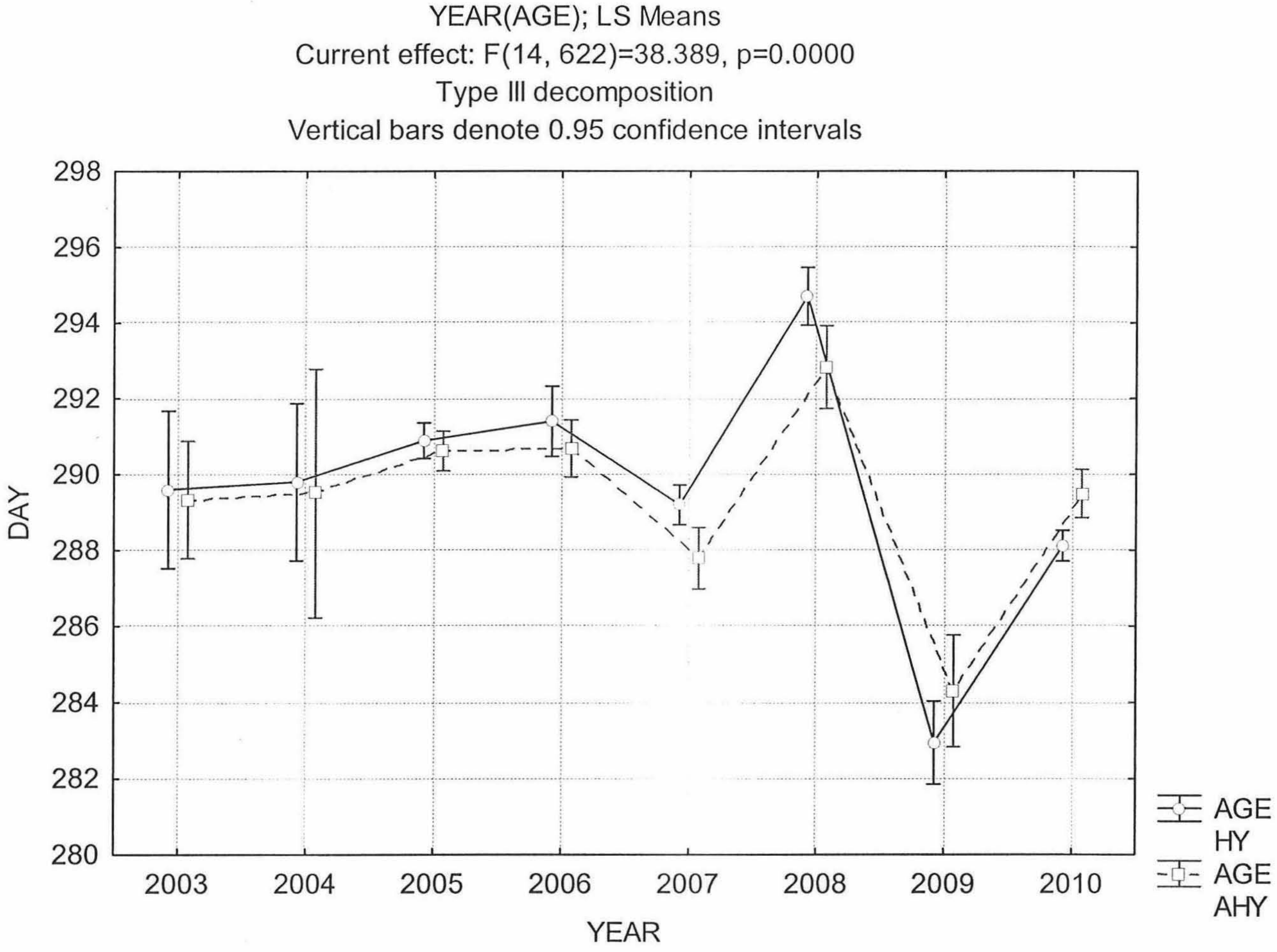
	AHY			HY					
	n	mean	SD	*n*	mean	SD	*t*	df	*P*
MASS	231	11.29	1.307944	387	10.77	1.24	-5.01415	616	<0.0001
WING	241	72.99	2.675681	385	71.99	2.37	-4.86257	624	<0.0001
ADJM	232	0.159	0.085	377	0.149	0.017	-2.24916	607	0.0248

Table 3. Fat score, sample size, mean mass and standard deviation (g) within fat score, for adult (AHY) and hatch-year (HY) Blackpoll Warblers captured during autumn migration, Guana Island, British Virgin Islands, Octobers of 2003 – 2010.

		AHY			HY	
FAT SCORE	*n*	mean	SD	*n*	mean	SD
0	79	10.36	0.94	177	9.98	0.74
1	48	11.06	0.85	74	10.73	0.86
2	50	11.74	0.95	64	11.41	1.00
3	42	12.64	0.89	56	12.17	0.86
4	6	13.80	0.68	10	13.36	1.32
Total	225	11.33	1.30	381	10.78	1.24

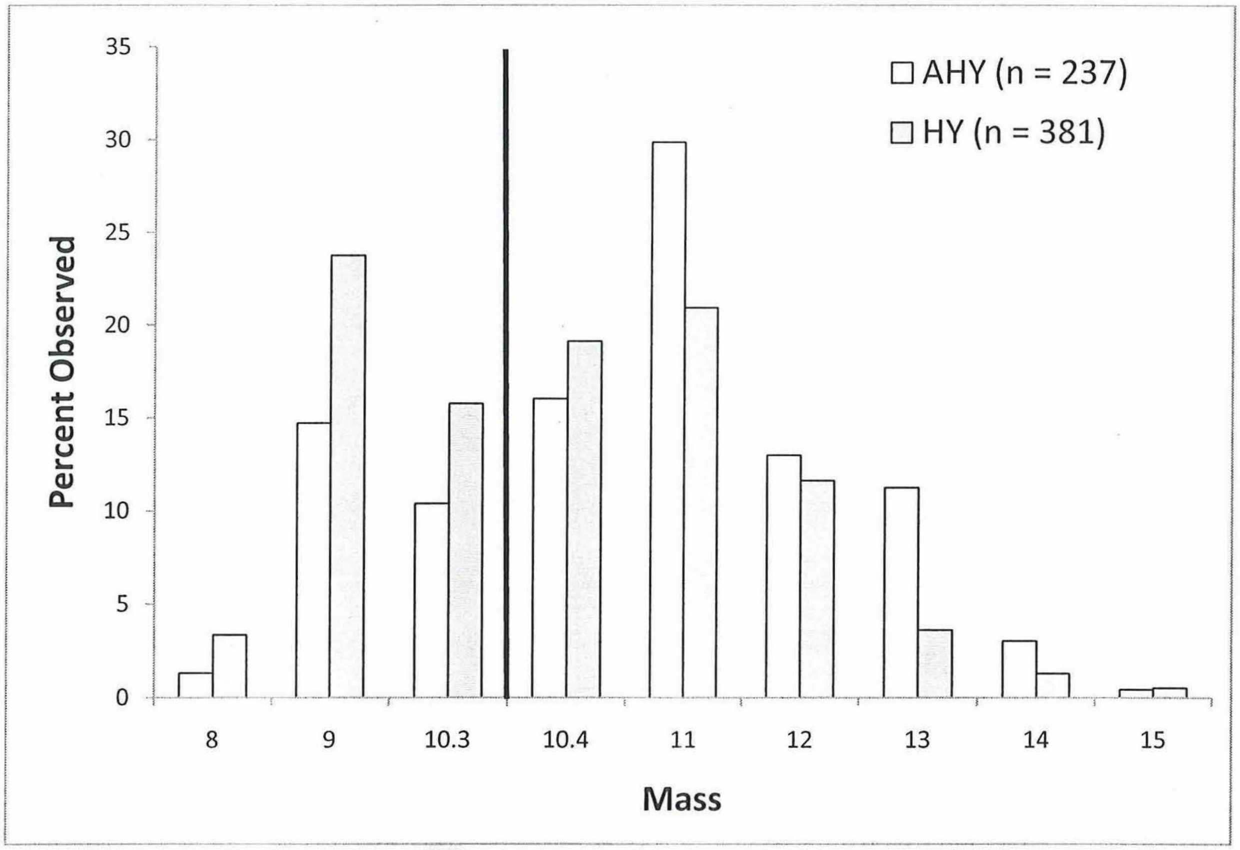
APPENDIX II

Figure 1. Age-specific passage dates of Blackpoll Warblers among years on Guana Island, British Virgin Islands, Octobers 2003 – 2010 (temporary figure, will be revised).



APPENDIX II

Figure 2. Distribution of mass of after-hatch-year (AHY) and hatch-year (HY) Blackpoll Warblers captured on Guana Island, British Virgin Islands, Octobers 2004 – 2010. Vertical black line indicates estimated fat free mass for the species.



APPENDIX III

Morphometric-Based Sexual Determination of Bananaquits (*Coereba flaveola*)

Brent D. Bibles, Utah State University, Uintah Basin Regional Campus, Vernal, UT 84078

Clint W. Boal, U. S. Geological Survey, Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock, TX 79409

APPENDIX III

Abstract: Bananaquits (*Coereba flaveola*) are a common passerine throughout the tropics and have been a convenient species for ecological studies. Bananaquits have sexually monomorphic plumage and cannot be reliably sexed unless in breeding condition. This is problematic for demographic and comparative studies, which are contingent upon accurately aging and sexing individuals. Although male Bananaquits are larger than females, there is overlap in both wing chord and mass. We used morphometric data collected over 8 years to develop a predictive model based on logistic regression to assign adult Bananaquits to sex. Our model classified 96% of validation individuals to the correct sex. We suggest that this approach may enhance ecological studies of the species by facilitating correct sex determination independent of breeding status. We believe our modeling approach is applicable elsewhere but, because there may be geographical variation across the species distribution, models will need to be customized to local populations.

Key Words: Bananaquit, logistic regression, monomorphic plumage, sexing, size dimorphism

APPENDIX III

Bananaquits (*Coereba flaveola*) are an abundant passerine found throughout much of the new world tropics. Generally, they have small territories and occur at high densities on many Caribbean islands (Wunderle 1984). The diet of Bananaquits has made them an interesting species for studies of sugar preferences and physiological aspects of nectivory (Mata and Bosque 2004) and competition with other nectivorous birds (Askins et al. 1987). The species exhibits plumage polymorphism in parts of its range, such as Grenada, and has been closely studied in context of temporal shifts in the morph ratio cline (Wunderle 1981a, b, 1983, MacColl and Stevenson 2003). The extensive variation in plumage and other features, including size, have prompted several studies to document and explain the variation (e.g., Diamond 1973, Prys-Jones 1982), and infer evolutionary history (Seutin et al. 1994, Bellemain et al. 2008). Despite its abundance and widespread distribution, however, relatively few studies have examined the basic biology (Biaggi 1955, Gross 1958, Wunderle et al. 1987, Wunderle et al. 1992) and breeding ecology (Wunderle 1982, 1984) of Bananaquits.

Because they have sexually monomorphic plumage, Bananaquits cannot be reliably sexed unless in breeding condition (i.e., presence of brood patch or cloacal protuberance). However, this is contingent upon banding studies being conducted during the breeding season. Many studies in the tropics are conducted during the migration or wintering season when most resident tropical birds are not in a breeding state (Faaborg et al. 1984, Murphy et al. 2004, Boal et al. 2006). Sophisticated modeling of survival and demography are contingent upon accurately aging and sexing individuals in the marked sample. Failure to account for sex ratio, or removing unsexed individuals from samples, can lead to introduction of bias, weak inference, and erroneous conclusions. Wolfe et al. (2009) recently emphasized this need for better quantitative data on gender determination and other characteristics.

We have attempted to take a step toward filling this need for one of the most common of Caribbean passerines. We analyzed measurements for Bananaquits captured on Guana Island, British Virgin Islands, to determine if the sexes can be differentiated using measurements commonly obtained during banding efforts.

Methods

We conducted bird surveys on Guana Island (18° 30′ N, 64° 30′ W), a small (3 km^2) island located approximately 0.5 km north of Tortola, British Virgin Islands. The British Virgin Islands, along with the U. S. Virgin Islands, are a chain of approximately 76 islands and cays located roughly 150 km east of Puerto Rico that, combined with Puerto Rico, constitute the Puerto Rican Bank (Lazell 2005). Temperature in the British Virgin Islands normally ranges from 28–33°C, with annual mean rainfall for Guana Island estimated at 92 cm (Lazell 2005).

Guana Island is topographically rugged with elevations ranging from sea level to 246 m. It is privately owned and has undergone little development or fragmentation. A resort area occupies approximately 3% of the island; the remainder of the island is a de facto nature preserve. The majority of the island is vegetated with subtropical dry forest (90%) and mesic ghaut forest (5%) (Lazell 2005). The primary native vegetation on Guana Island is *Tabebuia heterophylla, Bursera simaruba, Pisonia subcordata, Conocarpus erectus, Plumeria alba, Acacia muricata*, and *Coccoloba uvifera*. *Leucaena leucocephela* is common in disturbed areas. Other introduced species include *Cocos nucifera, Tamarinda indica*, and *Delonix regia* (Lazell 2005).

We operated a banding station on Guana Island during each October of 2003 - 2010. As many as 12, 32-mm mesh nets were opened for an average of 422 (± 57 SE) h each year (Boal

2010). All nets were placed in subtropical dry forest and in human altered areas near the island hotel. Nets were located in the same locations along a northeast–southwest ridge on the west side of the island at ca. 70 m elevation each year.

Captured Bananaquits were placed in temporary holding bags and transported to a banding station for processing. We recorded unflattened wing chord with a stopped wing ruler. We measured mass with an electronic scale accurate to 0.1 g (Ohaus Model CS200). We aged each Bananaquit as adult or juvenile based on plumage (Raffaele et al. 1998), and examined adults for evidence of breeding status (i.e., brood patch, cloacal protuberance). To ensure consistency, one person performed all measurements and classifications. We attached an aluminum leg band provided by the U. S. Geological Survey Bird Banding Laboratory and, beginning in 2005, we attached unique combinations of two plastic colored bands to adults.

Preliminary examination of wing chord and mass of known sex Bananaquits led us to suspect we could use these metrics to determine sex of individuals with a high level of confidence. We compared mass and wing chord of all adult Bananaquits, male only, and females only using linear regression. We used these individuals to calculate 95% confidence intervals on mass and wing chord for male and female Bananaquits. We used logistic regression to develop a predictive model for classification of individuals of unknown sex. The logistic model was developed using individuals captured from 2003 to 2010 for which sex was verified by presence of brood patch or cloacal protuberance. Adult individuals classified as unknown sex were included if they were sexed at a later capture, with the measurements from the initial capture utilized for the analysis. Only one set of measurements was included for each individual to avoid lack of independence of data. We randomly selected 50 known-sex adults, 25 of each sex, for removal from the dataset to use for model validation. Four logistic regression models were run: 1) wing chord only, 2) mass only, 3) wing chord-mass additive model, and 4) wing chord-mass interaction model. The model best fitting the data was chosen using AIC (Burnham and Anderson 2002). Sex of validation individuals was predicted using the best model with a predicted probability of being female ≥0.5 indicating females. We then compared the assigned values with the known sex. Sex of all individuals used to develop the model was also predicted. Percent of successful classification was calculated, with >80% success considered a validated model. The model was then applied to all unknown sex individuals for whom we had wing chord and mass measurements.

Results

A total of 519 captures of adult Bananaquits from 2003-2010 represented 304 individuals, of which 285 had both wing chord and mass measured. Of these, 222 birds were field-sexed (131 ♂, 91 ♀). Wing chord for all individuals was 57.0 mm (SE = 0.155 mm, range 51-62 mm). Males had larger wing chords ($\bar{x}$ = 59.1 mm, SE = 0.114 mm, range 55-62 mm) than females ($\bar{x}$ = 54.6 mm, SE = 0.133 mm, range 51-58 mm) ($t_{220} = -25.523$, P < 0.0001). Males also were heavier (♂: $\bar{x}$ = 10.2 g, SE = 0.063 g, range 8.0-12.5 g) than females (♀: $\bar{x}$ = 9.4 g, SE = 0.086 g, range 6.4-11.8 g) ($t_{220} = -8.151$, P < 0.0001). Wing chord exhibited substantially less variation (♂: CV = 2.2; ♀: CV = 2.3) than mass (♂: CV = 7.1; ♀: CV = 8.7). Unknowns generally exhibited the full range of observed wing chords ($\bar{x}$ = 56.0 mm, SE = 0.324 mm, range 51-62 mm) and mass ($\bar{x}$ = 9.3 g, SE = 0.086 g, range 6.4-11.8). Overlap of sexes was observed with both metrics, with extensive overlap in mass and overlap in the 55-58 mm wing chord range (Fig. 1). In addition, average mass varied considerably between years, ranging from 9.8 g in

2009 to 10.9 g in 2008 for males, and from 8.8 g in 2009 and 9.8 g in 2007 for females. Mass and wing chord exhibited a positive relationship for both sexes (linear regression: ♂, P = 0.0010; ♀, P = 0.0064), although the relationship was noisy and mass provided little explanation for variation in wing chord (♂ R^2 = 0.0815, ♀ R^2 = 0.0805). The relationship appeared to be additive, with no difference in slope of the relationship between sexes (♂Slope = 0.516, 95% CI [0.214, 0.817]: ♀ Slope = 0.439, 95% CI [0.127, 0.751]), but males had a somewhat higher intercept (♂Intercept = 53.829, 95% CI [50.741, 56.917]: ♀ slope = 50.490, 95% CI [47.555, 53.425]).

Measurements from 172 birds (106 ♂, 66 ♀) were used to perform the logistic regressions. The best model was the Wing Chord + Mass additive model (AIC = 46.715), followed by Wing Chord only (ΔAIC = 1.47), and the Wing Chord * Mass interaction (ΔAIC = 1.955) models. The Mass only model performed poorly compared to the other models (ΔAIC = 149.082). The best model provides the probability of the bird being female given the measurements by the equation:

Pr,Female-Mass, Wing Chord.=,1-1+,e-

−,136.8+0.8947,Mass.−2.5749(WingChord)...

The 95% profile likelihood confidence interval on the slope parameter for wing chord (=-2.5749) did not encompass zero [-3.8901, -1.7311], but the confidence interval for mass did include zero [-0.0450, 1.9341], suggesting that wing chord has significant explanatory power in classifying sex. When applied to the validation samples, the model correctly classified 100% of males and 92% of females. The 95% confidence intervals on the probability included 0.5 for six (12%) of the classifications, including one of the two misclassifications. Censoring of individuals for which the 95% confidence interval included any value between 0.4 and 0.6 resulted in 100% classification success, but required removal of nine (18%) of the validation individuals. In both failed classifications, the females had larger than average wing chords (both 57.0 mm) and larger than average mass (9.6 and 10.2 g). Based on this model, adult Bananaquits with wing chords < 55.0 mm can be assumed female, and those with wing chords > 57.5 mm can be assumed males. Within the 55.5-57.5 mm wing chord, mass becomes important with, counter-intuitively, larger mass individuals being females (Fig. 2). When the model was applied to the all 222 known sex individuals, the model correctly assigned sex to 96% of individuals. The model classified the 63 unknown sex individuals as 29 males and 34 females. Certainty of classification was similar to that for the validation test. Ninety-five percent confidence intervals on the probability of being female included 0.5 for eight (13%) individuals, and included a value between 0.4 and 0.6 for 13 (21%) individuals.

Discussion

Bananaquits exhibit sexual dimorphism in wing chord although some overlap exists. Based on presence of breeding criteria, we observed males with wing chords as short as 55 mm, and females with wing chords as long as 58 mm. This range of overlap was supported by the results of our predictive model. In a well-developed guide for aging and sexing Bananaquits in Jamaica, Susan Koenig (unpub. data) found individuals with wing chord < 52 mm can be reliably sexed as female, and those > 57 mm can be reliably sexed as males. On Dominica, 89% of individuals with wing lengths less than a median of 62 mm showed evidence of brood patches (Prys-Jones 1982). These data suggest that sexing individuals based only on wing chord is questionable, and requires classifying individuals within the zone of overlap as unknowns, which may compromise results of subsequent demographic analyses. Other measurements likely present the same problem. We found substantial overlap (62% of the observed range) in mass of males and females.

The observed variation in size due to sex suggests that averaging morphometrics in ecological studies of Bananaquits without accounting for sex may be problematic. Diamond (1973) found positive correlations between elevation and several morphometrics (i.e., mass, wing length, and bill length) of unsexed Bananaquits in Jamaica. However, when museum specimens of known sex from Central and South America were measured, the relationship was only significant for wing length and elevation in males (Diamond 1973). Prys-Jones (1982) found a strong positive correlation between wing length and mass of Bananaquits in Dominica without accounting for differences in sex. We observed a similar relationship although mass had little explanatory power for wing chord for either sex (♂ $R^2 = 0.0815$, ♀ $R^2 = 0.0805$). This weak relationship is probably due to high yearly variation in mass.

Determining sex base on morphometrics may be confounded by not only altitudinal variation in size (Diamond 1973) but also variance in sizes across the species distribution. For example, examining data from disparate locations within the range of the Bananaquit reveals the potential for substantial spatial variation in body size, even though direct comparison is difficult due to differences in measurement technique. In the South and Central America, flattened wing chord of male and female Bananaquits averaged 57.0 mm ($N = 64$, SE = 0.378, 5.30 CV) and 54.1 mm ($N = 25$, SE = 0.011, 5.44 CV), respectively (Diamond 1973). In the northeast region of the Caribbean within the BVI, we found males had a much longer average unflattened wing chord of 59.1 mm whereas females only had a slightly larger average wing chord of 54.6 mm than that of mainland females. Southward at the center of the Lesser Antilles, Prys-Jones (1982) reported an overall average wing chord for Bananaquits on Dominica as 60.6 mm (± 3.2mm). However, Prys-Jones (1982) used maximum chord rather than unflattened chord. Converting unflattened wing chord to maximum chord (Pyle 1997) suggests that average wing chord in the BVI is similar to that on Dominica. Unflattened wing chord measurements used for sexing on Jamaica (♂ > 57 mm, ♀ < 52 mm; Susan Koenig, unpub. data) suggests that Bananaquits on Jamaica are similar in size to mainland birds.

Ecological studies involving size should either avoid using unsexed individuals or censor individuals of unknown sex. First, averaging morphometrics using unsexed individuals requires the assumption that comparison samples have equivalent sex ratios. For example, when removing unknown sex individuals (22% of 285 individuals), we observed a sex ratio of 59♂:41♀ and obtained an average wing chord of 57.3 mm. Using the averages for each sex and assuming a 50:50 sex ratio results in a drop of 0.5 mm (56.8 mm) in the estimated average, which is 5% of the overall range in observed measurements. Second, use of threshold criteria that create a zone of "unknown" create a bias by tending to censor larger individuals of the smaller sex, and vice versa, leading to an apparent larger difference between sexes than exists. In addition, this censoring leads to smaller variance estimates than appropriate, increasing the probability of finding a non-existent difference (i.e., committing Type I error). For example, we found that coefficients of variation on wing chord for males and females were 2.2 and 2.3%, respectively, when Bananaquits were sexed based on breeding characters. Had we used a wing chord criteria classifying individuals from 55 – 57.5 mm as unknown sex, the coefficients of variation for males and females would have been 1.7 and 1.4%, respectively.

Errors in classifying sex using our model could have deleterious effects on an analysis. However, we believe that the level of error is very low and unlikely to have significant influence, especially in comparison to the impact of censoring unknown sex individuals from the analysis. In our classification of the 63 individuals of unknown sex, classifying using the 55-57.5 wing chord criteria would have resulted in censoring 28 (44%) of individuals from further analysis. Using the conservative approach of censoring individuals in which the probability of being female was approaching 0.5 (e.g., 0.4 to 0.6) would have only removed 13 individuals (21%) from further consideration, resulting in substantially less bias. We believe the model we have developed is a valid, field-applicable approach for determining sex of non-breeding adult Bananaquits. We suggest Bananaquits should be sexed using breeding criteria, if possible, and then classifying the remaining unknown sex individuals using our approach. This approach had a high success rate (96%) in classifying individuals that did not exhibit breeding characteristics, and has the potential to significantly reduce the analysis problems associated with having unknown sex individuals within a dataset. We believe our current model is applicable to Bananaquits in the British and U.S. Virgin Islands, but have not yet tested it beyond our study island. However, we also suspect it will need to be modified to account for regional variance across the Bananaquit distribution, but see no reason the approach we took to developing morphometric-based sexing criteria could not be applied elsewhere. Development of localized models using this approach and existing morphometric data is currently possible for many portions of the species' range. In addition, incorporation of other metrics, such as tail chord or exposed culmen, may benefit the model and should be explored.

Acknowledgements

Our thanks to the Jarecki family, the Falconwood Foundation, and The Conservation Agency for their continued access to Guana Island and support for this research, and to the USGS Cooperative Research Units and Utah State University for facilitating this research. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Special thanks to J.D. Lazell and G. Perry for coordinating research opportunities on Guana Island. We thank T. S. Estabrook, T. Willard, S. Cooper, E. P. Estabrook and several other volunteers that have assisted in the ornithological research program on the island. This manuscript benefitted from the thoughtful reviews and suggestions of #### and ####.

Literature Cited

ASKINS, R.A., K.M. ERCOLINO AND J.D. WALLER. 1987. Flower destruction and nectar depletion by avian nectar robbers on a tropical tree, *Cordia sebestena*. Journal of Field Ornithology 58:345-349.

BELLEMAIN, E., E. BERMINGHAM, AND R. E. RICKLEFS. 2008. The dynamic evolutionary history of the bananaquit (*Coereba flaveola*) in the Caribbean revealed by a multigene analysis. BMC Evolutionary Biology 8:240

APPENDIX III

Biaggi, V. 1955. The Puerto Rican honeycreeper (Reinita) Coereba flaveola (Bryant). Special Publication University of Puerto Rico Agricultural Experiment Station 1-61.

BOAL, C.W. 2010. Ornithological monitoring and research on Guana Island, British Virgin Islands. Project Report 2009 to The Conservation Agency. 29 April 2010.

Boal, C. W., F. C. Sibley, T. S. Estabrook, and J. Lazell. 2006. Insular and migrant species, longevity records, and new species records on Guana Island, British Virgin Islands. Wilson Journal of Ornithology 118:218-224.

BURNHAM, K.P., AND D.R. ANDERSON. 2002. Model selection and multimodel inference: a practical information-theoretic approach, second edition. Springer, New York.

DIAMOND, A.W. 1973. Altitudinal variation in a resident and a migrant passerine on Jamaica. Auk 90:610-618.

FAABORG, J., W. J. ARENDT, AND M. S. KAISER. 1984. Rainfall correlates of bird population fluctuations in a Puerto Rican dry forest: a nine year study. Wilson Bulletin 96:575-593.

GROSS, A. O. 1958. Life history of the Bananaquit of Tobago Island. Wilson Bulletin 70:257-279.

LAZELL, J. 2005. Island: fact and theory in nature. University of California Press, Berkeley, California, USA.

MACCOLL, A. D. C., AND I. R. STEVENSON. 2003. Stasis in the morph ratio cline in the Bananaquit on Grenada, West Indies. Condor 105:821-825.

MATA, A., AND C. BOSQUE. 2004. Sugar preferences, absorption efficiency and water influx in a neotropical nectarivorous passerine, the Bananaquit (*Coereba flaveola*). Comparative Biochemistry and Physiology, Part A 139:395-404.

MURPHY, M. T., J. ZYSIK, AND A. PIERCE. 2004. Biogeography of the birds of the Bahamas with special reference to the island of San Salvador. Journal of Field Ornithology 75:18-30.

PRYS-JONES, R. P. 1982. Molt and weight of some land-birds on Dominica, West Indies. Journal of Field Ornithology 53:352-362.

PYLE, P. 1997. Identification guide to North American birds: Part I Columbidae to Ploceidae. Slate Creek Press, Bolinas, CA.

RAFFAELE, H., J. WILEY, O. H. GARRIDO, A. KEITH, AND J. I. RAFFAELE. 1998. A guide to the birds of the West Indies. Princeton University Press, Princeton, NJ

SEUTIN, G., N. K. KLEIN, R. E. RICKLEFS, AND E. BERMINGHAM. 1994. Historical biogeography of the Bananaquit (*Coereba flaveola*) in the Caribbean region: a mitochondrial DNA assessment. Evolution 48:1041-1061.

WOLFE, J. D., P. PYLE, AND C. J. RALPH. 2009. Breeding seasons, molt patterns, and gender and age criteria for selected northeastern Costa Rican resident landbirds. Wilson Journal of Ornithology 121:556-567.

WUNDERLE, J. M. 1981a. An analysis of a morph ratio cline in the Bananaquit (*Coereba flaveola*) on Grenada, West Indies. Evolution 35:333-344.

WUNDERLE, J. M. 1981b. Movements of adult and juvenile Bananaquits within a morph-ratio cline. Auk 98:571-577.

WUNDERLE, J. M. 1982. The timing of the breeding season in the Bananaquit (Coereba flaveola) on the island of Granada, WI. Biotropica 14:124-131.

WUNDERLE, J. M. 1983. A shift in the morph ratio cline in the Bananaquit on Grenada, West Indies. Condor 85:365-367.

WUNDERLE, J. M. 1984. Mate switching and a seasonal increase in polygyny in the Bananaquit. Behaviour 88:123-144.

Wunderle, J. M., M. S. Castro, and N. Fletcher. 1987. Risk-averse foraging by bananaquits on negative energy budgets. Behavioral Ecology and Sociobiology 21:249-255.

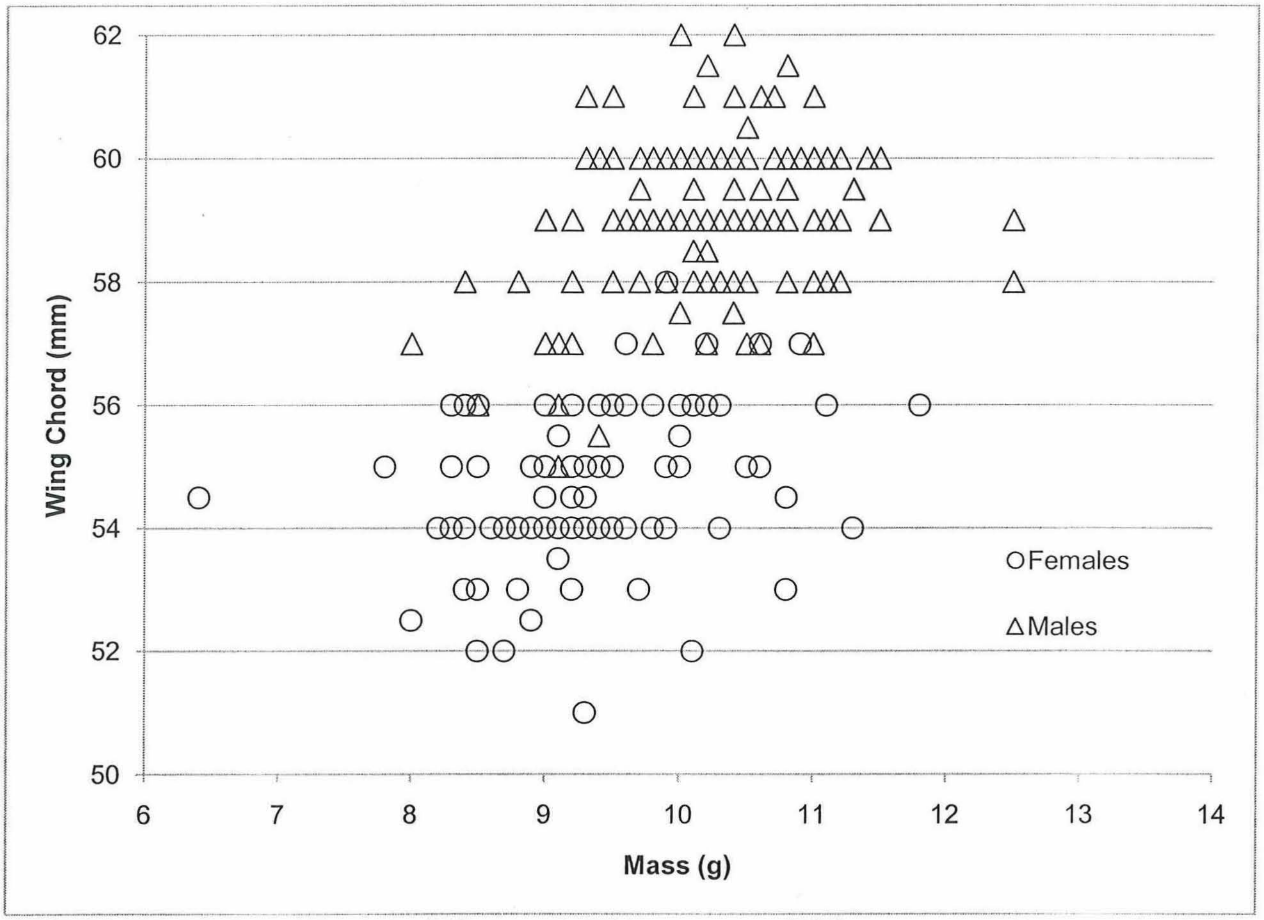
WUNDERLE, J. M., R. A. CORTES, AND W. CARROMERO. 1992. Song characteristics and variation in a population of Bananaquits on Puerto Rico. Condor 94:680-691.

APPENDIX III

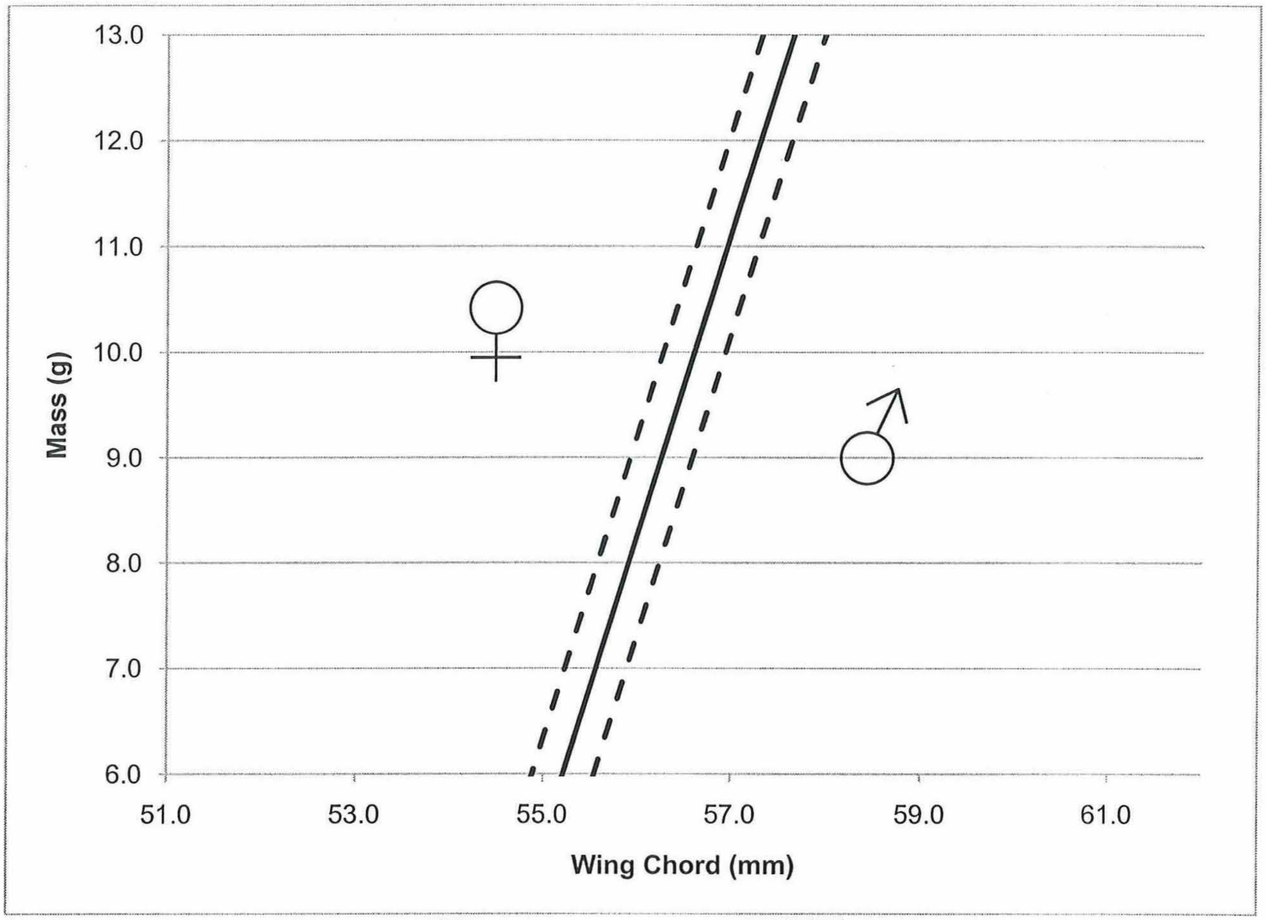
Figure 1. Scatterplot illustrating mass (g) and wing chord (mm) of adult Bananaquits, by sex, on Guana Island, BVI, 2003-2010. Data from 222 individuals (131 M, 91 F).

Figure 2. Assignment of sex of adult Bananaquits based on logistic model using wing chord (mm) and mass (g). Solid line indicates predicted probability of being female = 0.5. Dashed lines indicate predicted probabilities of being female = 0.7 (left) and 0.3 (right).

APPENDIX III



APPENDIX III



PROC. ENTOMOL. SOC. WASH.
112(4), 2010, pp. 565–575

PSEUDOCOCCUS SACCHARICOLA TAKAHASHI (HEMIPTERA: PSEUDOCOCCIDAE) IN THE BRITISH VIRGIN ISLANDS: FIRST WESTERN HEMISPHERE RECORDS, WITH RECORDS OF A CO-OCCURRING LADY BEETLE, *HYPERASPIS SCUTIFERA* (MULSANT) (COLEOPTERA: COCCINELLIDAE)

A. G. Wheeler, Jr., Gregory A. Evans, and Natalia J. Vandenberg

(AGW) Department of Entomology, Soils, and Plant Sciences, Clemson University, Clemson, SC 29634-0315, U.S.A. (e-mail: awhlr@clemson.edu); (GAE) USDA-APHIS, Systematic Entomology Laboratory, PSI, BARC-West, 10300 Baltimore Ave., Beltsville, MD 20705, U.S.A. (e-mail: Gregory.A.Evans@aphis.usda.gov); (NJV) Systematic Entomology Laboratory, PSI, USDA-ARS, c/o National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, MRC-168, Washington, DC 20013-7012, U.S.A. (e-mail: Natalia.Vandenberg@ars.usda.gov)

Abstract.—*Pseudococcus saccharicola* Takahashi was collected on Guana Island, and nearby Beef Island and Tortola, in the British Virgin Islands (BVI). The records are the first in the Western Hemisphere for this potentially important Old World pest of sugarcane and certain other graminoid crops. Host plants on Guana were *Chloris barbata* Sw. (swollen fingergrass), *C. radiata* (L.) (radiate fingergrass), *Cynodon dactylon* L. (bermudagrass), and *Saccharum officinarum* L. (sugarcane). A probable mealybug predator associated with colonies of *P. saccharicola* on all three islands was the hyperaspidine coccinellid *Hyperaspis scutifera* (Mulsant), previously recorded in the West Indies only from the Leeward Antilles (Curaçao). Both the mealybug and lady beetle are considered adventive in the BVI. Diagnoses and illustrations of both species are provided to facilitate their recognition. *Hyperaspis sanctaeritae* Dobzhansky, 1941, described from Arizona, USA, is proposed (by N.J.V.) as a junior synonym of *H. scutifera* (Mulsant 1850).

Key Words: Insecta, yellowish sugarcane mealybug, adventive species, insect detection, new records, new synonymy, West Indies

DOI: 10.4289/0013-8797.112.4.565

Guana is a small (340 ha) volcanic island east of Puerto Rico and just north of Tortola, with a maximum elevation of 246 m. Guana's biota is remarkably diverse, the number of species in certain groups of plants, reptiles, and mammals often substantially greater than would be predicted by species-area relationships (Lazell 2005). Among the Insecta, groups such as beetles (Valentine and Ivie 2005), butterflies (Becker and Miller 1992), dragonflies (Lazell 2005), planthoppers (Bartlett 2000),

---

* Edited by Thomas J. Henry; accepted by Michael W. Gates

and termites (Lazell 2005) show greater-than-expected species richness. Many insect species on Guana are widely distributed in the Neotropics, some are strictly Antillean in distribution, whereas others are precinctive (endemic) to the Puerto Rico Bank or to Guana and a few nearby islands (Becker and Miller 2002, Lazell 2005). Recently, several insects new to science have been described from Guana (Slipinsky 1989, Scarbrough 1997, Norrbom 1998, Becker and Miller 2002), whereas other species have been recognized as undescribed (Bartlett 2000, Genaro and Franz 2008) but have yet to receive formal taxonomic descriptions.

Guana's impressive biotic diversity cannot be attributed solely to a greater collecting intensity compared to that on many other Caribbean islands. That numerous groups on Guana are unexpectedly speciose is attributable in part to the island's geological history as part of a landmass—"Greater Guania"—comprising a larger Puerto Rico and the Virgin Islands minus St. Croix. Speciation was favored by a pattern of continuity during glacial maxima, alternating, during interglacials, with island fragmentation (ca. 8,000 to 10,000 years ago) that created an archipelago as sea levels rose (Heatwole et al. 1981; Lazell 1996, 2005). Much of today's Guana Island was cleared for agriculture and horticulture in the eighteenth century, but steeper portions of the island were spared. Goats might never have been present, or at least have been absent since the 1930s (Proctor 2005). Sheep were introduced in the 1930s, but their effects on the island's vegetation apparently have been relatively small (Kraus 2002). Communities on Guana remain diverse (e.g., dry forest, dry lowland scrub and cactus, mangroves, mesic ravine forests), and the vegetation is better preserved than on most other dry islands (Becker and Miller 1992; Collins et al. 1997; Kraus 2002; Lazell 1996, 2005); such conditions favor a diverse fauna of phytophagous insects (Procter 2005). For additional information on the natural history and geology of Guana, readers are referred to the book by Lazell (2005).

The insect fauna of Guana, like that of other Caribbean islands (Kairo et al. 2003, Peck 2006), also includes immigrant species, such as the red imported fire ant (*Solenopsis invicta* Buren) (Davis et al. 2001, Wetterer and Snelling 2006), that have become established as the result of human activities. Here, based on recent collecting in the British Virgin Islands (BVI)—mostly on Guana but also on nearby Beef Island and Tortola—we give the first Western Hemisphere records of the yellowish sugarcane mealybug, *Pseudococcus saccharicola* Takahashi. In addition, we give the first BVI records of a co-occurring coccinellid, *Hyperaspis scutifera* (Mulsant), known previously in the West Indies only from Curaçao. We provide diagnoses and illustrations for both species and discuss their distributional status in the BVI—that is, native or adventive.

MATERIALS AND METHODS

On 20 October 2008, one of us (A.G.W.) collected a mealybug on Guana by rolling back the dense turf of bermudagrass (*Cynodon dactylon* [L.] Pers.; Poaceae) from around rocks and walls of outbuildings and shaking the thick mats over a white enamel pan. In October 2009, mealybugs were found on bermudagrass at the same site and were collected from other Poaceae on Guana, as well as Tortola and Beef Island, by tapping shoots into a beating net placed at the base of grasses. Immature and mature females of the mealybug were preserved in 70% ethanol and later were identified as *Pseudococcus saccharicola* by G.A.E. Adult coccinellids from bermudagrass turf and other grasses were point mounted and identified by N.J.V. The proposed synonymy of *Hyperaspis sanctaeritae* Dobzhansky, 1941 with *H. scutifera* (Mulsant 1850) is to be attributed to N.J.V. Voucher specimens of the mealybug are deposited in the National Museum of Natural History (USNM) Coccoidea Collection, Beltsville, MD; those of the coccinellid are in the USNM, Smithsonian Institution, Washington, DC.

RESULTS

Pseudococcus saccharicola Takahashi (Fig. 1)

Diagnosis.—*Pseudococcus saccharicola* can be distinguished from other *Pseudococcus* species by having 16 pairs of cerarii, with most cerarii (except those of the anal lobe) lacking auxiliary setae or containing 1 or 2 at most; circulus either present or absent; hind coxae and hind tibiae each with a few translucent pores, hind femora without translucent pores; discoidal pores absent next to eyes; and anal lobe cerarii on membranous areas. Most *Pseudococcus* species have 17 pairs of cerarii and 2 or more auxiliary setae surrounding the conical setae of each cerarius with anal lobe cerarii on heavily sclerotized areas. Among Neotropical species of *Pseudococcus* (Williams and Granara de Willink 1992), *P. saccharicola* is most similar to *P. sorghiellus* (Forbes), which in addition to having 17 pairs of cerarii, each containing several auxiliary setae, has short, stout legs with translucent pores on the hind coxa, femur, and tibia.

Distribution.—*Pseudococcus saccharicola* was described from Shinkwa, Taiwan (Takahashi 1928). It is widely distributed elsewhere in the Oriental Region: Andaman Islands, Bangladesh, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, and Thailand. The mealybug also is found in Papua New Guinea (Ben-Dov 1994, 2009; Williams 2004). Our records from the British Virgin Islands (Beef Island, Guana, and Tortola) are the first for the Western Hemisphere.

Bionomics.—*Old World:* Rao (1942) studied the life history and pest status of *P. saccharicola* on sugarcane (*Saccharum officinarum*) in India. In the Philippines, high densities (>100/hill) in rice (*Oryza sativa* L.) can cause wilting and plant death (Pathak and Khan 1994), but this mealybug tends to be prevalent only during droughts (Litsinger et al. 2009). Previously recorded host associations include numerous other grasses: *Arundo donax* L., *Echinochloa colona* (L.) Link, *E. crus-galli* (L.) Beauv., *E. glabrescens* Munro ex Hook. f., *Eleusine indica* (L.) Gaertn., *Eriochloa polystachya* Kunth, *Imperata conferta* (J. Presl) Ohwi, *Ischaemum rugosum* Salisb., *Leptochloa chinensis* (L.) Nees, *Panicum repens* L., *Paspalidium flavidum* (Retz.) A. Camus, *Paspalum conjugatum* Berg., *P. scrobiculatum* L., *Saccharum bengalense* Retz., *S. robustum* Brandes and Jesw. ex Grassl, *S. spontaneum* L., *Sorghum halepense* (L.) Pers., *Triticum aestivum* L., *Urochloa distachya* (L.) T. Q. Nguyen, and *U. mutica* (Forsk.) T. Q. Nguyen (Catindig et al. 1994, Galinato et al. 1999, Ben-Dov 2009). The sedge *Cyperus iria* L. is an "ovipositional" host (Galinato et al. 1999). In tests of the mealybug's host range, nymphs survived on 17 of 24 graminoid species; rates were highest on rice, followed by *Echinochloa glabrescens* and *Panicum repens*. Life cycles were shortest on rice and *E. glabrescens*, followed by wheat (*T. aestivum*) and *Paspalidium flavidum* (Catindig et al. 1994). The mealybug feeds on the roots and lower (abaxial) leaf surfaces of host plants (Rao 1942, Ben-Dov 2009).

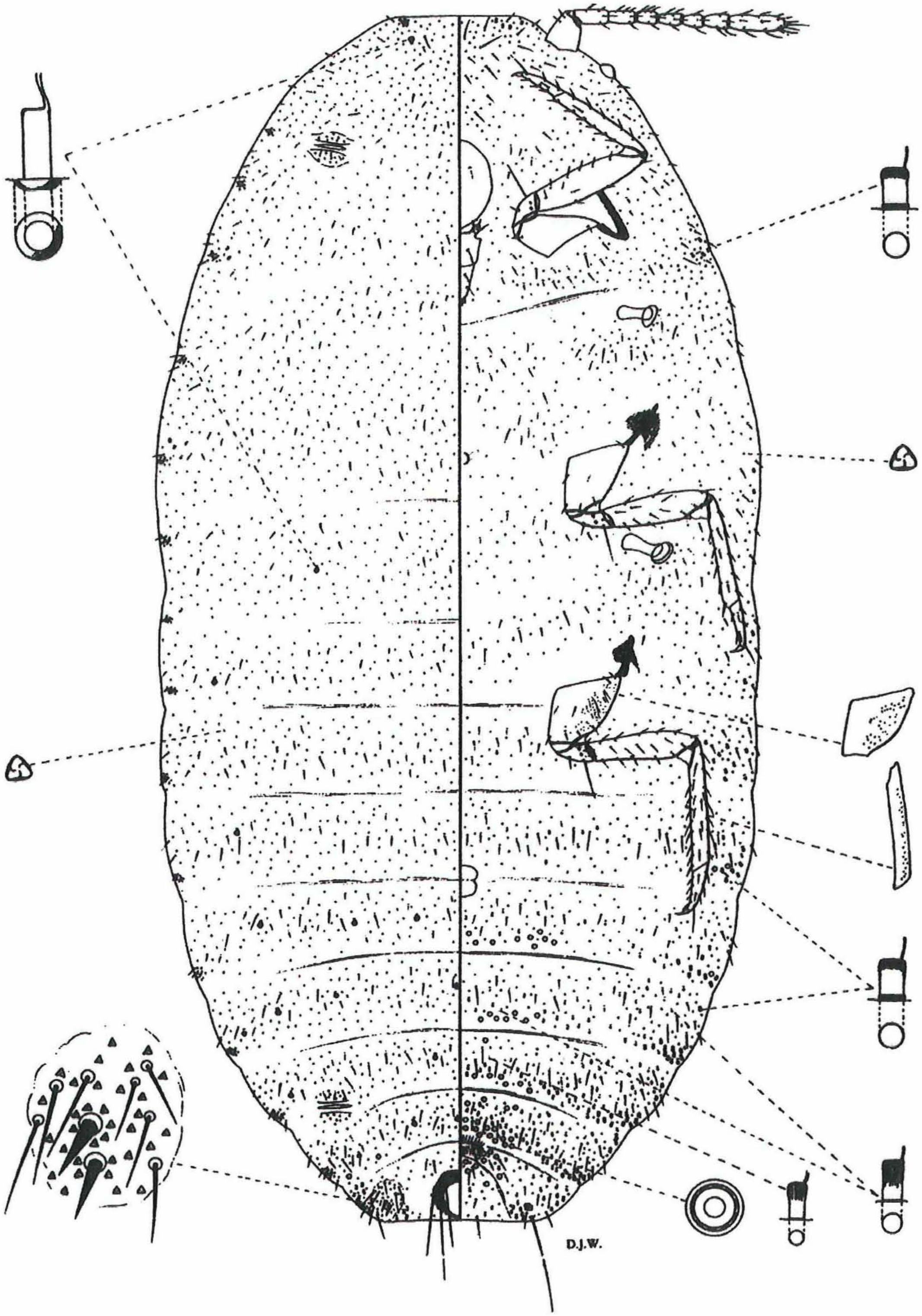


Fig. 1. Adult female *Pseudococcus saccharicola* from Taiwan (from Williams 2004, courtesy of Southdene Sdn. Bhd Publishers).

Fig. 2. Bermudagrass, *Cynodon dactylon*, at desalinization facility, Guana Island, BVI, where *Pseudococcus saccharicola* was discovered by rolling back the thatch from the cement wall to expose females of the mealybug.

British Virgin Islands: Pseudococcus saccharicola was common in mats of bermudagrass (Fig. 2) at the desalinization facility on Guana (18°28.656′N, 64°34.601′W) in October of 2008 and 2009. Fieldwork on Guana in 2009 yielded records of the mealybug from other grasses in disturbed areas. Females were beaten from shoots of swollen fingergrass (*Chloris barbata*) at a construction site near the west end of North Beach (18°28.813′N, 64°34.519′W) and in a gravel pit near the beach's east end (18°28.777′N, 64°34.443′W). Foliar chlorosis occasionally was observed on *C. barbata* near mealybug colonies. Mealybugs also were beaten from leaves and stems of five sugarcane (*S. officinarum*) plants in the orchard on Guana (18°28.463′N, 64°34.406′W). Host grasses on Tortola along a bay near the island's east end (18°25′48.10″N, 64°33′51.73″N) were *C. barbata* and radiate fingergrass (*C. radiata* (L.) Sw.). *Chloris barbata* also was the host near the airport on Beef Island (18°26′48.33″N, 64°33′.41.78″W).

Specimens examined.—BVI: Beef Island: near airport, 15 Oct. 2009, 4♀, ex *Chloris barbata*. Guana Island: desalinization facility, 20 Oct. 2008, 38♀ ex *Cynodon dactylon*; construction site, nr west end of North Bay, 13 Oct. 2009, 51♀, ex *Chloris barbata*; gravel pit, nr east end of North Bay, 17 Oct. 2009, 5♀, ex *C. barbata*; orchard, 16 Oct. 2009, 2♀, ex *S. officinarum*. Tortola: along bay nr east end, 15 Oct. 2009, 23♀ ex *C. barbata* & *C. radiata*.

Hyperaspis scutifera (Mulsant)
(Figs. 3, 4a–d, 5c, 6)

Cleothera scutifera Mulsant, 1850: 565.

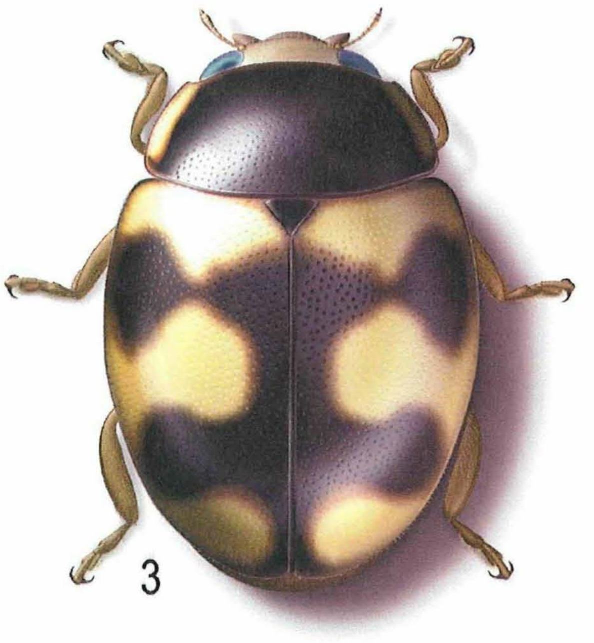
Hyperaspis scutifera: Crotch 1874: 216; Korschefsky 1931: 195; Blackwelder 1945: 448; Gordon and Canepari 2008: 303.

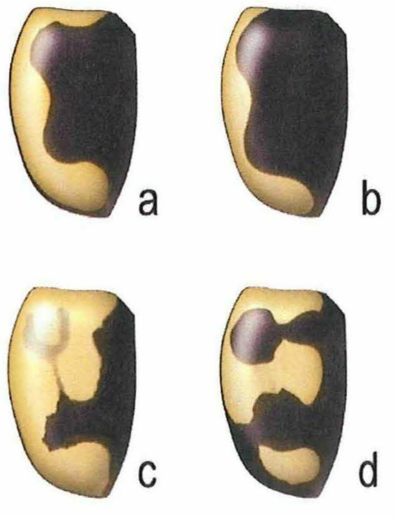
Hyperaspis incompleta Crotch, 1874: 225; Korschefsky 1931: 190; Blackwelder 1945: 445; Gordon 1987: 28; Gordon and Canepari 2008: 303 (as synonym of *scutifera*) (lectotype designated).

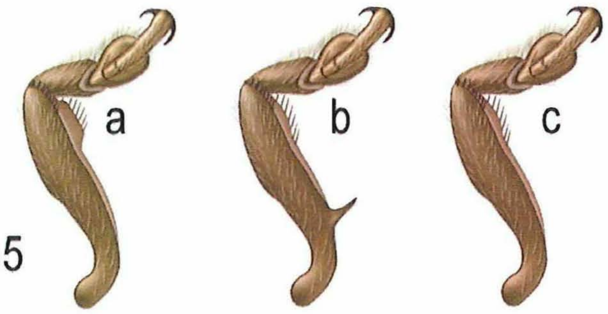
Hyperaspis sanctaeritae Dobzhansky 1941: 60; Gordon 1985: 487. **New synonymy**.

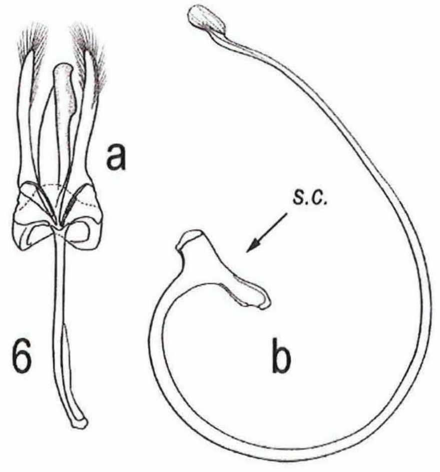
The most reliable means of distinguishing the polymorphic *H. scutifera* from other species with similar elytral markings is through examination of the male genitalia. If the specimen is not dissected, or if only females are available, *H. scutifera* can be recognized by the general body form along with several details of external morphology (anterior tibia, antenna, prosternum, metapostcoxal line), none of which is definitive on its own.

Diagnosis.—Hyperaspidinae with body form oval, approximately 2.5 mm in length (range 2.0 to 2.8 mm). Dorsal surfaces glabrous except for clypeus and short fimbriolate margin of pronotum and elytron; dorsal color pattern ochre yellow and dark brownish black: head entirely black in female, yellow with black base in male; prono-









Figs. 3–6. *Hyperaspis scutifera*. 3, Male habitus of a representative specimen from Guana Island showing the "Curaçao" elytral color pattern. 4a-d, Dorsolateral view of left elytron showing a range of color patterns. 4a, "Scutifera" color pattern described by Mulsant (drawn from USNM specimens from Meta and Puerto Gaitan Colombia); 4b, Modified "scutifera" color pattern showing reduction of the anterior yellow border (drawn from the type series of *H. sanctaeritae*); 4c, "Incompleta" color pattern (redrawn from Gordon and Canepari 2008); 4d, "Curaçao" color pattern (drawn from a specimen collected on Guana Island). Figs. 5a–c, Right prothoracic leg showing variable morphologies of the tibia in the Hyperaspidinae. 5a, *Hyperaspis* sp. showing abrupt distal expansion of the ventral face of the tibia characteristic of certain species; 5b, *Brachiacantha* sp. showing sub-basal tibial spine; 5c, *Hyperaspis scutifera* showing unmodified tibia; Fig. 6a, b, Male genitalia of *Hyperaspis scutifera*. 6a, Ventral view of phallobase showing relative length of parameres (lateral setiferous structures) and basal lobe (asymmetrical median structure); 6b, Left lateral view of sipho (=penis), *s.c.*=siphonal capsule.

tum black with narrow yellowish border; elytron bicolored, variable, but falling within the range of patterns illustrated (Figs. 3, 4a–d). Legs yellow brown with tibiae darker brown. Anterior tibia narrow, unmodified (Fig. 5c), lacking an abrupt distal expansion or sub-basal spine (compare Fig. 4a, b). Antenna composed of 10 articles. Metapostcoxal line extended nearly to posterior margin of first abdominal ventrite and evenly recurved, fading before attaining anteriolateral margin, area inside of arc weakly alutaceous with sparse unevenly scattered punctures. Prosternum coarsely punctate; punctures contiguous or separated by less than ½ diameter of a puncture. Elytral epipleuron foveate to accommodate tibial apices. Male genitalia with phallobase (Fig. 6a) elongate; basal lobe sinuous on one side near apex, subequal in length to parameres; sipho (Fig. 6b) with basal capsule bearing truncate outer arm and longer digitiform inner arm.

Remarks.—The North and South American members of the tribe Hyperaspidini (Hyperaspidinae) have been revised in separate monographs within the last 25 years (Gordon 1985, Gordon and Canepari 2008), but no one has tackled the Caribbean and Central American fauna. Gordon and Canepari (2008) synonymized *Hyperaspis incompleta* Crotch (described from Colombia) with *H. scutifera* Mulsant (described from Valencia, Venezuela), and tentatively included specimens from Curaçao as part of their species concept. Both the "scutifera" and "incompleta" color patterns are illustrated in the South American monograph (Gordon and Canepari 2008: 441) and reproduced here (Figs. 4a and c, respectively), but the "Curaçao" pattern (Figs. 3, 4d) was neither described nor illustrated in the aforementioned work. This made the identification of BVI material somewhat problematic. The USNM specimens of *H. scutifera*, identified by Gordon, include examples from Curaçao, and the color pattern matches that of our BVI specimens and the single USNM specimen examined from Tocayo, Venezuela. Individuals from both areas show only minor variations in this pattern, with a tendency toward confluence of adjacent dark maculae in more heavily marked specimens. A few of the BVI specimens with the lightest markings have a slight separation of the rounded humeral spot from the transverse basal band. Male genitalia of BVI material were the same as those of USNM specimens from Colombia, Venezuela, and Curaçao. In composing a diagnosis for *H. scutifera*, N.J.V. also examined North American material and reviewed the corresponding North American monograph (Gordon 1985). Consequently, an additional synonym of *H. scutifera* was discovered: *Hyperaspis sanctaeritae* Dobzhansky, from Arizona. The type series of *H. sanctaeritae* has a modified "scutifera" pattern (Fig. 4b), with the yellow elytral border reduced in width, and absent along the anterior margin of the elytron (a pattern also exhibited in some of the material from Puerto Gaitan, Colombia). A comparison of the male genitalia showed no differences between the two nominal species.

Distribution.—Colombia, Venezuela, Curaçao, British Virgin Islands, USA (Arizona).

Type material.—of *scutifera*, Valencia,Venezuela (lectotype, female, designated Gordon and Canepari 2008), Deutsches Entomologisches Institut, Muncheberg, Germany; of *incompleta*, Colombia (holotype, female), Cambridge University Museum, Cambridge, England; of *sanctaeritae*, Santa Rita Mountains, Arizona (holotype and 2 paratypes, males), USNM.

Specimens examined.—BVI: Beef Island: near airport, 15 Oct. 2009, 1 adult, ex *Chloris barbata*. Guana Island: desalinization facility, 20 Oct. 2008, 42 adults & 12 Oct. 2009, 2 adults & 1 last-instar larva, ex *Cynodon dactylon*; construction site, nr west end of North Bay, 13 Oct. 2009, 2 adults, ex *C. barbata*; gravel pit, nr east end of North Bay, 17 Oct. 2009, 1 adult, ex *C. barbata*. Tortola: along bay nr island's east end, 15 Oct. 2009, 1 adult, ex *C. radiata*.

Localities outside of BVI (total of 13 specimens examined): Colombia: Meta, Puerto Gaitan. Curaçao: Schottgatwee [=Schottegatweg]; Damacar [=Damacor]; Zapateer. Venezuela: Tocayo. USA: Arizona, Santa Rita Mountains.

Bionomics.—*South America:* Material from Gaitan, Colombia, was collected from the cassava mealybug, *Phenococcus herreni* Cox and Williams, on cassava, *Manihot esculenta* Crantz (label data on USNM specimen).

British Virgin Islands: Hyperaspis scutifera was collected consistently with the mealybug *P. saccharicola*. Adults were most numerous (>40) in mealybug-infested mats of bermudagrass at the desalinization facility on Guana in October 2008. Adults were found in smaller numbers at the same site the following October. A last-instar larva beaten from bermudagrass mats at this site on 12 October 2009 and held in an 8-dram plastic vial yielded an adult of *H. scutifera* by early November. The hyperaspidine was collected on Guana in 2009 at two additional sites from mealybug-infested *Chloris barbata*: near North Bay at the east end (1 adult) and west end (2 adults). An adult also was collected with the yellowish sugarcane mealybug on *C. barbata* near the airport on Beef Island and another adult from mealybug-infested *C. radiata* on Tortola.

DISCUSSION

We consider the mealybug *P. saccharicola* to be adventive on Guana. Miller (1994) documented the arrival on Guana of insect-infested ornamental plants from southern Florida nurseries. The yellowish sugarcane mealybug might have arrived with infested plant material originating in Asia. Even though *P. saccharicola* has been collected only in the British Virgin Islands, it initially might have entered and become established elsewhere in the Caribbean, where its populations have remained undetected. Not only are quarantine procedures and specific legislation that would limit the introduction of potentially invasive species into the Caribbean generally lacking or insufficient, but in many regions knowledge of established adventive species is inadequate or anecdotal (Kairo et al. 2003).

Pseudococcus saccharicola, although found on ornamental sugarcane plants on Guana, is unlikely to become an agricultural pest on this private island where no graminoid crops are grown. It could, however, pose a threat to sugarcane and certain other cultivated grasses on other islands of the West Indies. Moreover, Old World pests, such as the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Kairo et al. 2000, Chong et al. 2008), often are detected in Florida soon after they become established in the Caribbean. Sugarcane, an important crop in Florida (Hall 1988), and other grass hosts of *P. saccharicola* known to occur in Florida thus warrant monitoring for the possible presence of this mealybug. It has been listed among exotic mealybug species not known to occur in the United States that, if established, could threaten U.S. agriculture (Miller et al. 2002).

The range of the coccinellid *H. scutifera* is poorly known and might be more extensive than the relatively few published records would indicate. We consider it adventive rather than native in the British Virgin Islands, following recommendations to regard as adventive those species for which evidence is insufficient to resolve distributional status (Whitehead and Wheeler 1990, Carlton 1996). *Hyperaspis scutifera* might have entered the BVI with shipments of plant material. It

54

might also have become established in the BVI through active or passive aerial dispersal from South America or, having been attracted to ship lights (Holzapfel and Harrell 1968, Roque-Albelo et al. 2008), arrived with a cruise ship docking at Tortola (or another Caribbean island).

Hyperaspis scutifera was the most abundant coccinellid in mealybug-infested mats of bermudagrass at the desalinization facility on Guana. Also present was the scymnine *Diomus roseicollis* (Mulsant), a widespread Caribbean species previously recorded from Guana (Valentine and Ivie 2005, Peck 2006). It preys on mealybugs and other homopterans (Peck 2009).

The consistent occurrence of *H. scutifera* with *P. saccharicola* on grasses, high density observed on mealybug-infested bermudagrass, collection of a larva from a mealybug colony on bermudagrass, and records of predation on mealybugs by other *Hyperaspis* species (Gordon 1985, Vandenberg 2002, Hodek and Honěk 2009) suggest that this coccinellid feeds on *P. saccharicola* in the British Virgin Islands. Adventive lady beetles that are generalist predators, such as *Harmonia axyridis* (Pallas), can disrupt communities by displacing native coccinellids (Evans 2004). *Harmonia axyridis* sometimes also damages commercial fruits and becomes a nuisance when adults invade buildings and houses during autumn and winter (Koch 2003, Koch et al. 2004, Roy and Wajnberg 2008). *Hyperaspis scutifera*, however, is a presumed specialized predator of scale insects. It might compete with other small coccidophagous lady beetles, but any adverse environmental effects on Guana (or elsewhere in the West Indies) probably would be minimal. Even if the establishment of *H. scutifera* should affect the abundance and distribution of native hyperaspidine and scymnine coccinellids in the Caribbean, such changes likely would go undetected (Wheeler and Hoebeke 2009).

ACKNOWLEDGMENTS

We thank Douglass Miller (SEL, PSI, USDA-ARS, Beltsville, MD) for confirming the identification of the mealybug and Southdene Sdn. Bhd. Publishers, Kuala Lumpur, for permission to use the figure of *Pseudococcus saccharicola* from Williams (2004); Jens Prena (SEL, PSI, USDA-ARS, Washington, DC) for assistance in interpreting label data taken from specimens of *Hyperaspis scutifera* collected on Curaçao; and Richard Hoebeke (Department of Entomology, Cornell University, Ithaca, NY), David Nickle (SEL, Beltsville, MD), and Allen Norrbom (SEL, Washington, DC) for reviewing the manuscript. AGW is grateful to James Lazell (The Conservation Agency, Jamestown, RI) for the invitation (via Thomas Henry, SEL, Washington, DC) to participate in surveys of the biota of Guana Island; Henry Jarecki, MD and Gloria Jarecki for their support of inventories on the island; the staff on Guana for their hospitality; and Thomas Henry for companionship in the field and the photograph used in Fig. 2. Lisa Roberts (SEL, Washington, DC) made multiple digital images of *H. scutifera* that were referenced in creating the habitus illustration.

LITERATURE CITED

Bartlett, C. R. 2000. An annotated list of planthoppers (Hemiptera: Fulgoroidea) of Guana Island (British Virgin Islands). Entomological News 111: 120–132.

Becker, V. O. and S. E. Miller. 1992. The butterflies of Guana Island, British Virgin Islands. Bulletin of the Allyn Museum 136: 1–9.

Becker, V. O. and S. E. Miller. 2002. The large moths of Guana Island, British Virgin Islands: a survey of efficient colonizers

(Sphingidae, Notodontidae, Noctuidae, Arctiidae, Geometridae, Hyblaeidae, Cossidae). Journal of the Lepidopterists' Society 56: 9–44.

Ben-Dov, Y. 1994. A Systematic Catalogue of the Mealybugs of the World (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with Data on Geographical Distribution, Host Plants, Biology and Economic Importance. Intercept, Andover, UK. 686 pp.

———. 2009. ScaleNet, *Pseudococcus saccharicola* Takahashi. http://www.sel.barc.usda.gov/catalogs/pseudoco/Pseudococcussaccharicola.htm. Accessed 15 September 2009.

Blackwelder, R. E. 1945. Checklist of the Coleopterous insects of Mexico, Central America, the West Indies, and South America. Bulletin of the United States Natural History Museum 185(3): 343–550.

Carlton, J. T. 1996. Biological invasions and cryptogenic species. Ecology 77: 1653–1655.

Catindig, J. L. A., A. T. Barrion, and J. A. Litinger. 1994. Host plant range of *Pseudococcus saccharicola* Takahashi. International Rice Research Notes (Philippines) 19: 21.

Chong, J.-H., A. L. Roda, and C. M. Mannion. 2008. Life history of the mealybug, *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae), at constant temperatures. Environmental Entomology 37: 323–332.

Collins, M. S., M. I. Haverty, and B. L. Thorne. 1997. The termites (Isoptera: Kalotermitidae, Rhinotermitidae, Termitidae) of the British Virgin Islands: distribution, moisture relations, and cuticular hydrocarbons. Sociobiology 30: 63–76.

Crotch, G. R. 1874. A Revision of the Coleopterous Family Coccinellidae. E. W. Janson, London. xv + 311 pp.

Davis, L. R., Jr., R. K. Vander Meer, and S. D. Porter. 2001. Red imported fire ants expand their range across the West Indies. Florida Entomologist 84: 735–736.

Dobzhansky, T. 1941. Beetles of the genus *Hyperaspis* inhabiting the United States. Smithsonian Miscellaneous Collections 101(6): 1–94.

Evans, E. W. 2004. Habitat displacement of North American ladybirds by an introduced species. Ecology 85: 637–647.

Galinato, M. I., K. Moody, and C. M. Piggin. 1999. Upland Rice Weeds of South and Southeast Asia. International Rice Research Institute, Los Baños, Philippines. 156 pp.

Genaro, J. A. and N. M. Franz. 2008. The bees of Greater Puerto Rico (Hymenoptera: Apoidea: Anthophila). Insecta Mundi 40: 1–24.

Gordon, R. D. 1985. The Coccinellidae (Coleoptera) of America north of Mexico. Journal of the New York Entomological Society 93: 1–912.

———. 1987. A catalogue of the Crotch collection of Coccinellidae (Coleoptera). Occasional Papers on Systematic Entomology 3: 1–46.

Gordon, R. D. and C. Canepari. 2008. South American Coccinellidae (Coleoptera), Part XI: a systematic revision of Hyperaspidini (Hyperaspidinae). Annali del Museo Civico di Storia Naturale "Giacomo Doria" 99: 245–512.

Hall, D. G. 1988. Insects and mites associated with sugarcane in Florida. Florida Entomologist 71: 138–150.

Heatwole, H., R. Levins, and M. D. Dyer. 1981. Biogeography of the Puerto Rican Bank. Atoll Research Bulletin 251: 1–55.

Hodek, I. and A. Honěk. 2009. Scale insects, mealybugs, whiteflies and psyllids (Hemiptera, Sternorrhyncha) as prey of ladybirds. Biological Control 51: 232–243.

Holzapfel, E. P. and J. C. Harrell. 1968. Transoceanic dispersal studies of insects. Pacific Insects 10: 115–153.

Kairo, M., B. Ali, O. Cheesman, K. Haysom, and S. Murphy. 2003. Invasive species threats in the Caribbean Region: Report to the Nature Conservancy. CAB International, Oxford, UK. http://www.bu.edu/scscb/working_groups/resources/Kairo-et-al-2003.pdf. Accessed 16 February 2010.

Kairo, M. T. K., G. V. Pollard, D. D. Peterkin, and V. F. Lopez. 2000. Biological control of the hibiscus mealybug, *Maconellicoccus hirsutus* Green (Hemiptera: Pseudococcidae) in the Caribbean. Integrated Pest Management Reviews 5: 241–254.

Koch, R. L. 2003. The multicolored Asian lady beetle, *Harmonia axyridis*: a review of its biology, uses in biological control, and nontarget impacts. Journal of Insect Science 3: 32: 1–16.

Koch, R. L., E. C. Burkness, S. J. Wold Burkness, and W. D Hutchison. 2004. Phytophagous preferences of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) for autumn-ripening fruit. Journal of Economic Entomology 97: 539–544.

Korschefsky, R. 1931. Pars 118: Coccinellidae. I., pp. 1–224. *In* W. Junk and S. Schenkling, eds. Coleopterorum Catalogus. W. Junk, Berlin.

Kraus, F. 2002. Ecology and conservation of *Sida eggersii* (Malvaceae), a rare tree of the Virgin Islands. Caribbean Journal of Science 38: 184–194.

Lazell, J. 1996. Guana Island: A natural history guide. Third ed. Conservation Agency Occasional Paper (Jamestown, RI) 1: 1–20.

———. 2005. Island: Fact and Theory in Nature. University of California Press, Berkeley, California. 382 pp.

Litsinger, J. A., B. L. Canapi, J. P. Bandong, M. D. Lumaban, F. D. Raymundo, and A. T. Barrion. 2009. Insect pests of rainfed wetland rice in the Philippines: population densities, yield loss, and insecticide management. International Journal of Pest Management 55: 221–242.

Miller, D. R., G. L. Miller, and G. W. Watson. 2002. Invasive species of mealybugs (Hemiptera: Pseudococcidae) and their threat to U.S. agriculture. Proceedings of the Entomological Society of Washington 104: 825–836.

Miller, S. E. 1994. Dispersal of plant pests into the Virgin Islands. Florida Entomologist 77: 520–521.

Mulsant, E. 1850. Species de Coléoptères Trimères Sécuripalpes. Annales des Sciences Physiques et Naturelles de Lyon 2: 1–1104.

Norrbom, A. L. 1998. A revision of the *Anastrepha daciformis* species group (Diptera: Tephritidae). Proceedings of the Entomological Society of Washington 100: 160–192.

Pathak, M. D. and Z. R. Khan. 1994. Insect Pests of Rice. International Rice Research Institute [Los Baños, Philippines]; International Centre of Insect Physiology and Ecology [Nairobi, Kenya]. 89 pp.

Peck, S. B. 2006. The beetle fauna of Dominica, Lesser Antilles (Insecta: Coleoptera): diversity and distribution. Insecta Mundi 20: 165–209.

———. 2009. The beetles of Barbados, West Indies (Insecta: Coleoptera): diversity, distribution and faunal structure. Insecta Mundi 73: 1–51.

Proctor, G. R. 2005. Flora Guanae: an annotated list of the vascular plants, pp. 158–174. *In* J. Lazell, ed., Island: Fact and Theory in Nature. University of California Press, Berkeley, California.

Rao, S. R. 1942. Life-history and bionomics of *Pseudococcus saccharicola* Takh. (Homop.-Coccidae).—a new pest of sugarcane in India. Proceedings of the Indian Academy of Sciences 16: 79–86.

Roque-Albelo, L., E. Lomas Chauca, and O. Castillo Gaona. 2008. Dispersal of insect species attracted to ship lights: conservation implications for Galapagos, pp. 107–109. *In* CDF, GNP & INGALA Galapagos Report 2007–2008, Puerto Ayora, Galapagos, Ecuador.

Roy, H. E. and E. Wajnberg. 2008. From biological control to invasion: The ladybird *Harmonia axyridis* as a model species. Springer, Dordrecht. 287 pp. http://dx.doi.org/10.1007/978-1-4020-6939-0. Accessed 16 February 2010.

Scarbrough, A. G. 1997. West Indian species of *Beameromyia* Martin (Diptera: Asilidae). Insecta Mundi 11: 237–246.

Slipinsky, S. A. 1989. A review of the Passandridae (Coleoptera, Cucujoidea) of the world. II. Genus: *Catogenus* Westwood. Polska Pismo Entomologiczne 59: 85–129.

Takahashi, R. 1928. Coccidae of Formosa. Philippine Journal of Science 36: 327–347.

Valentine, B. D. and M. A. Ivie. 2005. Beetles: Coleoptera, pp. 274–282. *In* J. Lazell, ed. Island: Fact and Theory in Nature. University of California Press, Berkeley, California.

Vandenberg, N. J. 2002. Coccinellidae Latreille 1807, pp. 371–389. *In* R. H. Arnett, Jr., M. C. Thomas, P. E. Skelley, and J. H. Frank, eds. American Beetles, Vol. 2. Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, Boca Raton, Florida.

Wetterer, J. K. and R. R. Snelling. 2006. The red imported fire ant, *Solenopsis invicta*, in the Virgin Islands (Hymenoptera: Formicidae). Florida Entomologist 89: 431–434.

Wheeler, A. G., Jr. and E. R. Hoebeke. 2009. Adventive (non-native) insects: importance to science and society, pp. 475–521. *In* R. G. Foottit and P. H. Adler, eds. Insect Biodiversity: Science and Society. Wiley-Blackwell, Chichester, UK.

Whitehead, D. R. and A. G. Wheeler, Jr. 1990. What is an immigrant arthropod? Annals of the Entomological Society of America 83: 9–14.

Williams, D. J. 2004. Mealybugs of Southern Asia. Natural History Museum, Southdene, Kuala Lumpur, Malaysia. 896 pp.

Williams, D. J. and M. C. Granara de Willink. 1992. Mealybugs of Central and South America. CAB International, Wallingford, Oxon., UK. 635 pp.

NEW BUTTERFLY RECORDS FROM GUANA ISLAND, BRITISH VIRGIN ISLANDS (LEPIDOPTERA: NYMPHALIDAE)

SCOTT E. MILLER[1] AND RICHARD A. LUTMAN[2]
[1]National Museum of Natural History, Smithsonian Institution, Washington, DC 20013-7012

[2]Myrtle Beach, South Carolina

Guana is a small island of only 297 ha (18°28'N, 64°35'W), located on the north side of Tortola in the British Virgin Islands. Becker & S. Miller (1992) published a list of butterflies known from Guana, based on collections made between 1984 to 1990. They recorded 31 species from the small island, which is quite a high count considering that nearby but much larger islands have about the same recorded number (Tortola at 5444 ha has 31 species and St. Thomas at 7660 ha has 32 species; J. Miller 1994; Davies & Smith 1998). Lazell (2005) discussed the high number of butterfly species relative to the island size, and also commented that despite many entomologists visiting Guana (including the late Robert Denno), no one had captured any new butterfly species (see also Becker & S. Miller 2002). No new species were recorded until Oct 2008 when *Anaea astina* (Fabricius) and *Anartia jatrophae* (Linnaeus) were collected by one of us (Lutman). The known food plants for both species have been found on Guana Island (Proctor in Lazell 2005), although neither species has been reared there.

To test existing taxonomic concepts (Smith et al. 1994), we obtained *cytochrome c oxidase I* ("DNA barcode") sequences from these specimens and comparative material, based on standard techniques at the University of Guelph (Craft et al. 2010; Ratnasingham & Hebert 2007). Genetic distances are expressed by Neighbor Joining with the Kimura 2 parameter as implemented in the Barcode of Life Database (Ratnasingham & Hebert 2007). Voucher specimens are deposited in the National Museum of Natural History, Smithsonian Institution.

Anartia jatrophae was predicted by Becker & Miller (1992) as a species that would eventually be found on Guana, because it occurs on the neighboring island of Tortola. In 2008, it was one of the most common species on Guana, especially on the plains around the salt pond. The DNA barcodes from Guana (Specimens USNM ENT 719001-3, Genbank HM900671-HM900673) are identical to each other, and to one of several haplotypes from Costa Rica (Genbank GU333749), consistent with the view of this as a widespread polymorphic species (Gillham 1957; Silberglied et al. 1980), rather than requiring recognition of the Puerto Rican Bank subspecies *Anartia jatrophae semifusca* Munroe (Smith et al. 1994).

One *Anaea astina* was collected and another was observed: not as common as *Anartia* in 2008. The taxon *astina* has variously been considered a subspecies of *Anaea troglodyta* (Fabricius) or a species restricted to the Virgin Islands (Smith et al. 1994). The DNA barcode of the Guana specimen (USNM ENT 719004, Genbank HM900674) is 1.24-1.4% different from 3 specimens of *Anaea troglodyta* from the Dominican Republic (Genbank GQ256760, and new sequences from USNM ENT 719005-6, Genbank HM900593-HM900594). The Guana sequence differs by 1.61% from a specimen published as *Anaea troglodyta* from a butterfly farm with Florida origins (Genbank DQ338573, Aduse-Poku et al. 2009). These levels of genetic distance are often found within Lepidoptera species, but could also be consistent with distinct species (Craft et al. 2010). Unfortunately, no material suitable for DNA analysis is immediately available from Puerto Rico to test the status of *Anaea borquenalis* as recognized by Smith et al. (1994). Further data from more localities will be necessary to fully evaluate the status of taxa in the *Anaea troglodyta* complex, so for now we follow the classification of Smith et al. (1994).

We thank the Paul Hebert, Biodiversity Institute of Ontario, University of Guelph, for providing DNA barcodes as part of the iBOL project funded by Genome Canada, and Lauren Helgen, Smithsonian Institution, for assisting with the barcodes. This project was sponsored by The Conservation Agency through a grant from Falconwood Foundation.

SUMMARY

The butterflies *Anaea astina* and *Anartia jatrophae* (Lepidoptera: Nymphalidae) are recorded for the first time from Guana Island, British Virgin Islands. This brings the total of butterfly species recorded from Guana to 33, which is very high for its small size. DNA barcode data are provided for these specimens.

REFERENCES CITED

ADUSE-POKU, K., VINGERHOEDT, E., AND WAHLBERG, N. 2009. Out-of-Africa again: A phylogenetic hypothesis of the genus *Charaxes* (Lepidoptera: Nymphalidae) based on five gene regions. Molecular Phylogenetics and Evolution 53: 463-478.

BECKER, V. O., AND MILLER, S. E. 1992. The butterflies of Guana Island, British Virgin Islands. Bull. Allyn Museum 136: 1-9.

BECKER, V. O., AND MILLER, S. E. 2002. Large moths of Guana Island, British Virgin Islands: a survey of efficient colonizers (Lepidoptera: Sphingidae, Notodontidae, Noctuidae, Arctiidae, Geometridae, Hyblaeidae, Cossidae). J. Lepidopterists' Soc. 56: 9-44, 191-192.

CRAFT, K. J., PAULS, S. U., DARROW, K., MILLER, S. E., HEBERT, P. D. N., HELGEN, L. E., NOVOTNY, V., AND WEIBLEN, G. D. 2010. Population genetics of ecological communities with DNA barcodes: An example from New Guinea Lepidoptera. Proc. Natl. Acad. Sci. USA 107: 5041-5046.

DAVIES, N., AND SMITH, D. S. 1998. Munroe revisited: A survey of West Indian butterfly faunas and their species-area relationship. Global Ecology and Biogeography Letters 7: 285-294.

GILLHAM, N. W. 1957. Subspecies versus geographic variation in Caribbean populations of Anartia jatrophae Johansson (Lepidoptera, Nymphalidae). American Mus. Novitates 1845: 1-22.

LAZELL, J. D. 2005. Island: Fact and Theory in Nature. University of California Press, Berkeley. xx + 382 pp.

MILLER, J. Y. 1994. Behavior in butterflies as a means of conservation: Comparison of insular and continental fauna. Florida Entomol. 77: 74-84.

RATNASINGHAM, S., AND HEBERT, P. D. N. 2007. BOLD: The Barcode of Life Data System (http://www.barcodinglife.org). Molec. Ecol. Notes 7: 355-364.

SILBERGLIED, R. E., AIELLO, A., AND LAMAS, G. 1980. Neotropical butterflies of the genus *Anartia*: systematics, life histories and general biology (Lepidoptera: Nymphalidae). Psyche 86: 219-260.

SMITH, D. S., MILLER, L. D., AND MILLER, J. Y. 1994. The Butterflies of the West Indies and South Florida. Oxford University Press, Oxford. x + 264 pp., 32 pl.

POLISH JOURNAL OF ENTOMOLOGY
POLSKIE PISMO ENTOMOLOGICZNE

VOL. **79**: 187-193 Bydgoszcz 30 June 2010

Systematic and faunistic data on Neotropical Bactrini (Lepidoptera: Tortricidae)

JÓZEF RAZOWSKI*, VITOR O. BECKER**

* Institute of Systematics and Evolution of Animals PAS, Sławkowska 17, 31-016 Kraków, Poland, e-mail: Razowski@isez.pan.krakow.pl
** Reserve Serra Bonita, PO Box 01, 45880-970 Camacan, BA, Brazil

ABSTRACT. Neotropical species of *Bactra* and *Endothenia* are listed and commented. Seven species are recorded from Central and South America. *Bactra goiasia* and *Endothenia tuxtlasia* are described as new.

KEY WORDS: Lepidoptera, Tortricidae, new species, new data, Neotropic.

INTRODUCTION

A. DIAKONOFF the late leading specialist to *Bactra* and its allies dealt (DIAKONOFF 1964) with ten species of this genus found in the Neotropics. Currently 13 species (see the list below) are recorded.

This cosmopolitan genus is widely destributed and known from all geographic regions.

Another genus, *Endothenia* currently included in this tribe is represented by three Neotropical species. The Holarctic *E. hebesana* (WALKER, 1863) was mentioned from Puerto Rico but this identification should be confirmed. Some data on Neotropical *Endothenia* (included in Endotheniina) are provided by RAZOWSKI & PELZ (2002).

60

Systematic list of Neotropical *Bactrini*

Bactra STEPHENS, 1834
goiasia sp. n., Brazil: Goias; male genitalia; this paper.
diachorda MEYRICK, 1932 (*Bactra*), Brazil: Santa Catarina; DIAKONOFF (1964): male genitalia.
seria MEYRICK, 1917 (*Bactra*), Peru; DIAKONOFF (1964): male and female genitalia.
clarkei DIAKONOFF, 1964 (*Bactra*), British Guiana: male and female genitalia.
adoceta DIAKONOFF, 1964 (*Bactra*); Brazil: Paraná; male genitalia.
clarescens MEYRICK, 1912 (*Bactra*), Dutch Guiana; male and female genitalia. Distribution: Dutch Guiana, French Guiana, Jamaica, Dominica, Grand Cayman, Brazil: Santa Catarina, Argentine.
philocherda DIAKONOFF, 1964 (*Bactra*), British West Indies: Dominica; male and female genitalia; distribution: U.S.A.: Florida, British West Indies, Jamaica, Cuba, Guatemala, Panama, Peru, Brazil: Pará; West Africa: Angola.
perisema DIAKONOFF, 1964 (*Bactra*), British Guiana; female genitalia.
priapeia HEINRICH, 1923 (*Bactra*), U.S.A.: Louisiana, male genitalia; DIAKONOFF (1964) male and female genitalia; distribution: U.S.A.: Louisiana, Texas; Panama; British Honduras; Cuba.
verutana ZELLER, 1875 (*Bactra lanceolana* var.); U.S.A.: Texas; DIAKONOFF (1964): male and female genitalia; distribution: U.S.A.: Florida, Texas, California; Cuba, Porto Rico, Bahama, Paraguay.
cultellana ZELLER, 1877 (*Bactra*), Colombia; DIAKONOFF (1964): male genitalia; distribution: U.S.A.: Florida; Colombia, Paraguay.
neuricana ZELLER, 1877 (*Bactra*), Colombia; not examined.
fuscidorsana ZELLER, 1877 (*Bactra*), Columbia; not examined.
Endothenia STEPHENS, 1852
anthracana (FORBES, 1931) (*Olethreutes*), Puorto Rico.
eidolon RAZOWSKI & PELZ, 2002, Ecuador; male genitalia; RAZOWSKI et al. (2008); female genitalia, Galapagos.
tuxtlasia sp. n., Mexico: Veracruz; male genitalia; this paper.

SYSTEMATICS

Bactra goiasia sp. n.

Diagnosis

Very close to *adoceta* but with large spined part of uncus, short cucullus, and the presence of a row of four spines dorsally to middle of sacculus.

61

Description

Wing span 22 mm. Head yellow-brown, thorax brownish. Forewing of usual bactrine shape but termen rather weakly oblique. Ground colour cream brown in apical field more ochreous, sprinkled and suffused brown; costal area finely strigulated brown; veins brown. Cilia dark brown. Hindwing brown with paler, more grey anal area; cilia brownish.

Male genitalia (Fig. 1). Uncus large with posterior half armed with lateral, rather short spines; socius large; valva slender with weak postmedian incision; sacculus weakly convex with subterminal group of ventral spines and four longer spines above it; cucullus short; aedeagus very short.

Female not known.

Material examined

Holotype male: "Brasil: GO[ias], Alto Paraiso, 1400 m, 3. X. 1985, V.O. BECKER Col; Col. BECKER 64429"; GS 975.

Etymology

The name refers to the terra typica of this species, the state of Goias.

Bactra seria MEYRICK, 1917

Material examined

Several specimens from Paraná: Curitiba, 10. II. 1974 and Sao Joaquim 1400 m, 22-24. I. 1983.

Remarks

This species was described from Peru; DIAKONOFF (1964) recorded it from Entre Rios, Brazil.

Bactra clarkei DIAKONOFF, 1964

Material examined

Ten specimens from Paraná, Brazil (Curitiba, 6-9 II. 1974, ex. 1. from *Cyperus papyrus*, leg. A. Saka KIBAM).

Remarks

This species was described from British Guiana from four specimens.

Bactra clarescens MEYRICK, 1912

Material examined

Twelve specimens from Brazil: Pará (Belem, 20 m, I. 1984 and Capitao Poco, 28 - 31. I. 1984); Bahia (Bonito, 1000 m, 25. IV. 1991); Esprito Santo (Linhares, 40 m, III).

Remarks

Facies slightly variable; usually rather dark, brownish specimens, one example is whitish, tinged and dotted brownish grey. Male genitlia (Fig. 2) with terminal thorn of sacculus more or less long; usually one strong subterminal spine of sacculus, rarely there are two spines; dorsal thorn of aedeagus more or less distinct; number of cornuti varying from 2 to 5.

Bactra philocherda DIAKONOFF, 1964

Material examined

Numerous specimens from Mexico: Veracruz (Los Tuxtlas, 11 - 16. VI. 1981); Puerto Rico (Patillas, 590 m, VIII. 1987); British Virgin Is. (Guana Is., 0 - 80 m, 9 - 23. Vii. 1987); Costa Rica (Turrialba, 600 m, V. 1972; Guayacan, 650 m, 28. VII. 1972); Brazil: Rio de Janeiro (Mangaritiba, 150 m, 20. I. 1993); Pará (Belem, 20 m, I. 1984); Espirito Santo (Linhares, 40 m, 20 - 29. II. 1992); Ecuador (Misahualli, 450 m, XII. 1992).

Remarks

This species is widely distributed in this region (cf. the list), from Florida, U.S.A. to Peru and Ecuador; RAZOWSKI et al. (2008) recorded it also from Galapagos. Male genitalia varying in the shape of sacculus and number of cornuti (one or two large or three smaller); rarely a small subtreminal thorn of the dorsum of aedeagus occurs.

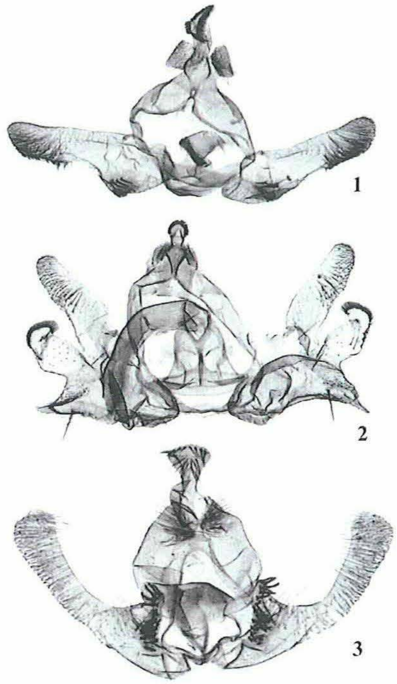
Bactra priapeia HEINRICH, 1923

Material examined

Three specimens from Puerto Rico (Patillas, 590 m, VIII. 1987); three ones from Costa Rica (Turrialba, 600 m, IX.1971 and El Coco, VIII. 1971).

Remarks

Described from Louisiana, known also from Texas and Florida, the U.S.A. DIAKONOFF (1964) recorded it from Canal Zone, Panama, British Honduras, and Cuba.



Figs 1-3. Male genitalia: 1 – *Bactra goiasia* sp.n., holotype, 2 – *Bactra clarescens* MEYRICK, Bonita, Bahia, Brazil, 3 – *Endothenia tuxtlasia* sp. n., holotype.

Bactra verutana ZELLER, 1875

Material examined

Fiveteen specimens from the U.S.A.: Virgin Is. (St Thomas, 300 m, 25 - 30. VII. 198; Guana I., 0-80 m, 9-23. VII. 1987); 5 specimens from Cuba (Matanzas, Cienag. Zapata, 18. VIII. 1990); 1987.

7 Mexico: Federal District (Mexico, 2600 m, 24. VIII. 1981); Brazil: Paraná (Curitiba, 900 and 920 m,, 2. II. 1970 and 18. IX. 1974 and 25. X. 1974), Sao Paulo (Jacupiranga, 800 m, 8. II. 1993); Alagoas: Ibateguara 400 m, 10-20. III. 1994; Goias (Alto Paraiso 1400 m, 1 - 6. XI. 1996 and 30. V. 1994, 1300 m).

Remarks

In the New World *verutana* is distributed from Florida, Baja California, and Texas, U.S.A. through Cuba, Puerto Rico to Paraguay (DIAKONOFF 1964). Based on our material one can suppose it is widely distributed in Brazil.

Etymology

The name refers to the type locality.

Endothenia tuxtlasia sp. n.

Diagnosis

This species is closely related with *E. hebesana* (WALKER, 1863) from Puerto Rico and Ecuadoran *E. eidolon* RAZOWSKI & PELZ, 2002 but tuxtlasia uncus much shorter, with shorter base and subtriangular posterior part.

Description

Wing span 12 mm. Head and thorax greish brown, thorax with darker marks. Forewing weakly expanding terminally, costa and termen somewhat convex. Ground colour cream brown with grey suffusions and brown marbling. Markings brown consisting of weak basal blotch, almost complete median fascia with paler and darker marks, and brown subterminal fascia. Cilia brown. Hindwing brownish, cilia paler.

Male genitalia (Fig. 3). Posterior part of uncus broad, triangular; socius triangular; valva expanding dorso-terminally with broad spined lobe; aedeagus short.

Female not known.

Materaial examined

Holotype male: "Mexico: Veracruz, Est. Biol. Tuxtlas, 11-16. VI. 1981, V. O. Becker Col; Col. Becker 42461"; GS 982.

REFERENCES

DIAKONOFF A. 1964. Further records and descriptions of the species of *Bactra* STEPHENS (Lepidoptera, Tortricidae. Zool. Meded., Nr. 70: 1-81, pl. 1.

RAZOWSKI J., LANDRY B., ROQUE-ALBELO L. 2008. The Tortricidae (Lepidoptera) of the Galapagos Islands, Ecuador. Revue suisse Zool., **115**(1): 18 -220.

RAZOWSKI J., PELZ V. 2002. Endotheniina, an olethreutine subtribe new to the South American continent, with description of one new species (Lepidoptera: Tortricidae). Polskie Pismo entomol., **71**: 313-315.

Received: April 28, 2010
Accepted: May 07, 2010

66

Davis, D., and J. Stonis. 2007.

A Revision of the New World Plant-Mining Moths of the Family Opostegidae

(Lepidoptera: Nepticuloidea)

Smithsonian Contributions to Zoology 625: 1-212.

INTRODUCTION

Opostegidae 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 Jasiukonytė, 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.
BMNH	The Natural History Museum (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, 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.

in a narrow, rounded lobe. Valva with a relatively large cucullar lobe ~0.45× length of genital lobe, bearing a pectinifer consisting of 27–30 blunt spines; pedicel elongate, relatively broad, width ~0.2× length of cucullar lobe; valva relatively short, length along sacculus ~0.65× length of genital capsule; saccular lobe moderately stout, extending halfway along pedicel; basal process of valva relatively short, less than length of elongate costal process. Juxta undeveloped.

Female Genitalia: Figures 428, 429. Abdomen tapering to a narrow, rounded apex. Each posterior apophysis divided ~half its length, short, slender. Papillae anales bilobed; lobes divergent, short, slightly broader than long, broadly truncate; bearing numerous long setae. Vestibulum with minute, broadly dentate spicules extending mostly into ductus bursae. Ductus bursae moderately slender, elongate, with a zone of dense, broadly pectinate, mostly 4–6-dentate spicules. Corpus bursae relatively small, elliptical, with a zone of broad pectinated spicules consisting of fused, transverse rows of 4–6 minute spicules at junction with ductus; a faint, partially U-shaped band of numerous, irregular, exterior tubercles extending most of length of bursa. Ductus spermathecae relatively short, ~0.3× length of bursa copulatrix; outer membranous canal bulbous at bursa, then narrowing distally; inner canal with 3–4 distal convolutions and slightly enlarging to small, bulbous vesicle.

LARVA AND PUPA. Unknown.

HOLOTYPE. ♂; USA: VIRGIN ISLANDS: St. Thomas, 300 m: 25–30 Jul 1987, V. O. Becker 67213 (USNM).

PARATYPES. PUERTO RICO: Centro Vacacional, Monte del Estado, near Maricao, 650 m: 5 ♂, 7 ♀, 5 UNK, 1–9 Mar 1971, C. P. Kimball, slides USNM 31847, 32745, 32744, 32746, 32963, 32962 (USNM). U.S. VIRGIN ISLANDS: ST. THOMAS, 300 m: 1 ♂, 25–30 Jul 1987, V. O. Becker (VOB).

HOST. Unknown.

FLIGHT PERIOD. Adults collected in March and July.

DISTRIBUTION. (Map 3) West Indies: Puerto Rico and St. Thomas, U.S. Virgin Islands.

ETYMOLOGY. The specific name is derived from the Latin *ferruginus* (reddish brown, rust-colored), as suggested by the reddish brown, forewing apical band diagnostic for this species.

DISCUSSION. The conspicuous ferruginous apex of the forewing easily distinguishes this species from all other New World Opostegidae. The pronounced, caudally extended basal fold of the male gnathos and proportionately broader caudal lobe further distinguishes *P. ferruginea* from its nearest relative, *P. serrata*.

The *lateriplicata* group

The members of this group are characterized primarily by the variable development of a pair of lateral folds on the male gnathos. A basal fold may be present (in *P. abrupta*) or absent. The length of the valvae along the sacculus ranges from ~0.5 to 0.7× the length of the genital capsule. The juxta may be present or absent.

Pseudopostega abrupta (Walsingham)

FIGURES 141, 269, 270, 430, 431; MAP 4

Opostega abrupta Walsingham, 1897:139.—Forbes, 1930:149.—Davis, 1984:18.

Pseudopostega abrupta (Walsingham).—Davis, 1989:75.—Puplesis and Diškus, 2003:417.

ADULT. Figure 141. Length of forewing 2.5–3.0 mm. Small white moth with white forewings marked by a small, dark brown apical spot, 2–3 light to dark brown subapical, costal strigulae, and rarely with faint brownish middorsal spot. Male with caudal lobe of gnathos stout, apex broadly round; basal fold deeply incised, thickened laterally (Figures 269, 270). Papillae anales of female consisting of a pair of extremely short, tuberculate lobes divided for less than half their length (Figure 431).

Head: Vestiture white. Scape white; flagellum light brown, ~49–56-segmented. Maxillary palpus white. Labial palpus white to cream, suffused with brown laterally.

Thorax: Entirely white. Forewing white marked by a small, dark brown apical spot (lacking in many specimens), 2–3 light to dark brown subapical, costal strigulae, and rarely with a faint, light brown middorsal spot; first strigula the shortest and barely separated from strigula 2; terminal strigula sinuate, curving around apical spot; terminal cilia and venter of forewing brown except for basal white area. Hindwing and cilia golden brown dorsally and ventrally except for white subhumeral suffusion. Legs mostly cream; foreleg with lateral and dorsal surfaces brown; mid- and hindlegs white to cream.

Abdomen: Light golden brown dorsally, white to cream ventrally.

Male Genitalia: Figures 269, 270. Socii a pair of moderately large, elongate, rounded, setose lobes, widely separated by a distance ~equal to length of cucullar lobe; caudal rim of uncus slightly concave. Vinculum broad; anterior margin subtruncate. Gnathos weakly sclerotized, broad at base, gradually tapering to broadly rounded, often slightly enlarged, dorsally recurved, caudal lobe;

anterior margin with a narrow, deep incision extending ~0.7× length of gnathos; basal fold broad laterally, gradually narrowing caudally along medial incision; a pair of slender, secondary lateral folds extending nearly the entire length of gnathos. Valva with small cucullar lobe ~0.3× length of genital capsule, bearing short pectinifer consisting of ~26–33 blunt spines; terminal apex of cucullar lobe prominently extended as a small, setose, rounded lobe; pedicel moderately stout, width ~0.14× length of cucullar lobe; valva elongate, ~0.7× length of genital capsule; saccular lobe moderately broad, with irregularly setose, rounded apex; basal process of valva short, acute; costal process of valva stout, relatively short but slightly longer than basal process. Juxta well developed, broad basally, tapering to an elongate rod-like sclerite.

Female Genitalia: Figures 430, 431. Abdomen tapering to a moderately broad, subacute, slightly cleft apex. Each posterior apophysis fused most of its length, slender, elongate. Papillae anales consisting of a pair of extremely short, tuberculate lobes divided for less than half their length; length of entire papilla ~0.33× maximum width; each lobe bearing ~6 elongate setae, the longest ~0.5× length of posterior apophyses (Figure 430). Vestibulum relatively broad, membranous with a dense zone of minute pectinate spicules at anterior end extending into ductus bursae; spicules arranged usually 5–8 per transverse row; ductus bursae broad, mostly joined with broad spermathecal canal, with an elongate, relatively narrow zone of minute, pectinate spicules arranged in long transverse rows of 7–9 spicules at anterior end. Corpus bursae relatively large, broad, with a faint, irregular U-shaped band bearing numerous, minute, blunt to acute, external tubercles partially encircling anterior half of the bursae (Figure 430). Spermathecal duct ~0.75× length of bursa copulatrix; membranous outer canal broad, elongate, nearly as long as inner canal; inner canal long, sinuous, terminating in ~3–4 convolutions; vesicle relatively short, curved.

LARVA AND PUPA. Unknown.

HOLOTYPE. ♂; USA: VIRGIN ISLANDS: St. Thomas: 19 Mar 1914, Hedemann, slide 2362 (MGAB).

MATERIAL EXAMINED. BRITISH VIRGIN ISLANDS: Guana Island, 0–80 m: 1 ♂, 1–14 Jul 1984, S. E. & P. M. Miller, slide USNM 32723; 3 ♂, 6 ♀, 1 UNK, 10–25 Jul 1988, S. E. Miller & C. O. Connell, slide USNM 32487; 25 ♂, 30 ♀, 1 UNK, 9–23 Jul 1987, V. O. Becker & S. E. Miller. slides USNM 32921, 31845, 32722; 6 ♂, 9 ♀, 10 UNK, Oct 1989, V. O. Becker, slide USNM 32485 (USNM, VOB); 1 ♀, 24–31 Oct 1990, 4 ♂, 12 ♀, 1–5 Nov 1990, S. E. Miller & T. M. Kuklenski, slide USNM 33147 (USNM). Guana Island, Clubhouse, 40–60 m: 2 ♀, 1 UNK, 13–26 Jul 1986, S. E. Miller & M. G. Pogue.

Pogue, slide USNM 32724 (USNM). North Bay, 0 m: 1 ♀, 13–26 Jul 1986, S. E. Miller & M. G. Pogue (USNM). U.S. VIRGIN ISLANDS: St. Thomas: 1 ♂ (holotype), 19 Mar 1914, Hedemann, slide 2362 (MGAB); St. Thomas, 300 m: 4 ♂, 1 ♀, 25–30 Jul 1987, V. O. Becker, slide USNM 32726 (USNM).

HOST. Unknown.

FLIGHT PERIOD. Adults collected in March, July, October, and November.

DISTRIBUTION. (Map 4) West Indies: Guana Island (British Virgin Islands) and St. Thomas (U.S. Virgin Islands).

DISCUSSION. Previously *P. abrupta* was known only from the male holotype collected in 1914 and now lacking its head. One result of the Guana Island survey (see Acknowledgments) was the collection of a large series of this (and other) species together with associated females. Males of *abrupta* differ from other members of the group in the gnathos possessing a well-developed, deeply incised basal fold and are similar to *P. floridensis* in the broadly rounded caudal lobe of the gnathos and presence of a relatively well developed juxta.

***Pseudopostega floridensis*, new species**

FIGURES 142, 271, 432, 433; MAP 4

ADULT. Figure 142. Length of forewing 2.4 mm. Small white moth with a variably distinct dark brown dorsal spot on forewing and dark brown apical spot, 2 brownish costal and 1 tornal strigulae. Male gnathos with slender lateral folds and deep median cleft extending to broadly rounded apex (Figure 271). Papillae anales of female consisting of a pair of relatively long, slender, widely divergent lobes (Figure 433).

Head: Vestiture white. Scape white; flagellum dark cream, ~52-segmented. Palpi cream to ochreous cream; labial palpus with brownish suffusion dorsolaterally.

Thorax: White. Forewing white in holotype without distinct dorsal spot except for a few brownish scales present along middle of dorsal margin on right wing; female with a small, more distinct, dark brown dorsal spot; 2 brown, subapical, costal strigulae present; first strigula fading to light ochreous yellow, triangular area before dark brown apical spot; strigula 2 elongate, curving distally around apical spot; a faint, tornal strigula continuing a short distance below ochreous yellow area; terminal cilia light brown between costal strigulae, becoming white around tornus, then light brown along dorsal

2011 in: Hailey, A., B. Wilson, and J. Horrocks, eds.
Conservation of Caribbean Herpetofaunas Vol. 2.
Regional Accounts of the West Indies, pp. 105-127.
Brill, Leiden, Netherlands.

Conservation of amphibians and reptiles in the British Virgin Islands: Status and patterns

G. Perry[1,2], G.P. Gerber[3]

[1] Dept. of Natural Resource Management, Box 42125, Texas Tech University, Lubbock, TX 79409-2125, USA
[2] Corresponding author; e-mail: Gad.Perry@ttu.edu
[3] Conservation and Research for Endangered Species, Zoological Society of San Diego, 15600 San Pasqual Valley Road, Escondido, CA 92027-7000, USA

Abstract. The British Virgin Islands (BVI) forms part of the Puerto Rican Bank and its fauna is closely related to that of the US Virgin Islands and Puerto Rico. Humans have inhabited the region for several thousand years and their impacts have continuously included habitat modification, hunting, and introduction of invasive species. Those are the three main causes of concern for the present-day herpetofauna of the BVI, which contains 34 amphibian and reptile species. Of these, five (15%) are common, three (9%) are at risk, eight (23%) are endangered, ten (29%) are data deficient, two (6%) are extinct, and six (18%) are introduced or cryptogenic. Several endemic species are only found on tiny islets where stochastic events can easily lead to their extinction. The native iguana, *Cyclura pinguis*, and the sea turtles found in the region are in an especially sensitive condition. Habitat destruction and fragmentation are ongoing and likely to accelerate. Invasive species are still arriving, establishing, and spreading. Thus, although the short-term conservation status of the BVI herpetofauna appears unlikely to change, we are more concerned about the mid-term outlook. We recommend some specific remedies intended to offset these pressures and provide long-term protection to the biota of the BVI.

Key words: Amphibians; British Virgin Islands; conservation; *Cyclura pinguis*; invasive species; reptiles; sea turtles.

Introduction

Human impacts on species and ecosystems are still expanding, despite often already being more pervasive than can be sustainably supported. Global amphibian declines have drawn considerable attention and debate. They appear primarily correlated with a complex and often site-specific combination of the loss of appropriate habitat, pollution, and the introduction of invasive predators and diseases (e.g., Adams, 1999; Stallard, 2001; Blaustein and Kiesecker, 2002; Muths et al., 2003; Lannoo, 2005). Less attention has been paid to the rapid disappearance of reptile species

(Gibbons et al., 2000). The IUCN (1996) classified vertebrates into four categories based on conservation status and found similar rates of endangerment in both groups (Critically endangered: 9% in amphibians, 10% in reptiles; Endangered: 16% and 14%, respectively; Vulnerable: 39% and 38%). In a recent update (IUCN, 2004) they identified 61% of evaluated reptile species as endangered, compared to 32% of evaluated amphibians. Similar patterns and concerns are apparent in the Caribbean. For example, Powell and Henderson (2005) estimated that almost half of Lesser Antillean terrestrial reptiles have been substantially negatively affected by human activities. Unfortunately, the herpetofauna of the British Virgin Islands (BVI, about 150 km^2 total land area) has not been systematically evaluated since MacLean (1982), the exception being a recent book (Lazell, 2005) that focuses on a single island. Here we review the current conservation status of all reptiles and amphibians known from the BVI, drawing upon both published and unpublished work. We begin with a brief description of the historical and biogeographical setting, then provide species accounts. Taxa of special concern are then discussed in additional detail, and we close with a review of broad patterns and likely future trends.

The Setting

History

Humans first arrived in the BVI some 4000-6000 years ago, primarily inhabiting the larger islands (Wilson, 2001) but utilizing some of the smaller ones for protracted periods. Their presence has clearly had extensive impacts on the local fauna (Lazell, 2005), which suffered both additions and extinctions. The current name was given to the islands by Columbus, whose 1493 visit ultimately resulted in the extirpation of Amerindians from the area and in additional plant and animal introductions and extinctions. European settlement began in 1648, when the Dutch claimed Tortola (Jenkins, 1923), and the islands changed hands multiple times before the British finally acquired them in 1672 (Rogozinski, 1992). Slaves were brought in from Africa to support the agricultural effort which converted much of the land area into plantations. England abolished slavery in 1808 and enacted the Emancipation Proclamation in 1834, and the islands have enjoyed various levels of self-rule ever since. The population in 1844 was 6,689 (Fergus, 2003), declined to 4,639 by 1891, grew to 10,000 in the late 1970s, and is currently estimated at 22,643 people, more than three times what it was 150 years ago (BVI Government, 2005). The current annual population growth rate is 2.06%, and population pressure in the BVI is growing, especially on Tortola (which has over 80% of the total population on less than 40% of the BVI land area). The second largest island, Virgin Gorda, doubled its population between 1960 and 1980 and saw an increase of almost 75% from 1980 to 1991. Despite a relatively high emigration rate, the population of the BVI is expected to double in about 35 years (BVI Government, 2005). The current economy is primarily based on tourism and offshore banking. Growth in population

73

and tourism has resulted in ongoing construction throughout the islands, with roads and buildings being added on a regular basis, natural habitats increasingly being lost and fragmented, and increasing problems with trash disposal.

Biogeography

In the late Pleistocene, a single land mass stood where Puerto Rico, its associated islands, the US Virgin Islands (USVI, except St. Croix) and the BVI now lie (fig. 1). Today called the Puerto Rican Bank, it was roughly twice the area of Puerto Rico today, and became increasingly fragmented as sea-levels rose in the Holocene (Heatwole and MacKenzie, 1967). As a result, the biotas of these politically disparate units are highly similar (see for example, Platenberg and Boulon, 2006). However, rapid evolution has produced a number of unique species on some of the islands, and dispersal and extinction related to island biogeographic processes resulted in a mosaic of distribution patterns. Some of the species, such as *Anolis cristatellus* and *Sphaerodactylus macrolepis*, are present on nearly every piece of dry land in the region (Lazell, 1983), whereas others, such as *A. ernestwilliamsi*, are only found on a single small rock. The genera, however, are all wide-spread throughout the region: there are no endemic genera on the Puerto Rican Bank, and the taxa found there have been shown to be related to species found both to the east and west (Thomas, 1999). Much additional information about the biogeography of the region can be found in Woods and Sergile (2001).

Species Accounts

Information in this section is heavily based on MacLean (1982), with updates drawn from our own observations and from additional sources, which are the only ones cited in the text. Scientific names follow the most accepted current usage. Common names given are those normally in general or regional use. These are often abbreviated for local use, and 'Puerto Rican racer', for example, is normally locally simply referred to as 'racer'. Distribution information primarily follows MacLean (1982) and Mayer and Lazell (1988). The 'major islands' referred to are Anegada, Tortola, and Virgin Gorda (fig. 1). Few studies have assessed the population sizes of any of these species, and our assignment of status is based on what literature exists and our personal experience. Species are identified as Common (present on many islands in large or stable numbers); At risk (distribution is limited and numbers are declining); Endangered (the species has a very limited distribution and small numbers and is thus in immediate risk); Data deficient (studies identifying population trends are lacking); Extinct (in the BVI — the species may still exist elsewhere); Introduced (non-native taxa which arrived in the BVI relatively recently and with human assistance); or Cryptogenic (impossible to reliably classify as native — see Carlton, 1996). Most species are not locally protected or considered to be of concern, the exception being the iguana and sea turtles.

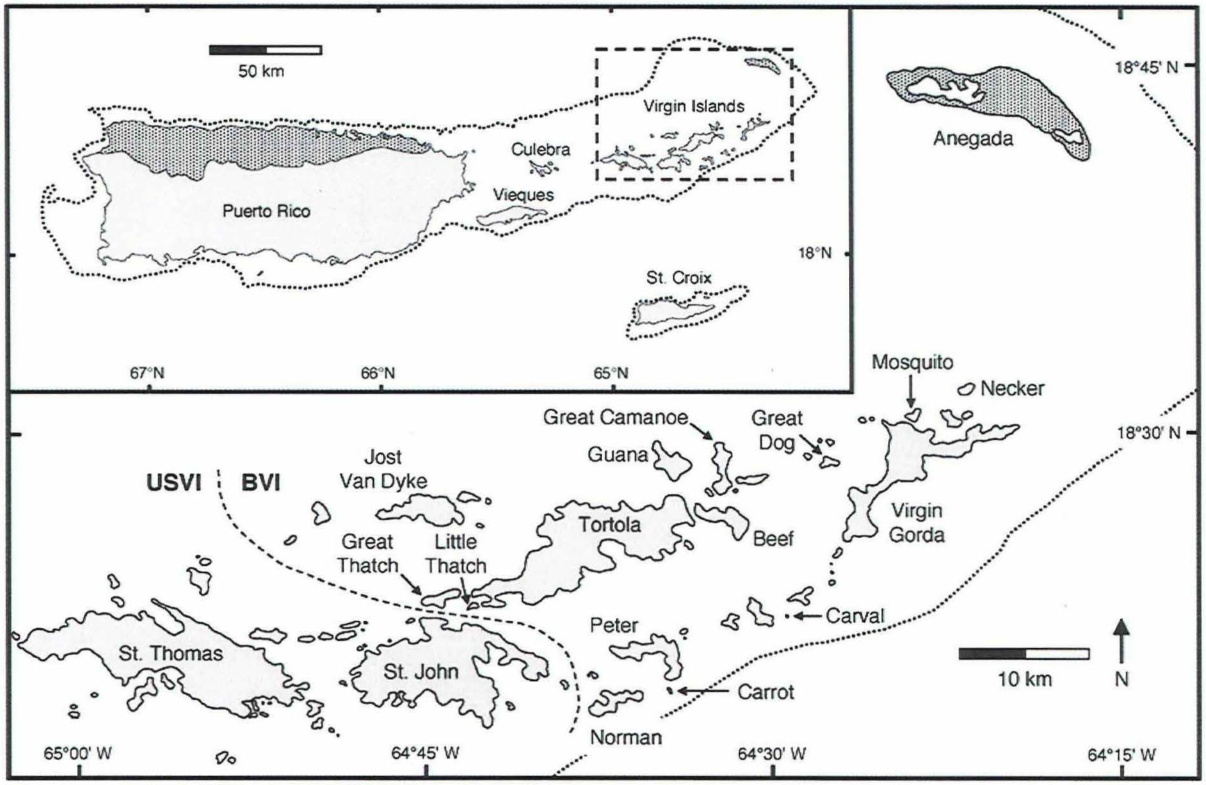


Figure 1. Map of the Puerto Rico Bank (inset) and the British Virgin Islands. Islands named in the text are indicated, but not all islets are named on the map. Dotted lines represent the 100 m depth contour and the approximate areas above sea level during the last glacial maximum. Stippling shows the distribution of karst habitats on present day islands.

Amphibia

Leptodactylidae. *Leptodactylus albilabris* (white-lipped frog). All major and some smaller islands: At risk. This species requires fresh water for reproduction. Although it can breed in ditches, populations appear to be declining. Its tadpoles may be vulnerable to competition from *Osteopilus septentrionalis* tadpoles (see Smith, 2005, for related work). A study of population trends is desirable. *Eleutherodactylus antillensis* (bo-peep, Antillean or churi coqui). Tortola, Virgin Gorda, and many small cays: Common. MacLean (1982) reported it as being found on 'all major islands' but we are not aware of any populations on Anegada. This species appears to be declining wherever *Osteopilus septentrionalis* spreads, but numbers are still high. Populations appear to positively respond to increased rainfall (Ovaska, in Lazell, 2005). *Eleutherodactylus cochranae* (bo-peep, whistling coqui). Tortola, Virgin Gorda: Data deficient. This species appears to be declining wherever *Osteopilus septentrionalis* spreads. *Eleutherodactylus schwartzi* (bo-peep, Virgin Islands coqui). Tortola, Virgin Gorda, Great Dog; (re?)introduced: Little Thatch (Lazell, 2002): At risk. This species appears to be declining wherever *Osteopilus septentrionalis* spreads, has disappeared in the USVI (Philibosian and Yntema, 1976; Platenberg and Boulon, 2006), and has been identified by the IUCN as Endangered (IUCN, 2004). The Great Dog population is somewhat distinct (Ovaska et al., 2000), extremely limited in range, and very susceptible to development there. Additional study, and perhaps protection, of that population is urgently needed, and protection of other remaining BVI populations may well be warranted.

Bufonidae. *Bufo* (*Peltophryne*) *lemur* (Puerto Rican crested or lowland Caribbean toad). Virgin Gorda: Extinct. No specimens have been collected from the BVI in many decades. Captive husbandry and reintroduction are ongoing in Puerto Rico (Miller, 2005). Whether such a program can succeed in the BVI will depend on the ability to provide and protect appropriate low-elevation habitat, much of which has been destroyed by development.

Hylidae. *Osteopilus septentrionalis* (Cuban treefrog). Tortola, Virgin Gorda, Beef Island, Peter Island (Owen et al., 2005a, 2006): Introduced. Individuals have also been collected on Necker and Guana Island (Owen et al., 2005a, 2006), but neither island appears to have a breeding population at the moment. This species is spreading rapidly, with frequent new island records. The diet suggests the potential to severely impact native species (Owen, 2005) and the tadpoles are known to impact those of some native anurans (Smith, 2005).

Testudines

Sea turtles. See additional information under Species of Special Concern, below. Dermochelyidae. *Dermochelys coriacea* (leatherback or trunk turtle). Nesting only, primarily on Tortola and adjacent Beef Island: Endangered. Cheloniidae. *Chelonia* *mydas* (green turtle). Common in coastal waters, nesting widespread in low numbers: Endangered. *Eretmochelys imbricata* (hawksbill turtle). Common in coastal waters, nesting widespread in low numbers: Endangered. *Caretta caretta* (loggerhead turtle). Infrequent in coastal waters, nesting extremely rare, if at all: Endangered.

Testudinidae. *Geochelone carbonaria* (red-legged or red-footed tortoise). Tortola, Virgin Gorda; (re?)introduced: Guana, Necker (Lazell, 2002): At risk (Introduced?). These turtles may not be native to the BVI, as populations have been widely transported throughout the Caribbean starting in Amerindian times (Censky, 1988). Both the Guana and Necker populations appear to be breeding well in their new habitats (Lazell, 2002), but Tortola and Virgin Gorda animals are uncommon in the wild, presumably as a result of habitat loss.

Emydidae. *Pseudemys nelsoni* (Florida red-bellied turtle). Tortola (Owen et al., 2005b): Introduced. A few individuals have been collected at the botanical garden ponds, but absence of suitable habitat and fresh water bodies makes them of relatively little concern. *Trachemys scripta elegans* (red-eared slider). Tortola, Virgin Gorda (Owen et al., 2005b): Introduced. Several individuals of this damaging invasive, including juveniles, have been collected, suggesting reproduction is occurring. However, absence of suitable habitat and ecologically similar native species makes them of relatively little concern.

Sauria

Polychrotidae. *Anolis cristatellus* (Puerto Rican crested anole; man-lizard [mostly used for the males]). All major islands and most small rocks and cays: Common. This species is ubiquitous, highly tolerant of human presence and development, and well-studied (Perry, 2005). It has been introduced in other locations (e.g., Brach, 1977). Diet occasionally includes other lizards (Owen and Perry, 2005). *Anolis ernestwilliamsi* (Carrot Rock or Ernest's anole). Carrot Rock, Peter Island: Endangered (possibly extinct on Peter Island; Perry, 1995). This large anole is only found on Carrot Rock, a tiny and highly exposed location. Population size is doubtlessly small and susceptible to stochastic events such as hurricanes. *Anolis stratulus* (Puerto Rican saddled anole). All major islands and many smaller cays: Common. BVI populations (Rodda et al., 2001) are much less dense than those seen in Puerto Rico (Reagan, 1992), and the species is rarely seen on Anegada, for example. However, there is no indication of population declines. Contrary to the view of MacLean (1982), these animals will occasionally take vegetable material (Perry and Lazell, 1997; Rios-López, 2004). *Anolis pulchellus* (Puerto Rican grass or bush anole). All major islands and some smaller ones: Common. This species is restricted to open or edge habitats where grass or narrow stems are available, and can tolerate human-impacted areas. They are often hard to see, both because of their excellent camouflage and tendency to be active during cooler times of day (G. Perry and

K.R. LeVering, unpublished). Like *A. stratulus*, these animals will occasionally take vegetable material (Perry and Lazell, submitted). *Anolis roosevelti* (Culebra Island giant anole). Tortola: Extinct (in the BVI). MacLean (1982) was not sure whether Tortola sightings were genuine but Gaa (1987) unearthed museum specimens. Some animals may remain on Culebra off the Puerto Rico shore and a recovery plan exists (Campbell and Dodd, 1982), but the species may be globally extinct.

Iguanidae. *Cyclura pinguis* (Anegada or stout iguana). Anegada; (re?)introduced: Guana, Necker (Lazell, 2002), Norman, Little Thatch (Perry et al., 2006): Endangered. See expanded discussion in Species of Special Concern, below. *Iguana iguana* (green or common iguana). Peter Island (Carey, 1972), Tortola: Introduced. Green iguanas are certainly native to part of the Lesser Antilles (e.g., Saba, Netherlands Antilles; Powell et al., 2005), and MacLean (1982) considered Virgin Islands populations to also be native. However, BVI animals appear more similar in appearance to animals found in the pet trade than to native Caribbean populations. Genetic studies to identify their origin are warranted. The main concern is their ability to take over habitat that might otherwise be appropriate for the native *Cyclura pinguis*.

Gekkonidae. *Hemidactylus mabouia* (common house gecko; wood slave). All major islands and some smaller ones: Cryptogenic. This species is common around human habitation, but generally uncommon or absent in native habitats (Rodda et al., 2001). There is no evidence of broad impacts on native species, but little effort has been devoted to identifying such patterns. The house gecko was likely introduced throughout the region in slave ships arriving from Africa. *Thecadactylus rapicauda* (turnip-tailed gecko). Necker Island: Cryptogenic. This species is widespread in the Lesser Antilles but is only recorded from one location in the BVI. The population on Necker is often associated with human habitation, but can also be found in native habitats (Lazell, 1995). It may be anthropogenic in origin. Despite being small the population appears stable.

Sphaerodactylus macrolepis (Puerto Rican dwarf gecko or sphaero). All major islands and most small cays and rocks: Common. This species reaches incredibly high densities in areas with deep leaf-litter (Rodda et al., 2001). It shows some signs of physiological variation even within islands (MacLean, 1985), suggesting that future speciation may occur on a small scale. *Sphaerodactylus parthenopion* (BVI dwarf gecko or sphaero). Tortola (?), Virgin Gorda: Data deficient. Carey (1972) and MacLean (1982) only reported this species from Virgin Gorda, but Procter and Fleming (1999) also report it from Tortola and Heatwole et al. (1981) from Mosquito Island. One of the world's smallest lizards, the biology of this species is poorly understood and population trends are unknown. Distribution within the islands it resides on appears fairly limited and likely to be further curtailed by development. *Sphaerodactylus* sp. (proposed: Carvel Rock dwarf gecko or sphaero). Carvel Rock: Endangered. This population appears morphologically distinct but is yet to be described. Given the extremely limited range — a small part of a single small rock — it appears especially susceptible to stochastic events such as hurricanes.

Scincidae. *Mabuya sloanii* (Antillean slipperyback or skink). All major islands and some smaller ones: Data deficient. This species appears widespread but is never common. Its biology is poorly understood and population trends are unknown. Carey (1972) reports that their numbers in the BVI were much reduced because of the introduced mongoose (*Herpestes javanicus*). Given the broad range of the mongoose in the BVI, this is a source of concern. *Mabuya macleani* (Carrot Rock slipperyback or skink). Carrot Rock: Endangered. Only recently described (Mayer and Lazell, 2000), this species has an extremely limited range and is thus highly vulnerable. However, the Carrot Rock population is relatively dense. Almost nothing is known about its biology or population trends.

Teiidae. *Ameiva exsul* (Puerto Rican ground lizard). All major islands and some smaller ones: Data deficient. Members of the genus *Ameiva* appear especially susceptible to predation by the introduced mongoose (*Herpestes javanicus*; Henderson, 1992). Given the broad range of the mongoose in the BVI, this is a source of concern for many populations. This species is common on the mongoose-free islands of Guana (Nicholson et al., 2005) and Anegada (G. Gerber, unpublished) but infrequently seen on most other islands, despite being very tolerant of development and fragmentation.

Amphisbaenidae. *Amphisbaena fenestrata* (Virgin Islands worm lizard). Great Camanoe, Great Thatch, Guana, Tortola, Virgin Gorda: Data deficient. This secretive species spends most of its time underground as it cannot avoid dehydration on the surface (Perry et al., 2004). Very little is known about its biology, but there is no indication of population decline and it is likely to exist on additional islands.

Serpentes

Typhlopidae. *Typhlops richardii* (Virgin Islands blind snake). Guana, Necker (?), Tortola: Data deficient. These subterranean animals are not often seen above-ground and little is known about their biology. However, data collected by Rodda et al. (2001) suggest they are found in large numbers. The Necker population may belong to *T. catapontus* (J. Lazell, pers. com.) and needs to be reexamined. Populations are known from additional islands but which of the two species they belong to has not been studied. *Typhlops catapontus* (BVI blind snake). Anegada, Virgin Gorda: Data deficient. These subterranean animals are not often seen above-ground and little is known about their biology and population trends. Blind snakes are known from additional islands, but whether they belong to this species or to the one that precedes remains unstudied.

Boidae. *Epicrates monensis* (Virgin Islands boa). Tortola: Data deficient. This species is considered endangered in the USVI (US Fish and Wildlife Service, 1980), where a reintroduction program is ongoing (Tolson, 2005). In contrast, Lazell (2005) believes it 'is the most common snake on Tortola'. Proposed studies of population status in the USVI (R. Platenberg, pers. com.) may help shed light on this issue, but a study of the BVI population is highly desirable.

Colubridae. *Arrhyton exiguum* (Puerto Rican garden or ground snake). All major islands and some smaller ones: Data deficient. This small, nocturnal snake is only found at low densities and is very poorly studied. Sightings on Guana appear fairly constant, but broad population trends are unknown. *Alsophis portoricensis* (Puerto Rican racer). All major islands and many smaller ones: Data deficient. Members of the genus *Alsophis* appear especially susceptible to predation by the introduced mongoose (*Herpestes javanicus*; Henderson, 1992). Given the broad range of the mongoose in the BVI, this is a source of concern. Populations on the mongoose-free islands of Guana (Barun et al., submitted) and Anegada (G. Gerber, unpublished) appear healthy, but numbers on other islands are generally much lower. Recent information suggests these animals swim well, perhaps enhancing their inter-island dispersal abilities (Powell et al., in press).

Species of Special Concern

Two types of organisms native to the BVI are of particular concern, and we provide more detailed information about both in this section. The first is the endemic iguana, *Cyclura pinguis*, which is one of the most endangered lizards on Earth and the most endangered animal species in the BVI. *Cyclura pinguis* is listed as Critically Endangered in the IUCN Red List of Threatened Species (IUCN, 2004) and Endangered in the U.S. Fish and Wildlife Service List of Endangered and Threatened Wildlife and Plants (USFWS, 1999). It is protected from international trade by inclusion in Appendix I of the Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES, 2005). The other is a group of species, marine turtles, which are at risk world-wide and which are likewise protected by a number of international agreements, including CITES. Their situation will likely require regional cooperation to resolve.

The endemic iguana

Cyclura pinguis was described approximately 90 years ago (Barbour, 1917), at which time it was restricted to Anegada, a 39 km^2 island located on the northeastern edge of the Puerto Rican Bank in the BVI (fig. 1). However, fossils of *C. pinguis* are common in late Pleistocene deposits (15,000-20,000 years old) from limestone caves in northern Puerto Rico (Pregill, 1981). There is considerable debate over when population declines occurred. Pregill (1981) and Pregill and Olson (1981)

80

provide evidence of the disappearance of *C. pinguis* and other xerophylic reptile species in Puerto Rico at the end of the Pleistocene, well before human colonization of the region. They hypothesize that the extinctions resulted from a significant reduction in xeric habitats, brought about by climatic changes associated with the end of the last ice age and rising ocean levels throughout the West Indies. Pregill (1981) and Pregill and Olson (1981) view Anegada as exemplifying prototypical *Cyclura* habitat and serving as a climatic refugium for *C. pinguis*. Anegada is similar to Caribbean islands with other *Cyclura* (Alberts, 2000) and different in substrate, topography, and vegetation from other large islands on the Puerto Rican Bank. Anegada is composed entirely of sedimentary substrates (limestone, coral, and sand), is flat and low-lying (8.5 m max.), and supports only xerophylic vegetation. In contrast, other islands are characterized by volcanic and metamorphic substrates, mountainous terrain (up to 523 m in the BVI), and semi-mesic vegetation. However, remains of *C. pinguis* have been recovered from Native American middens on St. Thomas, USVI (Barbour, 1919; Pregill, 1981), and some authors (e.g., Wing, 2001; Lazell, 2005; S.T. Turvey, pers. com.) believe the iguana survived much later and was extirpated from most of its range by humans. Ultimately, this issue must take a back seat to the urgent problem of guaranteeing the survival of the species beyond the next few years.

Iguanas were reported to be plentiful and sometimes hunted in parts of Anegada in the early 1800's (Schomburgk, 1832), but were described as rare by the early 1900's (Barbour, 1917). In 1968, Carey (1975) observed that adult iguanas outnumbered juveniles and concluded that the population was in decline. He attributed this to negative interactions with introduced mammals, which included rats, cats, dogs, goats, sheep, donkeys, and cattle. Mitchell (1999), who conducted her studies between 1988 and 1994, corroborated Carey's conclusions and described further declines in range, abundance, and individual condition. She estimated the total population at 164 animals. Consistent with this information, Perry et al. (2006) showed that body condition declined from Carey's (1975) work to that of Mitchell (1999). The most recent studies on Anegada, ongoing since 1998, indicate the population is largely restricted to a core area of 3 km^2 on the north coast and likely numbers less than 300 individuals, although a recent population estimate is needed. Most of the current population is comprised of adults, and although successful reproduction is still noted, almost no recruitment occurs because of predation of juveniles by feral cats (Gerber, 2004).

Current conservation efforts consist of two largely disparate programs; one aimed at preserving the species and its habitat on Anegada, another that seeks to establish the species on other islands as a precaution against extinction. In 1997, the BVI National Parks Trust and the IUCN Iguana Specialist Group (ISG) established an in situ headstart and release program for *C. pinguis* on Anegada to bolster recruitment until feral cats and other introduced mammals could be controlled (Bradley and Gerber, 2005). Nests are located each summer and fenced off for protection. When hatchlings emerge in the fall they are collected for captive rearing until large enough to survive with cats. Since 2003, 12 male and 12 female headstarted iguanas have been fitted with radiotransmitters and released each October. Survival of released iguanas has averaged 85%, providing the population with a substantial increase in young adults (Bradley and Gerber, 2006).

The other conservation program has focused on translocating *C. pinguis* to privately owned islands with limited development and few introduced mammals. Between 1984 and 1986, eight *C. pinguis* (three males and five females, 224-509 mm SVL) were moved from Anegada to Guana Island, north of Tortola (Goodyear and Lazell, 1994). The translocation was successful and in 2002 the Guana population of *C. pinguis* was estimated at 100 individuals (Perry and Mitchell, 2003). Four hatchling *C. pinguis* from Guana were released on Necker Island, north of Virgin Gorda, in 1995 (Lazell, 1995). This translocation has also been successful, with reproduction reported on site (Lazell, 2002), but no population estimate is available. Two adults (a male and a female) and 10 juveniles from the Guana population have recently been released on Norman Island, south of Tortola, and five hatchlings have been placed in a headstart facility on Little Thatch Island, between Tortola and St. John (J. Lazell, pers. com.), but it is too early to evaluate the success of either translocation.

Despite these efforts, full recovery of *C. pinguis* will require considerable additional effort. The Anegada population, potentially the largest and certainly the best documented historically, requires habitat protection and eradication of feral mammals. Anegada's western salt ponds and surrounding habitat were declared a Ramsar site in 2000, providing limited protection for approximately half of the core iguana area on the island. However, establishment of a proposed National Park, encompassing the entire core iguana habitat, is needed to adequately protect this area from ongoing development and other direct human impacts. A detailed feral mammal eradication plan for Anegada is currently being developed, but funding for implementation has not been obtained yet. Other populations likely remain extremely genetically limited (Perry et al., 2006), raising concerns about their long-term viability without an influx of additional animals. A recovery plan for the Anegada population (in press) does not take into consideration the translocated populations, as lack of coordination between the two programs has hampered cooperative efforts.

Sea turtles

Four species of marine turtle, belonging to two families, are known from the BVI. Adult leatherbacks are largely pelagic, feeding on jellyfish and other soft-bodied invertebrates. They can be found in the BVI between March and July, when females visit coastal waters and come onto sandy north-shore beaches to nest. Juvenile leatherbacks have been reported from a variety of coastal waters worldwide (Eckert, 1999), but not from the BVI. In contrast, both adult and juvenile green and hawksbill turtles are commonly found in BVI coastal waters year-round and predominantly feed on marine vegetation and sponges, respectively. Both species nest, in low numbers, on beaches throughout the BVI. Loggerheads, which feed primarily on crustaceans and mollusks, are the least common turtle in the BVI.

Sea turtles have historically been harvested in the BVI, and are consequently much less abundant today than during past times (Eckert et al., 1992; Godley et al., 2004). Eggs of all marine turtles have been exploited for food in the BVI, as elsewhere. Leatherbacks (locally known as trunks) were traditionally slaughtered for their meat and to render oil, thought to have medicinal value, when they came ashore to nest (Lettsome, 1989). In the 1920s and 1930s, 'trunkers' recall as many as six females coming ashore per night on several Tortola beaches (Lettsome, 1989; Eckert et al., 1992). In the 1960s, two or more females were still coming ashore each night on some beaches, but by the 1980s leatherbacks had all but disappeared from the BVI, with fewer than 10 nesting attempts per year (Chambers and Lima, 1990; Eckert et al., 1992; Hasting, 2003). Other marine turtle species were also taken on nesting beaches in the BVI but levels of exploitation and numbers of females nesting are not well documented. In 1981, Fletemeyer (1984) estimated the number of females in the BVI nesting population at 75±25 greens, 50±25 hawksbills, and a 'few' loggerheads. In contrast, surveys conducted in 1990 and 1991 (Hasting, 1992) reported only 6 and 17 nests for the three species combined, respectively. Unlike leatherbacks, other sea turtles, primarily greens and hawksbills, have traditionally also been harvested from the sea. Fletemeyer (1984) reported a direct catch of 600 greens and 300 hawksbills, and an incidental catch of 200 unspecified turtles by other fisheries, in 1981.

All of the marine turtle species reported from the BVI are listed in the IUCN Red List of Threatened Species (IUCN, 2004) as either Critically Endangered (leatherback, hawksbill) or Endangered (green, loggerhead). All marine turtles are also protected by inclusion in Appendix I of two Multilateral Environmental Agreements to which the BVI is a party; CITES and the Convention on Migratory Species (CMS). BVI legislation pertaining to marine turtles includes the Turtles Ordinance 1959, the Turtles Protection Amendment Notice 1986, the Fisheries Act 1997, and the Fisheries Regulation 2003. In compliance with CITES, the BVI prohibits international trade of marine turtles and products. It is currently illegal to (1) take leatherback and loggerhead turtles, (2) disturb or harm sea turtle eggs or nesting females, (3) use any turtle capture device within 100 m of shore, (4) fish for turtles from 1 April-30 November, or (5) take green and hawksbill turtles with carapace lengths less than 61 cm (24 inches) and 38 cm (15 inches), respectively. Additional recommendations to amend legislation, including maximum size limits to protect reproductive stocks, establishment of a limited turtle fishing licensing scheme with strict regulations, catch quotas, compulsory biometric reporting prior to slaughter, and increased fines for infringements were proposed by Godley et al. (2004). Although all nesting marine turtles and their eggs have been protected in the BVI since 1986, commercial trade of marine turtles and products is permitted within the BVI. Government-regulated turtle harvest appears to go beyond accommodating 'the needs of subsistence users', as provided by the CMS. Godley et al. (2004)

estimated that over 150 green and 50 hawksbill turtles are taken annually, and illegal take is still ongoing as well.

Sea-turtle soup and products can still be readily obtained in the BVI, but increased law enforcement, public awareness, and monitoring and conservation activities have allowed sea turtle populations to begin recovering. The Wider Caribbean Sea Turtle Network (WIDECAST) has provided training in marine turtle biology and management and assisted in development of a national sea turtle recovery action plan (Eckert et al., 1992). Leatherback nesting activities have been monitored annually by the Conservation and Fisheries Department since the 1980s (Hasting, 2003; Godley et al., 2004). Most recently, the BVI participated in two UK sponsored projects aimed in whole or in part at marine turtle conservation: Turtles in the Caribbean Overseas Territories (TCOT), from 2001-2004, and the Darwin Initiative Assessment of Coastal Biodiversity in Anegada, from 2003-2006. TCOT-initiated activities in the BVI included training and capacity building, extensive sociological surveys to document trends in the harvest of marine turtles and attitudes toward conservation efforts, aerial and ground surveys of beaches to assess marine turtle nesting activities, and an overall assessment of the status and exploitation of marine turtles in the BVI (Godley et al., 2004). The ongoing biodiversity assessment of Anegada (www.seaturtle.org/mtrg/projects/anegada) initiated an extensive in-water tagging, monitoring, and sampling program for marine turtles. Several hundred green and hawksbill turtles have been marked to date, and an action plan for preserving Anegada's biodiversity is being produced. As a result of this effort, the outlook for marine turtles in the BVI has improved dramatically in recent years. As many as 65 leatherback nesting attempts per year have been reported for the north-shore beaches of Tortola and adjacent Beef Island (Hasting, 2003; Godley et al., 2004). Populations of other species also appear to be on the rise, but have not rebounded to the extent that leatherbacks have (Godley et al., 2004).

The take of marine turtles and their eggs by humans remains the greatest threat to BVI turtle populations. Other threats reported by Godley et al. (2004) include accidental boat strikes; loss of beach nesting habitat from erosion, sand mining, and development; indirect impacts from increased development, including artificial lighting; pollution, including litter at sea and on beaches; and general environmental degradation. In addition, fibropapilloma disease has been observed in green turtles in the BVI (Overing, 1996) and, although undocumented, introduced predators, such as mongoose and dogs, likely prey on turtle eggs in the BVI, as they do in the US Virgin Islands (Platenberg and Boulon, 2006). Livestock, which on some islands (e.g., Anegada) frequent beach areas in large numbers at night, probably also damage nests. To adequately protect marine turtle stocks in the BVI and aid in their recovery, we strongly urge authorities to (1) increase protection of critical nesting and foraging habitats, (2) implement country-wide beach and in-water monitoring programs to better document turtle population trends, and (3) increase oversight of the turtle fishery, including strict enforcement of regulations, detailed documentation of the annual take and evaluation of its impacts, and establishment of size limits that encourage maximum reproduction. Experience has shown that taking primarily large individuals in fish populations results in a reduction in reproductive output, and we urge the government to consider setting both upper and lower limits on size of turtles which can be killed.

Discussion

Of the 34 amphibian and reptile species documented in the BVI, five (15%) are common, three (9%) are at risk, eight (23%) are endangered, ten (29%) are data deficient, two (6%) are extinct, and six (18%) are introduced or cryptogenic. There are several causes for alarm in this breakdown. One is that we have little or no information about the population trends of almost a third of the species, a lack that urgently needs to be rectified. A second concern is that another third of the species are already at immediate or low-level risk and an additional number are already extinct. Given the increasing population and development pressure, this is not a good sign for the future. Of especially great concern are the sea turtles, which have traditionally been harvested in the area (Eckert et al., 1992) and remain an exploited resource; the native iguana; and species found on single, tiny, and highly vulnerable islets. However, leatherback nesting activities appear to be on the rise (Hasting, 2003), and both in-situ and ex-situ efforts to protect the iguana are having some success (Lazell, 2002; Bradley and Gerber, 2006; Perry et al., 2006). Finally, over a tenth of the herpetofauna of the BVI is already comprised of introduced species, some of which have documented negative impacts on native species. Additional species may have been introduced long enough ago and their origin is hard to ascertain.

Primary causes of endangerment and extinction in the BVI include habitat loss and introduction of invasive species such as mongooses, cats, goats, and sheep. Development is an especially large concern for sea turtles, both because of the loss of nesting beaches and the additional night-lights that are detrimental to juvenile post-hatching dispersal (Salmon, 2005). Some work has taken place or is planned for control of invasives. For example, goats were successfully eradicated from Norman Island. However, most invasive species remain common and prospects for eradicating species such as the mongoose in the foreseeable future are minimal. Worse, additional species keep arriving in the BVI, and some taxa that are already in the region, such as *Bufo marinus* and *Eleutherodactylus coqui* have great potential for harm should they invade the BVI. Luckily, we have not yet seen signs of chytridiomycosis, a disease implicated in the severe declines of many amphibian populations (Berger et al., 1998), in BVI amphibian samples sent to the United States Geological Survey National Wildlife Health Center in Madison, Wisconsin for analysis (D.E. Green, Pers. Com.). Moreover, most BVI amphibians do not match the profile of especially susceptible taxa identified by Lips et al. (2003). Nonetheless, monitoring of BVI populations must be a high priority, given the broad declines of amphibians identified in Puerto Rico (Burrowes et al., 2004).

For species with single-island distributions, the risk of extinction as a result of stochastic events such as storms remains a major concern. On Puerto Rico, hurricanes are known to affect birds (Wauer and Wunderle, 1992) and boas (Wunderle et al., 2004). Similar effects are likely in the BVI, especially given the prediction that global climate change will result in more frequent and more severe storms (Goldenberg et al., 2001; Emannuel, 2005). Climate change is expected to affect forests in additional ways as well (Dale et al., 2001), and changes in factors such as the frequency of drought are sources for concern. Although extinctions of small isolated populations are a natural event, the increased likelihood caused by human activities may merit efforts to protect such taxa. For example, Carrot Rock may not be facing development but the unique species it contains are nonetheless affected by developments on nearby Peter Island (where the Carrot Rock anole is probably already extinct) and by global climate change, thought to be responsible for increased storm severity and higher sea levels.

In the short-term, the conservation status of the BVI herpetofauna appears unlikely to change. However, we are more concerned about the mid-term outlook, which includes increasing impacts from habitat loss and invasive species. To offset these pressures, we recommend the following strategies be adopted:

1. Set aside additional areas for conservation. This is especially true for marine turtle nesting beaches; the proposed National Park on Anegada, which is essential for the survival of *C. pinguis*; and for expanding the size of the two peak reserves already recognized, Gorda Peak and Sage Mountain, both of which are very small. Islets containing unique taxa, such as Carrot Rock, Carvel Rock, and Great Dog, should also be a high priority for protection.
2. Minimize the impacts of development via better enforcement of existing regulations and improved planning. For example, impacts to sea turtles from beach-side night-lights can be reduced by use of improved lighting technology (Bertolotti and Salmon, 2005). Improved international collaboration on conservation of sea turtles would also benefit the conservation of these animals, which migrate among political units and are therefore subject to variable protection.
3. Establish a baseline for population size of data-deficient species and a long-term program for monitoring all amphibian and reptile species to ensure declines are not occurring. Studies of the molecular systematics of local species should be a high priority, as such work has repeatedly identified the presence of cryptic species.
4. Support the eradication of existing harmful invasives, a process which has become increasingly feasible in recent years (Veitch and Clout, 2001; Krajick, 2005), and enhance prevention of additional invasive species arrivals. New Zealand is a leader in this, and much information is available on their governmental web site (http://www.biosecurity.govt.nz/) and on the IUCN Invasive Species Specialist Group web site (http://www.issg.org/).

86

5. Improve public education about the value of conservation in general and herpetofauna in particular.

The motto of the BVI is 'nature's little secrets', but its ability to sell itself as an ecotourism destination is rapidly being eroded by the same processes that are endangering the herpetofauna of the nation. The five strategies we identified above are not unique to the herpetofauna, but will rather provide protection to many species and habitats. We hope that the government of the BVI will continue to show foresight in protecting its natural assets.

Acknowledgements. We thank Kate LeVering, James Lazell, and an anonymous reviewer for useful comments on this manuscript. This review would not have been possible without 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 grants from the Falconwood Corporation, the Dallas Zoo, the Fort Worth Zoo, the International Iguana Foundation, IUCN Sir Peter Scott Fund for Conservation Action, Texas Tech University, the UK Foreign and Commonwealth Office, and the Zoological Society of San Diego. This is manuscript T-9-1089 of the College of Agricultural Sciences and Natural Resources, Texas Tech University.

References

Adams, M.J. (1999): Correlated factors in amphibian decline: Exotic species and habitat change in western Washington. J. Wildl. Manage. **63**: 1162-1171.

Alberts, A.C. (Ed.) (2000): West Indian Iguanas: Status Survey and Conservation Action Plan. Gland, Switzerland, IUCN — The World Conservation Union.

Barbour, T. (1917): Notes on the herpetology of the Virgin Islands. Proc. Biol. Soc. Wash. **30**: 99-103.

Barbour, T. (1919): A new rock iguana from Porto Rico. Proc. Biol. Soc. Wash. **32**: 145-148.

Berger, L., Speare, R., Daszak, P., Green, D.E., Cunningham, A.A., Goggin, C.L., Slocombe, R., Ragan, M.A., Hyatt, A.D., McDonald, K.R., Hines, H.B., Lips, K.R., Marantelli, G., Parkes, H. (1998): Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proc. Nat. Acad. Sci. **95**: 9031-9036.

Bertolotti, L., Salmon, M. (2005): Do embedded roadway lights protect sea turtles? Environ. Manage. **36**: 702-710.

Blaustein, A.R., Kiesecker, J.M. (2002): Complexity in conservation: lessons from the global decline of amphibian populations. Ecol. Letters **5**: 597-608.

Brach, V. (1977): Notes on the introduced population of *Anolis cristatellus* in south Florida. Copeia **1977**: 184-185.

Bradley, K.A., Gerber, G.P. (2005): Conservation of the Anegada iguana (*Cyclura pinguis*). Iguana **12**: 78-85.

Bradley, K.A., Gerber, G.P. (2006): Release of headstarted iguanas in Anegada, British Virgin Islands. Re-introduction News **25**: 14-16.

Burrowes, P.A., Joglar, R.L., Green, D.E. (2004): Potential causes for amphibian declines in Puerto Rico. Herpetologica **60**: 141-154.

BVI Government (2005): British Virgin Islands CD Atlas: population (http://www.bvingis.gov.vg/population.htm).

Campbell, H.W., Dodd, C.K., Jr. (1982): Culebra Island giant anole recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia (http://ecos.fws.gov/docs/recovery_plans/1983/830128.pdf).

Carey, M. (1972): The herpetology of Anegada, British Virgin Islands. Carib. J. Sci. **12**: 79-89.

Carey, W.M. (1975): The rock iguana, *Cyclura pinguis*, on Anegada, British Virgin Islands, with notes on *Cyclura ricordi* and *Cyclura cornuta* on Hispaniola. Bull. Fla. State Mus. Biol. Sci. **19**: 189-233.

Carlton, J.T. (1996): Biological invasions and cryptogenic species. Ecology **77**: 1653-1655.

Censky, E.J. (1988): *Geochelone carbonaria* (Reptilia: Testudines) in the West Indies. Fla. Sci. **50**: 108-114.

CITES (2005): Appendices I, II, and III to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. United Nations Environment Programme, 47 pp. (http://www.cites.org/eng/app/index.shtml).

Chambers, G., Lima, H. (1990): Leatherback turtles disappearing from the BVI. Martine Turtle Newsletter. **49**: 4-7.

Dale, V.H., Joyce, L.A., McNulty, S., Neilson, R.P., Ayres, M.P., Flannigan, M.D., Hanson, P.J., Irland, L.C., Lugo, A.E., Peterson, C.J., Simberloff, D., Swanson, F.J., Stocks, B.J., Michael, W.B. (2001): Climate change and forest disturbances. BioScience **51**: 723-734.

Eckert, K.L., Overing, J.A., Lettsome, B.B. (1992): WIDECAST Sea Turtle Recovery Action Plan for the British Virgin Islands. CEP Technical Report No. 15. Kingston, Jamaica, UNEP Caribbean Environment Programme, xv + 116 pp.

Eckert, S. (1999): Global Distribution of Juvenile Leatherback Sea Turtles. Hubbs Sea World Research Institute Technical Report 99-294.

Emmanuel, K.A. (2005): Increasing destructiveness of tropical cyclones over the past 30 years. Nature **436**: 686-688.

Fergus, H.A. (2003): A History of Education in the British Leeward Islands, 1838-1945. Kingston, Jamaica, University of the West Indies Press.

Fletemeyer, J. (1984): National report for the British Virgin Islands to the western Atlantic Turtle Symposium, 17-22 July 1983, Costa Rica. In: Proceedings of the Western Atlantic Turtle Symposium, p. 70-117, Vol. 3, Bacon, P., et al., Eds, Miami, Florida, University of Miami Press.

Gaa, A. (1987): Culebra Giant Anole Status Determination Study. Final Report, Department of Natural Resources, San Juan, Puerto Rico.

Gerber, G.P. (2004): An update on the ecology and conservation of *Cyclura pinguis* on Anegada. Iguana **11**: 23-26.

Gibbons, J.W., Scott, D.E., Ryan, T.J., Buhlmann, K.A., Tuberville, T.D., Metts, B.S., Greene, J.L., Mills, T., Leiden, Y., Poppy, S., Winne, C.T. (2000): The global decline of reptiles, deja vu amphibians. Bioscience **50**: 653-666.

Goodyear, N.C., Lazell, J. (1994): Status of a relocated population of endangered *Iguana pinguis* on Guana Island, British Virgin Islands. Rest. Ecol. **2**: 43-50.

Godley, B.J., Broderick, A.C., Campbell, L.M., Ranger, S., Richardson, P.B. (2004): An assessment of the status and exploitation of marine turtles in the British Virgin Islands. In: An Assessment of the Status and Exploitation of Marine Turtles in the UK Overseas Territories in the Wider Caribbean, p. 96-123. Final project report for the Department of Environment, Food and rural Affairs and the Foreign and Commonwealth Office (http://www.seaturtle.org/mtrg/projects/tcot/finalreport/).

Goldenberg, S.B., Landsea, C.W., Mestas-Núñez, A.M., Gray, W.M. (2001): The recent increase in Atlantic hurricane activity: causes and implications. Science **293**: 474-479.

Hasting, M. (1992): Survey of Hawksbill/Green Turtle Nesting Sites in 1990 and 1991 in the British Virgin Islands. Technical Report No. 13. Conservation and Fisheries Department, Ministry of Natural Resources and Labour, British Virgin Islands.

Hasting, M. (2003): A conservation success: leatherback turtles in the British Virgin Islands. Marine Turtle Newsletter **99**: 5-7.

Heatwole, H., MacKenzie, F. (1967): Herpetogeography of Puerto Rico. IV: Paleogeography, faunal similarity and endemism. Evolution **21**: 429-439.

Heatwole, H., Levins, R., Byer, M.D. (1981): Biogeography of the Puerto Rican Bank. Atoll Res. Bul. no. 251.

Henderson, R.W. (1992): Consequences of predator introductions and habitat destruction on amphibians and reptiles in the post-Columbus West Indies. Carib. J. Sci. **28**: 1-10.

IUCN (1996): 1996 IUCN Red List of Threatened Animals. Gland, Switzerland, World Conservation Union.

IUCN (2004): 2004 IUCN Red List of Threatened Species — A Global Species Assessment. Gland, Switzerland, World Conservation Union (http://www.iucn.org/themes/ssc/red_list_2004/summarytables_EN.htm).

Jenkins, C.F. (1923): Tortola: a Quaker Experiment of Long Ago in the Tropics. London, Friends' Bookshop.

Krajick, K. (2005): Winning the war against invaders. Science **310**: 1410-1413.

Lannoo, M.J. (Ed.). (2005): Amphibian Declines: the Conservation Status of United States Species. Berkeley, California, University of California Press.

Lazell, J. (1983): Biogeography of the Herpetofauna of the British Virgin Islands, with Description of a New Anole (Sauria: Iguanidae). In: Advances in Herpetology and Evolutionary Biology, p. 99-117. Rhodin, A., Miyata, K., Eds, Harvard, Museum of Comparative Zoology.

Lazell, J. (1995): Natural Necker. The Conservation Agency Occasional Paper **2**: 1-28.

Lazell, J. (2002): Restoring vertebrate animals in the British Virgin Islands. Ecol. Rest. **20**: 179-185.

Lazell, J. (2005): Island: Fact and Theory in Nature. Berkeley, California, University of California Press.

Lettsome, B.B. (1989): Subsistence Leatherback Sea Turtle Fishery on Tortola, BVI. BVI Conservation and Fisheries Internal Report.

Lips, K.R., Reeve, J.D., Witters, L.R. (2003): Ecological traits predicting amphibian population declines in Central America. Conserv. Bio. **17**: 1078-1088.

Mayer, G.C., Lazell, J. (1988): Distributional records for reptiles and amphibians from the Puerto Rico Bank. Herp. Rev. **19**: 23-24.

Mayer, G., Lazell, J. (2000): A new species of *Mabuya* (Sauria: Scincidae) from the British Virgin Islands. Proc. Biol. Soc. Washington **113**: 871-886.

MacLean, W.P. (1982): Reptiles and Amphibians of the Virgin Islands. London, MacMillan Caribbean.

MacLean, W.P. (1985): Water-loss rates of Sphaerodactylus *parthenoprion* (Reptilia: Gekkonidae), the smallest amniote vertebrate. Comp. Biochem. Physiol. **82A**: 759-761.

Miller, T.J. (2005): Husbandry and breeding of the Puerto Rican toad (*Peltophryne lemur*) with comments on its natural history. Zoo Biol. **4**: 281-286.

Mitchell, N.C. (1999): Effect of introduced ungulates on density, dietary preferences, home range, and physical condition of the iguana (*Cyclura pinguis*) on Anegada. Herpetologica **55**: 7-17.

Muths, E., Corn, P.S., Pessier, A.P., Green, D.E. (2003): Evidence for disease-related amphibian decline in Colorado. Biol. Conserv. **110**: 357-365.

Nicholson, K.L., Torrence, S.M., Ghioca, D.M., Bhattacharjee, J., Andrei, A.E., Owen, J., Radke, N.J.A., Perry, G. (2005): The influence of temperature and humidity on activity patterns of the lizards *Anolis stratulus* and *Ameiva exsul* in the British Virgin Islands. Carib. J. Sci. **41**: 870-873.

Ovaska, K., Caldbeck, J., Lazell, J. (2000): New records and distributional and ecological notes of leptodactylid frogs, *Leptodactylus* and *Eleutherodactylus*, from the British Virgin Islands. Breviora **508**: 1-25.

Overing, J.A. (1996): Green turtles with fibropapilloma disease in the BVI. Marine Turtle Newsletter **75**: 17-18.

Owen, J. (2005): The Cuban Tree Frog (*Osteopilus septentrionalis*): Diet, Reproduction, and Distribution of an Invasive Species in the British Virgin Islands. MS thesis, Texas Tech University.

Owen, J., Perry, G. (2005): *Anolis cristatellus wileyae* (Virgin Islands Crested Anole). Saurophagy. Herp. Rev. **36**: 444.

Owen, J., Perry, G., Lazell, J., Egelhoff, J. (2005a): *Osteopilus septentrionalis* (Cuban tree frog). Distribution. Herp. Rev. **36**: 76.

Owen, J., Perry, G., Lazell, J., Petrovic, C. (2005b): *Pseudemys nelsoni* (Florida red-bellied turtle). Distribution. Herp. Rev. **36**: 466.

Owen, J., Perry, G., Lazell, J., Petrovic, C., Egelhoff, J. (2006): *Osteopilus septentrionalis* (Cuban tree frog). Colonization of the British Virgin islands. Herp. Rev. **37**: 74-75.

Perry, G. (1995): The Evolutionary Ecology of Lizard Foraging: a Comparative Study. Ph.D. dissertation, University of Texas, Austin.

Perry, G. (2005): The *Anolis* lizards of Guana Island. In: Island: Fact and Theory in Nature, J. Lazell (Ed.), p. 186-190. Berkeley, California University Press.

Perry, G., Lazell, J. (1997): *Anolis stratulus* (Saddled Anole). Nectivory. Herp. Rev. **28**: 150-151.

Perry, G., Mitchell, N. (2003): Guana and Necker Island population assessments 2002. Iguana **10**: 49.

Perry, G., Dmi'el, R., Lazell, J. (2004): *Amphisbaena fenestrate* (Virgin Islands worm lizard). Evaporative water loss. Herp. Rev. **35**: 165-166.

Perry, G., Lazell, J., LeVering, K., Mitchell, N. (2006): Reproduction and size in the highly endangered stout iguana, *Cyclura pinguis*. Carib. J. Sci., in press.

Philibosian, R., Yntema, J.A. (1976): Records and status of some reptiles and amphibians in the Virgin Islands. I. 1968-1975. Herpetologica **32**: 81-85.

Platenberg, R.J., Boulon, R. (2006): Conservation status of reptiles and amphibians in the U.S. Virgin Islands. Appl. Herp. **3**: 215-235.

Powell, R., Henderson, R.W. (2005): Conservation status of Lesser Antillean reptiles. Iguana **12**: 2-17.

Powell, R., Henderson, R.W., Parmerlee, J.S., Jr. (2005): The Reptiles and Amphibians of the Dutch Caribbean: St. Eustatius, Saba, and St. Maarten. St. Eustatius, Netherlands Antilles, St. Eustatius National Parks Foundation.

Powell, R., Perry, G., Henderson, R.W., Barun, A. (2006): *Alsophis portoricensis anegadae* (NCN). Aquatic activity. Herp. Rev., in press.

Pregill, G. (1981): Late Pleistocene herpetofaunas from Puerto Rico. Univ. Kansas Mus. Nat. Hist. Misc. Pub. **71**: 1-72.

Pregill, G.K., Olson, S.L. (1981): Zoogeography of West Indian vertebrates in relation to Pleistocene climatic cycles. Ann. Rev. Ecol. Syst. **12**: 75-98.

Procter, D., Fleming, L.V. (Eds) (1999): Biodiversity: the UK Overseas Territories. Peterborough, Joint Nature Conservation Committee (www.jncc.gov.uk/pdf/OT_BVI.pdf).

Rios-López, N. (2004): *Anolis stratulus* (Saddled Anole). Extrafloral herbivory. Herp. Rev. **35**: 386.

Reagan, D.P. (1992): Congener species distribution and abundance in a three-dimensional habitat: the rain forest anoles of Puerto Rico. Copeia **1992**: 392-403.

Rodda, G.H., Perry, G., Rondeau, R.J., Lazell, J. (2001): The densest terrestrial vertebrate. J. Trop. Ecol. **17**: 331-338.

Rogozinski, J. (1992): A Brief History of the Caribbean. Facts on File, New York.

Salmon, M. (2005): Protecting sea turtles from artificial night lighting at Florida's oceanic beaches. In: Ecological Consequences of Artificial Night Lighting, p. 141-168, Rich C., Longcore, T., Eds, Washington, D.C., Island Press.

Schomburgk, R.H. (1832): Remarks on Anegada. J. Royal Geog. Soc. Lond. **2**: 152-170.

Smith, K.G. (2005): Effects of nonindigenous tadpoles on native tadpoles in Florida: Evidence of competition. Biol. Conserv. **123**: 433-441.

Stallard, R.F. (2001): Possible Environmental Factors Underlying Amphibian Decline in Eastern Puerto Rico: Analysis of U.S. Government Data Archives. Conserv. Bio. **15**: 943-953.

Thomas, R. (1999): The Puerto Rico area. In: Caribbean Amphibians and Reptiles, p. 169-179. Crother, B.I., Ed., San Diego, Academic Press.

90

Tolson, P.J. (2005): Reintroduction Evaluation and Habitat Assessments of the Virgin Islands Tree Boa, Epicrates *monensis granti*, to the U.S. Virgin Islands. Grant T-1. Final report. Division of Fish and Wildlife, St. Thomas, 13 pp.

U.S. Fish and Wildlife Service, (1980): Status of Virgin Islands boa clarified. Endangered Species Tech. Bul. **5**: 12.

U.S. Fish and Wildlife Service, (1999): Endangered and Threatened Wildlife and Plants 50 CFR 17.11 and 17.12. Division of Endangered Species, U.S. Fish and Wildlife Service, Washington, D.C. (http://www.fws.gov/endangered/wildlife.html#Species).

Veitch, C.R., Clout, M.N. (Eds) (2002): Turning the Tide: the Eradication of Invasive Species (proceedings of the international conference on eradication of island invasives). Occasional Paper of the IUCN Species Survival Commission No. 27. (http://www.hear.org/articles/turningthetide/turningthetide.pdf).

Wauer, R.H., Wunderle, J.M., Jr. (1992): The effect of hurricane Hugo on bird populations on St. Croix, U.S. Virgin Islands. Wilson Bul. **104**: 656-673.

Wing, E.S. (2001): Native American use of animals in the Caribbean. In: Biogeography of the West Indies, 2nd ed., p. 481-518. Woods, C.A., Sergile, F.E., Eds, Boca Raton, Florida, CRC Press.

Wilson, S.M. (2001): The prehistory and early history of the Caribbean. In: Biogeography of the West Indies, 2nd ed., p. 519-527, Woods, C.A., Sergile, F.E., Eds, Boca Raton, Florida, CRC Press.

Woods, C.A., Sergile, F.E. (Eds) (2001): Biogeography of the West Indies: Patterns and Perspectives, 2nd ed. Boca Raton, Florida, CRC Press.

Wunderle, J.M., Mercado, J.E., Parresol, B., Terranova, E. (2004): Spatial ecology of Puerto Rican boas (*Epicrates inornatus*) in a hurricane impacted forest. Biotropica **36**: 555-571.

Accepted: May 29, 2006 (AH).
Reprinted from Applied Herpetology **3**: 237-256 (2006).

Addendum

With few exceptions, the original paper remains accurate and the recommendations remain appropriate and largely un-implemented. However, some changes have occurred in the ensuing years that are worth noting.

Eleutherodactylus antillensis — Native to the region, a population was recently intentionally established on Necker by the island's owners. It is currently limited to the hotel area (C. Petrovic, unpubl. data).

Eleutherodactylus johnstonei — The frogs were noted on August 16, 2008 by amateur herpetologist Alejandro Sanchez (pers. comm.), who is very familiar with the regional herpetofauna. He "found several males singing at night on the grounds of a restaurant at sea level" on Tortola and thought that this "seems to point at an introduction in plant produce or the like".

Eleutherodactylus lentus — 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 well-established population is most likely the result of a recent introduction, but impacts are unknown and the appropriate management response is unclear (Perry, 2009a).

Osteopilus septentrionalis — 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, unpubl. data). The 2009 drought appears to have slowed the spread of this species, which is not yet found in Jost Van Dyke, Great Camanoe, or Anegada (G. Perry and G. Gerber, unpubl. data). The species is now established on Moskito, however, following arrival within the last two years, probably as stowaways in containers of construction material (C. Petrovic, unpubl. data).

Trachemys scripta elegans — Persistent reports of additional turtles in the retention ponds by the Beef Island airport have yet to be confirmed.

Cyclura pinguis — 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 plan for feral mammal removal, funding for which 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 survival rate of 79% or higher (G. Gerber and K. Bradley, unpubl. data). A set of polymorphic microsatellite markers has been developed for the species (Lau et al., 2009) and studies of genetic diversity utilizing these markers are underway. Perry et al. (2007) 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. The Guana population was estimated in 2009, using mark-recapture and modern estimation techniques, at about 100 adults and 150 hatchlings (B. Bibles, unpubl. 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. Unfortunately, many of the objectives identified by the IUCN (2007) and the original paper have yet to be carried out. In late May 2010, at least ten juvenile iguanas caught on Necker were released on Moskito, which is owned by the same person. More releases are apparently planned with the goal to establish a population on Moskito (C. Petrovic, unpubl. data).

Iguana iguana — Repeated reports suggest green iguanas are arriving on Tortola via a barge operating between St. Thomas and West End (C. Petrovic, unpubl. data). Those reports suggest that at least some of the introductions may be intentional. There are unrelated regular reports of them throughout Tortola, including small numbers of individuals collected from Road Town, Cane Garden Bay, and East End. These are presumably escaped or released pets. Green iguanas may now be found

92

on Jost Van Dyke, also as a result of an intentional attempt to establish them there (C. Petrovic, unpubl. 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.

Elaphe guttata — The corn snake was not recorded in the original paper, but is known from the region. Several BVI reports and specimens have materialized since then. A snake was killed at the commercial port (18°25′38.3″N, 64°36′31.2″W) on May 2006 (C. Petrovic, unpubl. 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, unpubl. data). Given the locations of initial sightings the source is likely to be related to commerce, rather than pets. The growing prevalence of *Elaphe guttata*, a human-tolerant species with broad diet and climatic needs, is of great concern. It has the potential of becoming a major predator on native lizards, birds, and mammals, and may be able to compete with the native boa, *Epicrates monensis*.

In addition there are new records of *Hemidactylus mabouia* (G. Perry, unpubl. data) and *Epicrates monensis* (Barker et al., 2009) from Great Camanoe. Encouragingly, a population of *Sphaerodactylus parthenopion* was found on Moskito Island, (C. Petrovic, unpubl. data) bringing the total number of known populations to two. A release of Red-footed Tortoises (*Geochelone carbonaria*) on Moskito is currently planned by the island's owners (C. Petrovic, unpubl. data).

We are concerned that future additions to the list of invasives in the BVI are likely, especially as much of the material used in "development" projects originates in Puerto Rico, the USVI, and Florida. We therefore recommend additional training of workers at the port and nursery industry to monitor invasive herpetofauna. An informal survey of BVI pet stores (C. Petrovic, unpubl. data) indicates that many people simply bring in their "pets" — often birds or turtles — from Puerto Rico or elsewhere, which makes both control and education efforts especially challenging. Although the global economic downturn has slowed or caused cancellation of some "development" plans, major projects are ongoing on Scrub Island (see http://scrubisland.com/) and Oil Nut Bay on Virgin Gorda (http://www.oilnutbay.com/home). These further decrease the amount of dry tropical forest available, and increase transport of both material and people within the BVI and between them and other locations.

We thank Clive Petrovic (Road Town, Tortola) and Nancy K. Woodfield (BVI National Parks Trust) for crucial help with this update. Primary financial assistance came from The Conservation Agency via a grant from the Falconwood Corporation and the Zoological Society of San Diego.

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. IRCF Rept. Amphib. **17**: 158-165.

Barker, B.S., Henderson, R.W., Powell, R. (2009): Geographic distribution. *Epicrates monensis granti*. Herpetol. Rev. **40**: 455-456.

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., 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., Mitchell, N. (2003): Guana and Necker island population assessments 2002. Iguana **10**(2): 49.

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. (2007): Reproduction and size in the highly endangered stout iguana, *Cyclura pinguis*. Carib. J. Sci. **43**: 155-159.

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.

2011: in: Hailey, A., B. Wilson, and J. Horrocks, eds.
Conservation of Caribbean Herpetofaunas Vol 1. Conser-
vation Biology and the Wider Caribbean, pp. 63-143.
Brill, Leiden, Netherlands.

Introduced amphibians and reptiles in the greater Caribbean: Patterns and conservation implications

Robert Powell[1], Robert W. Henderson[2], Michael C. Farmer[3], Michel Breuil[4], Arthur C. Echternacht[5], Gerard van Buurt[6], Christina M. Romagosa[7], Gad Perry[8,9]

[1] Department of Biology, Avila University, Kansas City, MO 64145, USA
[2] Section of Vertebrate Zoology, Milwaukee Public Museum, Milwaukee, WI 53233, USA
[3] Department of Agricultural and Applied Economics, Texas Tech University, Box 42132, Lubbock, TX 79409, USA
[4] Département de Systématique et d'Évolution, Taxonomie et Collections, Reptiles et Amphibiens, Muséum national d'Histoire naturelle, 75005 Paris, France
[5] Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996, USA
[6] Kaya Oy Sprock 18, Curaçao
[7] Department of Biological Sciences, Auburn University, Auburn, AL 36849, USA
[8] Department of Natural Resource Management, Texas Tech University, Lubbock, TX 79409, USA
[9] Corresponding author; e-mail: Gad.Perry@ttu.edu

Abstract. Non-native species are a growing worldwide conservation problem, often second only to habitat destruction and alteration as a cause of extirpations and extinctions. Introduced taxa affect native faunas through competition, predation, hybridization, transmission of diseases, and even by confounding conservation efforts focused on superficially similar endemic species. The number of known introductions of amphibian and reptilian species continues to grow. Herein, 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 130 species (25 amphibians and 105 reptiles) responsible for 364 individual introductions, of which 70.3% resulted in populations established for at least a short period. The impact of those 256 established populations ranges from minimal (localized effects largely restricted to dramatically altered habitats) to severe (displacement of native species from natural and modified habitats). Although intentional introductions for putative pest control (mostly historical) and food (historical and ongoing) are factors in some instances, the primary pathways for introductions today are inadvertent. Nearly all are associated with either the ever-growing pet trade or stowaways in cargo and ornamental plants. To document the extent of the live animal trade for pets and food, we review the surprisingly large numbers of documented individuals exported from the Caribbean into the United States (US) and from the US to the Caribbean. The extent of such trade and the rates of non-native arrivals continue to increase, and both are related to indices of regional economic activity. Because prevention is by far better — and more economical — than eradication of an established alien, we recommend increased scrutiny of transported goods and animals to and from the islands. An integrated policy response is clearly necessary to address what is a regional issue. Although the region

95

is highly fragmented both geographically and politically, we urge an increased regional cooperation for fighting invasive species in general and invasive herpetofauna in particular. Precedents for such cooperation include the Caribbean Community and Common Market (CARICOM) and the Caribbean Cooperation in Health initiative.

Key words: Amphibians; Caribbean; economic activity; eradication; introduced species; live animal trade; prevention; regional cooperation; reptiles; urban; vectors.

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 (e.g., Bomford et al., 2009), 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. Félix-Louis L'Herminier, as director of the "Jardin de naturalization de la Guadeloupe" in the early 19th century, had a goal of introducing and acclimating new species to the island (Breuil, 2002, 2003). Among the species he attempted to establish were *Kinixys erosa*, *Kinixys homeana*, and *Pelusios castaneus*, which are native to western Africa and which he might have purchased from slave traders. In addition, his son, François-Joseph, visited Puerto Rico and caught *Trachemys stejnegeri*, which was liberated in Marie-Galante. Other 19th-century reports include Schomburgk (1848), Gosse (1851), Feilden (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.

especially desirable. This can help reduce the spread of other problem species, such as agricultural pests, that also are a source of concern for local governments.

To address these concerns, we urge an increased regional and global cooperation on fighting invasive species in general and invasive herpetofauna in particular. Although the region is highly fragmented both geographically and politically, precedents for such cooperation exist; these include the Caribbean Community and Common Market (CARICOM) and the Caribbean Cooperation in Health initiative (www.caricom.org/index.jsp). We urge the adoption of a similarly integrated approach that incorporates not only governmental controls but also investments in local response capacity, such as that advocated by Perry and Farmer (2011). Our combined decades of work in the region show a strong need for considerably more monitoring, education, and research in this area.

Acknowledgements. Support for fieldwork leading to this project was provided by a series of National Science Foundation grants (Research Experiences for Undergraduates) to RP and The Conservation Agency through a grant from the Falconwood Foundation (GP, RP, RWH), by Texas Tech University (GP), Avila University (RP), and the Milwaukee Public Museum and the Windway Foundation (RWH). We are indebted to many governmental agencies that have provided permits to conduct research throughout the greater Caribbean and to the owners of several private islands (Guana, Necker, Little Thatch, and Little St. James islands), many private residences, and hotels or resorts who have tolerated our antics over the years. Facundo Franken, Department of Agriculture and Fisheries in Aruba (DLVVM) and Mikael Lundberg provided information (GVB). Michael E. Seidel helped to clarify our understanding of pond turtles (*Trachemys* spp.) in the Bahamas. This is manuscript T-91202 of the College of Agricultural Sciences and Natural Resource Management, Texas Tech University.

References

Ackley, J.W., Muelleman, P.J., Carter, R.E., Henderson, R.W., Powell, R. (2009): A rapid assessment of herpetofaunal diversity in variously altered habitats on Dominica. Appl. Herpetol. **6**: 171-184.

Alderton, D. (1988): Turtles and Tortoises of the World. New York, Facts on File Publ.

Arias Cornielle, Y.A. (1975): *Anolis chlorocyanus* y *Anolis porcatus* (Sauria, Iguanidae) en la ciudad de Santo Domingo. Unpubl. Tesis, Univ. Autón., Sto. Domingo.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C., Pimentel, D. (1995): Economic growth, carrying capacity, and the environment. Ecol. Econ. **15**: 91-95.

Avila-Pires, T.C.S. (1995): Lizards of Brazilian Amazonia (Reptilia: Squamata). Zool. Verh. Leiden **299**: 1-706.

Ayala, S.C. (1986): Saurios de Colombia: lista actualizada, y distribución de ejemplares colombianos en los museos. Caldasia **15**: 555-575.

Barbour, T. (1910): Notes on the herpetology of Jamaica. Bull. Mus. Comp. Zoöl. **52**: 273-301.

97a

Distribution and Habitat Use by the Critically Endangered Stout Iguana (*Cyclura pinguis*) on Guana Island, British Virgin Islands

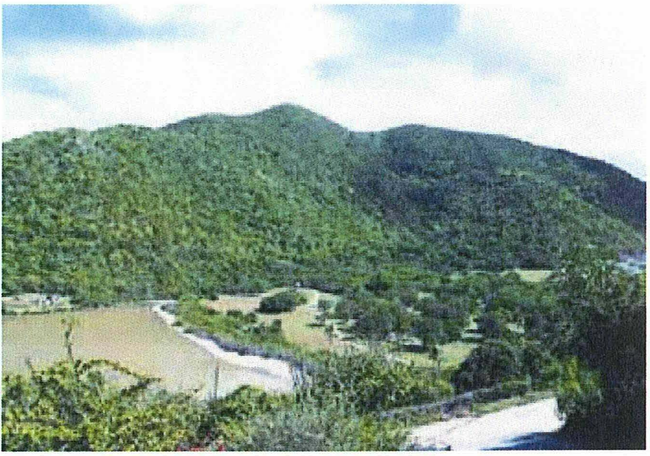
Wesley M. Anderson[1], Grant E. Sorensen[1], Jenny D. Lloyd-Strovas[2], Renaldo J. Arroyo[1], J. Alan Sosa[1], Sarah J. Wulff[1], Brent D. Bibles[3], Clint W. Boal[4], and Gad Perry[1]

[1]Department of Natural Resource Management, Texas Tech University, Lubbock, Texas 79409-2125, USA
[2]Department of Biological Sciences, Texas Tech University, Lubbock, Texas 79409-3131, USA
[3]Department of Wildland Resources, Utah State University - Uintah Basin, Vernal, Utah 84078, USA
[4]United States Geological Survey, Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock, Texas 79409-2120, USA

The Stout Iguana (*Cyclura pinguis*, Fig. 1) is a large lizard endemic to the Greater Puerto Rico Bank (Lazell 2002, Lazell 2005). It is one of the largest species in the genus, and, like all congeners, is imperiled. *Cyclura pinguis* is listed as Critically Endangered by the International Union for Conservation of Nature (IUCN 2004) and as Endangered by the U.S. Fish and Wildlife Service (USFWS 1999). For at least several hundred years, these lizards have presumably been confined to the 4,000-ha island of Anegada in the British Virgin Islands, where they currently face many threats, including non-native mammals. For example, introduced ungulates, such as sheep, compete directly for resources. By the early 1990s, only an estimated 164 individuals remained on Anegada (Mitchell 1999). Because of the continued decline of the iguana population on Anegada, eight individuals were introduced to Guana Island, British Virgin Islands between 1984 and 1986 (Goodyear and Lazell 1994), with subsequent introductions to Necker and Norman islands. All three of these islands have the advantage of being privately owned, thus restricting human access, and harbor few introduced mammals (Perry and Gerber 2006). The most recent population estimates for the islands are 250 individuals on Anegada (Gerber 2004), 130 on Guana Island, and 30 on Necker Island (Perry and Mitchell 2003).


WESLEY ANDERSON

Fig. 1. Stout Iguanas have been very successful at establishing themselves on Guana. The hundreds of iguanas living on the island are all descended from just eight individuals released in the 1980s.



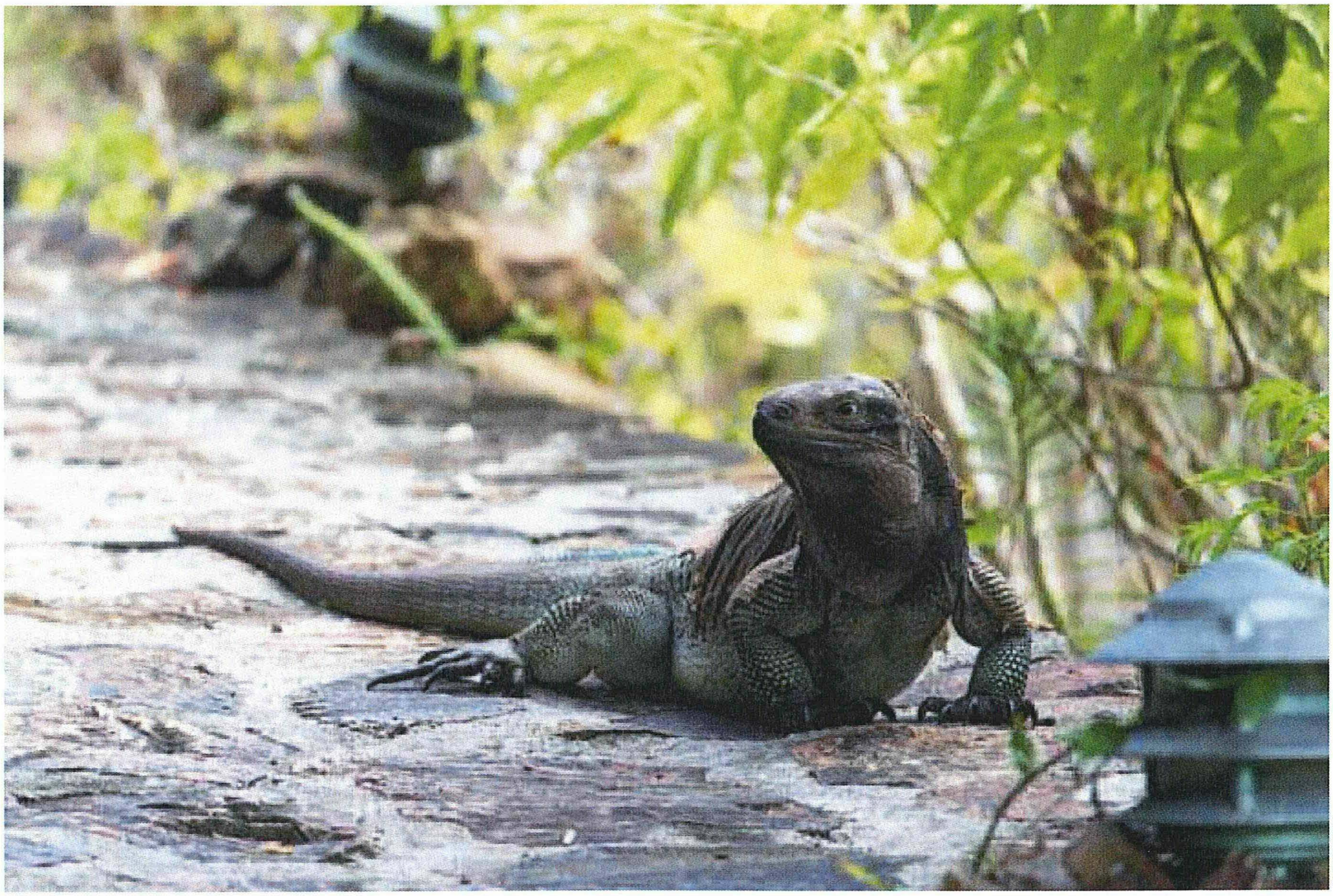
SARAH WULFF

Fig. 2. Although translocated from the flat, sandy island of Anegada, the population on Guana appears to be thriving in an area with considerably more topographic relief.

Despite substantial conservation concerns, little is known about the natural history of this species (but see Goodyear and Lazell 1994, Mitchell 1999, Levering and Perry 2003, Perry and Mitchell 2003, Lazell 2005, Perry et al. 2007). Because habitat use has never been studied in the Guana population, we sought to determine age-class specific habitat use on the island. As Guana Island differs markedly from Anegada Island in both geologic substrate and topography (Fig. 2), these results could have important habitat management implications. A second objective was to examine the distribution of iguanas on Guana Island. Over 15 years ago, Goodyear and Lazell (1994) noted that the distribution of iguanas on Guana appeared patchy, with no individuals observed in the northeastern or southern sections of the island.

Methods

In 2009, every marked trail on the island was surveyed by a group of two to three people, and most trails were revisited at least once and up to three times on separate occasions (Fig. 3). Because we could not determine if we were observing new or previously sighted individuals, we recorded all locations if an iguana had not been observed in the immediate vicinity within the past two hours. Once an iguana was observed, we recorded the time of day, percent cloud cover, location on the island relative to trails and/or landmarks, and general habitat at the spot of initial observation. Location coordinates (UTM, NAD83) were recorded using a geographic positioning system (Garmin International, Inc., Olathe, Kansas), and the lizard was categorized as an adult, yearling, or hatchling based on size. Once the iguana moved from the initial point of observation, we recorded air temperature with a mercury thermometer at 5 cm above the ground. We then positioned a 3-sided ½ m x ½ m quadrat at the original location and oriented it toward the north (Fig. 4). We took photographs of both the quadrat (ground cover) and the canopy cover above the quadrat with a digital camera (Canon, USA, Inc., Lake Success, New York) held 1 m above the ground. Both ground and canopy cover pictures were analyzed using SamplePoint, version 1.48 to determine percent composition of cover types. We categorized ground cover types as herbaceous vegetation, woody vegetation, litter, bare ground (including rocks < 2.5 cm in diameter), rock (> 2.5 cm in diameter), man-



SARAH WULFF

Fig. 3. Whereas many iguanas along the trails would flee at the approach of people, individuals living in close proximity to humans on Guana Island were readily visible during the surveys.

ROBERT POWELL

Despite substantial conservation concerns, little is known about the natural history of the Stout Iguana (*Cyclura pinguis*). This individual sought a shady retreat from the early afternoon heat on Guana Island (British Virgin Islands).


WESLEY ANDERSON

Fig. 4. A quadrat was placed at the site where an iguana was encountered and a photograph was taken. Photographs were later analyzed with computer software to determine percentage of ground cover types.

made, or unknown (ground cover we could not identify from our photographs). Canopy was classified as either vegetative cover or sky. A random direction was selected and the quadrat was repositioned 5 m from the original location along that azimuth in order to establish random locations to compare with encounter locations. Ground cover and canopy cover photographs were then taken in the same fashion as before. Differential use of cover types between both age classes and between encounter and random locations were analyzed using a chi-square analysis in Tadpole, version 2.

We recorded slope and aspect at each location. Aspect was divided into five ordinal categories: 315–44°, 45–134°, 135–224°, 225–314°, and flat. Finally, a designation of developed (if location was in close proximity to man-made structures) or undeveloped was assigned to each location.

We attempted to capture hatchling and yearling iguanas with nooses (Figs. 5 & 6). Captured hatchlings were weighed to the nearest gram, snout-vent length (SVL) and tail lengths were measured, individuals were marked with a unique number using white correction fluid for identification purposes (Fig. 7), and were released at the site of capture. Repeated observations of these individuals were recorded as re-sightings and habitat measurements were taken at these new locations and at associated random points.

Locations of iguanas observed by other researchers not directly involved with the project were marked with flagging by the observer. The primary investigators later visited these locations and recorded the same environmental measurements excluding temperature, percent cloud cover, and time of day (if not recorded during initial sighting). Additionally, for distribution analysis only, we used location data for both adult and hatchling iguanas recorded by researchers in 2004–2008.

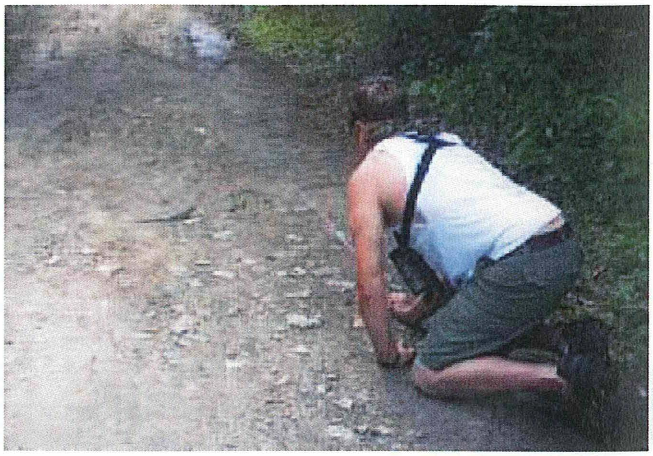

JENNY STROVAS

Fig. 5. Hatchling iguanas were generally captured using a noose.


SARAH WULFF

Fig. 6. Once an iguana was captured by researchers, length and weight measurements were taken and habitat variables measured.

General slope, aspect, and elevation for each location were compared to data collected at random points in 2008 during an ecological study of the island. Random habitat data points were collected along transects adjacent to trails throughout the island. Those data are representative of habitats in which we could have encountered iguanas during our surveys. A one-way ANOVA was used to compare general slope and elevation among adult iguana locations, hatchling iguana locations, and random sites. Least


SARAH WULFF

Fig. 7. Hatchling iguanas were temporarily marked with white correction fluid by researchers to aid in identification if they were encountered again. Here, iguana no. 11 basks on a stone wall.

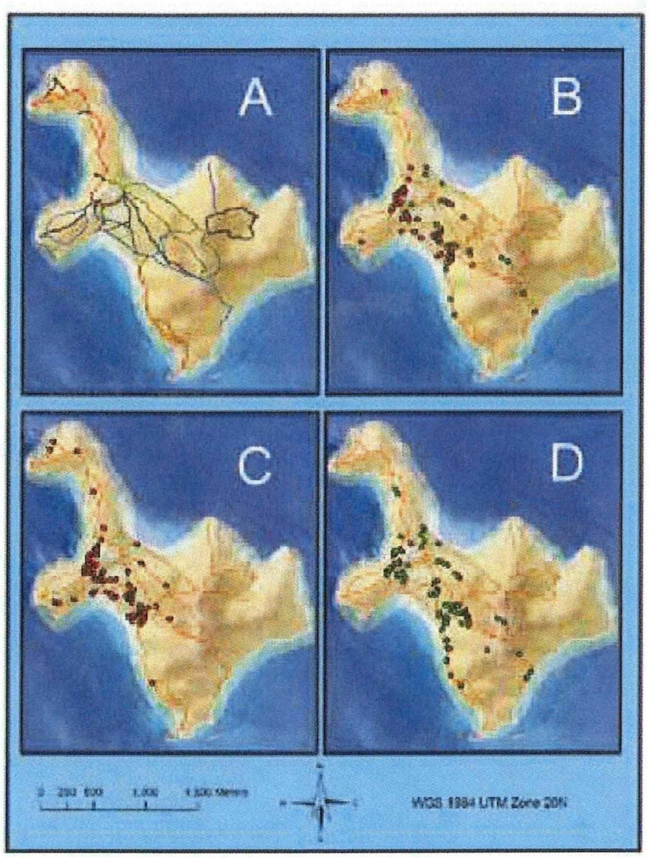


Fig. 8. Sampling effort and distribution of iguanas on Guana Island, BVI: (A) 2009 sampling effort based on number of times each trail was sampled (once-black, twice-blue, three times-green, four times-red); (B) 2009 iguana locations based on sampling effort from map A (green-adult and red-hatchling); (C) 2004–2009 locations of hatchling iguanas; (D) 2004–2009 locations of adult iguanas.

Significant Difference (LSD) post hoc tests were performed to evaluate pair-wise differences. Differences between general aspect among adult iguanas, hatchling iguanas, and random locations were compared using a chi-square test. The general aspect of the location at which an iguana was encountered was compared to time of day using a chi-square test. Time of day was classified into four categories: Early morning (beginning of surveys to 1000 h), late morning (1001–1200 h), early afternoon (1201–1400 h), and late afternoon (1401 to end of surveys). Finally, differences between iguana age class (adult or hatchling) and use of developed areas was analyzed using a chi-square test. Iguana locations within close proximity to human structures were categorized as "developed," whereas locations on or adjacent to trails were assumed to be representative of natural habitat across the island and were classified as "trails." All tests were performed within SPSS (SPSS Inc., Chicago, Illinois) with an alpha level of 0.05.

All UTM coordinate locations were mapped and analyzed in ArcGIS 9.3 (ESRI, Redlands, California). UTM coordinates were added and created into a shape file for adult iguanas, hatchling iguanas, and trails. Trails were categorized into classes based on numbers of surveys we conducted during 2009 to denote sampling effort. These shapefiles were then overlaid on a digital elevation model (DEM) and hillshade raster file to produce an elevational gradient map. Overall iguana distribution, elevational distribution, and age class distribution can be extrapolated from these maps.

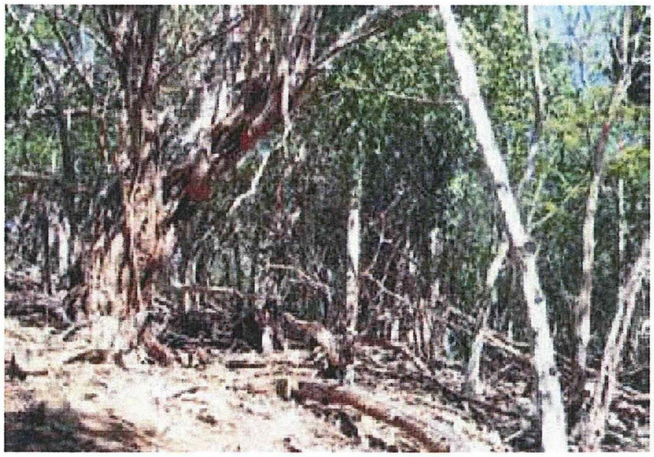
Results

In 2009, we recorded 96 iguana sightings (43 adults, 52 hatchlings, 1 yearling). Sampling efforts are illustrated in Fig. 8, Map A, and iguana locations are illustrated in Fig. 8, Map B. All iguana sightings from 2004–2009 (N = 285: 123 adults, 160 hatchlings, 2 yearlings) are illustrated in Fig. 8, Maps C and D.

The majority of hatchling sightings (75%) occurred in developed areas, whereas the majority of adult sightings (51%) occurred on or near trails throughout the island (Maps C & D). Hatchlings represented 65% of the sightings in developed areas; however, adults represented 63% of the sightings on trails. Sightings of age class and location on the island differed significantly. No iguanas of either age class were observed on the eastern half of the island. This appeared to correspond strongly with feral sheep spoor, such as tracks, scat, and evidence of foraging on vegetation (Fig. 9).

Microhabitat characteristics and canopy cover for random versus iguana sightings are summarized in Table 1. Hatchlings were most frequently found in areas of bare ground (30.8%) with 55% cover, whereas adults were most frequently found in areas of leaf litter (54.7%) with 80% cover. When age classes were pooled, the difference between iguana and random sites for microhabitat or cover were not significant (Table 1). However, we did find a significant difference between adult and hatchling sightings for both microhabitat and canopy cover.

Slope, elevation, and aspect data are summarized in Table 2. Adults were generally encountered on steeper slopes and at higher elevations than hatchling iguanas. Random points along trails often had steeper slopes and higher elevations than both adult and hatchling iguana locations.



CLINT BOAL

Fig. 9. Most groundcover and low-hanging vegetation on the eastern half of Guana Island has been consumed by feral sheep. Feral sheep compete directly with Stout Iguanas for food, and their presence may account for the lack of iguanas on this part of the island.

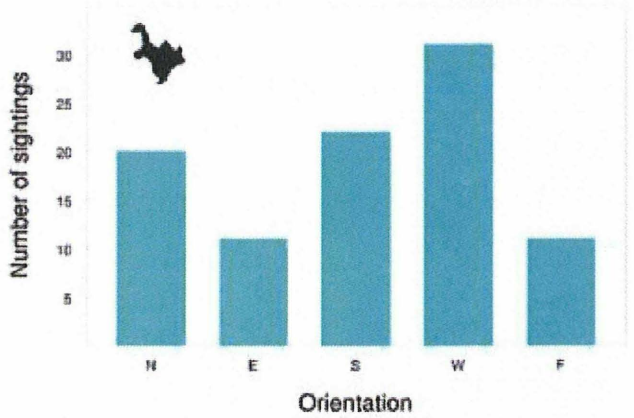


Fig. 10. Iguanas found on northern, eastern, southern, western, or flat aspects of Guana Island, BVI during 2009 sampling.

Table 1. The mean percentage of microhabitat characteristics or canopy cover (± 1 standard deviation) for random and all iguana locations in 2009 on Guana Island, BVI. Iguana locations then were divided into adult and hatchling categories. Differences between both adult and hatchling microhabitat and canopy cover use were statistically significant at $p < 0.005$.

	Herbaceous	Woody	Litter	Bare	Rock	Manmade	Unknown	Cover	Open
Random	10.1 ± 21.2	4.2 ± 9.0	44.6 ± 30.2	16.7 ± 25.5	14.3 ± 19.3	9.8 ± 28.5	0.5 ± 1.6	71.0 ± 32.2	29.0 ± 32.2
All Iguanas	9.7 ± 20.0	4.4 ± 7.9	41.3 ± 31.9	23.7 ± 30.8	13.7 ± 19.2	7.1 ± 24.2	0.1 + 0.5	66.3 ± 30.9	33.7 ± 30.9
Hatchlings	13.8 ± 24.0	4.4 ± 8.3	29.6 ± 27.8	30.8 ± 34.5	13.2 ± 20.4	8.3 ± 26.2	0.1 ± 0.5	55.4 ± 34.2	44.6 ± 34.2
Adults	4.2 ± 11.7	4.3 ± 7.1	54.7 ± 32.0	15.8 ± 24.5	14.9 ± 18.2	5.9 ± 22.5	0.2 ± 0.6	78.9 ± 20.6	21.1 ± 20.6

Table 2. The average slope and elevation (± 1 standard deviation) for each location class, and percentage of locations within each aspect category in 2009 on Guana Island, BVI. Differences among adult, hatchling, and random locations for both slope and elevation were significant at $p < 0.001$. Significant differences at $p < 0.001$ were detected when comparing adult and random aspect as well as hatchling and random aspect, but no significant difference existed between adult and hatchling aspect.

	Slope (degrees)	Elevation (m)	Aspect (% of occurrences)				
			North	East	South	West	Flat
Adult	20 ± 11 (0–38)	51 ± 52.6 (5–223)	16.3	16.3	20.9	37.2	9.3
Hatchling	12 ± 12.0 (0–38)	31 ± 20.9 (7–80)	25.0	7.7	25.0	30.8	11.5
Random	34 ± 14.3 (2–80)	92 ± 62.4 (3–245)	32.6	23.8	22.1	21.0	0.5

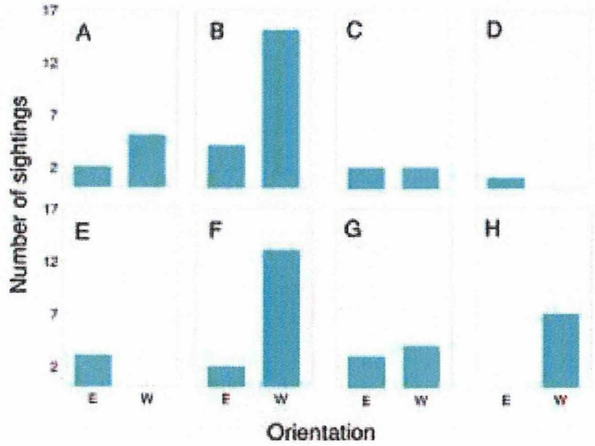


Fig. 11. Hatchling or adult iguanas found on eastern or western aspects according to time of day on Guana Island, BVI during 2009 sampling: (A) Hatchlings – early morning (before 1000 h); (B) Hatchlings – late morning (1001–1200 h); (C) Hatchlings – early afternoon (1201–1400 h); (D) Hatchlings – late afternoon (after 1401 h) (E) Adults – early morning; (F) Adults – late morning; (G) Adults – early afternoon; (H) Adults – late afternoon.

Significant differences existed in general slope and elevation among adult iguanas, hatchling iguanas, and random sites. A significant difference also was detected among adult iguanas, hatchling iguanas, and random sites when comparing general aspect. We found significant differences in aspect between hatchling and random sites and between adult and random sites, but not between hatchling and adult sites. Figure 10 illustrates the relationships between the number of iguanas encountered and aspect.

The number of iguanas sighted on easterly or westerly aspects in relation to time of day is illustrated in Fig. 11. The majority of iguana sightings (49%) occurred during late morning, and 44% of those iguanas were found on slopes facing southwest to northwest (225–314°).

Discussion

The Stout Iguana has become successfully established on Guana Island since the translocation of eight individuals 25 years ago (Goodyear and Lazell 1994). Continued successful reproduction is evident in the numerous hatchlings encountered by researchers each year.

The distribution of iguanas throughout the island does not seem to be uniform. Iguanas appear to be in high densities on the western half of the island, particularly around developed areas, whereas they appear to be largely absent from eastern sections of the island.

Distribution also varied between adults and hatchlings. Hatchlings were typically in developed areas, whereas adults were found along both trails and in developed areas (Fig. 12). Some additional differences in habitat characteristics can likely be explained by preferred nesting locations. Stout Iguanas preferentially nest in sandy locations (Perry et al. 2007). Unlike Anegada, which is a low-lying island composed of limestone and sand, Guana is formed of igneous rock hills (to 246 m; Goodyear and Lazell 1994). Therefore, many

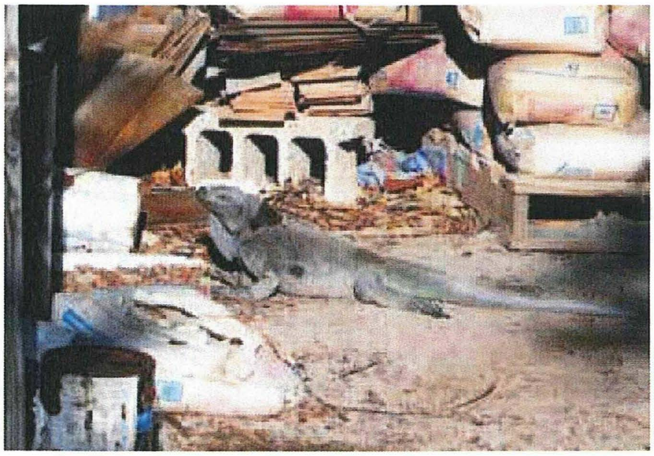
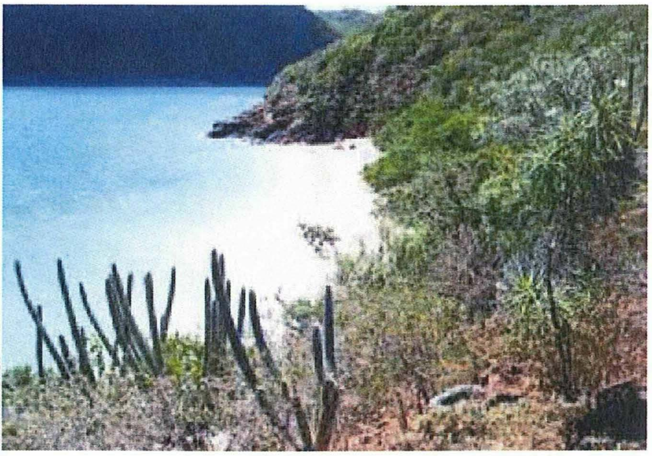

WESLEY ANDERSON

Fig. 12. Both adult and hatchling iguanas were frequently encountered in areas with noticeable human activity or influence.



GRANT SORENSON

Fig. 13. Stout Iguanas prefer to nest in sandy substrate. Beaches provide some of the best nesting habitat on Guana.

ROBERT POWELL

Fig. 14. Hatchling iguanas often remain near beaches; this unmarked individual thermoregulated by shuttling back and forth between sun and shade.

of the sandy areas suitable for nesting are along the beaches (Fig. 13). As iguanas on Guana are likely hatching near sea level, they may not have had enough time to disperse from their natal beaches to the higher elevations within the confines of the sampling periods (Fig. 14). This might explain the differences in elevations at which hatchlings and adults are encountered. Similarly, the areas nearest the beaches are generally flat, which might explain the differences between slopes at which age classes were encountered.

Differences in percentage canopy cover use between age classes may be a function of physiological constraints related to size. Smaller iguanas have a much higher surface area-to-volume ratio, and thus have less thermal inertia (Bell 1980). We suspect that the percentage canopy cover utilized by hatchlings is lower because of their need to actively thermoregulate more frequently. It might also explain why hatchlings were found more often in developed areas and the lowland flats. These areas appeared to be generally more open, whereas the trails are generally forested.

Finally, we believe that the feral sheep population is having a direct impact on this species. Although sheep eradication efforts have been in place since the 1980s and numbers have been reduced, reproduction still occurs. Sheep may outcompete iguanas by consuming much of the desirable understory vegetation within 2 m of ground level (Goodyear and Lazell 1994). Although not within the scope of this study, an apparent correlation between the presence of sheep — whether direct sightings of individuals or indirect evidence, such as tracks and scat — and the absence of iguanas was evident. Mitchell (1999) found that on Anegada, where feral livestock also is a problem, iguanas have altered their diets to include greater amounts of less palatable or even toxic leaves avoided by livestock. On Guana Island, iguanas may simply avoid areas overbrowsed by sheep, possibly explaining why none are encountered on the eastern side of the island.

Overall, the outlook for this species on Guana Island appears favorable. Not only has the species become established over the past 25 years, it seems to be flourishing. Still, long-term persistence of this population will depend on sound management strategies. These strategies should consider the fact that hatchlings and adults do differ in numerous habitat requirements. Removal of the feral sheep from the island would almost certainly be beneficial for iguanas. As protection for the Stout Iguana continues to be a contentious subject on the island of Anegada (Mitchell 2000, Perry and Gerber 2006), Guana Island currently represents this species' best chance for continued survival.

Acknowledgements

We thank the owners and staff of Guana Island for assistance and support. We also thank the other researchers not directly involved in this project for assistance in locating iguanas, particularly J. Lazell, R. Powell, and M. Gifford. J. Lazell provided comments that improved this manuscript. Support for this project was provided by The Conservation Agency through a grant from the Falconwood Foundation and by Texas Tech University. The use of trade, product, industry, or firm names or products is for informative purposes only and does not constitute an endorsement by the U.S. Government or the U.S. Geological Survey. This is manuscript T-11-1188 of the College of Agricultural Sciences and Natural Resource Management, Texas Tech University.

Literature Cited

Bell. C.J. 1980. The scaling of the thermal inertia of lizards. *Journal of Experimental Biology* 86:79–85.

Gerber, G.P. 2004. An update on the ecology and conservation of *Cyclura pinguis* on Anegada. *Iguana* 11:23–26.

Goodyear, N.C. and J. Lazell. 1994. Status of a relocated population of endangered *Iguana pinguis* on Guana Island, British Virgin Islands. *Restoration Ecology* 2:43–50.

IUCN. 2004. *Red List of Threatened Animals.* International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Lazell, J. 2002. Restoring vertebrate animals in the British Virgin Islands. *Ecological Restoration* 20:179–185.

Lazell, J. 2005. *Island: Fact and Theory in Nature.* University of California Press, Berkeley.

LeVering, K. and G. Perry. 2003. Juvenile predation. *Cyclura pinguis* (Stout Iguana, Anegada Rock Iguana). *Herpetological Review* 34:367–368.

Mitchell, N. 1999. Effect of introduced ungulates on density, dietary preferences, home range, and physical condition of the iguana (*Cyclura pinguis*) on Anegada. *Herpetologica* 55:7–17.

Mitchell, N. 2000. Anegada Iguana, pp. 22–27. In: R.P. Reading and B. Miller (eds.), *Endangered Animals: A Reference Guide to Conflicting Issues.* Greenwood Press, Westport, Connecticut.

Perry, G., J. Lazell, K. LeVering, and N. Mitchell. 2007. Body size and timing of reproduction in the highly endangered Stout Iguana, *Cyclura pinguis*, in the British Virgin Islands. *Caribbean Journal of Science* 43:155–159.

Perry, G. and G.P. Gerber. 2006. Conservation of amphibians and reptiles in the British Virgin Islands: Status and patterns. *Applied Herpetology* 3:237–256.

Perry, G. and N. Mitchell. 2003. Guana and Necker Island Population Assessments 2002. *Iguana* 10:49.

U.S. Fish and Wildlife Service. 1999. Endangered and Threatened Wildlife and Plants 50 CFR 17.11 and 17.12. Division of Endangered Species, U.S. Fish and Wildlife Service, Washington, D.C. (http://www.fws.gov/endangered/wildlife.html).

101

Juvenile Stout Iguanas (*Cyclura pinguis*) spend much of their time in trees. This individual (marked #12) was taking an afternoon nap in a White Cedar (*Tabebuia heterophylla*). It was not disturbed while this photograph was taken.

102

TRAVELOGUE

What Stout Iguanas (Don't) Do All Day

Katharina Gebert

Princeton High School, Princeton, New Jersey

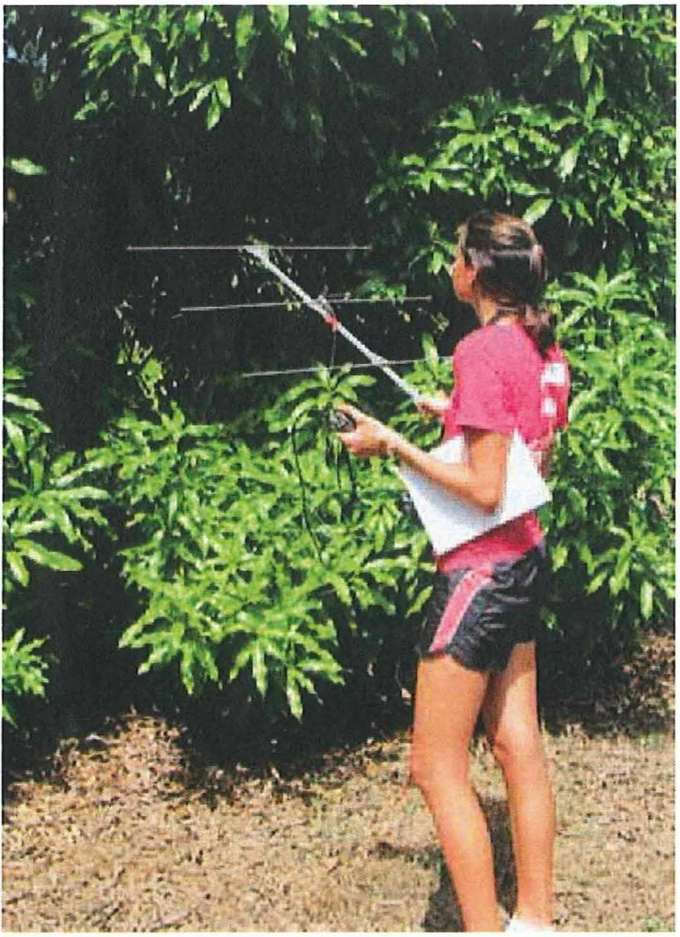
Photographs by the author except where indicated.

While some 16-year-olds are busy debating the meaning of life or determining their purpose in the world, I spent a week doing field research in the British Virgin Islands (BVI). Guana Island, where the work was conducted, is a private island. It is home to at least 50 species of birds, five species of bats, more than 14 species of reptiles and amphibians, and hundreds of plant and insect species (Lazell, 2005). I have visited the island a few times in the past and had the chance to assist with a bird study last fall.

This past October, I designed and executed my own behavioral study on juvenile Stout Iguanas. *Cyclura pinguis*, commonly referred to as the Stout Iguana or Anegada Ground Iguana, is a critically endangered lizard that can be found only in the BVI. Eight individuals were moved to Guana Island in the 1980s in an effort to protect the species, whose one remaining population on Anegada was declining. I would be responsible for observing a critically endangered species, of which only a few hundred exist, but also be one of the lucky few to get the chance to study them. While writing up my project proposal, I grew more and more excited, dreaming up incredible scenarios of never-before-seen iguana interactions.

I set out to do a basic behavioral study on juveniles, as few had been done. I would be looking for time spent on the ground, time spent in trees, time spent sunning, what and when they were eating, and more. In my procedure, I assumed that once I arrived on the island, the iguanas would basically come flocking to my feet, begging me to study them. I had planned to radio-track five iguanas, hoping I would find three in one location and two in another. This way I would experience interactions between them, as well as see whether or not their behavior changed depending on the habitat in different location. Unfortunately, finding five iguanas proved to be quite a challenge. They were present in abundance at the beginning of October, but by the time I arrived on Guana in late October, most of them had suddenly disappeared (perhaps because they knew a reckless adolescent was coming). However, two were found near the dining area and transmitters

Guana Island, home to all the juvenile *Cyclura pinguis* in this investigation.



GAD PERRY

The author using telemetry equipment to find one of the juvenile *Cyclura pinguis* in a Mango Tree (*Mangifera indica*) in the late afternoon.

were attached. Three more were found in the orchard, and so I had all five iguanas ready to go, thanks to the scientists already there. I now needed to learn how to use the equipment to track them, which proved to be another challenge. The receiver made beeping sounds I was supposed to interpret. Even during practice, while finding immobile transmitters, I picked up wrong signals, went in the opposite direction of the signal, or simply turned around in circles until I became dizzy. Nonetheless, by the end of the week, I had "mastered" the tracking equipment.

Being the unlucky teenager I am, a juvenile iguana died the first morning I was on the island. I followed a signal all the way to a pool behind one of the guesthouses. After looking around on the edge and in the surrounding bushes, I finally discovered the baby at the bottom of the pool. It had drowned. Although the death of the lizard had nothing to do with the study, I felt like a murderer. Not only that, but via Facebook — what else? — word got around my high school back home that I had chased a baby iguana into a pool and held it under water until it died. This was social suicide at its finest.

In the bio lab courses at my high school, the experiments are for the most part already set up, with clear instructions that, when carefully followed, earn an almost automatic A. On Guana, although I had to write the procedure myself, as long as I followed it exactly as written, I was *bound* to be successful, right? Boy, was I wrong! After the death of the iguana, I put my sadness and confusion aside, picked up the signal of my second iguana, and tracked it to a Spider Lily. I sat next to the Spider Lily, staring at it, for three hours. I recorded every rustle, movement, and bird overhead for three hours, then decided to recheck the signal and make sure it was still in the plant. Lo and behold, the signal was now coming from somewhere entirely different. I had sat staring at a plant, sweat pouring out of me, for *three hours*, and to no avail. I packed up my gear and followed the signal to the actual location of the iguana. When I spotted it sitting on a branch in a tree a ways off the path, my heart rejoiced. I had found my iguana, and it was alive! I then commenced my note-taking once again, writing down every movement, occurrence, sound, anything. By the end of the week I

Juvenile #19 basking in the afternoon sun.

Juvenile #12 doing "push-ups" around midday.

Juvenile #22 on the ground munching a vegetarian meal.

The author marking an iguana with Wite-out®.

discovered that juvenile Stout Iguanas do not do much. Even so, I kept myself busy writing down anything and everything that occurred.

The next day, we found a new iguana and attached a transmitter. All I could hope was that this juvenile survived, despite the cursed transmitter on its back. Further complications arose when one of the three iguanas from the orchard was released in the wrong location. This was the second detour from my thoroughly thought-out procedure. Why wasn't everything going as planned? I wanted an "A" on this lab! After trying and not succeeding in finding the misplaced iguana, I decided to make a little experiment out of the situation — I would see whether the iguana made it back to the orchard by the time I left. I figured, if nature was changing my experiment's course, so could I. I further amended my experiment, not only taking down behavioral observations but also taking a picture of the iguanas and of their surroundings every half hour. I would then determine the amount of sun exposure the iguanas had in their current location and the amount of sunlight available in their current environment.

I spent all of that second day watching the iguana near the dining area. I found it sitting in the exact location where I had left it the evening before. By the third day, I got into the rhythm of things — eating breakfast, sitting and watching iguanas for hours, eating lunch, sitting and watching iguanas for hours, eating dinner, checking location of iguanas, sleeping (with occasional nightmares of iguanas drowning). I had not expected this little excitement and movement to cause such exhaustion. That morning, I watched the iguana near the dining area until it began to rain and the lizard took cover. I headed to the orchard and, to my surprise, found one of the two lizards roaming around on the ground. Apparently, what I had laid out in my procedure was finally occurring. The iguana moved around on the ground almost all of that morning. While nibbling on some plants, it suddenly lurched toward me. A few seconds later, a snake (a Puerto Rican Racer, *Borikenophis portoricensis*) came out of a nearby bush, stopped, then continued on. My heart nearly jumped out of my chest, as I stood there with my baby at my feet. I began to imagine scenarios of the snake whipping its head around and attacking the juvenile. Part of me wanted to save the baby iguana if that were to happen, but another part of me shouted: "No! The baby must die because nature wills it!" Luckily I did not have to make that decision — the snake slithered off and never came back. I later found out that it was too small to have even considered eating the baby. When I came back in the afternoon, the juvenile was sitting in a tree. Patterns began to develop as I found that the juveniles usually roam, forage, and eat in the mornings, with activity peaking around 9 or 10 AM. They then retreat to higher, safer locations in the afternoon. More often than not, the location they were in around 3 PM was where I would find them the next morning.

The lizards often head-bobbed as soon as they became aware of my presence, as well as when other lizards were nearby. On the fourth day, both of the iguanas in the orchard were on the ground foraging. Although they were not close to one another, I stood between them hoping for some interaction. Naturally, nothing happened, but I still found them eating the same plants and climbing the same trees. In fact, when the iguanas were sitting in trees, they were always found in White Cedars (*Tabebuia heterophylla*). By the fifth day, one of the iguanas had shed its transmitter under a Mango Tree (*Mangifera indica*). I watched the one iguana left in the orchard for the rest of the morning, with foraging occurring around 10 AM, as every other morning. In the afternoon, I began to search for the mis-released iguana that belonged in the orchard. The signal was still coming from the general area of where it was released, although it had moved in the direction of the orchard. On the sixth day, I watched the lone orchard iguana yet again. After tracking the mis-released juvenile, I discovered it had made great headway in moving toward the orchard. It had moved 79 m closer after just a few days. It did the same again on the next day, moving another 71

Map of Guana Island showing movements of the iguana mistakenly released at a site other than where it was originally caught. "1" marks where the iguana was caught, and "2" where it was later released.

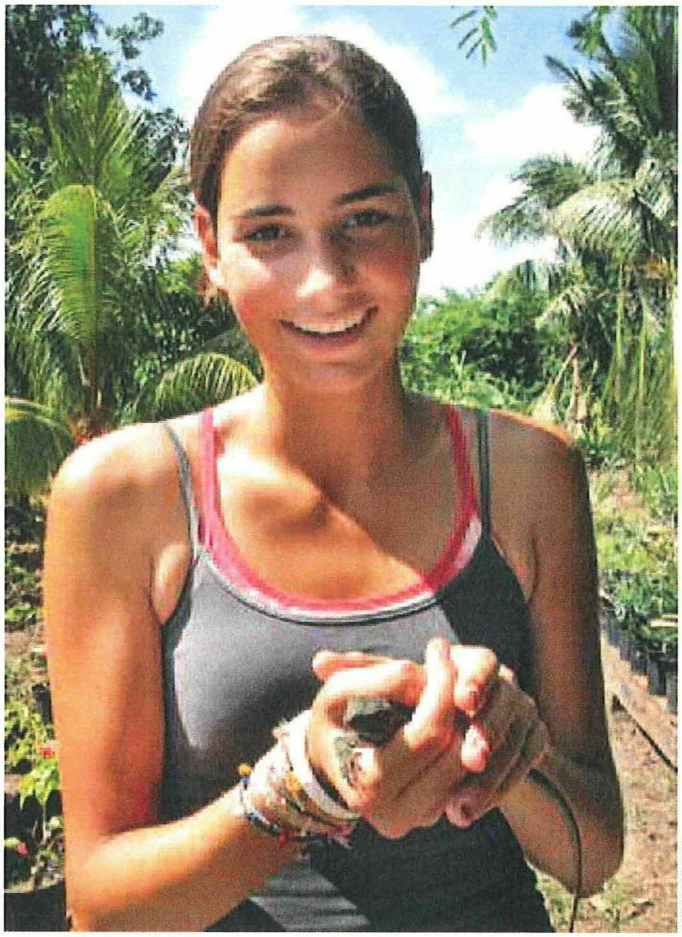
m toward the orchard. A few days after I left Guana, however, the iguana moved 54 m back toward the location where it had been released and away from where I first found it in the orchard.

On my last day on the island, I needed to catch all my iguanas and take the transmitters off. After an iguana was caught, I got a chance to hold it. As most transmitters had been put on before I got to the island, this was the first time I was able to hold one. My attachment to the little guys grew, as I finally got to experience what they felt like, see their faces up close, and marvel at the beauty of their coloration. Once the transmitter was removed, each iguana scampered off, and that was the last I saw of it.

When I got back home to freezing cold New Jersey, not only did I miss the warmth of Guana Island, but I also found myself longing to track the life of my newfound friends. I wanted to know what they were doing, where they were sleeping, whether they were still alive or not. I took stock of what I had learned. I found that juvenile *Cyclura pinguis* spend most of their time in trees. I observed them on the ground for an average of three hours a day, almost invariably in the morning, but found them in trees the rest of the time. Although I did not observe them for 24-hour periods, they apparently spend almost 90% of their time in trees. Not only do they spend a good amount of their day in trees, they were relatively high as well. On average, the iguanas were 5.5 m above the ground, although they occasionally were so high I was unable to see them at all. Being high in trees presumably offers juveniles added protection; they are well camouflaged in the foliage. Previous reports indicate that they are eaten by American Kestrels (*Falco sparvarius*) and snakes, both of which are common. Although I had hypothesized that the juveniles were actively seeking to maximize their sun exposure, I found that this was not necessarily the case. On average, 57 ± 24% of the iguana was exposed to sunlight, compared to 60 ± 17% of their environment. The difference between insolation at and away from iguana locations was not significant (Wilcoxon Signed Ranks Test; Z = 0.87, P = 0.39). Consequently, I concluded that the lizards do not appear to be choosing perches based on available sunlight. As the experimental group was relatively small (only 23 data pairs were tested) and the camera settings might have varied between photographs, these numbers should be considered preliminary data in need of further verification.

During my observations, lizards fed mainly on grasses and other vegetation on the ground, often small ground plants such as those in the genus *Ruellia*. Nonetheless, I occasionally spotted them eating leaves of trees in which they perched, and I cannot rule out the possibility that they feed on an occasional insect. I realized that other than eat and bask, the juveniles essentially did not do much. I also realized that these Stout Iguanas would not be critically endangered if everyone had the chance to follow them around for just a day. Their manners, their beauty, simply put, everything about them is fascinating. They need to be conserved for generations to come.

I also learned a lot about field research. Having done field research in the past, I am surprised time and time again by how much more I am able to learn doing hands-on work versus sitting in a classroom. Not only this, but I have finally learned how unpredictable working in nature is. Although high school experiments do serve an educational purpose, they dramatically misrepresent field research. The procedures provided in textbooks assist in organizing your thoughts, but such guidelines cannot anticipate every


KRISTA MOUGEY

The author holding one of the juvenile iguanas at the end of the project. Once the transmitter was removed, the iguana scampered off, and that was the last we saw of it.

Once Stout Iguanas are fully mature, their cuteness is replaced by a regal air.

eventuality. When Nature presents the unexpected, true researchers must quickly adapt to the situation for the good of the investigation. While the mis-releasing of one of the iguanas was an unforeseen accident, I ended up observing its attempt to return home, something nobody had previously reported.

Having to detour from my pre-determined procedures, although scary, emphasized the realization that nature is unpredictable. Although I am certainly no expert — yet, I was forced to practice making the necessary adjustments on several occasions during my week on Guana Island. I began to appreciate the times when my experiment did go as planned. I found indescribable joy in discovering my iguanas within a few minutes, rather than a few hours or not at all. Although the experiments in the high school lab will continue, I can now appreciate the amount of effort, energy, and reworking of procedures necessary for conducting most scientific investigations.

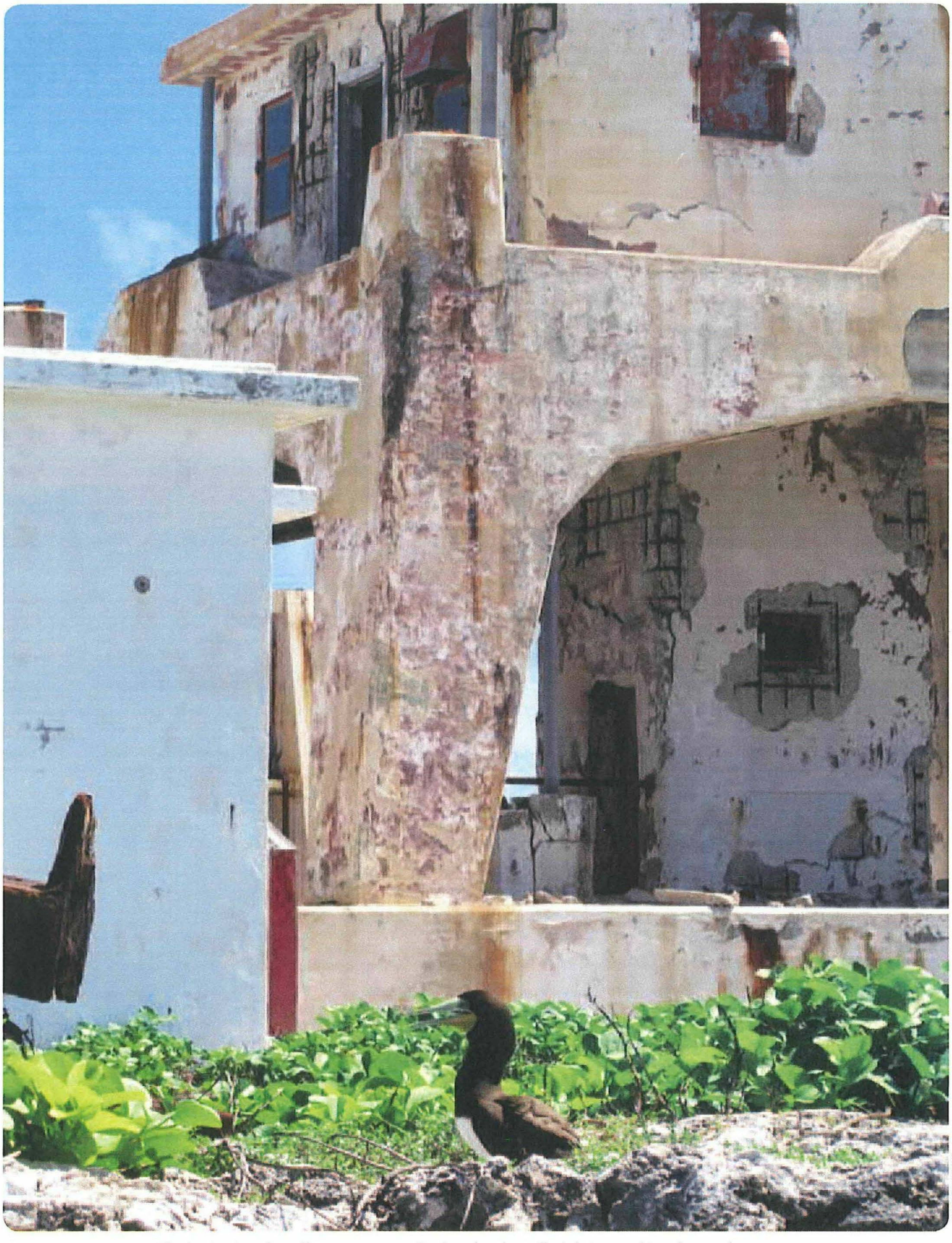
Finally, I learned a lot about myself (including that being tall is not necessarily an advantage when bushwhacking through dense vegetation). It was incredibly tedious to concentrate on one small, fluorescent green object for hours on end. In school, classes are only 50 minutes long, meaning I concentrate on a given topic for a maximum of 40 minutes (depending on the subject). These fairly stationary lizards taught me patience and extreme concentration. Not only that, but I am fairly certain my eyesight improved while on the island, seeing as I needed to strain my eyes more than I ever have before, trying to discover a green blob clutching a leafy, green tree. I am in awe of those who dedicate their life to this kind of work. However tedious the effort, the brief moments of movement provided me with a day's worth of excitement and gaiety. I grew attached to my juveniles, memorizing their transmitter numbers, and speaking of them as if they were my own. I had debated giving the iguanas names before beginning, to help me differentiate between them, but in retrospect I am glad I did not, otherwise the separation would have been unbearable.

Having this opportunity to work with critically endangered iguanas is one I will never forget. I cannot thank Dr. Henry and Gloria Jarecki enough for their interest in my project and for their vision to preserve the wildlife and natural beauty of this magical island. Guana would not be what it is today without their constant work and effort in caring for it. I also am deeply indebted to Drs. James "Skip" Lazell and Gad Perry for sharing their knowledge, being so generous with their time, showing infinite patience, providing constant encouragement, and a refreshing sense of humor — in short, being amazing mentors. I learned so much from them. My experience with telemetry equipment, discovery of iguanas, tagging of iguanas, and overall lack of insanity in the hours spent in the heat would be nothing without Krista Mougey. Special thanks to Renée Rondeau, whose unmatched plant knowledge proved to be indispensable when looking at multiple images of green, leafy specimens. I will be forever grateful for this opportunity that has further fueled my passion for biology, and I cannot wait until I get a chance to do field research again. Which is why I part with these words: "Beware iguanas. Katharina will be back."

Reference

Lazell, J. 2005. *Island: Fact and Theory in Nature.* California University Press, Berkeley.

107



ELIZABETH WRIGHT

The deteriorating relicts of human presence on Sombrero have been effectively integrated into the natural ecosystem.

TRAVELOGUE

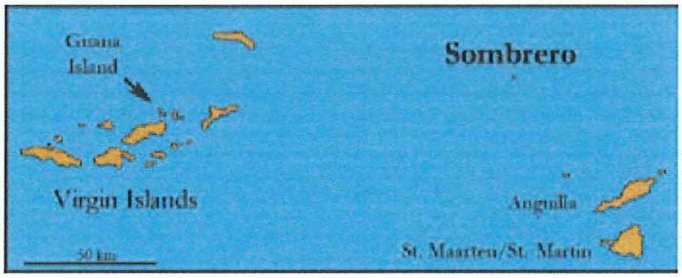
Sombrero: Lizards Among the Ruins

Elizabeth Wright

Department of Forestry, University of Missouri, Columbia, Missouri

This is an interesting time to be alive. Humans are running out of land and constantly searching for new opportunities to fuel economic growth. At the same time, we see a growing awareness of the natural environment, the resources it provides, and the harmful effects of human population growth on the Earth's other species. Some people deny that a problem exists and suggest that we should continue as we are. Others believe that we should park our cars, move into the woods, abandon technology, and become one with nature. Most of us fall somewhere between those two extremes. I believe that we must learn to coexist with nature while finding a way to foster economic growth without destroying our planet. I am fascinated by that goal and think that the first step is in understanding what is at stake. How can we coexist with nature if we remain ignorant of her components? I had an opportunity to witness a few implications of this age-old paradox during a recent visit to Sombrero, a tiny island about 60 km north of Anguilla.

On a fine morning in October 2010, I was one of a team boarding the aptly named *Ocean Girlz*, a catamaran chartered by The Conservation Agency for a trip to Sombrero. Sombrero is unique. Rising out of the ocean some time in the early Pliocene, it is about 1.5 km long and about 0.4 km at its widest point and has never been part of another body of land. Sombrero is the northernmost of the Lesser Antilles, and is part of the nation of Anguilla. Life on the 38 ha of marly limestone arrived by migrating from the mainland or smaller islands on floating debris, by flying, or



JOHN S. PARMERLEE, JR.

As the northernmost of the Lesser Antilles, Sombrero is a long way from everywhere, sitting on its own island bank and never connected to any other landmass.

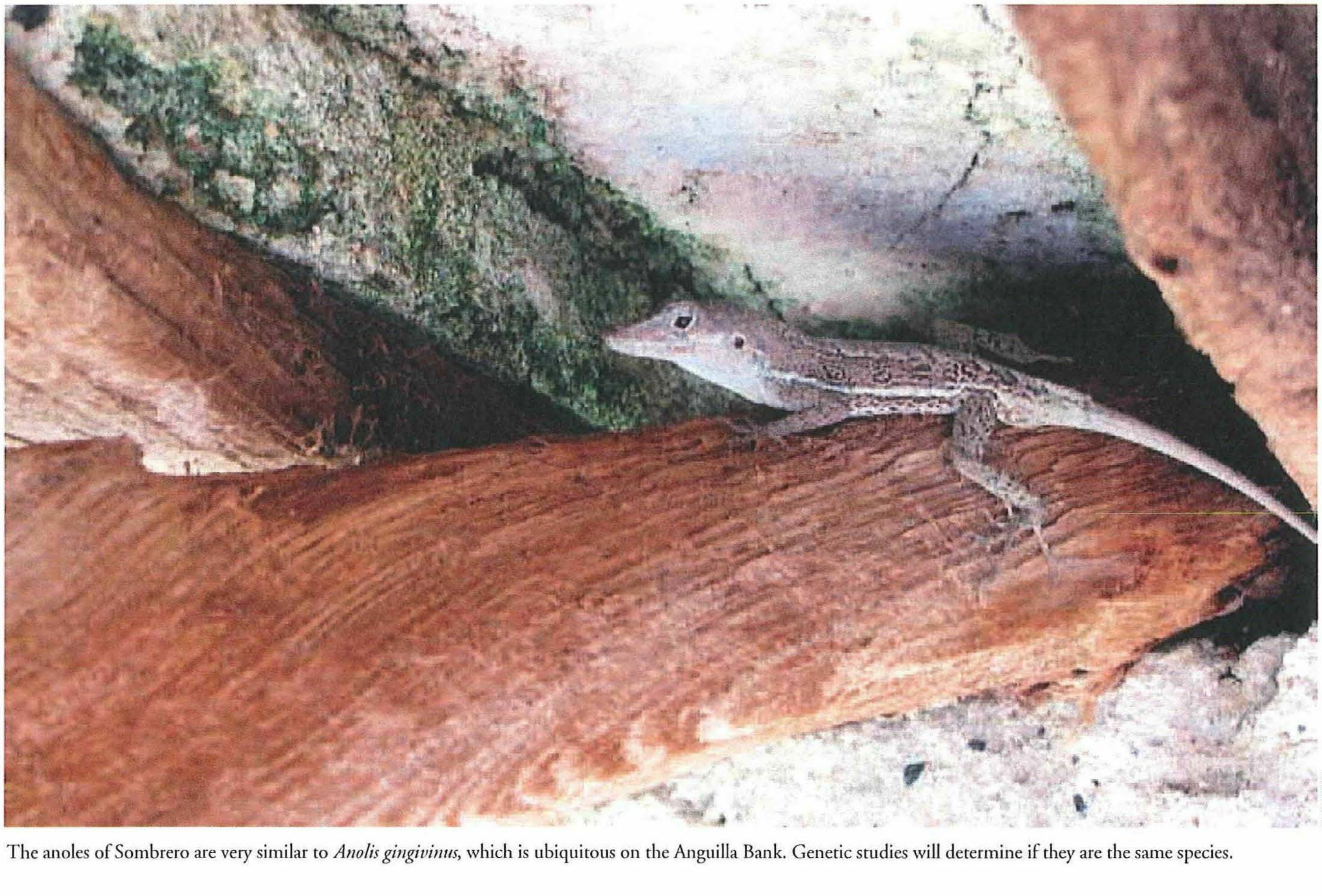
ROBERT POWELL

Sombrero is one of three Lesser Antillean islands that harbor black Ameivas. In addition to *Ameiva corvina* (named after equally black crows), *A. corax* lives on Little Scrub Island off the northeastern coast of Anguilla, and *A. atrata* lives on Redonda, another isolated "rock" emerging from the sea.

109

ROBERT POWELL

Access by ladder is necessary for scaling the sheer walls of the island, limestone cliffs shooting 12 m straight up out of the water.



GAD PERRY

The anoles of Sombrero are very similar to *Anolis gingivinus*, which is ubiquitous on the Anguilla Bank. Genetic studies will determine if they are the same species.

110

GAD PERRY

Island Girlz, here anchored off Sombrero, made the expedition to the island a comfortable experience — although the captain had not previously been to Sombrero.

GAD PERRY

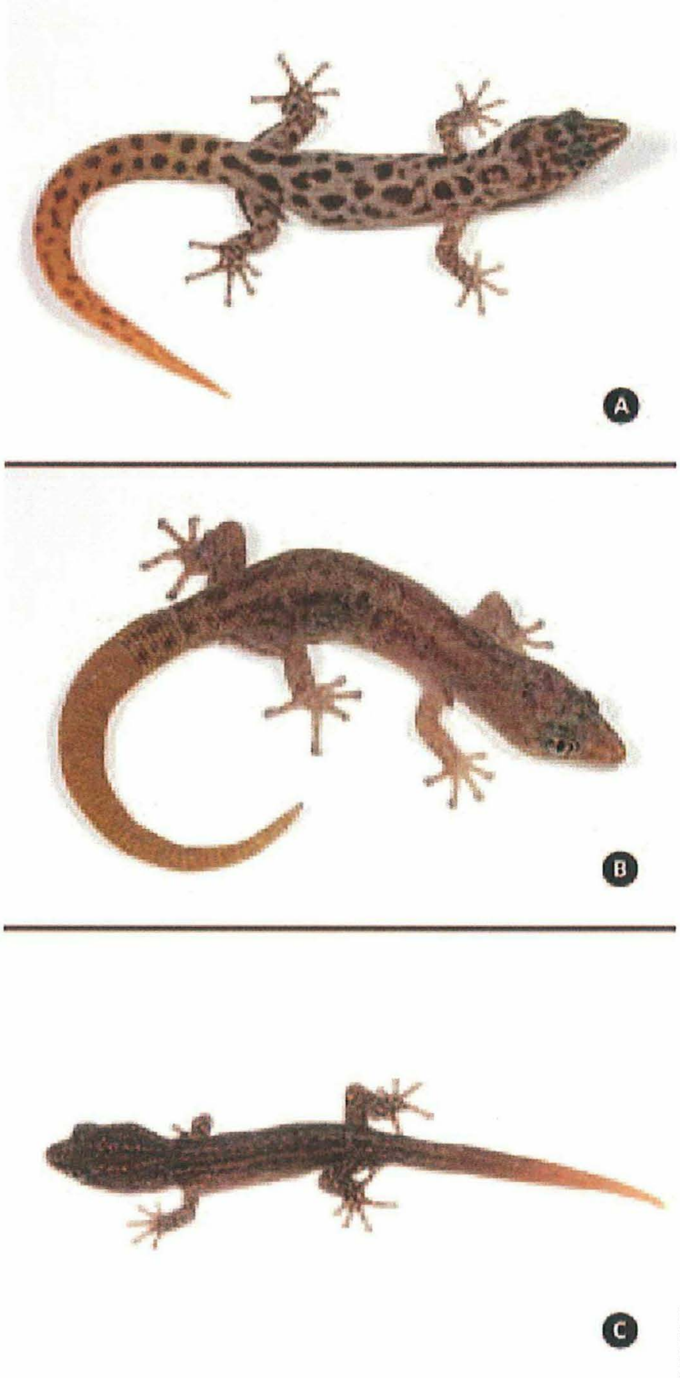
A Brown Booby (*Sula leucogaster*), silhouetted against the sunlit sky on what looked like a rusty loading crane, greeted our arrival.

ROBERT POWELL

Although proficient scavengers when birds or people provide welcome meals, the Ameivas of Sombrero usually have to dig and root for food.

being carried by storms, birds, or humans. The island is frequently deluged by giant waves, and might be entirely submerged during severe hurricanes. Such conditions make it hard to get there and even harder to survive. The resulting founder effect — the sometimes considerable impact that the few founding individuals can have on later generations — dramatically increases the chance of endemism (Ivie 1999). This is why we were going to Sombrero.

The trip was organized by Dr. Robert Powell, a herpetologist at Avila University, who wanted to learn more about the lizards of Sombrero. Dr. James Lazell, the president of the Conservation Agency, had visited the island in 1963 and had discovered that three species occurred on the island (not just the one that had been previously reported): An anole currently identified as *Anolis gingivinus*, the common species on the nearby Anguilla Bank; a Dwarf Gecko, which Lazell described as *Sphaerodactylus* "near" *sputator*, the species that occurs on both the Anguilla and St. Christopher banks; and the spectacular black Ground Lizard, *Ameiva corvina* (Lazell 1964). In

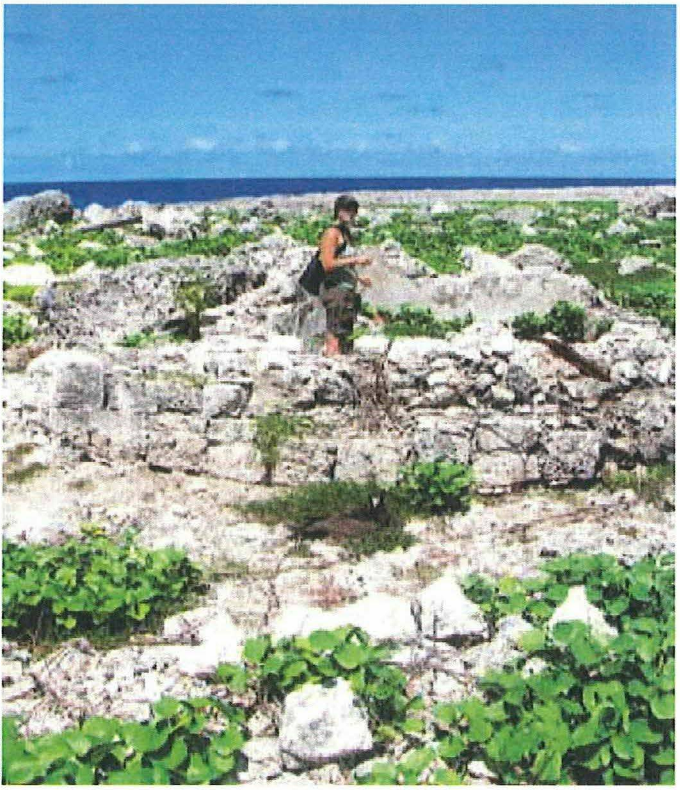


S. BLAIR HEDGES

The Dwarf Geckos on Sombrero exhibit variable patterns, some spotted, some almost unicolored, and others with stripes, as seen on these two adults (A/B) and one juvenile (C).

S. BLAIR HEDGES

The powerful claws on the forelimbs of Ameivas are ideally suited for rooting and digging for food.



GAD PERRY

The author, with aspirator in hand, searches for small arthropods among the ruins.

the 1960s, when Dr. Lazell visited Sombrero, no one was yet dreaming of the secrets that DNA might one day reveal, and tissues collected during a survey by Dr. Jenny Daltry (1999) were subsequently lost. The time had come to collect some more samples so that the relationships and perhaps true identities of these lizards could finally be established. Our team also included Dr. Gad Perry, a conservation biologist at Texas Tech University, Dr. Wenhua Lu, an entomologist with the Conservation Agency, and Susan Valentine-Cooper, an experienced entomologist, who, like me, had been invited to come along and help collect small arthropods.

So, there we were aboard *Ocean Girlz,* on our way from Guana Island in the British Virgin Islands, where we were conducting long-term research projects, to Sombrero. I was in awe of the flying fish as they exploded out of the water and soared for what appeared to be hundreds of meters across the waves. As we approached the island some three hours into our voyage, we saw a small vessel anchored near the ladder that provides access to the island. Access by ladder is necessary for scaling the sheer walls of the island, limestone cliffs shooting 12 m straight up out of the water. I almost fell into the water on my first attempt to step from the bow of our catamaran, moving up-and-down with the waves, onto the ladder, and was saved only by the quick action of the crew. My second attempt was successful and I climbed up, the metal hot under my hands.

ELIZABETH WRIGHT

ELIZABETH WRIGHT

ROBERT POWELL

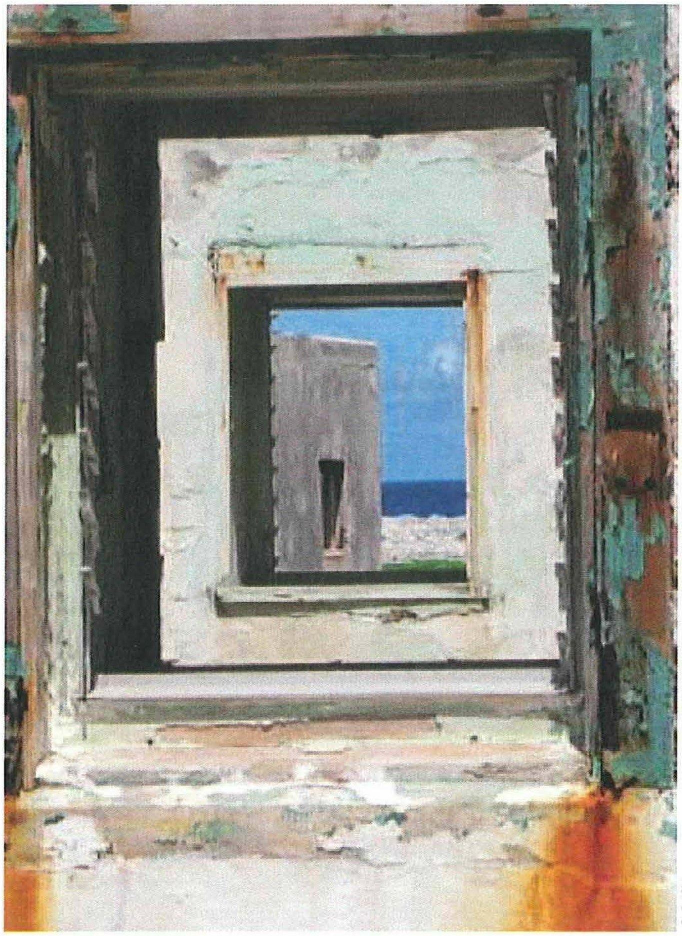
Migratory Blackpoll Warblers (*Dendroica striata*) darted about, searching for the same insects we were trying to collect (A). These tiny birds, which began their voyage in the northeastern United States, had flown over open ocean for days. Totally spent, some individuals unlucky at making their first landfall on a desolate island like Sombrero, were unable to scrounge for sparse food in time to fend off exhaustion and death (B). Although unfortunate for the birds, the Ameivas readily scavenged the carcasses (C).

112

The other boat had carried the immigration official from Anguilla who was to meet us and check our passports. I was nervous as I approached the top of the ladder, expecting a large Anguillian official with a scowl. What I encountered at the top of the ladder, however, was the most non-threatening immigration officer I could imagine. He was slender and wore a straw hat, a loose-fitting button-up shirt, and khaki pants, and he was sweating and smiling and settled on a rock. We gave him our passports, he verified that we were who we said we were, and began his long journey home. We turned to take in our surroundings.

The landscape was desolate. Not a tree in sight, just viney plants criss-crossing the rocks. Overhead, a Brown Booby (*Sula leucogaster*) was silhouetted against the sunlit sky on what looked like a rusty loading crane. Black Ameivas were abundant, scurrying a bit when we got too close. Magnificent Frigatebirds (*Fregata magnificens*) hovered in pockets of hot air, their red throat sacs flapping a little in the wind. Migratory birds, mostly Blackpoll Warblers (*Dendroica striata*) darted about, searching for the same insects I was intending to catch.

Despite its relative isolation, humans have had a considerable impact on Sombrero. Old rusty metal structures jutted up all over the island. Giant pits in the limestone peppered the otherwise flat terrain, testament to 19th-century American and British mining operations that quarried considerable volumes of phosphates (mineralized guano) for use as fertilizer in an effort to resuscitate the soils of the southern states that had been exhausted by the plantation system. They even blew up whole sections of the hat-shaped island until only the brim remained (Pappalardo 2001). However, this was not the only time the island was threatened by human activities. In 1999 and 2000, Beal Aerospace of Texas was considering Sombrero as a potential launching site for rockets carrying commercial satellites into space. Triggered by resistance from bird enthusiasts who claimed that Sombrero was an important nesting site for many West Indian species, Beal conducted an environmental assessment that claimed that the nesting site was not that important and that only one species of lizard lived on the island — and that the rockets would not affect them. Beal ultimately decided not


GAD PERRY

Windows in the ruins of the old lighthouse keeper's quarters look out over the desolate landscape of Sombrero to the Atlantic Ocean beyond.


GAD PERRY

Ravaged by 19th-century mining activities and eroded over time by rain and waves of water violently washing over the island, the surface of Sombrero is a maze of sharp and porous "dog-tooth" limestone.


GAD PERRY

One of the larger mining pits, relicts of 19th-century efforts to extract mineralized phosphates (guano) that had accumulated over the centuries courtesy of innumerable generations of nesting seabirds.


ELIZABETH WRIGHT

Catching elusive little geckos in the rubble of Sombrero was not always successful. In this instance, however, the broken tail will provide DNA for genetic studies to determine if the Dwarf Geckos of Sombrero are "near" *Sphaerodactylus sputator*, as Lazell (1964) indicated. The lizard escaped and will regenerate a new tail.


ROBERT POWELL

During the heat of the day, nesting Brown Boobies (*Sula leucogaster*) lifted their bodies off their eggs to prevent overheating. Squawking a bit if we approached too closely, they were otherwise indifferent to our presence.

to use Sombrero, not because of the destructive nature of the project but because the weather was not to their taste (Pappalardo 2001).

The island's guano deposits were exhausted by 1890, leaving "dog-tooth" limestone that is sharp and porous, eroded over time by rain and waves of water violently washing over the island. I was very aware of how exposed my feet were in Chaco sandals. Despite the apparent desolation, I knew the island was teeming with creatures. "Well, we don't have much time," Dr. Powell said, awakening me from my state of awe. "Let's start collecting." Drs. Powell and Perry went off in search of lizards. "Catch 'em if you can, ladies!" Dr. Perry called, referring to lizards, of course, as he trudged in the direction of the lighthouse.

The entomology team started collecting. Typically, we beat vegetation and catch falling insects in our nets below or sweep through grasses with

ELIZABETH WRIGHT

ROBERT POWELL

ROBERT POWELL

The abundance of down-covered Booby chicks testified to the dearth of predators on an isolated island.

ELIZABETH WRIGHT

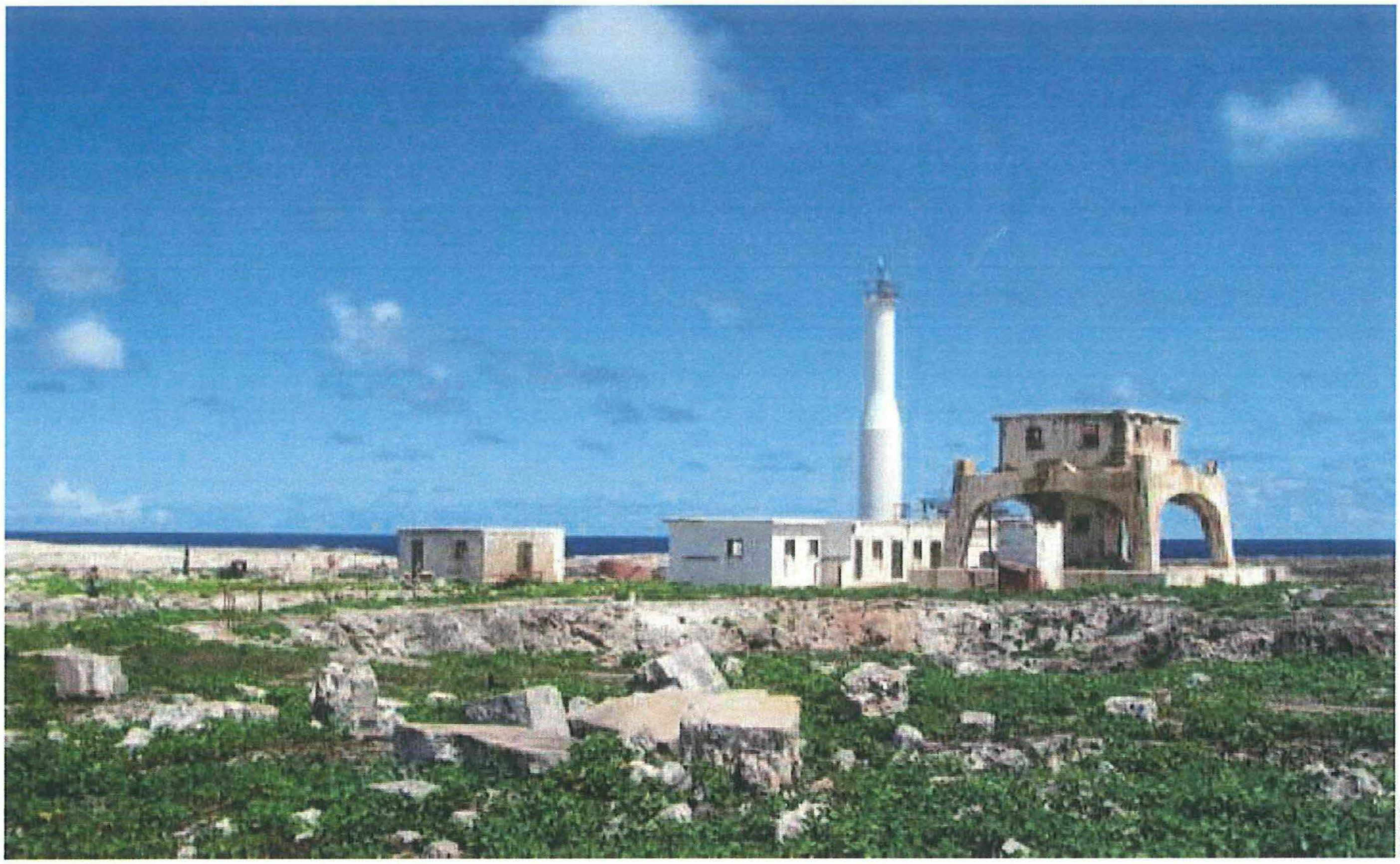
On a food-limited island, lizards must actively search for meals. This Ameiva was foraging through the remains of a Booby nest in search of food.

nets — but Sombrero has no tall vegetation. So, we started turning over rocks and pieces of rusty metal. We would be prepared with our aspirators — devices involving a small plastic jar equipped with tubes to suck up little critters. A rubber cork in the jar has two curved metal tubes sticking out either side, a short one with a screen that leads into the jar that is connected to a long rubber tube that you suck with and a longer one that is placed near the insect you want. You suck in and the insect is vacuumed into the jar (and not into your mouth because of the screen). I tried looking under rocks all over the island, but insects were few and far between — until we climbed down into one of the mining pits, where I found something that I had not seen — huge congregations of tiny mites. Perhaps they were in the pit because the temperature was lower or perhaps the pockets and crevices retained a little moisture.

After little success while flipping rocks, I started picking apart some of the small plants and, lo and behold, I found webspinners (order Embioptera). Webspinners are very cool primitive insects with silk glands used to spin the galleries in which they live. I ruthlessly sucked them up with my aspirator. I also looked through an old booby nest, where I found several beetle and fly larvae. I sucked those up, too — assisted by an *Ameiva* with whom I gladly shared the trove of insect larvae.

Already sunburned and with little time left on the island, I decided to explore some of the buildings. The lighthouse, built in 1868 after a ship had run into the island in 1859, was in ruins. Even after mining operations were abandoned, the British Board of Trade maintained the lighthouse to guide ships through the Anegada Passage. In 1960, a hurricane destroyed the lighthouse, which was replaced and has gone through several incarnations since. It was automated in 2002, but left a history clearly portrayed by the decaying ruins.

115


GAD PERRY

The concrete base of the old lighthouse and the remains of the lighthouse keeper's quarters stand side-by-side with the new automated lighthouse.


ROBERT POWELL

This Sombrero Ameiva had just excavated a beetle grub.

GAD PERRY

Lacking trees, typically the favored habitat of West Indian anoles, the anoles of Sombrero lived on rock faces or the deteriorating ruins — the only vertical habitats available on the island. This male (A) and female (B) were on poured concrete walls near the lighthouse.

Despite their ghostly appearance, the buildings have been integrated into the island's ecosystem. As I entered what was left of one of the old staff houses, I encountered two large Ameivas — and one had something yellow and insect-like hanging out of its mouth. I crept closer, determined to steal their snack. The lizards scurried under a pile of plywood planks. As I carefully lifted them, the Ameivas slipped out a doorway with empty mouths, leaving a yellow and brown scorpion that lay lifeless and stingerless on the plank. I collected it immediately.

I wandered into another building and saw an anole on the windowsill with something in its mouth. I was very confident now, and edged closer — but the anole was more skittish than the more relaxed ground lizards and it sprinted down the wall, across the floor, and under a large loose tile. I tiptoed closer and slowly started to flip the tile. The lizard ran out but left his lunch, a lively cricket. I grabbed it before it hopped away and slipped it into the plastic bag with the deceased scorpion. I thanked the lizards and apologized for stealing their lunches before heading back to where the others had gathered.

As the last specimens were being collected, I decided that I needed to catch my first lizard. What better place to do it than on an island literally crawling with hundreds of imperturbable black lizards? I crouched low to the ground and waited patiently as the lizards drew nearer. As soon as I reached out to grab one, however, it would dash out of the way. Dr. Perry approached and asked if I wanted a little help. He handed me a noose. "Just stick the noose near the head and pull up — pretty complicated." With lizards crawling around me like sassy little black dinosaurs, I had one within a minute. Dr. Perry taught me how to correctly hold a lizard by grasping both legs of one side in the same hand. I named him Bobert. My two minutes of lizard-catching bliss came to an abrupt end as we decided to call it a day.

When the captain and crew saw us heading to the ladder, they picked us up one by one. This time we had to jump from the ladder to the bobbing boat. Again, I almost fell in trying to impersonate Indiana Jones and barely made it onto the boat. I begged the captain to let me take a dip to cool my sunburned body before we headed out and as soon as he agreed, I was out of my field clothes, in my suit, and diving off the side of the boat. I have NEVER swum in such clear water. What I had assumed was only about 15 feet deep was, in fact, more like fifty! It was like swimming in liquid glass.

On the trip home, I thought about what I had seen, a snapshot of a very complex and delicate ecosystem. I wished that we had had more time, a chance to collect at night, to make more observations. I'm sure a whole book could be written about the ecology of Sombrero. Despite the mining operations and the proposed rocket-launching site, Sombrero has hung on. For the moment at least, little black lizards and big Brown Boobies live largely undisturbed by human interlopers — and maybe that's how it should stay.

Acknowledgements

Karim V. D. Hodge, Director, Department of the Environment, Anguilla, facilitated our visit to Sombrero and issued permits for collecting specimens and tissue samples. The Conservation Agency, with a grant from the Falconwood Foundation, chartered the boat that carried us to Sombrero. The staff of Guana Island made arrangements for the charter and supported our efforts in many ways.

Literature Cited

Daltry, J.C. 1999. Conservation assessment of the Sombrero Ground Lizard: With notes on the other reptiles of Sombrero. Flora & Fauna International – UK Overseas Territories Programme, Cambridge, United Kingdom.

Ivie, M.A. 1999. Initial Report, Invertebrate Biodiversity Survey of Sombrero, November 1999. <http://groups.yahoo.com/group/caribbean-biodiversity/message/521>.

Lazell, J.D., Jr. 1964. The reptiles of Sombrero, West Indies. *Copeia* 1964:716–718.

Pappalardo, J. 2001. Love and rockets. *The Dallas Observer.* 1 March 2001.

117

DEBORAH DAVIS, JD 517 W. Clay Ave., Plattsburg, MO 64477
davisarchaeology@gmail.com · 816.835.3305

31 January 2011

Dr. James D. Lazell
The Conservation Agency
6 Swinburne St.
Jamestown, RI 02835

Re: Review of the Archaeological Evidence for the Role of the British Virgin Islands in Prehistory

Dear Skip,

Enclosed please find as requested a hard copy of my dissertation, "Out of the Shadows: A review of the archaeological evidence for the isolation, interaction, and abandonment of the British Virgin Islands in the pre-Columbian Caribbean." Please feel free to share it with anyone you believe might have an interest.

I have spoken with Alfredo Figueredo and we would be eager to participate in Science Month in October 2012, if that is possible. Please do let me know what you might need from us in order to make the necessary arrangements.

Alfredo and I are also working on a paper for publication that might be of interest as it highlights the role of the BVIs in the region during prehistory following on the summary review of the evidence presented in my dissertation. I will forward a copy of our article to you when it's completed.

Thank you again for sharing your information about Guana Island and the archaeological research that has been undertaken there to date. The evidence thus far shows that Guana Island played an intriguing role in the Taíno political complex and culture which is worthy of further investigation.

I look forward to hearing from you and hopefully meeting in person one day soon!

Best regards,

Deborah

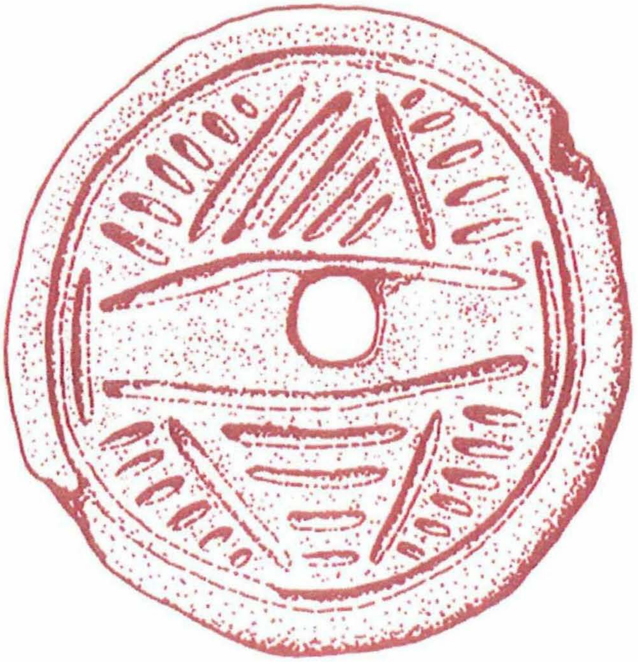
Enclosure

118

Out of the Shadows: A review of the archaeological evidence for the isolation, interaction, and abandonment of the British Virgin Islands in the pre-Columbian Caribbean

by

Deborah Diane Davis
(School reference number 079019194)



Submitted for the degree of
Master of Arts, Archaeology and Heritage
School of Archaeology and Ancient History
University of Leicester

January 2011

Abstract

Poised between the Lesser Antilles and the Greater Antilles, the position of the British Virgin Islands raises interesting questions regarding their role in regional interactions in the Antilles archipelago. Did they serve as an exploratory frontier, a marketplace, a bridge of communication, or a hub of interaction encompassing aspects of some or all of these functions for the peoples of the prehistoric Caribbean? Or were they an isolated chain of islands bypassed by longer distance trade and exchange networks? While much research has been undertaken by archaeologists concerning the prehistory of the Virgin Islands of the United States, the role of the British Virgin Islands ("BVIs") is in need of closer attention and additional archaeological investigation. This dissertation is a focused examination of the potential interaction and relative isolation of the British Virgin Islands within the context of the wider Antillean archipelago during the pre-Columbian period. Although there is less evidence for prehistoric habitation and interaction of the islands of the BVIs than for the U.S. Virgin Islands or other islands in the Antilles, what research has been conducted has given strong proof of occupation or activity in the BVIs from the Saladoid through to the Chican Ostionoid (Taíno) culture. At present, there is no evidence for long-term occupation of the British Virgin Islands in the late Ostionoid or protohistoric periods, likely depopulated prior to European contact although possibly used sporadically as a gathering place for festivals and later as a war-torn frontier between the Taíno and Caribs. By a focused examination and comparative review of the social dynamics and political structures illustrated by settlement patterns and cultural materials, increased understanding of the occupation of the role of the BVIs as a regional hub of interaction during prehistoric times may supplement and inform further areas of archaeological investigation.

This dissertation contains 22,177 words. *Cover page:* Fort Point style spindle whorl found on Virgin Gorda (drawing by Jeffrey M. Gross from Figueredo 1978: back cover).

TABLE OF CONTENTS

> *No one warned the previous inhabitants of these Virgins that Columbus was about to discover them and that their very lives were soon to be in danger. They were the discovered; their history begins in shadow and ends in shadow.*
>
> -- Florence Lewisohn (1966)

CHAPTER 1: INTRODUCTION

The first people to arrive in the Caribbean islands did so in approximately 5,000 B.C. (Wilson, *et al.* 1998; Kozlowski 1974; Saunders 2005: *xii*; Wilson 2007: 1). These early explorers found a chain of islands rich in resources and more than 200,000 sq km of uninhabited land (Figure 1). From these earliest human migrants entering the Caribbean, people have been developing inter-island networks for trade and settlement that lasted well into the historical contact period. When Christopher Columbus sailed into the Caribbean in 1492 (Cohen 2011), he found large and dense populations with established social hierarchies well-versed in intensive agriculture and the production of food, tools and other specialized goods (Wilson 2007: 155-158). A growing body of evidence suggests that interisland networks between culturally diverse groups made the continued occupation, economic sustainability and development of such complex polities possible (*cf.* Watters 1997; Righter 1997; Faber Morse 1997; Allaire 1997; Bates 2001; Drewett 2007; Hardy 2008; Figueredo 1980, 1987; Hofman 1993; Hoogland and Hofman 1999; Keegan and Rodriguez Ramos 2007; Knippenberg and Ziljlstra 2008; Reid 2009; Rodriguez Ramos 2008; Saunders 2005; Wilson 1997, 2007; Keegan 2008; Booden, *et al.* 2008; Coppa, *et al.* 2008; van Gijn, *et al.* 2008; Hofman, *et al.* 2007; Hofman, *et al.* 2008).

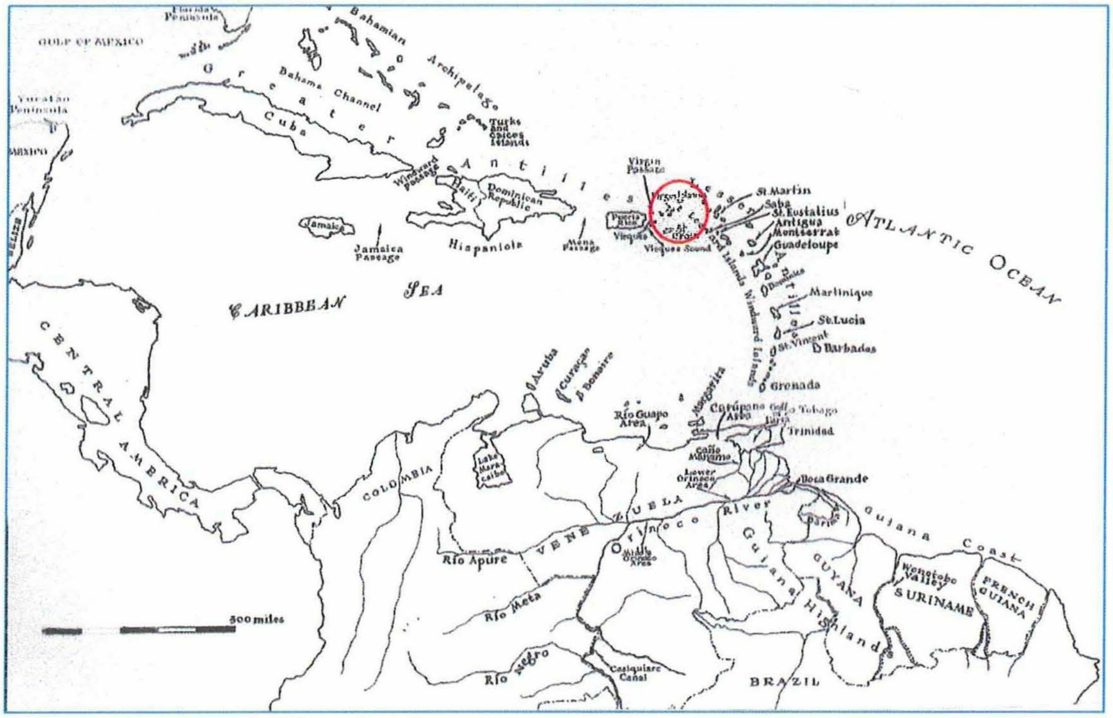


Figure 1. Map of Antillean archipelago with Virgin Islands Group (circled red) (figure after Rouse 1992: 2).

Poised between the northernmost islands in the Lesser Antilles chain and the eastern edge of the Greater Antilles, the centralized geographic location of the Virgin Islands (Figure 2) raises interesting research questions regarding the role they may have played in regional interactions in the Antilles archipelago. Did these islands serve as a frontier for exploration, a filter or marketplace for trade, a bridge of communication, or a general hub of interaction encompassing aspects of some or all of these functions for the peoples of the prehistoric Caribbean? While much research has been undertaken by archaeologists concerning the Virgin Islands of the United States (hereinafter, the "U.S. Virgin Islands") during the pre-Columbian eras, the role of the British Virgin Islands (hereinafter, the "British Virgin Islands" or "BVIs"; officially known as the United Kingdom's Overseas Territory of the Virgin Islands) in prehistory has been largely overlooked (with a few notable exceptions) (Righter 2007a: 807; Johnston and Lundberg 1985: 50; *cf.:* Bates 2001; Chenowith 2008, 2009; Davis and Oldfield 2003; Dookhan 1975, 1994; Drewett, L. 2000; Drewett and Bates 1999; Drewett, P. 2000, 2003a, 2003b, 2007; Figueredo 1972, 1974a, 1974b, 1980; Gross 1975, 1976; Hatt 1938; Hunt and Drewett 2000; Marler and Marler 1978; Pickering 1987; Saunders 2005:7, 286-288; Schomburgk 1832; and White 1983). Questions persist as to whether these islands were becoming increasingly and directly influenced by the cultural groups of the Greater Antilles and whether they were undergoing active change and a period of possible depopulation immediately prior to Columbus's arrival.

Given their central position in the Antilles chain and their rich environmental resources (despite their relatively small size when compared to the Greater Antilles), the author posits the British Virgin Islands were far more active during the prehistoric period than previously believed. While this dissertation touches on the history of Caribbean archaeology and period of migration into the British Virgin Islands, it is not meant as an exhaustive review of the subject but instead is a narrowly-focused examination of the role of the British Virgin Islands as a potential hub of interaction in the Antillean archipelago in prehistoric times. In particular, through an examination of the settlement patterns in the BVIs, I will look for evidence of cultural interaction with other islands in the Antilles through societal groups, economic factors, religious and ceremonial rites, and displays of power/status. I will also consider whether the evidence to date suggests the islands were, as reported by some historical sources (Lewisohn 1966: 7; Pickering 1987: 8), depopulated prior to the arrival of Columbus and, what may have led to changes in the island demography as reported from ethno-historical sources (Figueredo 2006: 393-399). Through an examination of these factors, this dissertation aims to help fill the current gap in knowledge and understanding of the role of the British Virgin Islands (Figure 3) in prehistoric times.

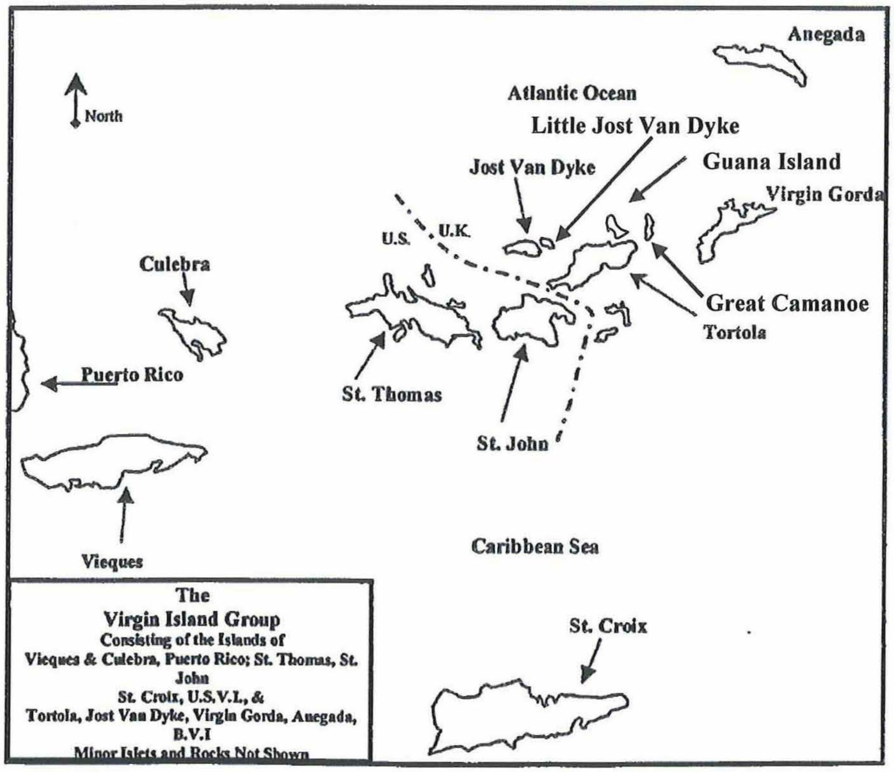


Figure 2. The major islands of the Virgin Islands Group (not to scale) (figure after Bates 2001: 19).

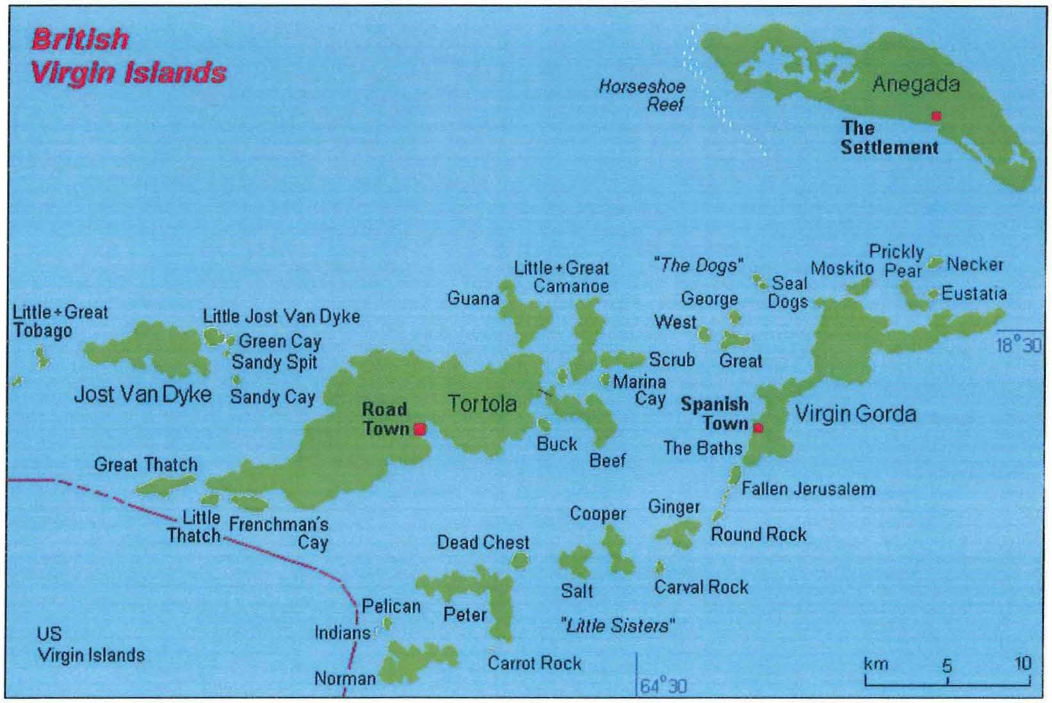


Figure 3. The British Virgin Islands.

Table 1. Periods of time in the prehistory of the Virgin Islands with comparative evidence from the British Virgin Islands (modified and adapted from Rouse 1964, 1985, 1986, 1990, Kozlowski 1974, Vescelius 1980, Figueredo 1974b, and Alfredo E. Figueredo, personal communication).

AGE	PERIOD	SERIES	PATTERN	YEARS	ISLANDS	EVIDENCE (by site)
Proto-historic			Taíno / Caribs	1493-?	Virgin Gorda, Tortola	No direct evidence of occupation; ethnohistoric accounts of Taino refugees and Caribs on the islands
Formative	IV	Ostionoid	Chican	1250-1492	Tortola, Virgin Gorda, Guana Island, Mosquito Island	**B**: major settlement with easternmost Taíno stone-lined ball court, sun petroglyph, cultural materials; **FP**: spindle whorls indicating textile industry **RT**: Chicoid wares; **T**: late Ostionoid wares; **G**: possible Taíno meeting place (see box below); **M**: turtle bowl of unknown provenance
Ceramic	IIIb	Ostionoid	Elenan	950-1250	Anegada, Tortola, Jost Van Dyke, Guana Island, Little Jost Van Dyke, Great Camanoe	**A**: multiple, expansive conch shell middens (also noted on early 1824 map as Indian monuments); Elenoid wares; radiocarbon dates from conch shells ca. A.D. 1245 ± 80; possible axe fragment from materials not locally available; redwares from unprovenanced collection **B**: major settlement with evidence of roundhouses, burials, extensive middens, Elenoid wares, and cultural materials; **CW**: long-term settlement with extensive shell midden, burials, possible ritual deposits; radiocarbon dates from Cal. A.D. 965 – 1040, Cal. A.D. 635-720, and Cal. A.D. 745-760; ceramics show

AGE	PERIOD	SERIES	PATTERN	YEARS	ISLANDS	EVIDENCE (by site)
						evidence of transition from Saladoid wares **G**: Taíno burial with signs of cranial modification, intact Elenoid bowl; ball belt/stone collar fragments; possible postholes and evidence of settlement ca. A.D. 1100-1400 **LJVD**: earthenware potsherds at rock shelter entrance, including griddle fragment; possible prehistoric redwares found at historic site nearby; one lithic artefact (very dark flint) **PB**: small seasonal camp with evidence of ritual deposits (time period not specified) **T**: late Ostionoid wares **CB**: Elenoid wares, blank stone petaloid, carved shell frog; radiocarbon dated to ca. A.D. 1250
	IIIa	Ostionoid	Magensian	650-950	Guana Island	**G**: possible early small settlement indicated by cultural materials and faunal remains Probable continuation of settlement on the islands of Tortola and Virgin Gorda; possible early settlement on Jost Van Dyke.
	IIb	Saladoid	Aklian (Gun Creek)	350-650	Tortola, Virgin Gorda	**B**: evidence of long-term settlement with abundance of cultural materials, and evidence of textile and stone/shell tool industries **CGB & JB**: Saladoid redwares **GC:** type site for Gun Creek series; spindle whorls indicating textile industry

AGE	PERIOD	SERIES	PATTERN	YEARS	ISLANDS	EVIDENCE (by site)
						G: "primitive barbecue" evidenced by faunal remains dated to ca. A.D. 450; imported chert arrowhead
	IIa	Saladoid	Cuevan	150-350		**G**: charcoal and stone axehead found in cave floor radiocarbon dated to ca. 50 B.C.-A.D. 450, though dates may be off by as much as 30%
	IIa	Saladoid	Cedrosian	50-150		None, except see "G" and "B" entries in boxes above and below
Archaic	Ib	Ortoroid	Krumian	2000 B.C.-A.D. 50	Tortola	B: 2 stone ovates similar to Krum Bay ovates of this period
Lithic	Ia	unknown	unknown	-2000 B.C.		None

Site Key: A=Anegada; B=Belmont, Tortola; CB=Cam Bay, Great Camanoe; CGB=Cane Garden Bay, Tortola; CW=Cape Wright, Jost Van Dyke; FP=Fort Point, Virgin Gorda; G=Guana Island; GC=Gun Creek, Virgin Gorda; JB=Josiah's Bay, Tortola; LJVD=Little Jost Van Dyke; M=Mosquito Island; PB=Paraquita Bay, Tortola; RT=Road Town, Tortola; SM=Sage Mountain, Tortola; T=multiple sites on Tortola.

Three broad cultural epochs which affected the British Virgin Islands

The Archaic Age

The Archaic Age signifies a period characterized by the use of lithics or stone tools in which settlements were becoming increasingly more common. Two groups of migrants were likely the first to enter the Caribbean. The Ortoiroids (ca. 5000 – 200 B.C.), named after Ortoire in eastern Trinidad, likely migrated from the Guianas in South America (Reid 2009: 14, citing Boomert 2000) to settle in the Lesser Antilles moving north up through the island chain all the way to Puerto Rico. The Casimiroids (ca. 4000 – 400 B.C.), named for the type-site of Casimira in southwestern Hispaniola, likely came directly to Cuba and

Figure 43. Shelf-like feature cut into boulder outside cave entrance on Little Jost Van Dyke.

Guana Island

Guana Island (Figure 44) lies directly north of Tortola's east end and to the west of Great Camanoe. It is a small (approximately 800 acres) and hilly island that is privately-owned and largely undeveloped. Until their value was recognized in the mid-1980s, local inhabitants who discovered prehistoric pottery would display it for guests (Righter 2007a: 807; Lazell 2005).

A scientist conducting biological research on the island, Michael Gibbons, found evidence of possible occupation, including a chert arrowhead, at cave sites on the island (Righter 2007a: 807). Gibbons, a non-specialist, excavated a cave floor finding charcoal and a stone axehead dated ca. 50 B.C. – A.D. 450 (Lazell 2005: 314), though his radiocarbon dates may admittedly be off by as much as 30% (Gibbons 1987: 21). Gibbons interpreted the cultural materials recovered to date from the Archaic period between 0 and A. D. 500 and faunal remains of a "primitive barbecue" to ca. A.D. 450, but did not consider the material as evidence of Saladoid occupation (Righter 2007a: 807; Gibbons 1987: 21; Pickering 1986). As there are no sources of chert on the island, the arrowhead represents evidence of trade or import to the island from elsewhere in the Caribbean, possibly from Puerto Rico or Antigua (Knippenberg 2007; Knippenberg and Ziljlstra 2008).

Lazell notes that the cave floors on the island generally have smooth, earthen floors rather than the boulder debris expected based on the geology of the island, and posits that perhaps early inhabitants of the island cleared the cave floors (Lazell 2005: 105). However, taphonomic changes resulting from animals kept at the site (i.e., sheep), historical use of the site (Gibbons 1986: 5), and environmental factors would first need to be considered in connection with any analysis as to the creation of the cleared, earthen floors. Notwithstanding these factors, their presence on Guana does raise interesting questions as the Taíno culture used caves as sanctuaries for ceremonial rites seeing them as portals to the underworld and the animals who inhabited the caves as living with the ancestors (Keegan and Carlson 2008: 94-99). Were the caves on Guana used for ritual offerings, as places of burial, or special ceremonies for communing with the ancestors as they have been elsewhere in the Caribbean (*Ibid.*)? Are there any petroglyphs with Taíno symbolism as found in caves on Hispaniola and the Turks and Caicos (*Ibid.*)? These research questions clearly require additional fieldwork on Guana Island and more carefully planned archaeological survey and excavation of these previously identified sites.

Figure 44. Guana Island, BVI. Courtesy, Google Earth.

Elizabeth Righter and Elaine Acevado shovel-tested the Whites Bay flat area (Figure 44) and found a substantial amount of prehistoric material (Righter 2007a: 807). Verbal reports of monk seal, fish and turtle bones had been reported, but vandalism at Harvard University (where the faunal material had been sent) precluded any further analysis (*Ibid.*). In 2003, a prehistoric midden identified based on surface finds was found in a former garden area. The area had been cleared and scraped to a depth of approximately 20 cm. Righter and others excavated about two cubic meters of the midden. The midden depth varied from 38 to 43 cm, but was excavated in 10 cm increments as the dark soils (likely caused by regular flooding or crab activity as suggested by the faunal record) prevented visible discernment of stratigraphic layers.

The midden was comprised of primarily food remains and utilitarian items, including poorly crafted ceramics and one Monserrate sherd (Righter 2007a: 807). Cultural materials of status or possible ceremonial significance were recovered, including one Oliva bead, *Strombus gigas* whorl tips that may have been crude forms of *zemis*, small celts crafted from *Strombus gigas* shells, and fragments of ball belts or stone collars which may have related to the Taíno ball game though of an earlier date (*Ibid.).* Faunal remains included 416 shells mostly made up of *Cittarium pica* (38%, some altered), *Codakia orbicularis* (4%), and juvenile *Strombus gigas* (2.4%). Hermit crab claws were found, but remains of blue land crab (*Cardisoma guanhumi*) otherwise common in the BVIs were absent *(Ibid.*). Fish remains were found in all units at all levels. Hutia and a small amount of sea turtle and iguana were also present. Bird bones included booby, Audubon's shearwater, white-cheeked pintail and dove. Subsequent excavations in 2006 revealed a posthole feature, though other postholes could not be located and thus the posthole could not be linked to any type of structure or function (Righter 2007b: 122).

Although no radiocarbon dates for the site were obtained, Righter posited a small settlement existed in the post-Saladoid (ca. 850 A.D.) through the Ostionoid (ca.1200 A.D.), and disused thereafter until the mid-eighteenth century based on the absence of later Ostionoid cultural materials and historical records (Righter 2007a: 807-809). The ball belts or stone collars recovered by Righter relating to the Taíno ball courts when considered with the possible use of the caves on the island as ceremonial spaces allude to the use of Guana Island, if not inhabited for permanent or long-term settlement, at least as a place where special events were held by the Taíno on the eastern frontier of their territory.

Figure 45. Elenan-Ostionoid Bowl from Guana Island (figure from Righter 2008: cover).

Excavations conducted in 2008 by Righter and Joshua Kehrburg uncovered additional evidence of Taíno presence on the island. During a shovel test, Kehrburg found a nearly intact bowl of the Elenan Ostionoid style (Figure 45), which Righter dates by its decorative features to both ca. A.D. 900 to 1200 and A.D. 1100 to 1400 in her report (Righter 2008: 2-4). Near the bowl, Righter and Kehrburg found the first prehistoric burial found on Guana located on a flat south of the southernmost road by the beach (Righter 2008: 4). Righter notes, "the head had been deformed" though she does not say how, citing such deformity as a common practice on some Caribbean islands although no references are provided (Righter 2008: 4). Righter removed the bones, wrapped them in foil and noted their provenience, precluding their study *in situ* (*Ibid.*). Referencing a paper she wrote in 2007 (not available to the author), Righter hypothesizes that the combination of several factors made the flat a desirable place to live during the prehistoric, and suggests further excavation of the areas where the bowl and skeleton were found, as well as "the undisturbed middens and remains of human activities at ca. A.D. 1100-1400" (*Ibid.*). Further systematic archaeological research and survey of the island should include, as suggested, thorough investigation of the possible settlement at the flat site and midden areas, and some excavation of the caves, involving a search for any petroglyphs or symbolic images, which could help to determine the settlement pattern and use of the island and identify other prehistoric burials at the flat or, possibly, in the caves (though none have been found in the caves to date) (Righter 2007b: 122).

Anegada

The low-lying coralline limestone island of Anegada has been a subject of archaeological interest since the early 18th century when, in 1722, Pere Labat noted the aboriginal population used the island to procure conch. R.H. Schomburgk affirmed in 1832 that large conch (*Strombus gigas*) shell heaps were still visible on the eastern end of the island (Schomburgk, 1832: 153; Figueredo 1974: 1). Schomburgk also noted footprints left at the west end of the island which he believed were left by the aboriginal people of the island (Schomburgk, 1832: 160). Herbert Krieger also noted the presence of a large shell mound near the eastern end of Anegada and established a collection of other artefacts of pottery, shell and polished stone, but failed to provide the location of his finds or advise whether they were from an identifiable site or were random surface collections (Figueredo 1974: 3; Davis and Oldfield 2003: 1).

In 1974, a three-day archaeological reconnaissance of Anegada was undertaken by a two-man team of Alfredo E. Figueredo and Jeffrey M. Gross of the British Virgin Islands Archaeological Survey (BVIAS) (Gross 1975: 13). Their goal was to locate and examine the previously reported conch shell middens and to assess difficulties in extending the activities of the BVIAS to Anegada. Figueredo and Gross found two shell mounds at the eastern end of the island (Figure 46), one of which they believe was the mound excavated by Krieger based on Krieger's photograph of the site (Gross 1975: 15).

CHAPTER 6: ANALYSIS & INTERPRETATION

Beginning in Shadows

Although there is currently less evidence for prehistoric habitation and interaction of the islands of the BVIs than for the U.S. Virgin Islands or other islands in the Antilles, what research has been conducted has given strong evidence of occupation or activity in the BVIs from the Saladoid through to the Chican Ostionoid (Taíno) culture. While the evidence is not extensive, there are indications of small settlements and possibly seasonal or temporary camps beginning in the Archaic (Krumian Ortoroid) age, as well as sites of organized manufacturing and production of textiles and pottery. Keeping in mind that many of the sites were located on or adjacent to the coast – areas subject to natural forces of destruction (such as hurricanes and flooding) and development by later inhabitants (both historic and modern) – the lack of governmental regulations protecting areas of archaeological interest, and the difficulty of conducting survey given the steep terrain, it is not surprising that only 2 of the 33 (6%) known or reported sites on Tortola (the main island of the BVIs) have been subjected to any systematic excavation. It is without doubt that further archaeological research in the BVIs will enhance our current understanding of the roles these islands played in pre-colonial times.

Detailed analyses of the settlement sites based on population size, geographic location, soil analysis and geological resources are needed to more accurately comprehend settlement patters and interaction of the BVIs in prehistoric periods. However, such in-depth analyses are not possible or are made less reliable at this time due to several factors. First, there are only about five sites that have received any investigation involving systematic excavation, and of those sites, only one of the major long-term settlements (Belmont) has been subjected to substantial investigation. While dozens of sites are known or reported for the more than 60 islands in the BVIs, most have been described only on the basis of pedestrian survey or local informants, many of whom have then established unprovenanced, private artefact collections. Surface scatters reported could be the result of sizeable settlements, smaller households moving across the landscape, temporary or seasonal camps, or could have resulted from the disturbing effects of land cultivation and modern development in the past few hundred years. There are few radiometric dates obtained for the known sites, and the reliability of these dates is questionable (*cf.* Fitzpatrick 2006). There is so much that is not yet known about the prehistory of the BVIs that the islands are ripe for comprehensive, systematic archaeological investigation.

Stepping Into the Light

A review of the existing research indicates the islands of the BVIs appear to have been first visited or settled in the Archaic Age circa 600 B.C. (Drewett 2003b, 2007) although there is scant evidence as of yet for occupation or settlement size in the Archaic and early Saladoid periods. It is likely the first inhabitants were hunter-gatherer foragers and fishermen as no ceramics or long-term settlements have been found for this period. There is evidence for use of the BVIs, Tortola in particular, for ceremonial use in this early pre-ceramic period where two ritually deposited Krum Bay style stone ovates equating to about 600 B.C. (Drewett 2007: 748) and archaic material has been found on Tortola's highest point at Sage Mountain (Alfredo E. Figueredo, personal communication). It is clear from the limited artefacts found from this period, whether the BVIs were settled in this period or not they were at least known by ancient mariners and visited, though their role may have been isolated at that time to a frontier for early explorers or a place of special significance.

The first long-term settlements appear circa A.D. 50 – 350 with red painted pottery characteristic of the later Saladoid found on the surface at Cane Garden Bay and Josiah's

Bay (Bates 2001: 137-138, 141; Drewett 2000: 114). Drewett describes these as major long-term settlements, though very little systematic research has been done to date which sheds light on the peoples of the island during this period. Even so, evidence from other islands may prove that the BVIs were, if not occupied, at least frequently visited during the Saladoid period (ca. 50 – 650 A.D.). For example, the copper carbonate on Virgin Gorda may have been used to craft artefacts recovered at the Tutu site on St. Thomas in the U.S. Virgin Islands (Righter 2003: 25).

Cultural materials found in the BVIs, though crafted of locally available materials, closely resemble Saladoid objects from other sites, particularly in the Greater Antilles to the west, highlighting the interaction of the BVIs with other islands in the region. A chert arrowhead stratigraphically dated to ca. A.D. 450 – 650 from Michael Gibbons's excavations on Guana Island was first thought to have been imported from a source in central Florida (Lazell 2005: 314; Gibbons 1986: 20-21) as there is no locally available source of chert (flint) recorded in the BVIs though this is unlikely as there are much closer known sources in the Lesser Antilles and on Puerto Rico for obtaining flint resources (Knippenberg 2007; Knippenberg and Ziljlstra 2008). Ceramics from Guana Island have been dated to the late Saladoid period and later (Righter 2007a: 808; Righter 2008: 3-4). Pottery from the earliest ceramics recovered at Belmont on Tortola display clear Saladoid traits (Drewett 2007: 748) found throughout the Antillean islands of the Caribbean. The abundance of pelagic fish among the lower levels of excavation at the Cape Wright site on Jost Van Dyke hint at the maritime capabilities of the late Saladoid occupants of the BVIs; if they could organize themselves to successfully fish deeper waters, they certainly possessed the technology and could travel to other islands for trade or other purposes.

There is ample evidence for increasing social complexity in the late Saladoid through early Ostionoid phase. Three radiometric dates for occupation obtained at the Cape Wright site on Jost Van Dyke fall within the range from A.D. 635 – 1040 (Bates 2001: 222-224). Pottery from excavations at Cape Wright exhibit common late-Saladoid qualities (most notably an increasing lack of painted decoration), but are noted as being "Elenan-like" having multi-coiled loop handle features (Bates 2001: 225). Similarly, potsherds from Gun Creek exhibit a later Saladoid (ca. 4th to 5th century) transitional style with less painted decoration but a distinctive analytic mode of a thumb-impressed rim on a beaker-shaped vessel indicative of local preference above regional style (Figueredo 1972: 134). Evidence for a possible textile industry was found at Gun Creek with the presence of perforated discoidal objects interpreted as spindle whorls (Figueredo 1980: 28) and at Belmont (Bates 2001: 162; Drewett 2007: 748), further demonstrating the shift from temporary camps to social groups capable of organizing themselves so as to manufacture cotton goods.

While the earliest artefacts found date the first peopling of Guana Island to the late Saladoid period, changes in diet and activity evident in cultural materials indicate they made use of previously unutilized or under-exploited resources and pottery belonging to a new series. At the small settlement on Guana Island, artefacts of ceremonial rites (crude *zemis*, and fragments of possible ball belts or stone collars associated with the ball game *batey*) were recovered (Righter 2007a: 808). As the settlement on Guana Island predates the establishment of the ball court at Belmont (ca. 1200), it is likely that the presence of ball belts or stone collars indicates the Guana Island settlers traveled to other islands to participate in the ball game (Alegría 1983), or that the island served as a site for such ritual activity (though no evidence of a ball court at Guana has yet been found) (Righter 2007: 809). This poses as lot of questions as to the use of Guana in the transitional period from the Saladoid into the Ostionoid (Taíno) complex societies as ball courts were located at important towns and centers where a variety of social interaction – ceremonies, rituals, marriages, trade, games, celebrations, and other exchanges – would have taken place (Wilson 2007: 120-121). Although of relatively small size (approximately 300 ha, or 3.~~00~~ sq km; Lazell 2005: 13) and unlikely to have supported a large population, the evidence for ritual activity related to the Taíno ball game suggests that Guana may have played an integral role in regional politics as a good place for interisland meetings to be held, a similar role posited for Mona Island (approximately 12.5 sq km) off the coast of Puerto Rico where evidence of 3 ball courts has been found (Alegría 1983: 113-114; Wilson 2007: 121).

Drewett posits the long-term settlement at Belmont began in this transitional period (ca. 600 A.D.) (Drewett 2007: 748). The settlement at Belmont included at least one roundhouse formed by two concentric circles of posts being 15 meters in diameter at the outermost circle, which was later replaced by two smaller roundhouses (Drewett 2007: 748). The shape and size of the roundhouse is strikingly similar to two roundhouses dating into the ninth century A.D. excavated at Golden Rock on St. Eustatius by Aad Versteeg and a team from the University of Leiden (Wilson 2007: 88-91). Four crouched burials lacking grave goods were discovered nearby in what is interpreted as the village's central courtyard (later to become a ball court), although it is unknown whether the burials relate to this earlier period or the later ball court phase (Drewett 2007: 749). This style of burial, too, is similar to the spatial organization of burials at other Saladoid sites, including Golden Rock and Maisabel located on the north-central coast of Puerto Rico (Wilson 2007: 90-94). This shift from what may have been smaller or seasonal/temporary camps to permanent settlements of increasing social complexity demonstrated by the manufacture and use of similar cultural materials, the building of roundhouses and the burial of the deceased in patterns similar to those of peoples on other islands exhibiting the same Saladoid cultural traits give evidence of the influence of a sphere of interaction for the BVIs with other islands in the Antilles during this period.

Thus far, I've addressed the first two questions set out at the beginning of this dissertation showing that the socio-political organization of the prehistoric people of the BVIs was influenced by those of other islands (indicative of interaction) adopting regional traits but also establishing their own local preferences, thus identifying with a larger cultural group while retaining their own distinct kinship groups. As to the third question of whether the BVIs were a regional hub of interaction linking nearby islands in the Antilles chain during prehistoric times, through continuing research it is becoming more clear that they were. "Tortola and its companion islands . . . appear to have served as a strategic crossroads between the Greater Antilles to the west and the Lesser Antilles to the east and south" (Saunders 2005: 287). As the easternmost outpost of the Taíno culture (with the easternmost ball court found to date in the Caribbean), the BVIs were part of a complex polity in the region of the Greater Antilles and the northern Lesser Antilles that was still in existence at the time of European contact. The presence of a central plaza space *cum* ball court at Belmont - the only one located to date in the British Virgin Islands (Drewett 2007: 749; Alegría 1983: 119-121) – constructed ca. A.D. 1200 indicates the status of the site in Taíno society. "The most important Taíno towns and ceremonial centers were organized around these plazas [ball courts]" (Wilson 2007: 120). The ball game was an important part of Taíno life accompanied with much feasting and entertainment (Wilson 2007: 120-123; Alegría 1983; Keegan and Carlson 2008: 80-93). There is also evidence of the Taíno *cohoba* ritual (Saunders 2005: 66) practiced at Belmont where a vomit spatula and a triton shell trumpet were found. A petroglyph of a sun aligned with Belmont Hill gives evidence of the ceremonial nature of the site where the sun appears to "roll" down the hill on Midsummer's Day, possibly enhancing the local shaman's powers by his apparent ability to predict the changing seasons in connection with that event (Drewett 2000, 2007; Saunders 2005: 287).

Evidence of the involvement of the BVIs as part of the Taíno culture was also found on Virgin Gorda where Chicoid pottery styles most closely resembled that from Hispaniola, and similar to the Taíno heartland styles (Boca Chica and Capá; Figure 9 a and b) as opposed to the geographically closer Esperanza style (Figure 9c) (Figueredo 1972: 135-135). Although the specific provenance is not known, a turtle bowl (Figure 55) from Mosquito Island is strikingly similar to one attributed to the Chican Ostionoid period from the Dominican Republic (Figure 56).

Figure 55. Chican bowl from Mosquito Island (not to scale). Courtesy, Smithsonian Institution.

Figure 56. Chican Ostionoid bowl (ca. AD 1200 - 1500) from the Dominican Republic. Courtesy, Smithsonian Institution [cat. no. 19/7696].

The Cape Wright site on Jost Van Dyke occupied ca. AD 635 – 1040 with prehistoric material remains associated late Saladoid to Elenan or possibly Chican Ostionoid styles may also given evidence for elements of the Taíno cultural traditions. Burials with grave goods, ritually deposited artefacts, a *zemi*, and what may have been the eye from a wooden statue mark the Cape Wright settlement as a transitional culture bridging the gap between the ancestor cult of the Saladoid as redefined in the chiefdoms and ritual traditions of the later Ostionoid (Taíno) societies (Rouse 1992: 118; Bates 2001: 346-351). There is also evidence for ceremonial rites having taken place at Cape Wright from remains in midden deposits, and possibly across the ecotone near the cave on Little Jost Van Dyke as discussed above, although additional research is needed to clarify the site on Little Jost and the nature of the inter-island interaction, if any.

Back into the Shadows

And what of our fourth question: did the BVIs suffer a decline in population prior to the arrival of Columbus? At present, there is no evidence for long-term occupation of the British Virgin Islands in the late Ostionoid or protohistoric periods, although they may have been used sporadically as a gathering place for festivals and later as a war-torn frontier fought over between the Taíno and Caribs (Figueredo 2006: 396-398). As set out above, ethnohistoric resources report the islands as uninhabited at the time of European contact, and there is no mention in the published research that contradicts their reports (although there may have been Carib refugees living on Tortola during the Dutch occupation in the mid-17th century, *see* Figueredo 2006: 397-398). Does this mean that the islands were uninhabited? Quite possibly, however given the lack of systematic archaeological research in the BVIs described above, it is also possible that evidence for settlement has been overlooked or has disappeared. Ecological conditions (rising sea levels, hurricanes, severe tropical storms, etc.) may have buried or altered sites rendering them inaccessible or unrecognizable. Land cultivation during the period of European occupation and modern development may have destroyed or damaged sites. Bias in the way archaeologists and others have searched for sites on the islands – generally looking for sites in known or reported areas, places close to critical resources, locations based on previous reported settlement patterning, or from surveys restricted to accessible areas and relying on surface visibility of cultural material remains – may have unduly limited the number of sites recognized. For example, Drewett's 1994 survey of Tortola was adversely impacted by the construction of a coastal road which possibly destroyed sites, and the rugged and irregular coastlines with steep slopes and dense vegetation making access to most of the eastern half of Tortola's north coast impossible to reach by land, forcing approach from the sea (Drewett 2000: 113). Although attempts were made to locate previously reported sites inland, they were generally unsuccessful and survey was otherwise limited only to the coastal fringe (*Ibid.* at 113-114) searching for evidence of settlement along the coastline as that was the pattern for settlement known on other islands (*Ibid.* at 1-4). Bates faced similar problems traversing the difficult terrain in his pedestrian survey of Jost Van Dyke and had to abandon the area of his planned survey due to "insurmountable" obstacles caused by the steep slopes and dense vegetation (Bates 2001: 182).

On the other hand, there is the possibility that geological conditions so affected the inhabitants of the BVIs as to force them to leave the islands or perish (Lazell 2005: 315). Geological research has shown that the BVIs were in an area of low rainfall from ca. 550 B.C. until about A.D. 850 followed by a pluvial (wet, rainy) period lasting several hundred years until about A.D. 1150 when more arid conditions returned (Curtis, *et al.* 2001: 35-54). While settlement may have flourished on the islands while fresh water flowed in the numerous ghuts cutting the steep hills, increasing scarcity of fresh water as those ghuts dried up over time would have made it difficult for people to continue living on the smaller islands of the BVIs with no inland lakes or freshwater springs causing the islands to become depopulated. Further research into the paleoenvironment as well as further archaeological investigation and palynological analysis in the BVIs is merited in order to determine whether the islands were, in fact, uninhabited prior to their "discovery" by Columbus in 1493 and their role in the pre-Columbian Caribbean.

Conclusion

In the past several decades, archaeological work in the British Virgin Islands has lagged behind that undertaken in the U.S. Virgin Islands, resulting in a false disparity of the use and occupation of the BVIs and downplaying their role in the pre-Columbian Caribbean. Building on the summary report prepared by Alfredo Figueredo (1974b), this dissertation attempts to redress part of the problem by providing a comprehensive summary of the archaeological investigations into the prehistoric settlement of the BVIs to date and including a comparative review of published (and unpublished, where accessible) reports. It also draws attention to the periods of isolation, interaction, and possible abandonment of the islands by examining the evidence for occupation, cultural complexes, and exchange with other islands throughout prehistoric times.

Archaeological research in the circum-Caribbean region is currently shifting from a view of unilinear migration (Rouse 1992) to one that encompasses a pan-regional, diachronic, and cross-cultural comparison of the ways in which prehistoric inhabitants established and maintained local and regional routes of mobility and exchange as people traveled the Caribbean waters and moved around the islands while also examining their cultural, social, biological, and linguistic particularities (Hofman, *et al.* 2010: 4). Mobility triggered by seasonal activities, expeditions or other causes for movement (i.e., feasting, marriages, establishing political alliances) and exchanges of goods and ideas trigger the building of complex networks of interaction (*Ibid.*). Having evidence of isolated settlement or temporary occupation in the Archaic Age through early long-term settlement during the Saladoid transitioning into the complex polities of the Taíno culture and finally possible abandonment in the centuries before European contact (as described above), the British Virgin Islands offer many unique opportunities to study their role in a sphere of interaction about which relatively little (compared to the U.S. Virgin Islands and elsewhere in the Caribbean) is currently known. Additional radiometric dates are needed to define the local chronology which has previously been based, in large part, on timelines developed for other islands and presumptions of similar framework patterns of cultural and historical development, and to further inform the interpretation of the cultural materials and settlement patterns reflected in the archaeological evidence with a view to understanding and defining the catalysts for preference and changes and their relation to the wider trends evident on other islands in the region.

This research has identified some key areas where future research should be directed to address questions of settlement structure so as to clarify the socio-political organization of the prehistoric inhabitants of the BVIs. The review of previous excavations has highlighted that large-scale excavations, such as those conducted at Belmont, should be designed to determine the spatial dispersion of houses, middens, cleared spaces, burials, and other features of settlements to determine the use and communal space in relation to the complexity and growth of the cultural inhabitants over time. Smaller excavations and test pits could help to establish the use of resources, intra-island interaction, and diversity of cultural groups occupying the islands. Systematic, island-wide field surveys designed to reduce the effects of bias (due to lack of access, historical development, etc.) should be undertaken for all of the islands in the BVIs as may be possible to examine the early isolation in the Archaic Age (as with cultural materials found at Sage Mountain on Tortola), regional interaction (such as the Taíno ball court at Belmont, possible inter-island meetings on Guana, conch gathering site on Anegada, and possible textile industry on Virgin

Gorda), and potential abandonment of the islands on the eve of Columbian contact (where no direct evidence of Amerindian cultural groups living on the islands at this time has yet been found). As many islands in the BVIs are privately-owned or uninhabited, the likelihood of identifying new or previously unrecorded sites is high as these landscapes would be less like to have been impacted by modern development, i.e., recent excavations on Guana Island finding evidence of settlement of the island that may illuminate its role as a possible inter-island meeting place or a center of Taíno society in the region (Righter 2007a, 2007b, 2008). Identification of prehistoric sites may also assist in their preservation and protection, as they may be suggested for areas for special conservation as Belmont on Tortola has been; without identification and protection or efforts to mitigate damage (i.e., recording), they may be destroyed by future development of the islands, lost due to the actions of modern "pot-hunters," or disappear forever as a result of environmental or taphonomic impacts.

Archaeological research at these prehistoric sites will help to understand the settlement patterns and cultural materials of prehistoric peoples of the BVI which is key to determining whether changes in societal groups, material goods and exploitation of resources was indicative of local preferences or reflective of the BVIs interaction in a wider regional or pan-Caribbean sphere. Future research should include an analysis of materials available to the Amerindian population of the BVIs and the technology used for comparison with that known for other islands to highlight the influence of other islands in the daily lives of the prehistoric inhabitants of the BVIs. The geology of the islands during the pre-Columbian should be examined, including analysis of paleoenvironmental cores and field survey (i.e., to determine whether there is, as rumored, a chert vein running from the West End of Tortola to Great Thatch) to understand the natural resources of the islands and how they might have been exploited for trade or exchange with other islands in the region. Palynological studies could shed light on agricultural activities, biodiversity and the environment, particularly with respect to the cultivation of wild cotton and possible presence of cotton textile industry on the islands, and the ability of the islands to support developing human communities and potentially encourage interaction between islands with different resources. Further analysis of the particular diet of the Amerindian populations should be continued, looking not only for components of meals but evidence of resource usage, depletion, preferences, and efforts in obtaining and processing food. Large-scale excavations such as those conducted at Belmont should be designed to determine the spatial dispersion of houses, middens, cleared spaces, burials, and other features of settlements to determine the use and communal space in relation to the complexity and growth of the cultural inhabitants over time. Focused comparisons of cultural materials, diet, settlement patterns and societal groups to other prehistoric sites in the Caribbean would be beneficial in defining trade routes and avenues of exchange for material goods, religious beliefs and practices, social interactions, and ideas. These programs of additional archaeological research building on the previous work described in this dissertation, if undertaken, will help to cast away the shadows surrounding the prehistoric inhabitants of the British Virgin Islands and shed light on their role as a central hub in a regional sphere of interaction in the complex web of relationships in the pre-Columbian Caribbean.

Deborah Davis, J.D.

April 11, 2011

Dr. James D. Lazell
President
The Conservation Agency
6 Swinburne Street
Jamestown, RI 02835

Re: Proposal for Archaeological Research on Guana Island

Dear Skip,

Thank you again for the information provided regarding previous archaeological research undertaken on Guana Island by Dr. Michael Gibbons and Elizabeth ("Holly") Righter. A review of results of their work indicates the importance of Guana Island in the pre-Columbian Caribbean and provided an invaluable resource for the completion of my master's degree thesis covering the isolation, interaction and abandonment of the British Virgin Islands during that time period (digitally published at www.cubaarqueologica.org; a copy has also been previously provided to you). Based on the research previously undertaken, it is clear that Guana Island played an interesting role in the pre-Columbian Caribbean during the Saladoid through the Taino cultural complexes, possibly as a regional meeting place or having more-or-less permanent settlements that might provide important archaeological evidence for the transitional changes in society and structure between several cultural periods. The archaeological reports available indicate that the settlement or use of Guana Island during prehistory is an area ripe for further research.

As a graduate student at the University of Leicester's School of Archaeology and Ancient History, I am working to revitalize interest and undertake significant research in the archaeology (specifically, the prehistory) of the BVIs. I have been working with Caribbean archaeologists with expertise in the prehistory of the Virgin Islands, and an example of our collaborative efforts reviewing the roles played by the British Virgin Islands in the pre-Columbian Caribbean will be published in the January 2012 edition of *Caribbean Connections* (http://journal.fieldresearchcentre.org/). I am planning a systematic program of research in the BVIs as part of my doctoral research, and would be pleased to incorporate investigations on Guana Island into my research plans.

Specifically, I propose to continue the research begun in 1986 and continued through 2008 by Elizabeth Righter. While I had hoped to work with Ms. Righter, I understand that personal circumstances may prevent her from continuing her work on Guana Island. I propose to pick up where she left off, moving forward and building on her results to inform a plan for future research. First, I propose to undertake a systematic field survey of the island utilizing current GIS/GPS technology to accurately identify the location of archaeological sites on the island. This will allow me to develop a detailed, interactive map enabling analysis of the island's archaeological resources and

517 W. Clay Ave., Plattsburg, MO 64477 • Tel: 816.835.3305 • Email: davisarchaeology@gmail.com

identifying areas requiring conservation, protection or mitigation to record sites in danger of disappearance or damage, where needed. I further propose three particular areas for intensive research: (1) systematic investigation of the flat land where, in 2008, Ms. Righter and her team discovered an intact Elenan-Ostionoid bowl and a burial, to determine (to the extent possible) settlement structure and societal organization on the island in prehistory; (2) further investigation of the caves to determine their use by Amerindian peoples, including the use of infrared, thermo-luminescent technology to determine the presence and age of any pictographs or petroglyphs, such as the sun petroglyph found on nearby Tortola at the Belmont site; and, (3) further investigation of the middens present on Guana to continue to shed light on the flora and fauna in the island's prehistoric past, with special emphasis on how these resources were utilized by the prehistoric peoples of the island not only as food but also in economic, religious, ceremonial, medicinal and other ways. While I recognize that the proposed program of research is ambitious for one field season, it is my hope to continue archaeological research on the island for many years to come as each season would inform and direct the path for future research, bringing the role of the BVIs – through a focus on Guana Island – in prehistory to light.

Thank you again for your assistance thus far, and I look forward to hearing from you regarding my proposal for undertaking further archaeological research on Guana Island.

Yours sincerely,

Deborah Davis

Deborah Davis

Cc: Elizabeth Righter (by email)