



Island

FACT AND THEORY IN NATURE



JAMES D. LAZELL

GUANA, 2004

The Conservation Agency

Exploration, Education, and Research

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16 May 2005

Dr. Henry Jarecki
10 Timber Trail
Rye, NY 10580

Dear Henry,

Herewith, my report for 2004. The cover represents the first trial-run for the front of the dust jacket on the book -- which is now through page proofs and scheduled to be out this summer. The top creature is Gloria's hunting wasp, one of our most spectacular animals. It was described originally from Guana Island by Roy Snelling, who provides new records for St. Croix and Puerto Rico in a new paper included in the body of the report. The row of images, from left to right, are: the grass anole lizard, Guana's least common anole whose latinized name, *Anolis pulchellus*, means "little pretty anole." Next, a view of Guana Island in mirror image, which the editor promises to correct! Then, Swainson's thrush, a neotropical migrant from North America never previously recorded east of Hispaniola migration; we are getting several annually now, indicating a possible migration route shift. Finally, the blossom of tam-tam, the abundant, early-seral-stage legume that helps fix nitrogen in our soils.

Here are thumbnail sketches of the contents:

Bats - I lead off with one of the two most remarkable 2004 discoveries: a fifth species of bat -- and not the one I predicted -- on Guana. The free-tailed bat has only been recorded once before in all the Virgin Islands, in 1975 on St. John. Thus a new record not just for Guana but for the BVI, and

I still believe another species lives out there, uncaught as yet. Could there be six? p.1

Birds - The Boals continue their excellent banding program -- the only one going on in the entire eastern Caribbean. But, that is not all: they spotted a red-necked phalarope -- a peculiar, aquatic (swimming) member of the sandpiper family -- on Guana's salt pond. Once again, not just a new Guana record, but never before recorded in the BVI. Two new BVI records of vertebrate species in one month! It may be some years before we do that again.....p.5

Then, the correspondence on West Indian whistling duck (WIWD), a species that lived in the BVI into the 1960's, and one we are longing to restore. I talked to Lisa Sorenson, who directs the entire WIWD project: she believes the restoration will get underway; it just is taking a lot of time (remember the flamingos!)p.15

Last, Caitlin, *et al.*, on the flamingo effort. What has happened to this project? They seemed to be succeeding. Did they -- will they --- comeback?p. 18

Anoles - Ah yes, the world's most important life forms, of course. All three of Guana's species are represented in this excellent phylogenetic study, but our most important contribution was the Carrot Rock specimens, collected on a Guana boat day. I have culled this paper and arrowed our species.....p. 26

Stout Iguana - John Binns produced an excellent overview articlep.43

This is followed by Gad and Numi's population estimatesp. 53

Rick Hudson, co-chair of IUCN's Iguana Specialist Group, wrote up the meeting Gad and I had with him at Fort Worth in December. This seemed very productive and positivep.54

Gad and I wrote up a brief note on the Guana population to distribute to Specialist Group members.....p 56

Gad managed to get a dialogue going with Glenn Gerber of the Specialist Group, but eventually he did not elect to contribute data or co-author, and our bright hopes for cooperation have faded. San Diego owns a breeding population but shows no inclination to help restore more wild populations or diversify existing gene pools. Their position is truly puzzling and never explained.....p.58

Cuban Treefrog. - Gad's student Jennifer has put together a fine flier which has been widely distributed in the BVI and elsewhere. Since she wrote, her continued stomach contents inventory proves these frogs eat birds and even snakesp. 59

Texas Tech Research Highlights. - In 2003 Gad brought the first graduate student class from TTU to Guana. Here are some highlights of the students' work on anole lizards, Cuban treefrog, and Gad's own ongoing research on the dreaded, invasive agave weevil.....p. 63

Jumping Spider. - We knew from Jim Ortiz's collecting of over a decade ago that we had a slender jumping spider of the genus *Hentzia*, but we did not know the species. Thanks to the diligence of Scott Miller, of butterfly and moth fame, we do now. Scott found Richman's 1989 60 page paper and sent it to me. I have extracted the pages relevant to Guana (four). Scott himself collected the Guana specimens in US National Museum (Smithsonian: "USNMNH"). But how about all those other BVI specimens in the American Museum ("AMNH")? Who collected those? And some, too, in the Museum of Comparative Zoology ("MCZ," Harvard)? I am on the casep. 67

Termites. - The authors of this paper are all wearing their Frass-eating Grins, *sensu* Berenbaum (2003. American Entomologist 49: 132-3). But, Hey!, this is pragmatic stuff! If you can identify termites to species without destroying what they are in, you well may be able to utilize tightly specific control measures instead of some wide-spectrum and unsafe agent to get rid of them. This is the kind of "pure" research that has real economic benefits. Guana's contribution is the long-horned termite, *P. corniceps*. I have culled the typescript accordingly. Mike tells me it has been accepted and is in press.....p. 71

Fungus Weevils. - These small beetles -- rarely as much as 1 cm, <1/2 inch -- are Barry Valentine's specialty. They are associated with dead wood, generally, and their larvae usually feed on fungi. Some, like the coffee bean weevil, are important pests, feeding on seeds and fruits, but so far none on Guana cause problems. Barry has produced a catalogue of the Antillean species -- most as yet undescribed! I have culled it down to those pages with species from Guana, or close by, collected by Barry and his team (Buena, Susan, sometimes Wenhua and Liao).....p. 96

Agave Weevil. - And other invasives in the BVI. Gad summarizes the situation. Most interestingly, I think, The Nature Conservancy contacted me (and I consulted Gad) on their proposed program and I (we) told them we felt their effort was inadequate. This note tells whyp. 107

A Benign Invader? Perhaps not all invaders wreak havoc and bring catastrophe. This little black beetle seems to have recently spread from the Western Greater Antilles to Florida, the Virgin Islands, and beyond. It seems to be following me around. Although some darkling beetles are major pests, especially in stored grain products, this one seems to do no harm -- at least not that we have seen yetp. 109.

Dragonflies. - Just a one-pager from Fred this year. He has an interesting problem there, rather like Wenhua's tumbling flower beetles, where we are not sure which females go with which males. Fred got his new island records to me in time to make the bookp. 117

Wasps. - Roy Snelling and the late Juan Torres (who never made it to Guana) have produced a 20 page treatise on the spider hunters, including Gloria's. I have culled it down to the pages directly relevant to Guanap. 118

Fire Ants. - Although I was aware of this note, and cited it in the book, I do not believe I included a copy of it in my earlier reports. This is the first record of the red imported fire ant on Guana, based on Barbara Thorne's specimens of October 1996. The species is a severe nuisance to those of us who work afield nowadays.....p. 125

A New Bee. - This is another paper that slipped by me -- one I was not even aware of. Roy cited it, so I knew where to get it. I preface Engel's paper with a sketch of the family and subfamily our bee belongs to. It is a nifty little species, does not sting people, and visits lots of flowers.....p. 127

Archeology. - Holly refers to a "little package," her book on the St. Thomas, USVI, Tutu site, which was occupied by Tainos up to within 60 years of Columbus. Guana's site is much older, *ca* 1,500 years before present, and much less extensive. I provide the text of Holly's symposium talk, which serves as a good report because it includes her 2004 finds. We are eagerly awaiting more details from David Steadman on animal remains, and possible solution to the ceramics question.....p. 133

Caribbean Coral Fruit. - Finally a colorful sketch of one of our more remarkable plants, now being cultivated at the USDA Center in Lane, Oklahoma, for potential use in gene modification experiments. This comes with a brief bio of Rudy, one of the authors, and already well-known to most of Guana scientist participantsp. 139

We are looking forward to much more field work on Guana in 2005.

All the best,

Skip

James Lazell, Ph. D

Summary of bat information collected on Guana Island

October 5 – 19, 2004

Michelle Theberge, Kristiina Ovaska, and Jeannine Caldbeck



New record for the BVI: free-tailed bat, *Tadarida brasiliensis*

Photo by Kristiina Ovaska

This year we initiated a study on bats on Guana Island. The objectives were to obtain information on the species present, building on previous work by Lazell and Jarecki (1985: American Museum Novitates 2819:1–7), and to record echolocation calls. We also made initial observations of bats feeding on different prey types.

Netting

Netting for bats occurred over 9 nights. Each night, we set 3 – 9 nets for a total of 48 netting nights. Nets were in the following locations: Orchard, Flats (on land and in the Salt Pond), across North Beach road, base of the Pyramid by Barbados House, halfway up the Pyramid, along Long Point trail, and at the Ruins by the Salt Pond. Bats were caught only in the Orchard and at the base of the Pyramid (beside Barbados House).

Mist-netting for bats.
Photo by Michelle Theberge



Summary of bats caught

In total, we caught 16 bats, representing four species, on Guana Island between October 5 and 19, 2004. The species were: *Artibeus jamaicensis* (ARJA) (10M, 2F); *Noctilio leporinus* (NOLE) (2M); *Tadarida brasiliensis* (TABR) (1M); and *Molossus molossus* (MOMO) (1M) (Table 1). Two specimens were collected as vouchers: *N. leporinus* (Bat #13) and *T. brasiliensis* (Bat #14) (Table 2). In the Virgin Islands, *T. brasiliensis* is previously reported from St. John but represents a new island record for Guana.



Fishing bat, *Noctilio leporinus*

Photo by Kristiina Ovaska



Fruit bat, *Artibeus jamaicensis*

Photo by Michelle Theberge

Table 1: Measurements from live bats caught in mist-nets. FA – fore arm length (mm); TL – total length (mm); WS – wing span; HF – hind foot length (mm); WT – weight (g)

Date	Location	Net ID	Bat ID	Species	Sex	FA	TL	WS	HF	WT
Oct-07	Orchard	O1	1	ARJA	M	59.8	70	30	9.4	31
Oct-07	Orchard	O1	2	ARJA	M	61.7	83.6	32.3	9.8	37
Oct-07	Orchard	O1	3	ARJA	M	61.5	75.8	34	10.1	43
Oct-07	Orchard	OB4	4	ARJA	M	61.7	81.6	32.5	10.9	46
Oct-07	Orchard	O2	5	ARJA	M	60.3	78.8	33.3	10.6	41
Oct-08	Orchard	O1	6	ARJA	F	61.5	74.6	33	9.4	40
Oct-08	Orchard	OB4	7	ARJA	F	59.4	77.6	32	10.4	40
Oct-08	Orchard	OB3	8	ARJA	M	58.7	78	36	9.1	49
Oct-08	Orchard	O2	9	ARJA	M	57.5	74.2	31	12.1	38
Oct-08	Orchard	O1	10	ARJA	M	61.1	77.2	32	11	42
Oct-14	Orchard	O5	11	ARJA	M	57.8	83	30.5	11.6	40
Oct-14	Orchard	O1	12	ARJA	M	58.8	84.7	31.5	10.7	35
Oct-16	Pyramid	PB1	13	NOLE	M	87.2	112	54	29.8	55
Oct-16	Pyramid	PB1	14	TABR	M	40	84	24.3	7.1	10
Oct-18	Pyramid	PB1	15	NOLE	M	85.8	99.4	54	26.2	74
Oct-18	Orchard	O1	16	MOMO	M	41	56.2	25.5	6	13

**note: all measurements are from live animals

Table 2: Measurements from dead bat specimens.

Bat #	Species	FA	TL	WS	HF	Tail	E	WT
13	NOLE	87	119.5	62	30	26	27	55
14	TABR	42	93		15	35	8.5	11

Echolocation Recordings

Bat echolocation calls were recorded using an Anabat Bat Detector. Recordings were made on the Flats, at the Ruins, and at Gloria Jarecki's pool. The calls will be analyzed for species identification as well for feeding preferences from an experiment conducted at the pool.

Parasites

Two species of bat-flies (Diptera: Streblidae) were found on five individual *A. jamaicensis*. The specimens collected have been tentatively identified as *Megistopoda* sp. and *Trichobius* sp.; further examination of the specimens is in progress. Two bats had two, three bats had one, and one bat had two bat-flies. The specimens will be stored at the Royal Ontario Museum, Toronto.

Many large, blood engorged mites were found on both individuals of *N. leporinus* caught. Several mites were collected and given to Barry Valentine for identification. Very small mites were also found on some *A. jamaicensis* but were not collected.



Bat release with kids
Photo by Jeannine Caldbeck

ORNITHOLOGICAL MONITORING AND RESEARCH ON GUANA ISLAND, BRITISH VIRGIN ISLANDS

PROJECT REPORT 2004

Dr. Clint W. Boal
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7 April 2005



Mangrove Cuckoo (*Coccyzus minor*)

ORNITHOLOGICAL MONITORING AND RESEARCH ON GUANA ISLAND, BRITISH VIRGIN ISLANDS: PROJECT REPORT 2004

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

INTRODUCTION

Ornithological research in the West Indies has focused on an array of topics including basic status surveys, ecology of individual species, effects of hurricanes on island bird populations, patterns of migration, and community dynamics (Wiley 2000). However, in terms of ornithological reports, the Virgin Islands, especially the British Virgin Islands (BVI), have received much less attention compared to the rest of the West Indies (Wiley 2000).

Guana Island, BVI has the only consistently operated bird banding station in the BVI and one of only three east of Puerto Rico. Information from the island has contributed to many of the few published reports on avian ecology from the BVI. For example, data collected on Guana Island has proven important in developing a better understanding of neotropical migrant bird use of the region (McNair et al. 2002), basic ecological information on insular resident species such as the Bridled Quail-dove (*Geotrygon mystacea*; Chipley 1991), and documentation of rare or previously unreported species in the region (Norton et al. 2003).

Guana Island likely is an important location for many neotropical migrants to rest and build up fat stores depleted on the western trans-Atlantic crossing during the annual autumn migration. Coupled with visual surveys, annual mist-netting on Guana Island has focused on detection of neotropical migrant species, relative abundance of those species, and detection of use of the island by rare species. For example, Faaborg and Terborgh (1980) considered the Red-eyed Vireo (*Vireo olivaceus*) as a rare transient migrant encountered only in the Greater Antilles, Arendt (1989) did not list Red-eyed Vireos as occurring in the BVI, and Norton (1996) noted an account of a Red-eyed Vireo in Puerto Rico as one of only a few confirmed records for the species in the Puerto Rico Bank. Thus, the regular occurrence of Red-eyed Vireos at Guana Island suggests the species is either more common as a migrant through the Virgin Islands than previously believed or, as has been suggested by Arendt (1989), migrants may be changing their routes to the eastern Caribbean as western Caribbean islands become more degraded by human activities and landscape change. Continued monitoring efforts on Guana and collaboration and sharing of information with researchers from other locations may further elucidate such patterns.

During October 2004 I continued my research on avian ecology on Guana Island. The primary component of my activities was the direction of mist-netting operations. As part of this, I also have taken a lead role in compiling and analyzing the data collected since 1994 when banding operations were initiated

on Guana Island. An additional component of the 2004 field season was to develop a network of survey points across the island. These points will allow annual, consistent and systematic surveys to enhance our ability to detect species presence and habitat use patterns.

RESULTS

Mist Netting and Bird Monitoring

I conducted mist netting for songbirds from 7 to 18 October 2004. I also conducted targeted mist netting for shorebirds at the Salt Pond one afternoon. My mist netting efforts totaled 218 net hours during which I captured 168 birds at a rate of 0.8 birds per net hour (Table 1). I recaptured 31 individual birds (37 total recaptures) representing six species. The majority of these were Bananaquits (*Coereba flaveola*) and Black-faced Grassquits (*Tiaris bicolor*; Table 2). One recaptured female Black-faced Grassquit had been banded in 1996 as an adult. This means she was at least 9 years old when recaptured in 2004 and is a new and substantially increased age record for the species. Another recapture was of a Spotted Sandpiper banded in 1997 as an immature at the Salt Pond. Fewer neotropical migrant landbirds were captured in 2004 than in 2003 (Table 3), but the diversity was similar. Notably, I captured two Northern Parulas and more Red-eyed Vireos and Indigo Buntings than in previous years.

Bird species observed were similar to that from previous years with one exciting addition (Table 4). An immature Red-necked Phalarope (*Phalaropus lobatus*) was observed for about one hour on the Salt Pond on 8 October. Tracy Estabrook originally spotted and identified the species, with follow-up verification by me. This is a new record for Guana Island and the BVI.

Associated Projects

I have compiled data collected by Fred Sibley (1994 – 2002) and myself (2003 – 2004) to develop a manuscript providing an overview of banding activities, examination of longevity of individual resident species, and reporting new island and regional records of species. This manuscript has been submitted for publication.

I co-advised a Tropical Conservation Biology class taught by Dr. Gad Perry. The class consisted of graduate students from Texas Tech University who conducted a course project on Guana Island. The project was an assessment of the current distribution and associations of Pearly-eyed Thrashers (*Margarops fuscatus*) with other species and vegetation communities on the island. In doing this, the students conducted surveys across the island. I am archiving the UTM coordinates from the survey points used by the students. These survey points will be used as the basis for annual surveys that will compliment mist netting efforts. Annual surveys conducted in a consistent and systematic manner will enhance our ability to detect species presence and habitat use patterns.

Future Work

In addition to annual mist netting, I will be initiating new directions of research on Guana Island in 2005.

1. Annual surveys to develop an understanding of bird species distribution patterns and relative abundances across Guana, and how these parameters change in relation to meteorological events (e.g., dry years, hurricane events, etc.).
2. Initiating a new color-banding program with Bananaquits. Bananaquits are one of the most abundant species on Guana Island and are represented among all of the Caribbean islands. This makes them an excellent species to study in terms of the influence of meteorological events on the population demographics, dispersal, and fluctuations of insular island species. New approaches in mark-recapture modeling will allow robust model development that allows estimation of survival in relation to parameters addressing weather patterns (e.g., hurricanes, dry periods). This will ultimately allow a more comprehensive understanding of the ecology of Caribbean bird species.
3. I am collaborating with a colleague from the University of Arizona to examine possible size dimorphism among Bananaquits. Morphologically, both sexes appear identical, but some preliminary evidence suggests males may be larger than females. We will be regressing morphological measurements (e.g., wing length, tarsus length, culmen length) from a sample of birds against their known sex as determined by molecular analysis of DNA from feathers. Developing a key to age based on measurements will facilitate studies of demographics of the species.

ACKNOWLEDGEMENTS

I thank the several people who assisted with mist-netting and bird banding this year. Specifically, these were Tracy Estabrook, Orly Perry, Susan Valentine, Fred Sibley, Tom Willard, and the graduate student class from Texas Tech University. I thank Drs. Gad Perry and James Lazell for facilitating my 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. 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.

Table 1. Mist netting effort and capture rates at Guana Island, BVI, 7 – 19 October 2004.

<u>Date</u>	<u>Net Hours</u>	<u>New Band</u>	<u>Recaptures</u>	<u>Not Banded^a</u>	<u>Total Captures</u>	<u>Captures /net hour</u>
7-Oct	8.0	3	0	0	3	0.4
8-Oct	10.0	4	1	1	6	0.6
9-Oct	30.5	19	7	6	32	1.0
10-Oct	10.0	5	7	1	13	1.3
11-Oct	30.5	20	7	2	29	0.9
12-Oct	25.0	14	1	3	18	0.7
13-Oct	18.0	5	1	2	8	0.4
14-Oct	10.0	6	4	4	14	1.4
15-Oct	32.0	11	2	2	15	0.5
16-Oct	36.0	16	4	1	21	0.6
17-Oct	4.0	5	1	0	6	1.5
18-Oct	4.0	1	2	0	3	0.6
Total	218.0	109	37	22	168	0.8

^a These were birds for which the appropriate size bands were not available or were not banded for other reasons.

^b Trapping efforts focused on Bananaquits at the nets erected at the kitchen area and on shorebirds at the salt pond.



Bridled-Quail Dove

Table 2. Total birds captured and banded, recaptured, and captured but not banded, and percent of total during mist-net, Guana Island, BVI, 7 – 19 October 2004.

Species	Banded	Recapture	No Band	Total	Percent
Bananaquit	36	20	0	56	33.3
Black-faced Grassquit	26	10	3	39	23.2
Pearly-eyed Thrasher	13	3	7	23	13.7
Green-throated Carib	0	0	8	8	4.8
Blackpoll Warbler	7	0	0	7	4.2
Zenaida Dove	3	2	2	7	4.2
Caribbean Elaenia	4	1	0	5	3.0
Red-eyed Vireo	4	0	0	4	2.4
Spotted Sandpiper	1	1	0	3	1.8
Indigo Bunting	3	0	0	3	1.8
Northern Parula	2	0	1	3	1.8
Mangrove Cuckoo	2	0	0	2	1.2
Wilson's Plover	2	0	0	2	1.2
Ovenbird	1	0	0	1	0.6
Magnolia Warbler	1	0	0	1	0.6
Semipalmated Plover	1	0	0	1	0.6
Kentucky Warbler	1	0	0	1	0.6
Lesser Yellowlegs	1	0	0	1	0.6
Lesser Antillean Hummingbird	0	0	1	1	0.6
Semipalmated Sandpiper	1	0	0	1	0.6
TOTAL	109	37	22	168	100



Ross Tsai with a Spotted Sandpiper originally banded on Guana Island in 1997

Table 3. Comparison of new captures of neotropical migrant landbirds in 2003 and 2004 on Guana Island, British Virgin Islands.

<u>Species</u>	<u>New Capture</u>	
	<u>2003</u>	<u>2004</u>
Blackpoll Warbler	19	7
Red-eyed Vireo	1	4
Indigo Bunting	1	3
Northern Parula	0	2
Ovenbird	2	1
Magnolia Warbler	1	1
Yellow-throated Vireo	1	0
Swainson's Thrush	1	0
Kentucky Warbler	1	1
Black-and-white Warbler	2	0
Rose-breasted Grosbeak	1	0
Hooded Warbler	1	0
Worm-eating Warbler	1	0
Total	32	19



Tracy Estabrook removing a Bananaquit from a mist net

Table 4. Species seen, captured, or both on Guana Island, BVI, 5-19 Oct. 2004.

<u>SPECIES</u>	<u>Seen</u>	<u>Captured</u>	<u>Both</u>
Magnificent Frigatebird	X		
Red-billed Tropicbird	X		
Brown Pelican	X		
Brown Booby	X		
Yellow-crowned Night-heron	X		
Little Blue Heron	X		
Greater Flamingo	X		
White-cheeked Pintail	X		
Blue-winged Teal	X		
Black-necked Stilt	X		
Wilson's Plover			X
Semipalmated Plover			X
Lesser Yellowlegs			X
Ruddy Turnstone	X		
Semipalmated Sandpiper	X		X
Spotted Sandpiper	X		X
Least Sandpiper	X		
Red-necked Phalarope*	X		
Red-tailed Hawk	X		
American Kestrel	X		
Peregrine Falcon	X		
Rock Dove	X		
Zenaida Dove			X
Scaly-naped Pigeon	X		
Common Ground-Dove	X		
Bridled Quail Dove	X		
Mangrove Cuckoo			X
Antillean Crested Hummingbird			X
Green-throated Carib			X
Gray Kingbird	X		
Caribbean Elaenia			X
Pearly-eyed Thrasher			X
Yellow-throated Vireo		X	
Red-eyed Vireo			X
Northern Parula			X
Cape May Warbler	X		
Yellow Warbler	X		
Magnolia Warbler			X
Blackpoll Warbler			X
Kentucky Warbler		X	
Ovenbird		X	
Indigo Bunting			X
Black-faced Grassquit			X
Bananaquit			X

Appendix I. Images of some activities and species captured and banded on Guana Island, British Virgin Islands, October 2004.



Mist-netting at the orchard



Magnolia Warbler



Red-eyed Vireo



Caribbean Elaenia



Ovenbird

West Indian Whistling Ducks

From: "Lisa Sorenson" <lsoren@bu.edu>
To: "Clive Petrovich" <CPetrovic@email.hlscc.edu.vg>
Cc: "Skip Lazell" <hq@theconservationagency.org>
Sent: Monday, December 20, 2004 9:08 AM
Subject: paper - please send! (URGENT)

I'm making slow progress on the reintroduction project. I spoke with folks in the Bahamas about the permits, etc. on my last visit there in early November - should be no problem. I have also been in touch with folks running the Darwin Anegada project - they've offered to help however they can, especially with monitoring afterwards. Geoff Hilton (RSPB) is there now and checking out specific possible reintroduction sites.

I've found some references and am now trying to get a proposal written up about the reintroduction. I think it's important to have this as a working plan for the project and also to document that WIWDs did indeed occur in Anegada historically. I need the proposal also to show to Peter Graham, owner of Hog Cay, where we would like to get the 24 ducks. I'm having trouble tracking down a couple of references, especially ANY that refer to WIWDs being on Anegada. Schomburgk (1832, Remarks on Anegada) and LaBastille and Richmond (1973, Birds and Mammals of Anegada Island, British Virgin Islands) don't document mention WIWDs. S. Oldfield is cited in litt. 1988 as stating that "it no longer occurs on Anegada." I presume this is Sara Oldfield - I've written to her about this but have had no response.

Could you please send me the following reference? I cannot locate this one here.

Nichols, A. 1936. The Breeding Birds of St. Thomas and St. John. Memorias de la Sociedad Cubana de Historia Natural

I also need to get a hold of this paper:

Wetmore, A. 1927. The Birds of Puerto Rico and the Virgin Islands. NY Acad. Sci. Scientific Survey, Vol. 9, pt. 3 245-406, pt. 4, 409-571. It's at the Harvard MCZ Library, but one needs to be a member to have access, so I need to find someone to get this for me.

If either of you have any other papers documenting the occurrence of WIWDs in BVI Anegada, could you please copy and send them to me ASAP? Especially those in gray/hard to find literature, even personal communications are okay.

If we are going to be able to pull this reintroduction off in Feb March of this year, we need to get organized very quickly. I'll be able to focus on this project after the first of the year.

Many thanks for your assistance. Please send the Nichols paper and any others mentioning WIWDs in BVI Anegada ASAP

Best wishes for a wonderful holiday season.

Lisa

p.s. Wrote to BVI NPT about the wetlands workshops - no reply yet. Could you check in with them and see if we can organize these decide on dates for early April?

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From: "Lisa Sorenson" <lsoren@bu.edu>
To: "Skip Lazell" <hq@theconservationagency.org>
Cc: "Clive Petrovich" <CPetrovic@email.hlscc.edu.vg>
Sent: Monday, January 10, 2005 2:10 PM
Subject: Fwd: WIWDs in the Virgin Islands

Hi Skip and Clive,

Quick update on the proposal: I have had other work that I've had to deal with (I'm spread way too thin!), but I am making good progress on the proposal and able to focus on it now. I'm still trying to determine if I've missed other records of WIWDs for BVI/Aneгада (see message below and species notes following each reference). Check out the website I mention below for a recent (2002) record of WIWDs in St. Croix.

Clive - would it be possible to get a hold of Rowan's bird records for BVI? I'd be very interested to see if he has any sightings for Aneгада or other islands of the BVI. Any progress on organizing the Wetlands Workshops for early April. I have not had a reply from anyone from my last (Jan. 3) email. Have you been in touch with Nancy or Esther at the Trust? We really need to decide on dates and begin to get organized. Please get back to me on this.

Thanks and best wishes,

Lisa

From: "Douglas B. McNair" <dbmcnair@vipowernet.net>
Date: January 10, 2005 4:46:42 PM EST
To: "Lisa Sorenson" <lsoren@bu.edu>
Subject: WIWD

Lisa -

See WIWD species account below for the USVI, taken from ms submitted to NAB (ca. 60 species accounts). Haven't heard back from reviewers yet. If you have any questions/comments, let me know. I've checked all the 'gray' literature in the USVI.

The two birds at Carambola GR were not seen again.

Like you, the most recent information I have on WIWD in BVI was at Virgin Gorda in the early 1970s, so I have nothing to add.

I rigorously monitor all wetlands on St. Croix, both freshwater ponds and brackish mangrove sites. This includes wading in. No WIWD, and I haven't overlooked them. We have had a few vagrant Fulvous Whistling-Ducks over the past year (one still present).

Great to see you're tied into the Aneгада project. Certainly a favored site for re-introduction efforts.

Since you're going to be in the area (i.e., Aneгада) at some time in the rather near future, I extend an invitation to you for a quick visit to St. Croix to examine Great Pond and perhaps several other potential reintroduction sites here. I would be most interested in your opinion on this matter.

West Indian Whistling-Duck *Dendrocygna arborea*—Two adults resting on a log at Bridge Pond (freshwater) on the Carambola Golf Resort on 25 October 2002 (DBM, F. E. Hayes; PUC 1, Fig. 2) was the first documented occurrence of this West Indian endemic in the USVI since 1941. Later sightings have been reported (e.g., Seaman 1955, Rodrigues 2002), but adequate documentation is lacking (although see Seaman 1973, 1993).

West Indian Whistling-Ducks were formerly resident in mangrove swamp forest on St. Croix and St. Thomas, although precise data are lacking for St. John (Newton and Newton 1859d, Beatty 1930, Nichols 1943, Seaman 1993). Newton and Newton (1859d) stated this species was pretty common on St. Croix in 1857-1858 and collected two specimens (whereabouts unknown), although its breeding status was not documented. Beatty (1930) and Nichols (1943) stated West Indian Whistling-Ducks were very rare throughout the USVI although Beatty added that 15 years earlier it used to breed on St. Croix when it was very common. Nichols (1943) added that it was formerly common and still occasionally seen on Water Island and on the St. Jameses cays off St. Thomas. The last verified records in the USVI until 2002 were seven specimens collected on St. Croix from 1939-1941 (FMNH 414023, 414694-414699). Two of these specimens were downy chicks collected on 15 January 1941, the only confirmed breeding record in the USVI.

Nichols (1943) stated that an adult West Indian Whistling-Duck with seven nestlings was seen on a pond at Sprat Bay, Water Island on 29 May (year unknown) and reported second-hand information that it nested in hollow butts of dead agaves (*Agave* spp.) on Great St. James Island. Seaman (1973, 1993) stated that a pair nested on Green Cay off St. Croix. The nest and clutch of 13 eggs were discovered on the ground underneath cactus and a bush on 16 September 1956. West Indian Whistling-Ducks are known to nest on offshore cays elsewhere (e.g., Antigua) and it is possible this was a whistling-duck nest (although possibly also a nest of the White-cheeked Pintail, which nests regularly on Green Cay). Seaman (1957b) also stated that West Indian Whistling-Ducks formerly nested at Southgate Pond, which may have occurred, but documentation is lacking.

Re-introduction of the West Indian Whistling-Duck would be a high priority for the USVI (cf., BVI, Lazell 2002), if suitable wetlands exist (cf., St. Kitts and Nevis where only one wetland contains suitable habitat for this species;

Childress and Hughes 2001). Great Pond, where this species used to occur on St. Croix (Seaman 1973) and where mangroves have increased for over the past decade, would probably be the best re-introduction site for this nocturnal species in the USVI. West Indian Whistling-Ducks prefer nesting in cavities and placement of artificial cavity structures at Great Pond would be a pre-requisite for re-introduction efforts

> Sent: Friday, January 28, 2005 9:45 AM
 > Subject: WIWD reintroduction update
 >
 >
 > Hi Skip,
 >
 > I've corresponded and talked recently with Esther Georges at the NPT
 > about the WIWD reintroduction project. The BVI NPT is not prepared to
 > rush ahead with this project this year. More time is needed to discuss
 > and consider all the issues, obtain permits and approval from various
 > departments, and make sure that the local community is on board and
 > supportive. The Trust has spent years spent building up a rapport with
 > the people of Anegada and will not rush into or participate in any
 > activity which will jeopardize that relationship. They would like to
 > consider the proposal as part of their management planning process.
 >
 > I will be there in early April to deliver wetlands education workshops
 > and will have the opportunity to meet with people then. Will proceed
 > from there with work on the proposal, etc. Please thank Dr. Jarecki for
 > his generous offer of support. Hopefully, he will be willing to
 > postpone until the management plan is prepared.
 >
 > Sorry not to have better news, but understand the Trust's position and
 > the need to move slowly on this.
 >
 > Best wishes,
 >
 > Lisa

> Hi Lisa. Disappointing indeed. However, I don't see why this should
 > affect bringing some to Guana. That is how we did the flamingo
 > restoration:
 > a few to Guana first, then a lot more to Anegada. (Lots of people on
 > Anegada
 > "forget" we brought them their flamingos!) I believe we should proceed
 > with
 > a couple pairs on Guana ASAP
 > All the best, Skip

Sent: Friday, January 28, 2005 12:29 PM
Subject: Re: WIWD reintroduction update

Hi Skip,

It will take considerable time and effort to arrange permits with both the Bahamas and BVI, and also to arrange all the logistics. In this case, I think it makes the most sense (and would be best from a public relations standpoint) to do it all as a coordinated effort. Best, Lisa

Artificially induced group display and nesting behaviour in a reintroduced population of Caribbean Flamingo *Phoenicopterus ruber ruber*

C. E. O'CONNELL-RODWELL, N. ROJEK, T. C. RODWELL,
and P. W. SHANNON

Summary

We used artificial social stimulation (decoys, vocalization playbacks, and artificial nests) to initiate group displays in six (two females, four males) Caribbean Flamingos *Phoenicopterus ruber ruber* that had not successfully bred since their introduction to Guana Island, British Virgin Islands, in 1992. During a control period prior to the introduction of stimuli, flamingos exhibited no social displays or nest building activities. All flamingos were observed approaching the decoy area as a flock within four hrs of the decoys being introduced, and Head-Flagging displays were exhibited by two birds within the first 24 hrs. In a 12-hr watch conducted two-weeks post decoy introduction, there were significantly more group display behaviours, as well as nest-building, as compared with the control period and immediately after the introduction (3.6% as compared with 0% and 0.35%). Two individuals performed the majority of group displays (although at least one social display posture was observed for each bird) and three birds exhibited nest-building behaviour. Overall, individuals spent most of their time feeding and resting/sleeping (>95%) during all observation periods. We show for the first time that decoys and vocalization playbacks could have a positive impact on breeding success in the wild by inducing group displays and nesting behaviours in this group of introduced flamingos. We suggest that social attraction techniques may be a useful tool to stimulate breeding in small captive and wild small populations of flamingos.

Introduction

Although their pre-Columbian distribution is not well known, Caribbean Flamingos *Phoenicopterus ruber ruber* historically occurred widely on islands and mainland shores in the Caribbean (Sprunt 1975). They were known to breed in the British Virgin Islands (BVI), particularly on Anegada Island where large numbers were recorded by European travellers in the 1800s (Lazell 2001), but the population quickly declined as the birds were hunted for food, and by the 1950s no resident flamingos were observed (Colli 1996). Although the species is not historically documented on Guana Island, BVI, the salt pond there could have provided foraging and nesting habitat.

In an attempt to re-establish Caribbean Flamingos in the BVI, eight birds from the Bermuda Zoo were brought to Guana Island, a wildlife sanctuary, in 1987

(Lazell 2001, 2002). By 1992, four of these birds (all pinioned) had died and the remaining four free-flying birds had flown off the island. In 1992, eight more birds were released on Guana Island and 18 were reintroduced to Anegada Island (Lazell 2002). Courtship behaviour and nest building were observed in the Anegada population, but no chicks were observed until 1995 after four new birds (possibly the four from the original Guana Island introduction) had joined the Anegada flock. It has been reported that both populations appear not to be limited by food supply or excessive predation (Colli 1996), yet only the Anegada population has successfully bred, and has grown from 18 to 63 individuals (Lazell 2002). Recent data on salt pond nutrition cycling suggests that the Guana Island flamingos may be resource limited at certain times and this could be a limiting factor in population growth, though when food has been supplemented, mating did not occur (Jarecki pers. comm.).

The Guana population consists of six individuals, four males and two females that range in age from 9 to 21 years (Bermuda Zoo Caribbean Flamingo stud book). In the year following the 1992 release of birds, nest-building activity was observed in the centre of the salt pond, where an artificial island had been created. No egg-laying occurred and no social displays or breeding activity has been observed in subsequent years. The island was removed several years later.

Successful restoration programmes for colonially breeding birds require available food, reproductive success and low rates of predation. A threshold population size is also required, providing the necessary social stimulation to initiate group displays and subsequent copulation. Methods to re-establish colonial waterbird colonies and artificially stimulate breeding and nesting activities using "social attraction techniques" were first developed in the 1970s (Kress 1983, 1997). These techniques involve the use of decoys and vocalization playbacks to artificially simulate a large breeding colony. They are an effective management tool for encouraging the recolonization of a variety of extirpated seabird breeding colonies. The combination of decoys, mirrors, tape recordings of vocalizations, and in some cases, predator control, has led to successful restoration in many species (Parker *et al.* 2000, Kress 1997, Schubel 1993, Podolsky and Kress 1991, Podolsky and Kress 1989, Podolsky 1985). The use of plastic flamingos (painted white) alone has been used to attract wading birds to desired sites (Crozier and Gawlik 2003).

Successful reproduction in flamingos may require a minimum flock size (Stevens and Pickett, 1994). The lack of breeding activity in the Guana population may be due to an inadequate colony size to stimulate breeding behaviour. In captivity, a relationship has been found between behavioural stimulation from group displays and breeding success. Increasing the flock size at Zoo Atlanta from 17 birds to 21 birds played a role in increasing the frequency of display activity by 48% and synchronous group displays by 100%, which resulted in a doubling in the frequency of mounts and copulation events (Stevens 1991). In captive flamingos, it has been shown that increases in group displays (which includes a vocalization component) stimulates breeding behaviour and increases reproductive success (Stevens 1991).

Studies of both captive and wild flamingos have indicated that artificial stimuli can enhance flamingo breeding. Large mirrors placed in the enclosure of captive Lesser Flamingos *Phoeniconaias minor* resulted in an elevated rate of

"marching displays" (a social group display) (Pickering and Duverge 1992). In France, the construction of an island and artificial nest mounds attracted wild flamingos, which had lost their nesting habitat nearby (Johnson 1976). In this case, the flamingos mated and produced young four years after the construction of the island. In our study, we tested whether the introduction of four artificial stimuli would induce group displays or any other reproductive behaviour in the Guana Island population of Caribbean Flamingos.

Methods

This study was conducted at the salt pond (approximately 300 m by 150 m) on Guana Island, BVI, over a three-week period during July 2001. All flamingos ($n = 6$) were observed for a 12-hr period over three days (3–5 July) during daylight hours (from 07h00 to 19h00), prior to the introduction of the artificial stimuli to obtain baseline data. All birds had numbered plastic leg bands allowing recognition of individuals. Observations were conducted from the west end of the pond, the furthest distance from the north-east end of the pond, where the birds were known to spend the majority of their time. The behaviour of each individual bird was recorded instantaneously every five min over the 12 hrs using binoculars and a 15–45 × spotting scope. Additionally, we recorded the same behaviour periods using a Sony Digital 8 video camera.

Normal behaviour was categorized as feeding, preening, wing-flapping, wing-stretching, walking, resting, or sleeping (Kahl 1975). Group or "ritualized" displays associated with breeding were categorized using established terms and descriptions (Kahl 1975, Studer-Thiersch 1975): Marching, Head-Flagging, Wing-Salute, Twist-Preen, Wing-Leg Stretch and Inverted Wing-Salute, False-Feeding, and Broken-Neck. Vocalizations associated with behaviours were also documented via video recorder. Courtship and nest-building behaviours were categorized as outlined in Shannon (2000). Courtship behaviour is not as discrete as group display behaviour, and involves a pairing off of a male and female, a female initiating copulation by stepping away from the group, the male following, and the female lowering her head into the water (False-Feeding) and spreading her wings. Nest-building behaviour was noted when a bird either stood on a nest, used its beak to fix a nest, or made contact with an artificial egg.

After the 12-hr baseline behavioural data were collected, four artificial stimuli were introduced to the site (decoys, nests, eggs and audio playbacks). Ten life-sized wooden flamingo decoys were placed near the shoreline of the south-east end of the pond to artificially increase the perceived population size, including seven decoys in Head-Flagging postures. Head-Flagging is the first in a series of group display postures that initiates subsequent group display postures (Kahl 1975, Studer-Thiersch 1975). A cluster of eight artificially constructed mud nests was built at the edge of the salt pond and three decoys in incubating postures and five artificial eggs were placed on various nests, an egg in each nest with the incubating decoys and two eggs on nests without decoy birds.

Head-Flagging calls were obtained from the Dallas Zoo and spliced together into a 30-min recording broadcast in a loop for 12 hours a day after the introduction of the decoys using a Sony water resistant CD player. A 12 V marine battery was used to power the CD player and was recharged once a week as needed.

We observed the flamingos for two 12-hour sampling periods following the introduction of artificial stimuli. Two additional periods of observation were made: one within 24 hrs after the introduction of the artificial stimuli (6–7 July) and a second two weeks later (16–18 July). For each observation period we calculated the percentage of observations of social/reproductive behaviours (group display or “ritualized” movements as listed above, plus courtship and nesting) for each individual bird and then calculated a mean for the time period. A univariate repeated measures ANOVA and Tukey’s multiple comparison procedure were applied to compare the percentage of social/reproductive behaviour displayed by the birds among the three observation periods. This test was calculated in SAS, version 8.02 with observation period as a fixed factor and individual bird as a random factor and $\mu = 0.05$.

Results

The occurrence of social/reproductive behaviour increased significantly following the introduction of artificial stimuli ($F_{2,10} = 5.80$, $P = 0.0212$), from 0 to 3.6%. There was no difference between the observation periods before and immediately following the introduction of stimuli but a significant difference between both of these observation periods and the observation period two weeks later (Figure 1).

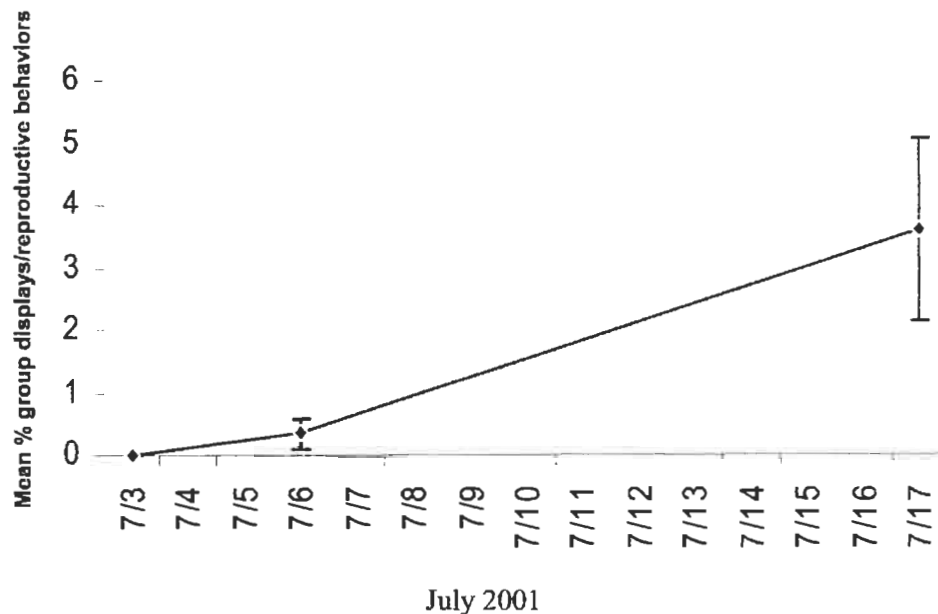


Figure 1. Percentage occurrence of group display/reproductive behaviour 12 hours prior to, 12 hours after, and two weeks after introduction of artificial stimuli to a group of Caribbean Flamingos. Tukey multiple comparisons test indicates a significant change in behaviour two weeks after the introduction of artificial stimulation. Error bars represent standard error. (The non-parametric equivalent test was also significant.)

Birds spent the majority of their time feeding during all observation periods (between 55 and 68% of time), followed by sleeping or resting (between 15 and 27% of time), and preening (between 8 and 11% of time). Two weeks after stimuli introduction, 3.6% of time was spent in social/reproductive behaviours and these behaviours were exhibited between the hours of 07h00–10h00 and 16h00–19h00. Out of the 3.6% time spent in social/reproductive behaviours, 50% of the behaviours were Head-Flagging displays and 25% consisted of nest-building activities.

No social display or reproductive behaviour was exhibited during the 12 hr observation period prior to the introduction of artificial stimuli. During the observation period immediately after stimuli introduction, three Head-Flagging social displays were recorded for two birds (0.003% of total behaviours). Two weeks after the stimuli introduction, a total of 31 social/reproductive behavioural patterns were observed. During this last observation period, all but one individual exhibited social displays (including Head-Flagging, Wing-Salute, Twist-Preen, Wing-Leg Stretch and Inverted Wing-Salute) and three individuals engaged in nest-building activities. Nest-building behaviours included standing on the nests and using their beaks to scrape up the sides of the nests to make them taller, as well as removing debris from the nests with their beaks. Two individuals (one male and one female) displayed more and investigated the nests more than the others (13 and 10 recorded social/reproductive behaviour for these two birds, respectively, versus 2, 2 and 4 reproductive behaviours recorded for the others and one male bird did not exhibit any of these behaviours).

Discussion

Flamingos perform mass, mixed-sex group displays thought to play a role in ensuring synchronous nesting and/or facilitating pair formation (Pickering and Duverge 1992). The frequency of displays varies widely between individuals, unrelated to sex (Pickering and Duverge 1992), a phenomenon we also observed in our population, which may be an indication that certain members of the flock play a key role in instigating group displays. One male in particular played a key role in initiating displays. This has also been observed in other Caribbean Flamingo flocks (Shannon 2000).

Key studies have demonstrated the importance of male vocalizations in priming female hormones for reproduction. Lehrman and Freidman (1969) demonstrated that vocal stimulation done without visual cues caused a doubling in size of ovarian follicles in Ring Doves *Streptopelia risoria*. This phenomenon is also thought to be the case for Budgerigars *Melopsittacus undulatus* (Ficken *et al.* 1960) and Canaries *Serinus canaries* (Warren and Hinde 1961). In Little Blue Penguin *Eudyptula minor*, it was further demonstrated that crested penguin *Eudyptes* sp. calls had no effect on their reproductive status, while male calls from their own species did (Waas 1988). In Royal Penguins *Eudyptes schlegeli*, the vocalizations from the colony as a whole facilitates sexual activities (Waas *et al.* 2000).

In flamingos, both sexes call during particular group displays, and Caribbean Flamingos have two distinct vocalizations associated with group displays, Head-Flagging and Wing-Salute calls (Kahl 1975). These vocalizations are most likely important to prime both sexes for reproduction. It is unclear what the relative

role of the group display vocalizations and visual stimuli play in priming hormones in flamingos. The flamingos we studied oriented towards the decoys when preparing to display. The decoys were investigated on many occasions, and outside of display periods, at least three of the flamingos spent time amongst the decoys during nest building, resting and sleeping. The source of the vocalizations, on the other hand, was never investigated.

Field experimentation with social attraction techniques demonstrate the probable importance of the presence of decoys as a visual cue to land from a distance and in creating the appearance of a larger flock or colony. The relative importance of decoys versus vocalization playbacks is not yet completely understood. It would be interesting to have a site devoted to vocalization playbacks, a site devoted to decoys and a third site containing both sources of stimulation to determine which stimuli was more important, if not both.

Although the Anegada population has bred between April and June (Jarecki pers. comm.), Caribbean Flamingos in captivity in North America usually breed between May–August (Reo and O'Gara 2001, Shannon 1996), some clutches occurring in April and September, but rarely in other months (Shannon 1996). Others report that breeding can occur at any time throughout the year in captivity, and they may breed twice in a year (Sedenko 2001). The Anegada population has previously had two clutches in a year, one in April and one in July (Jarecki pers. comm.). We expected, then, that the flamingo population on Guana Island may respond to breeding cues during the month of July. Although flamingos may not breed every year and breeding and nest-building may depend on rainfall and its effect on food supply, we expected that at least social group displays may be induced artificially at that time, regardless of the occurrence of any breeding behaviours. Although we observed nest-building behaviour in July, egg-laying may not have been possible due to the other environmental factors necessary for the flamingos to breed later than normal.

Having demonstrated that artificial stimuli induced group displays and nest-building in this group of Caribbean Flamingos, and caused a significant increase in these behaviours over time, we plan in the future to conduct these experiments prior to the breeding period (March–April) in order to maximize the potential of breeding. Typically, group displays are initiated one month prior to breeding, where the displays escalate throughout the month, culminating in pairing and mating in the following month (Shannon 2000). Additional studies are needed to determine nesting success, clutch size and population growth.

Our study indicates that the use of artificial stimuli could play an important role in flamingo reintroduction programmes, and perhaps even stimulate reproduction in wild populations of flamingos whose numbers have been drastically reduced. This technique could also be useful in captive breeding programs where other measures have failed to help stimulate breeding.

Acknowledgements

We would like to thank Steve Kress of the National Audubon Society for his support of the project and Jeanette Boylan of the Dallas Zoo for providing the Head-Flagging calls, and Byron Bodt of Bodt Decoys for making the decoys. We would also like to thank Lianna Jarecki, the director of the Marine Science

Program on Guana Island for her enthusiastic support of this project, as well as Henry and Gloria Jarecki and Guana Island staff for assistance on the island. We thank James Lazell of The Conservation Agency for his input and the BVI National Parks Trust for providing data on the Anegada population. We also thank Dean Kildaw for his helpful comments on this manuscript. Funding for this project was provided by the Falconwood Corporation and Guana Island Marine Science Month.

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Received 17 October 2002; revision accepted 23 September 2003

> Hi Matt, Thanks so much for the reprint and the Acknow. Since those
 > specimens were collected on an official TCA exped, I would put your
 > citation up on our website - theconservationagency.org - unless you
 > wish otherwise. We are in process of updating now (haven't since 2000!).
 > I agree with your idea that comparison of ewmsi to adjacent VI pops
 > would surely cut down the distance. I believe the separation time is
 > more like 3000 years; ewmsi is a classic "rock knockoff." I am
 > surprised by deseche, which I would have thought more distant from
 > cris. I think on p. 113, top part para, 4th line from bottom, you meant
 > to say western, not eastern....
 > Greg Mayer had told me about your paper, but I left in June for
 > China, Australia, and on to the BVI - not getting back til 7 Nov., so
 > I just got to read it now. What are you going to do next? Keep me
 > posted.... Best, Skip
 >

From: "Matt Brandley" <brandley@berkeley.edu>
To: "Wenhua Lu" <wenhua@etal.uri.edu>
Sent: Friday, November 12, 2004 5:11 PM
Subject: Re: Herp.Monog.

Hello Skip,

Please use the citation for your website. RE: ernestwilliamsi, Rich
 Glor has sequence data for a lot of A. cristatellus cristatellus and
 Kevin de Queiroz is currently collecting some A. c. wileyae in the
 Virgin Islands. I am hoping that Rich can also include these wileyae
 samples in his analysis.

For the time being, I am no longer working with Anolis. I've spent the
 past 3 years studying skink phylogenetics and will probably continue to
 do so for my PhD.

Thank you for contacting me (and thanks for collecting ernestwilliamsi).

Take care,
 Matt

--

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PHYLOGENY, ECOMORPHOLOGICAL EVOLUTION, AND HISTORICAL BIOGEOGRAPHY OF THE *ANOLIS CRISTATELLUS* SERIES

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ABSTRACT: To determine the evolutionary relationships within the *Anolis cristatellus* series, we employed phylogenetic analyses of previously published karyotype and allozyme data as well as newly collected morphological data and mitochondrial DNA sequences (fragments of the 12S rRNA and cytochrome *b* genes). The relationships inferred from continuous maximum likelihood reanalyses of allozyme data were largely poorly supported. A similar analysis of the morphological data gave strong to moderate support for sister relationships of the two included distichoid species, the two trunk-crown species, the grass-bush species *A. poncensis* and *A. pulchellus*, and a clade of trunk-ground and grass-bush species. The results of maximum likelihood and Bayesian analyses of the 12S, *cyt b*, and combined mtDNA data sets were largely congruent, but nonetheless exhibit some differences both with one another and with those based on the morphological data. We therefore took advantage of the additive properties of likelihoods to compare alternative phylogenetic trees and determined that the tree inferred from the combined 12S and *cyt b* data is also the best estimate of the phylogeny for the morphological and mtDNA data sets considered together. We also performed mixed-model Bayesian analyses of the combined morphology and mtDNA data; the resultant tree was topologically identical to the combined mtDNA tree with generally high nodal support. This phylogenetic hypothesis has a basal dichotomy between the Hispaniolan distichoids and the *bimaculatus* series, on the one hand, and the *cristatellus* series inhabiting the Puerto Rican Island Bank, its satellite islands, the Bahamas, and St. Croix, on the other. The trunk-crown species form a clade, while the trunk-ground and grass-bush species do not as *A. gundlachi*, a trunk-ground species, is nested within a clade of grass-bush species. The patterns of relationships among the trunk-ground and grass-bush species suggest that one of these ecomorphs may have been ancestral to the other and that one or both evolved convergently. In the context of our preferred phylogeny and divergence dates estimated by NPRS analyses, we propose several biogeographical hypotheses that explain the current distribution of the *cristatellus* series. The presence of endemic species on the islands of the Bahamas, Desecheo, Mona, Monita, and St. Croix are likely due to over-water dispersal. Vicariance resulting from Pliocene or Pleistocene changes in sea levels likely explains the occurrence of *A. cristatellus* (including *A. ernestwilliamsi*), *A. pulchellus*, and *A. stratulus* on different islands of the Puerto Rican Bank.

Key words: Bayesian; Caribbean Biogeography; Ecomorphology; Frequency coding; Maximum likelihood; Mixed-model; Puerto Rico Bank; Taxonomy.

ANOLIS LIZARDS of the Greater Antilles are of particular interest to evolutionary biologists because they represent a striking case study of convergent evolution and adaptive radiation (Beuttell and Losos, 1999; Losos 1990, 1992, 1994; Losos and de Queiroz, 1997; Williams 1972, 1983). Each of the islands of Cuba, Jamaica, Hispaniola, and Puerto Rico is inhabited largely by endemic species of anoles, yet the anole communities of the different

islands are remarkably similar in terms of the ecomorphological adaptations of their component species. These communities consist of species with different body plans, called ecomorphs, each of which is morphologically adapted to the structural microhabitat in which it occurs. Ecomorph names correspond to their associated microhabitats: trunk-crown, trunk-ground, grass-bush, crown giant, and twig (Williams, 1983). Higher-level phylogenetic studies based on morphology (Etheridge, 1959; Guyer and Savage, 1986; Poe, 1998; Williams, 1989) and mitochondrial DNA (Jackman et al., 1997, 1999; Losos et al., 1998) have demonstrated that, for the most part, the same set of ecomorphs (or a subset)

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TABLE 1.—Species of the *Anolis cristatellus* series included in this study, with distributions (from Schwartz and Henderson, 1991) and ecomorph designations (from Losos and de Queiroz, 1997).

Species	Locality	Ecomorph class
<i>A. acutus</i>	St. Croix (Virgin Islands)	Unclassified ¹
<i>A. evermanni</i>	Puerto Rico	Trunk-crown
→ <i>A. stratulus</i>	Puerto Rico and Virgin Islands	Trunk-crown
<i>A. cooki</i>	Puerto Rico	Trunk-ground
→ <i>A. cristatellus</i>	Puerto Rico and Virgin Islands	Trunk-ground
<i>A. desechensis</i>	Isla Desecheo (Puerto Rico)	Trunk-ground ²
→ <i>A. ernestwilliamsi</i>	Carrut Rock (British Virgin Islands)	Trunk-ground ¹
<i>A. gundlachi</i>	Puerto Rico	Trunk-ground
<i>A. monensis</i>	Isla Mona and Monita (Puerto Rico)	Trunk-ground ²
<i>A. scriptus</i>	Southern Bahamas, Turks and Caicos Islands	Trunk-ground
<i>A. krugi</i>	Puerto Rico	Grass-bush
<i>A. poncensis</i>	Puerto Rico	Grass-bush
→ <i>A. pulchellus</i>	Puerto Rico and Virgin Islands	Grass-bush

¹ But closest to trunk-crown (Losos and de Queiroz, 1997).² Descendants of trunk-ground ecomorphs, but possess a generalized or trunk-ground morphology (Losos and de Queiroz, 1997).³ Ecomorph status not confirmed morphometrically.

has evolved *in situ* on each of the four Greater Antillean Islands.

While studies of higher level *Anolis* phylogenetics continue, several recent studies have addressed the question of the evolutionary relationships within smaller groups of *Anolis*, including the *roquet* series of the Southern Lesser Antilles (Creer et al., 2001), the *bimaculatus* series of the Northern Lesser Antilles, (Schneider et al., 2001), the *grahami* series of Jamaica (Jackman et al., 2002), and the beta section or *Norops* (Nicholson, 2002). In keeping with this trend, we present a phylogenetic study of the *cristatellus* series. For the remainder of the paper, the term “*cristatellus* series” will refer to the taxon that Gorman et al. (1980a, 1983) termed the *cristatellus* subseries (excluding the distichoids = the *distichus* subgroup of Williams, 1976). This group also corresponds to the *cristatellus* series of Etheridge (1959) with the addition of *A. acutus*, *A. evermanni*, and *A. stratulus* from his *bimaculatus* series and excluding the cybotoid anoles (= the *cybotes* subseries and species group of Williams, 1976) of Hispaniola (see Jackman et al., 1999; Gorman et al., 1980a), with the *cristatellus* subseries of Williams (1976) plus *A. acutus*, *A. evermanni*, and *A. stratulus*, with the *cristatellus* series of Savage and Guyer (1989) minus *A. eugene-grahami* (see Williams, 1989), and the distichoids and with the *cristatellus* series of Burnell and Hedges (1990) (Table 1).

The *cristatellus* series consists of approximately 13 currently recognized species that

inhabit Puerto Rico and surrounding islands (Virgin Islands including St. Croix, Mona and Monita Islands, and Desecheo Island), although *A. scriptus* inhabits the Bahamas (Schwartz and Henderson, 1991; Fig. 1). The Puerto Rican members of the *cristatellus* series represent three of the five ecomorphs that inhabit the island: trunk-crown (*A. evermanni*, *A. stratulus*), trunk-ground (*A. cooki*, *A. cristatellus*, *A. gundlachi*), and grass-bush (*A. krugi*, *A. poncensis*, *A. pulchellus*) (Williams, 1983); the representatives of the other two ecomorphs, *A. cuvieri* (crown-giant) and *A. occultus* (twig), are relatively distantly related (Jackman et al., 1997, 1999; Gorman et al., 1980a; Losos et al., 1998; Guyer and Savage, 1986; Williams, 1989) and represent lineages that either colonized Puerto Rico separately or were already present when the Puerto Rican Bank became isolated from other landmasses.

A series of studies based on allozymes (Gorman et al., 1980b, 1983), karyotypes (Gorman et al., 1968, 1983; Gorman and Stamm, 1975), and immunological data (Gorman et al., 1980a) dealt explicitly with phylogenetic relationships within the *cristatellus* series. One broad conclusion from these studies is that the basal division in the *cristatellus* series is between a clade of trunk-crown anoles and a clade of grass-bush and trunk-ground anoles. Several osteological features also support the latter clade (Etheridge, 1959; Williams, 1972).

The relationships of the Hispaniolan and Bahamian distichoids (the *distichus* subgroup

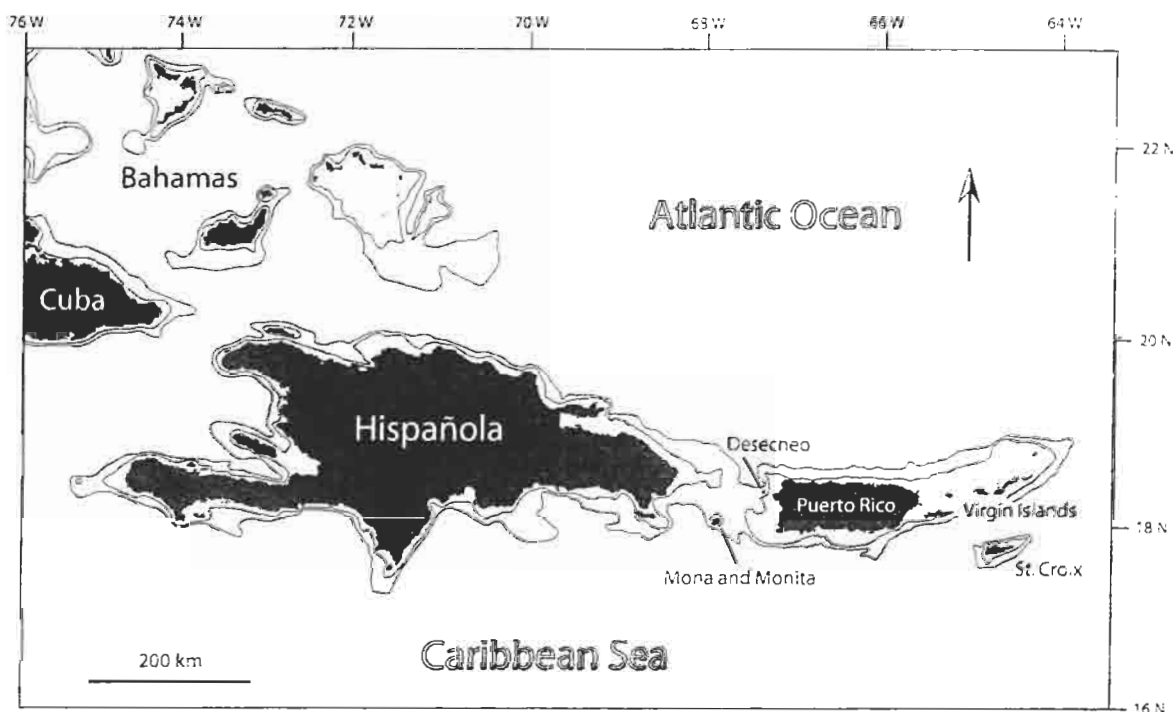


FIG. 1.—Map of the eastern Greater Antilles. The *cristatellus* series inhabits the islands shown east of Hispaniola as well as parts of the Bahamas. Contours indicate ocean depths of 200 and 1000 m.

of Williams [1976], which currently includes *A. altavelensis*, *A. brevirostris*, *A. caudalis*, *A. distichus*, *A. marron*, and *A. websteri* [Burnell and Hedges, 1990], but not *A. eugenegrahami* [Williams, 1989] to the *cristatellus* series are uncertain. Etheridge (1959) and Williams (1976) placed the distichoids, along with *A. acutus*, *A. evermanni*, and *A. stratulus* in the *bimaculatus* series. Gorman et al. (1980a, 1983) placed the distichoids and these other three species in a group exclusive of other anoles (their *acutus* species group). Recent studies have refuted the hypothesized relationship of the distichoids to *A. acutus*, *A. evermanni*, and *A. stratulus*, but have been unable to infer the precise placement of the distichoids with strong support. Jackman et al. (1999) weakly placed the distichoids as sister to the *cristatellus* series, whereas Poe (2004) found weak support for their placement as sister to the *bimaculatus* series.

Despite past phylogenetic work, certain relationships within the *cristatellus* series are uncertain, especially those of *A. acutus* and *A. gundlachi*. *Anolis acutus* of St. Croix possesses what may be considered a generalist body plan and does not fit into any recognized ecomorph class (Losos and de Queiroz, 1997). A previous

phylogenetic study based on allozymes and karyotypes either placed it sister to the trunk-ground and grass-bush species exclusive of *A. gundlachi*, or was unable to resolve its relationships, depending on the analysis (Gorman et al., 1983). An immunological study placed *A. acutus* closer to *A. cristatellus* (a trunk-ground species) than to *A. stratulus* (a trunk-crown species) (Gorman et al., 1980a). *Anolis gundlachi*, a trunk-ground species, shares a derived karyotype with the grass-bush anoles (Gorman et al., 1968, 1983), though analyses based on allozymes have been unable to unambiguously determine its phylogenetic relationships (Gorman et al., 1983). It has also been suggested that *A. gundlachi* represents the sister taxon to a clade composed of the grass-bush and other trunk-ground species (Williams, 1972).

Several studies have attempted to elucidate the pattern of ecomorph evolution on Puerto Rico. Williams (1972), making early use of a phylogeny, proposed a basal divergence between the trunk-crown and the grass-bush + trunk-ground species as well as evolution of the grass-bush ecomorph from the trunk ground ecomorph. Losos (1992) concluded that the ancestor was a generalist and proposed a sequence of ecomorph evolution from

generalist to trunk-ground to (separately) trunk-crown and grass-bush. A subsequent analysis of morphology and habitat use by species in one- and two-species communities led Losos and de Queiroz (1997) to hypothesize that the Puerto Rican species of the *crstatellus* series may have descended not from a generalist but from a trunk-crown ancestor. All of these hypotheses, however, were limited by the phylogenetic information available at those times.

Past biogeographic hypotheses for the *Anolis cristatellus* series are few, and are primarily theories based on limited phylogenetic and geological evidence (Gorman, 1980a; Williams, 1969). The geology of the Caribbean is complex, but dramatic improvements in the understanding of the geologic history of the region have been made (Pindell and Barret, 1991; Iturralde-Vinent and MacPhee, 1999; MacPhee et al., 2003) since the last thorough phylogenetic treatment of the *crstatellus* series.

The availability of new data and recent advances in analytical methods may help resolve the phylogenetic relationships within the *crstatellus* series and thus shed light on other aspects of its evolution. In this study, we first reevaluate the phylogeny of the *crstatellus* series, and the placement of the distichoids, synthesizing the information in data sets derived from morphological, mtDNA, allozyme and karyotype data. We then use this phylogeny to evaluate hypotheses about ecomorph evolution on Puerto Rico. Specifically, we attempt to assess which ecomorph, if any, represents the ancestral condition of *crstatellus* series anoles on Puerto Rico as well as the subsequent sequence of ecomorph evolution that gave rise to the three *crstatellus* series ecomorphs that exist today on the island. Finally, we incorporate phylogenetic and recent geological evidence as well as relative molecular divergence estimates to make inferences about the biogeographic history of the group.

MATERIALS AND METHODS

Taxon and Character Sampling of Multiple Data Sets

In the new data sets collected for this study (morphology and DNA), we sampled all

recognized species of the *crstatellus* series (Table 1), including *A. ernestwilliamsi* and *A. deseichensis*, two species never before included in a phylogenetic analysis. Two distichoids, *A. brevirostris* and *A. distichus*, representing both of the main superspecies (Williams, 1976) or complexes (Arnold, 1980) within this group, were sampled. *Anolis gingivinus* and *A. watti*, members of the *bimaculatus* series, and *A. cybotes* served as outgroups. The *bimaculatus* series is thought to be the sister of the *crstatellus* series and *A. cybotes* is more distantly related (e.g., Gorman et al., 1980a; Jackman et al., 1999).

Allozymes.—Gorman et al. (1983) presented two allozyme data sets that differ in numbers of both taxa and characters, both of which were reanalyzed for this study. The two allozyme data sets both lack *A. brevirostris*, *A. deseichensis*, *A. distichus*, *A. ernestwilliamsi*, *A. gingivinus*, and *A. watti*. The two data sets also included outgroup taxa not represented in our DNA and morphological data sets: *A. cuvieri*, *A. occultus*, and *A. oculatus* in the first data set; and *A. carolinensis*, *A. gadovi*, and *A. grahami* in the second. We included these taxa as outgroups in our reanalyses of the allozyme data.

Morphology and karyology.—Two karyotype, 18 scalation, and 13 osteological characters (hereafter referred to as the "morphological" data set; Appendix I) were scored for 13 ingroup species, 3 outgroup species, *A. brevirostris*, and *A. distichus* (Appendix II). An effort was made to sample widely among sex and age classes as well as across geographic ranges and subspecies. Scalation characters were scored on fluid preserved specimens ($N = 9$ –52 per species, median = 13; Appendix III). Cranial characters were scored from dry osteological specimens ($N = 1$ –23 per species, median = 10; Appendix IV). Axial skeleton characters were scored from radiographs and supplemented with data provided by R. Etheridge that had also been collected from radiographs and used in his 1959 study ($N = 5$ –30 per species, median = 17; Appendix III). Karyotype descriptions from Gorman (1973) and Gorman et al. (1983) served as the basis of two separate characters. Karyotype information was not available for *A. brevirostris*, *A. deseichensis*, and *A. ernestwilliamsi*.

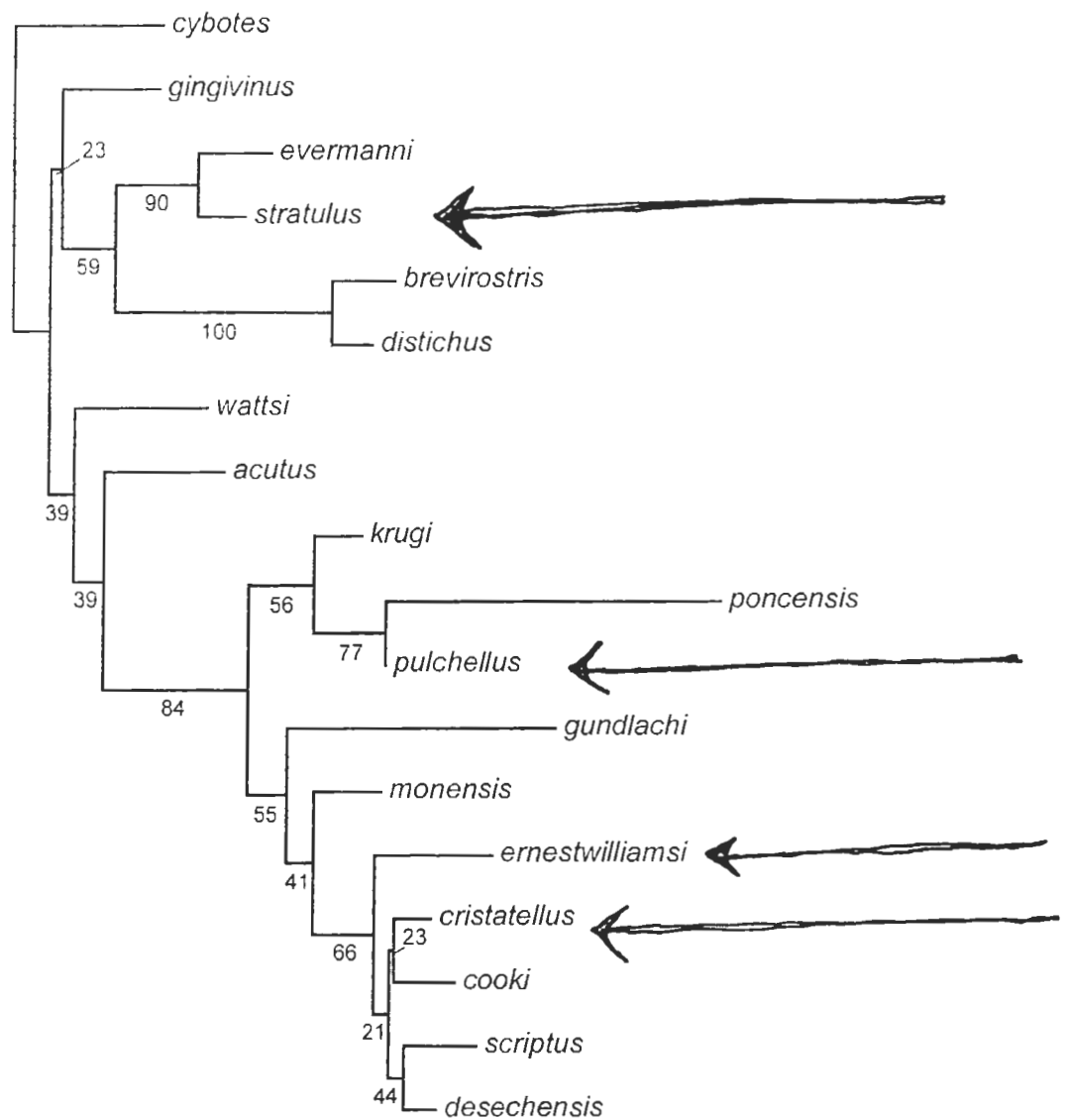


FIG. 4.—Rooted ML phylogram from the CONTML analysis of the morphological data set. Numbers below branches are bootstrap proportions. Outgroup taxa are shaded in light grey and the distichoids in medium grey.

some taxa, also supports the placement of *A. acutus* with the grass-bush and trunk-ground species.

The grass-bush + trunk-ground clade (LBP = 84%) is supported by several derived states. One hundred percent of all species examined have 23 (as opposed to 24) presacral vertebrae (character 20), and the vast majority of individuals of each species possess two attached and two free (versus three attached and one free) post-xiphisternal inscriptional ribs (character 21) and keeled (as opposed to smooth) scales of the supraocular disk (character 2). Except for *A. poncensis* and *A.*

pulchellus (the two species with the smallest body size), most adults in this clade possess anteroventral shelves on the basiptyergoid processes (character 23). In every species except *A. pulchellus* and *A. krugi* a majority of the individuals share the derived condition of the parietal foramen penetrating the parietal rather than the fronto-parietal suture (character 22). Finally, some specimens of all species within the grass-bush + trunk-ground clade possess some form of dentary sculpturing (character 27).

The grass-bush + trunk-ground clade splits into a clade of the grass-bush anoles + *A.*

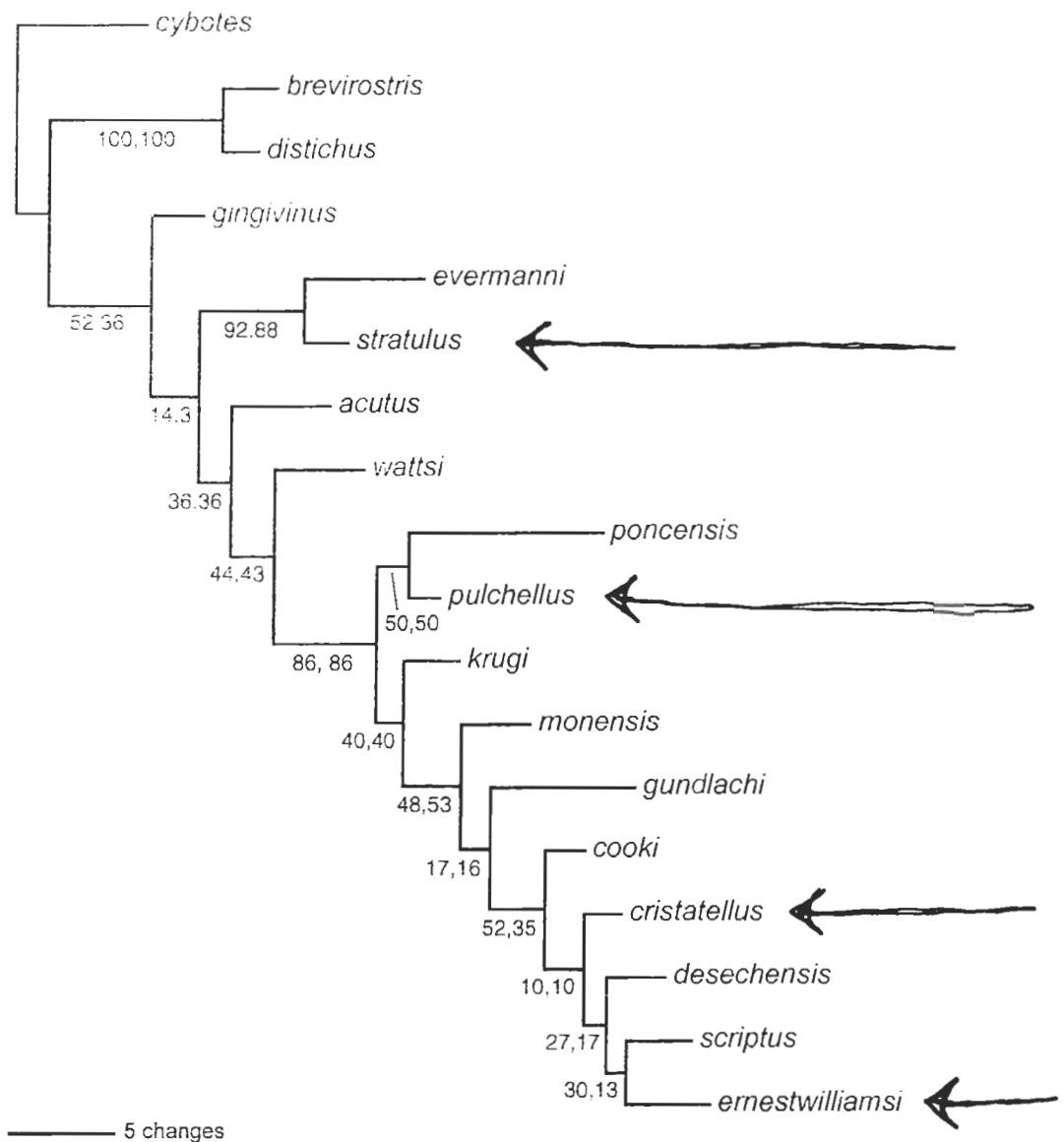
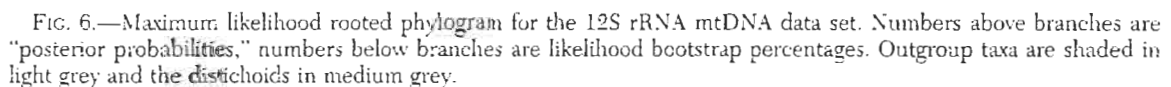


FIG. 5.—Rooted phylogram from the MANOB analysis of the morphological data set including all characters. Numbers below branches are bootstrap proportions. The first value indicates bootstrap percentages for the MANOB analysis of the complete character data set. The second value indicates bootstrap proportions for the MANOB analysis of the data set excluding characters 24, 31–33. Outgroup taxa are shaded in light grey and the distichoids in medium grey.

gundlachi and a clade of the remaining trunk-ground species. The former clade is supported by the presence of carinate head scales (character 1) found in 100% of all the individuals except *A. pulchellus* (83%). *Anolis pulchellus* and *A. poncensis* are the only species in this study possessing individuals with reduced toepads (character 16; 100% in *A. poncensis* and 30% in *A. pulchellus*). The sister relationship between *A. poncensis* and *A. pulchellus* is moderately supported (LBP = 77%). Among the remaining trunk-ground

anoles exclusive of *A. gundlachi*, *A. monensis* is sister to a clade of *A. cooki*, *A. cristatellus*, *A. desechensis*, *A. ernestwilliamsi*, and *A. scriptus* (LBP = 66%). Relationships within the latter clade appear to be based primarily on minor frequency differences and are poorly supported. Although part of the clade of trunk ground anoles, *A. monensis* shares several characters with the *A. gundlachi* + grass-bush clade including carinate head scales (character 1; 100%) and *krugi* type dentary sculpturing (character 27; 86%).



12S.—Thirteen sites were considered ambiguously aligned and were removed from the data set prior to analysis, leaving 320 characters, 93 of which were variable and 51 parsimony-informative. The GTR+I+ Γ was the most appropriate model of sequence evolution (according to the LRT) with all iterations of the successive likelihood searches. Parameter estimates for this model are summarized in Table 3. A maximum likelihood analysis using these parameters yielded one

tree with a score $\ln L = -1414.6175$ (Fig. 6). All four Bayesian analyses reached stationarity at a similar mean $\ln L$ (≈ -1440) and supported the same topology. The posterior probabilities estimated from these analyses are based on 36,000 trees sampled from stationarity and mapped onto the ML tree (Fig. 6).

The distichoids, *A. distichus* and *A. brevirostris*, form a well-supported clade ($LBP = 73\%$, $PP = 0.93$) and are weakly placed ($LBP = 42\%$, $PP = 0.49$) as the sister to the *cristatellus* series. The *cristatellus* series forms a

moderately ($LBP = 77\%$) to strongly ($PP = .99$) supported clade of trunk-crown, trunk-ground, and grass-bush species of the Puerto Rican Island Bank and satellite islands. The trunk-crown + *A. acutus* clade ($LBP = 67\%$, $PP = 0.92$) is sister to a weakly supported ($LBP = 60\%$; $PP = 0.79$) clade of trunk-ground and grass-bush anoles. *Anolis poncensis*, a grass-bush anole, is sister to a poorly ($LBP = 66\%$) to well-supported ($PP = 0.96$) clade of *A. krugi* and *A. pulchellus*, also grass-bush anoles, and *A. gundlachi*, a trunk-ground

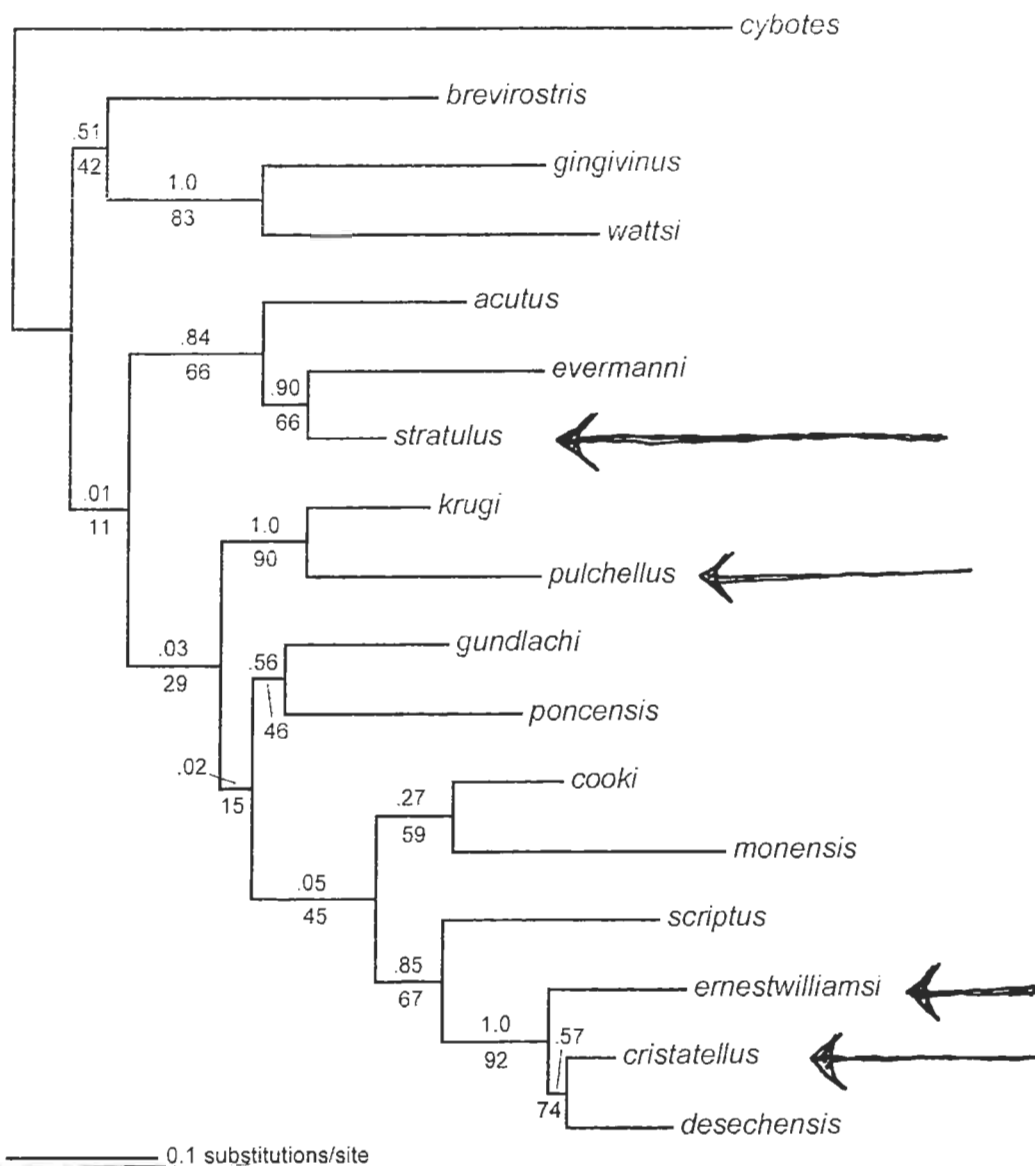


FIG. 7.—Maximum likelihood rooted phylogram for the cytochrome *b* mtDNA data set. Numbers above branches are "posterior probabilities," numbers below branches are likelihood bootstrap percentages. Outgroup taxa are shaded in light grey and the distichoids in medium grey.

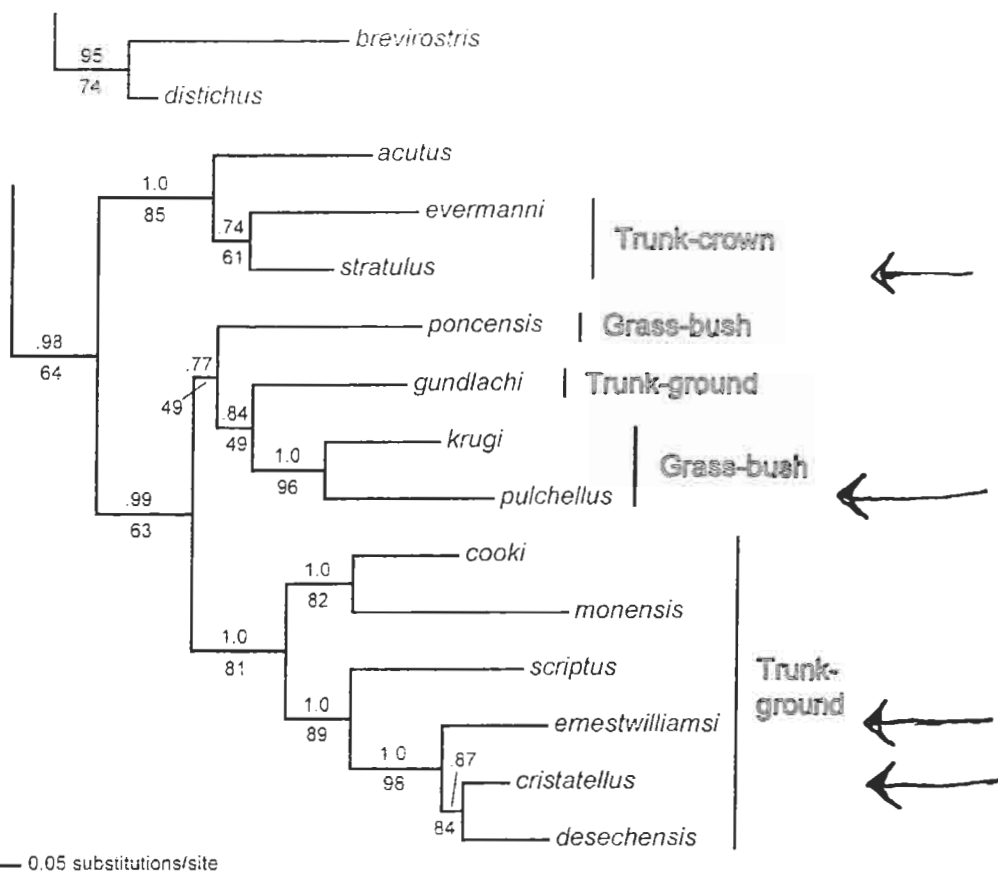


FIG. 8.—Maximum likelihood rooted phylogram of the combined 12S rRNA and cytochrome *b* data set. Numbers above branches are “posterior probabilities,” numbers below branches are bootstrap percentages. This topology is also favored by the combined (summed) likelihood analysis of mtDNA, morphological, and allozyme data (Table 5) as well as the mixed-model Bayesian analysis of the combined mtDNA and morphological data and is therefore our preferred phylogenetic hypothesis. The ecomorph status of each clade is shown to the right. Outgroup taxa are shaded in light grey and the distichoids in medium grey.

TABLE 3.—CTR+I+Γ model parameter values used in the maximum likelihood analyses of the separate and combined DNA data sets.

Data set	ln L	Base frequencies				Substitution rates								Rate heterogeneity	
		A	C	G	T	A → C	A → G	A → T	C → G	C → T	G → T	Γ	I		
12S	-1414.6175	0.3799	0.1959	0.1776	0.2466	0.7708	7.4419	2.2359	0.0127	14.9306	1	0.6103	0.5091		
cyt <i>b</i> ¹	-4925.8127	0.3009	0.2928	0.1136	0.2927	1.7655	12.0514	2.6603	1.1641	17.0250	1	1.5886	0.5396		
cyt <i>b</i> ²	-4651.0154	0.2998	0.2928	0.1141	0.2933	1.7391	12.9745	2.6950	1.2986	17.7324	1	1.8323	0.5499		
mtDNA ³	-6139.1713	0.3257	0.2573	0.1396	0.2774	1.9084	11.6723	3.1890	0.8870	22.4751	1	1.0697	0.5555		

¹ Parameters used in the analysis including *A. carolinensis* as an additional outgroup.

² Parameters estimated from the cyt *b* topology after removing *A. carolinensis*.

³ Combined 12S and cyt *b* data sets.

TABLE 5.—Summed likelihood scores for multiple data sets for the competing phylogenetic hypotheses. No *cyt b* data were obtained for *A. distichus*. The upper part of the table includes *ln Ls* calculated with *A. distichus* included in all data sets and trees, but coded as missing for the *cyt b* data and placed sister to *A. brevirostris* in the *cyt b* tree. The lower part of the table includes *ln Ls* calculated with *A. distichus* absent from all data sets. Taxon sampling in the second allozyme data set differs substantially from those of the other data sets; therefore, taxa unique to this data set were pruned from the tree and data set to make it comparable across trees. Characters of species for which no allozyme data were available were coded as missing. The tree of the second allozyme data set is not included in the array of alternative topologies because doing so would require the elimination of many taxa from all data sets and trees. Values for the morphological data tested on competing trees were calculated using the restricted maximum likelihood (REML) method implemented by PHYLIP v3.6a2.1. All other *ln Ls* were calculated using full likelihood in PAUP* 4b10. Total *ln Ls* sums closer to zero indicate better explanations of the data. The values in bold represent the best *ln L* for the particular data set or combination of data sets, and hence, the best explanation of the data set(s) in question.

Dataset	Topology			
	Morphology	12S	<i>cyt b</i>	Combined mtDNA
<i>Anolis distichus</i> included				
Morphology	1420.2920	1378.2287	1394.2805	1396.4772
12S	-1451.2427	-1414.6175	-1422.9215	-1415.5196
<i>cyt b</i>	-4737.6638	-4656.0301	-4651.0154	-4655.0195
Allozyme 2	450.3723	450.0681	448.8017	450.0681
Total	-4348.2422	-4242.3508	-4230.8547	-4223.9938
<i>Anolis distichus</i> excluded				
Morphology	1305.9061	1263.9600	1250.3425	1252.5320
12S	-1445.1977	-1377.7052	-1386.6032	-1378.8275
<i>cyt b</i>	-4737.6638	-4656.0301	-4651.0154	-4655.0195
Allozyme 2	450.3723	450.0681	448.8017	450.0681
Total	-4426.5831	-4319.7073	-4308.6744	-4301.2472

bined 12S and *cyt b* data set (hereafter called the mtDNA data set). A likelihood search using parameters in Table 3 inferred one tree with a *ln L* = -6139.1713 (Fig. 8). All Bayesian analyses attained stationarity at a similar *ln L* (\approx -6161) and supported the same tree. Posterior probabilities were calculated from 36,000 trees sampled at stationarity. The tree is generally well-supported and is identical to the 12S tree with the exception of the placement of the distichoids and *A. acutus*, and to the *cyt b* except the placement of the *A. gundlachi* and *A. poncensis*. As with the analyses of the individual gene fragments, the placement of the distichoids is weakly supported.

Incongruence Among the Data Sets

There is one case in which topologies estimated from different data sets moderately or strongly support (*LBP* \geq 70%) conflicting placements of taxa. The morphological tree places *A. poncensis* as the sister taxon of *A. pulchellus* (*LBP* = 77%); in contrast, the *cyt b* and combined mtDNA topologies strongly support *A. pulchellus* as the sister of *A. krugi*.

The morphological tree is a significantly worse explanation of all the other data sets (Table 4) according to the SH test. This tree is the only tree that places *A. gingivinus* and *A. watsi* within the ingroup, the trunk anoles sister to the trunk-crown anoles, *A. acutus* with the grass-bush + trunk-ground clade, *A. pulchellus* and *A. poncensis* as sister taxa, and does not place *A. monensis* and *A. cooki* as sister taxa. The morphological tree also differs from the 12S, *cyt b*, and combined mtDNA topologies regarding the weakly supported relationships among the species *A. cristatellus*, *A. desecheensis*, *A. ernestwilliamsi*, and *A. scriptus*. Conversely, the topologies inferred from the 12S, *cyt b* and combined mtDNA analyses are significantly worse explanations of the morphological data than is the morphological topology. The trees derived from the 12S, *cyt b* and combined mtDNA data sets are not significantly worse explanations for the alternative DNA data sets, which is not surprising given that the differences between the trees are relatively minor and not strongly supported.

Combined Analysis

The second allozyme tree was not included among the tested trees in the likelihood summing analysis because it lacks many taxa present in the DNA and morphological data set. To make the DNA and morphological trees comparable to the allozyme tree would necessitate the exclusion of many taxa from the corresponding data sets and thus reduce the explanatory power of the combined analyses. However, the second allozyme data set was used in the summed likelihood analysis. The combined mtDNA tree was also used. Two different analyses based on summed likelihoods were conducted to deal with the fact that *A. distichus* was not included in the *cyt b* data set. In the first, *A. distichus* was removed from all data sets and trees (the distichoids were still represented by the closely related *A. brevirostris*). In the second analysis, *A. distichus* was added to the *cyt b* tree as the sister taxon to *A. brevirostris*, a relationship that is strongly supported by the morphological and 12S analyses. These measures were necessary because when summing the log-likelihoods of the different data sets on competing trees, the sum of the *cyt b* tree would have been inflated relative to those of other trees simply because fewer taxa were used in calculating the summed $\ln L$. Results of summing the likelihood scores for all the data sets on all relevant topologies are provided in Table 5. The mtDNA tree is the best explanation of the combined data whether *A. distichus* is included or excluded, followed by the *cyt b*, 12S, and morphology trees.

The mixed-model Bayesian analyses of the combined mtDNA and morphology data reached stationarity at a similar $\ln L$ (≈ -6079) and supported the same topology. The consensus tree of 36,000 trees (not shown) is topologically identical to the combined mtDNA tree with the exception of the weakly supported relationship ($PP = 0.46$) of the distichoids sister to the *cristatellus* series. All other relationships are supported with a posterior probability ≥ 0.99 except the *A. gundlachi* + *A. krugi* + *A. pulchellus* clade ($PP = 0.71$).

Analyses of the Ancestral Ecomorph State and Estimated Times of Divergence

The ecomorph class of the ancestor that gave rise to the Puerto Rican *cristatellus* series radiation is ambiguous in the context of the combined mtDNA phylogeny: all of the ecomorph state assignments (trunk-crown, trunk-ground, and grass-bush) are equally parsimonious. The phylogenetic placement of each ecomorph class in the *cristatellus* series is provided on Fig. 8. The ultrametric tree inferred by the NPRS analysis, with nodes and branch lengths representing time is provided in Fig. 9; estimated divergence times are given in Table 6.

DISCUSSION

Incongruence Among the Data Sets

The optimal topologies for the 12S, *cyt b*, and combined mtDNA data sets are significantly worse explanations of the morphological data than is the optimal topology for the morphological data set (Table 4). This indicates that although most of the nodes of the morphology tree are poorly supported, as a whole, the morphological data still strongly support an alternative phylogenetic history of the *cristatellus* series. If the tree favored by the combined analysis of morphological, mtDNA, and allozyme data sets (Table 5), is the best phylogenetic hypothesis (see below), then incongruence with the tree favored by the morphological data is due primarily to convergent evolution of some morphological characters (see "Morphological implications of the preferred tree").

The Phylogenetic History of the cristatellus Series

According to the sums of likelihood scores (Table 5), the mtDNA tree (i.e., the one resulting from analysis of the combined 12S and *cyt b* data) is the best estimate of the phylogeny for the combined mtDNA, morphological, and allozyme data. This result may be due to the fact that the mtDNA data set is much larger than the others and thus has a greater impact on the overall likelihood score, though a smaller data set that strongly favors one tree over another should have more influence on the final result than a larger data set that only weakly discriminates between the

trees. With the exception of the weakly supported sister relationship between the distichoids and the *cratatellus* series, the mtDNA tree is topologically identical to the consensus tree of the mixed-model Bayesian analyses of the mtDNA and morphology data. Consequently, we will treat the tree based on the combined mtDNA data (as well as the ingroup relationships of the combined mtDNA, morphology, and allozyme data) (Fig. 8) as the best estimate of the phylogeny for the *cratatellus* series. With the exception of the sister relationship between *A. poncensis* and *A. pulchellus*, this tree does not conflict with any of the moderately to well-supported nodes of the morphological tree and is congruent with many of the fixed or nearly fixed morphological characters (including karyotype). The three other moderately to well-supported nodes of the morphological tree are also well supported in the mtDNA tree. With the exception of the relationships of *A. pulchellus* and *A. poncensis*, the combined mtDNA tree is also congruent with all the moderately- to well-supported nodes in the trees based on all the other data sets. Incongruent relationships between the combined mtDNA tree and other analyses involve nodes that are not even moderately supported in the separate analyses. Finally, the mtDNA tree is topologically identical to a MANOB (parsimony) analysis of combined second allozyme, morphology, and mtDNA data sets (not shown) except for a weakly supported, conflicting placement of *A. acutus* as the sister of *A. evermanni*.

The tree that best explains the combined data (Fig. 8) is similar to past phylogenetic hypotheses of the *cratatellus* series. In particular, our results agree with the summary tree of Gorman et al. (1983:Fig. 6), based on analyses of allozyme and karyotypic data, in supporting the sister relationships of *A. stratulus* with *A. evermanni*, *A. cratatellus* (and *A. scriptus*) with *A. cooki* (and *A. monensis*), *A. pulchellus* with *A. krugi*, and *A. gundlachi* with the grass-bush species. Our results strongly support the relationships of *A. acutus*, a taxon whose phylogenetic

affinities were ambiguous in the earlier study, with the trunk-crown anoles *A. evermanni* and *A. stratulus*. The morphological data place *A. acutus* as the sister taxon to the grass-bush + trunk-ground clade. *Anolis acutus* shares with this clade a distinct tail crest (character 19), keeled ventral scales (15), and the derived condition of the splenial overlap of the coronoid (31). However, the tail crest is absent in the grass-bush species, keeled ventrals are variably present in the grass-bush + trunk ground clade, and *A. stratulus* and *A. evermanni* lack splenials and therefore were not scored for character 31. The 12S, cyt *b*, and combined mtDNA, in contrast, support the placement of *A. acutus* with the trunk-crown anoles, *A. evermanni* and *A. stratulus* (LBP = 66–85%, PP = 0.86–0.99). Although not classified into any recognized ecomorph, *A. acutus* is morphometrically most similar to the trunk-crown anoles (Losos and de Queiroz, 1997).

One notable conflict with past studies is the placement of *A. gundlachi* and *A. poncensis* relative to the other grass-bush species. Gorman et al. (1983) placed *A. gundlachi* sister to a clade composed of the three grass-bush species. In contrast, our preferred tree places *A. gundlachi* nested within this grass-bush clade, however the combined mtDNA data cannot reject the hypothesis that the grass-bush anoles are monophyletic (SH test, $P = 0.184$).

The placement of the Hispaniolan and Bahamian distichoids relative to the *bimaculatus* and *cratatellus* groups is not well supported. Nevertheless, in contrast with earlier hypotheses (e.g., Gorman et al., 1980, 1983), our results indicate that the distichoids are not particularly closely related to *A. acutus*, *A. evermanni*, and *A. stratulus*, nor are they nested within the *cratatellus* series (here defined as the clade stemming from the most recent common ancestor of *A. cratatellus*, *A. pulchellus*, *A. evermanni*, and *A. stratulus*). However, the combined mtDNA data cannot reject the hypothesis that the distichoids form a clade with *A. acutus*, *A. evermanni*, and *A. stratulus* ($P = 0.07$), nor the hypothesis that the distichoids are sister to the *cratatellus* series ($P = 0.49$).

TABLE 6.—Divergence times (in millions of years) with 95% confidence intervals estimated by the NPRS analysis. The left side of the table represents estimated times with the basal divergence of the *cristatellus* series fixed to 8 MYA and the right to 16 MYA. Letters identify nodes in Fig. 9.

Node	8 MYA			16 MYA		
	Estimated Age	Lower 95% C.I.	Upper 95% C.I.	Estimated Age	Lower 95% C.I.	Upper 95% C.I.
A	10.2	10.0	10.4	20.3	19.8	21.2
B	9.1	9.0	9.3	18.2	17.7	18.9
C	5.7	5.5	5.8	11.3	10.7	12.0
D	6.4	6.2	6.6	12.8	11.9	13.6
E	4.8	4.6	5.0	9.7	9.1	10.2
F	3.8	3.6	3.9	7.5	7.0	8.1
G	6.1	6.0	6.1	12.1	11.8	12.4
H	5.5	5.4	5.5	10.9	10.6	11.2
I	4.6	4.5	4.7	9.3	8.9	9.6
J	3.0	3.0	3.1	6.1	5.7	6.4
K	4.4	4.3	4.5	8.7	8.4	9.1
L	3.1	3.0	3.2	6.2	5.9	6.5
M	3.2	3.1	3.3	6.4	6.1	6.7
N	1.7	1.6	1.7	3.4	3.1	3.6
O	1.3	1.2	1.4	2.6	2.4	2.8

turing seem to pass through a *cristatellus* type stage, suggesting that convergence may occur via hypermorphosis.

Historical Biogeography of the *Anolis cristatellus* Series

Any inferences about the biogeographic history of the *Anolis cristatellus* series must be made without aid of a detailed fossil record. Amber-preserved anoles exist from the mid-Miocene of the Dominican Republic (Rieppel, 1980; de Queiroz et al., 1995; Polcyn et al., 2002), but these species are not closely related to the *cristatellus* series. Puerto Rican fossils for the *cristatellus* series are limited to late Pleistocene deposits and include remains of species resembling *A. cristatellus*, *A. evermanni*, and *A. krugi* (Pregill, 1951). These data suggest that anoles have existed in the Caribbean at least since the Miocene and that all three ecomorphs found in the Puerto Rican members of the *cristatellus* series were already established by the late Pleistocene. Due to the lack of pre-Pleistocene fossil evidence, our biogeographic hypotheses are based primarily on our best estimate of the phylogeny of the group (Fig. 8), recent interpretations of the geologic history of the region, and divergence dates inferred by the NPRS analysis (Table 6; Fig. 9). Unless otherwise noted, the following geological discussions rely primarily on the work of Iturralde-Vinent and MacPhee (1999) and references therein. The Puerto Rican

island bank—which formed a single landmass when sea levels were lower during the Pleistocene and includes the island of Puerto Rico and most of the Virgin Islands, but not

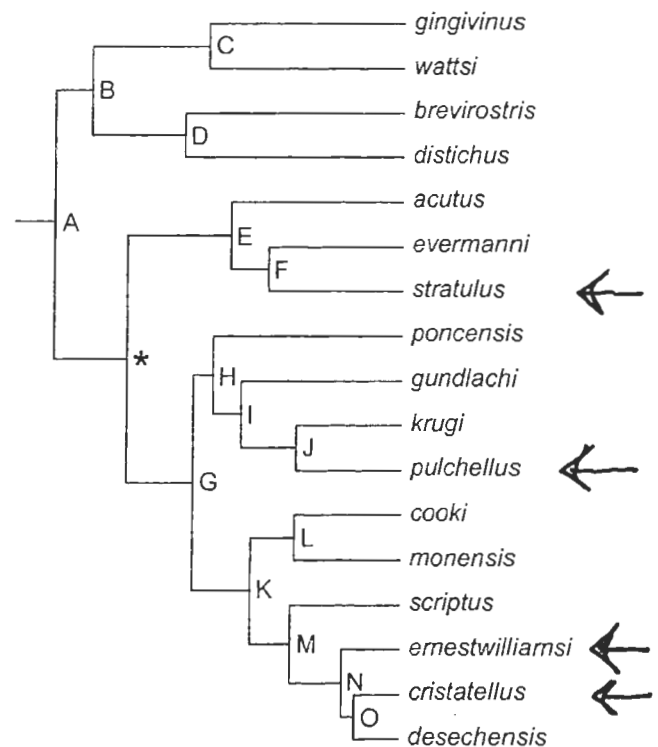


FIG. 9.—Chronogram inferred by the NPRS analysis. Branch lengths represent time. Node labels correspond to Table 6. The asterisk represents the node for which the age was fixed at 8 or 16 MYA.

the islands of St. Croix, Mona, Monita, or Desecheo (Heatwole and MacKenzie, 1967)—will be referred to simply as Puerto Rico in the following discussion. Because of the weakly supported relationships among the distichoids and the *bimaculatus* and *cristatellus* groups we restrict our biogeographical discussion to the members of the *cristatellus* series.

The presence of *A. acutus* on St. Croix is enigmatic. St. Croix has had no aerial connection to Puerto Rico since the Early Oligocene (33–35 MYA; Iturralde-Vinent and MacPhee, 1999) if ever. The dates inferred by the NPRS analysis suggest that *A. acutus* split from the common ancestor to *A. evermanni* and *A. stratulus* ~10 MYA. Thus, the isolation of this species on St. Croix is best explained by dispersal. Yet, the position of St. Croix to the southeast of Puerto Rico requires that the ancestor of *A. acutus* disperse against the prevailing east-west sea current. Although these currents generally flow east to west, experiments of satellite-tracked, free-floating buoys (Molinari et al., 1979) have demonstrated that a floating object does not necessarily follow an unaltered east-west journey. Rather, it is subject to local conditions such as cyclonic circulation or storms (Molinari et al., 1979; Kinder, 1983; Kinder et al. 1985; Sou et al., 1996; see Fig. 11A, Iturralde-Vinent and MacPhee, 1999). Therefore, local current conditions could possibly permit debris from Puerto Rico to reach nearby islands not immediately downstream. Hurricanes may provide another mechanism allowing dispersal of the ancestor of *A. acutus* to St. Croix. This phenomenon has been documented recently with the dispersal of multiple specimens of *Iguana iguana* to Anguilla from islands further south (Censky et al., 1998). Although currently, high-energy storms generally travel southeast to northwest, changes in the Circumtropical Current during the Mid to Late Miocene, if they existed, could have deflected these storms southward (Iturralde-Vinent and MacPhee, 1999).

A combination of vicariance due to Pliocene or Pleistocene changes in sea level and over-water dispersal on prevailing currents best explain the distribution of the *cristatellus* series taxa that currently inhabit the Virgin Islands (other than St. Croix) and satellite islands of Puerto Rico. During periods of

maximum glaciation, sea levels in the Caribbean were as much as 160 m lower than the present level (Donn et al., 1962). As a consequence, Puerto Rico and the Virgin Islands (except St. Croix) formed a single exposed landmass. As sea levels rose, they subsequently fragmented that landmass (Heatwole and Mackenzie, 1967) and isolated populations of widespread species, including *A. pulchellus*, *A. stratulus*, and *A. cristatellus*, on a number of different islands in this group. The isolation and subsequent evolution of large body size of an *A. cristatellus* population on one of the small cays known as Carrot Rock resulted in the currently recognized *A. ernestwilliamsi* (Lazell, 1983). It should be noted that *A. cristatellus* is a widespread taxon that exhibits substantial genetic substructure (R. Glor, personal communication), while *A. ernestwilliamsi* is a small, allopatric population that is likely most closely related to nearby populations of *A. cristatellus* in the Virgin Islands. Given that our sample of *A. cristatellus* is from the north central part of the main island of Puerto Rico, its divergence from *A. ernestwilliamsi* on Carrot Rock (Fig. 9) and estimated divergence date (~1.7–3.6 MYA) is likely greater than that for geographically more proximate populations of *A. cristatellus* in the Virgin Islands.

The prevailing southeast to northwest sea current has likely remained unchanged since the appearance of the Panamanian land bridge at the end of the Pliocene (Iturralde-Vinent and MacPhee, 1999). This current would bring debris from the Puerto Rican Island bank to islands off the western shore (Desecheo, Mona, Monita), where *A. desecheensis* and *A. monensis* now occur, as well as to the Bahamas, which are currently inhabited by *A. scriptus* (Heatwole and MacKenzie, 1967; Williams, 1969). The ability of animals to survive on floating debris in the Caribbean is well documented (Heatwole and Levins, 1972; Censky et al., 1998).

The well-supported sister relationship of *A. monensis* and *A. cooki* suggests that Mona and Monita were colonized by *A. cooki* or a common ancestor. Although geological information about these islands is scarce, they are composed of limestone and hypothesized to have been uplifted sometime in the Miocene and not previously connected to Puerto Rico

(Kaye, 1959). Given that *A. cooki* is restricted to the southwestern portion of Puerto Rico and that ocean currents lead directly from this region to the vicinity of Mona and Monita (see above), the occurrence of *A. monensis* on those islands is best explained by over water dispersal (Williams, 1969). As in the case of *A. cristatellus* and *A. ernestwilliamsi*, the age of the split between *A. cooki* and *A. monensis* (~3.2–6.5 MYA) may be overestimated. Although *A. cooki* is not nearly as widely distributed as is *A. cristatellus*, our sample of *A. cooki* is from the central part of the distribution of the species, while the most likely source of colonists for Mona and Monita is farther to the west. If *A. cooki* exhibits geographically structured mtDNA haplotypes, then samples of western *A. cooki* may exhibit smaller levels of divergence from *A. monensis*, implying a more recent divergence time.

It has been suggested that the Bahamas were submerged prior to 65,000 years ago (Alt and Brooks, 1965). If true, the isolation of *A. scriptus* in the Bahamas must have occurred since that time. Yet, our estimate for the divergence of this taxon relative to *A. cristatellus*, *A. ernestwilliamsi*, and *A. desecheensis* is much older (~3.3–7.6 MYA). This discrepancy may be explained simply as a gene tree split rather than a species split (similar to the cases of *A. ernestwilliamsi* and *A. monensis*, above). Alternatively, a Bahamian landmass may have remained continually aerial during periods of maximum sea level or was colonized via some geographically intermediate landmass on which the ancestral population is now extinct (as postulated to explain a similar phenomenon for the Galápagos iguanas [Rassman, 1997]). Given that the Bahamas and Puerto Rico have not been physically connected any time since the break-up of Hispaniola and Puerto Rico, the occurrence of *A. scriptus* in the Bahamas can only be explained by dispersal. In addition, *A. scriptus* is restricted to the southeasternmost islands in the archipelago (Schwartz and Henderson, 1991), which are the same islands that would most likely be colonized from Puerto Rico via ocean currents.

What little geologic information exists for Isla Desecheo indicates that it is not part of the Puerto Rico landmass and likely became aerial some time during the Pleistocene, remaining emergent since (Seiders et al., 1972). The

island is only 21 km offshore of Puerto Rico and in the direct path of ocean currents from that landmass. Thus, dispersal from a mainland population of *A. cristatellus* is probable. Once again, the estimated divergence between *A. cristatellus* and *A. desecheensis* (~1.4–2.5 MYA) is likely overestimated given that our sample of the former species is from north central Puerto Rico while the most likely source of colonists is the eastern part of the island. We can nonetheless infer that the isolation of *A. desecheensis* is a relatively recent event.

Taxonomy

The relationships inferred in this study (Fig. 8) have implications for the taxonomy of the *cristatellus* and *bimaculatus* series, and we therefore propose a revised taxonomy for those groups. Several studies have indicated a close relationship between the *cristatellus* and *bimaculatus* series (e.g., Etheridge, 1959; Jackman et al., 1999; Poe, 2004). We apply the name *Ctenonotus* to this putative clade, not as a genus name (Guyer and Savage, 1987), but as the name of a subclade of the larger clade *Anolis*. No formal definition is proposed for *Ctenonotus*, but the name is applied to the least inclusive clade containing *A. bimaculatus*, *A. watsi*, *A. distichus*, *A. cristatellus*, and *A. evermanni*. Subclades of *Ctenonotus* are given informal names composed of the specific epithet of the earliest named included species combined with one or more terms traditionally used as taxonomic ranks between genus and species (series, subseries, species group, and superspecies), following Etheridge (1959), Williams (1976), and many subsequent authors. In our taxonomy, however, these terms are not used as taxonomic ranks but simply as parts of the informal clade names. Nevertheless, these terms are used in a way that maintains their traditional hierarchical relationships (e.g., the *cristatellus* series includes the *cristatellus* subseries which includes the *cristatellus* species group). Otherwise, these terms are, for the most part, used arbitrarily (e.g., the *acutus* subseries could just as well have been the *acutus* species group). One exception is that we have reserved use of the term "superspecies" for clades composed of species

X₁W

all of which are mutually allopatric. Lists of terminal species within the smallest named clades begin with the species upon whose name the name of the clade is based. The remaining species are listed alphabetically (as opposed to being sequenced in order of phylogenetic branching). Because relationships of the distichoids remain uncertain, they are placed in their own series, following Burnell and Hedges (1990). Because our study focuses on the *cratatellus* series, subclades and lists of included species are given only for that series. For species included in the *bimaculatus* and *distichus* series, see Burnell and Hedges (1990), except that *A. eugenegrahami* is excluded from the *distichus* series (Williams, 1989).

Ctenonotus Fitzinger 1843

bimaculatus series

distichus series

cratatellus series

acutus subseries

A. acutus Hallowell 1856

A. evermanni Stejneger 1904

A. stratulus Cope 1861

cratatellus subseries

cratatellus species group

cratatellus superspecies

A. cratatellus Duméril and
Bibron 1837

A. deseichensis Heatwole 1976

A. ernestwilliamsi Lazell 1983

A. scriptus Garman 1887

monensis superspecies

A. monensis Stejneger 1904

A. cooki Grant 1931

pulchellus species group

A. pulchellus Duméril and Bibron
1837

A. gundlachi Peters 1876

A. krugi Peters 1876

A. poncensis Stejneger 1904

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Stout Iguanas: Historical Perspectives and Status Report

John Binns

International Reptile Conservation Foundation

(All photographs are by the author unless otherwise indicated)

Anegada

R.H. Schomburgk first noted the presence of *Cyclura pinguis* (Stout or Anegada Iguana) on Anegada in 1832, but literature documenting the status of this species has been sparse. However, each progressive publication has described or implied an ever-increasing concern for its survival. Accounts from the 1940s and 1950s are essentially non-existent. By the early 1960s, large-scale development was planned for Anegada. Although these plans were never fully realized, the initial groundwork destroyed the traditional stone paddocks used to corral livestock, unleashing goats, sheep, cattle, and burros to roam and propagate freely. Excessive grazing has since reduced the natural plant community to secondary, largely toxic vegetation. Today, almost all free-ranging cattle and burros are emaciated and only goats are thriving.



This Anegada Iguana was estimated to be over 20 years old.

In 1968, W. Michael Carey conducted a field study on the ethoecology of the Stout Iguana and, in his classic 1975 paper, stated: "whatever the methods, steps must be taken now to ensure the continued existence of *C. pinguis* on Anegada."



Emaciated cattle are a common sight on Anegada. Although the vegetation appears rich, the plant matter is all secondary growth.

This statement was based in large part on his observations of competition for available food between Stout Iguanas and livestock and of predation on iguanas by domestic mammals.

Following Carey, James Lazell worked with Stout Iguanas in 1980 and 1982–1986 and Numi Mitchell worked with them in 1987–1996. Glenn Gerber, then with the University of Tennessee and presently with the Zoological Society of San Diego, began working on the species in 1998 under auspices of the IUCN/SSC Iguana Specialist Group (now funded by the International Iguana Foundation) and the British Virgin Islands National Parks Trust (BVINPT).

James Lazell first observed Stout Iguanas on Anegada in 1980 while employed by The Department of Natural Resources and the Environment (DNRE), Government of the British Virgin Islands. Expecting to find large densities at Citron Bush, the site of Carey's 1968 study, he instead found that iguanas had completely disappeared from the area in the intervening 11 years. Lazell subsequently found the highest remaining



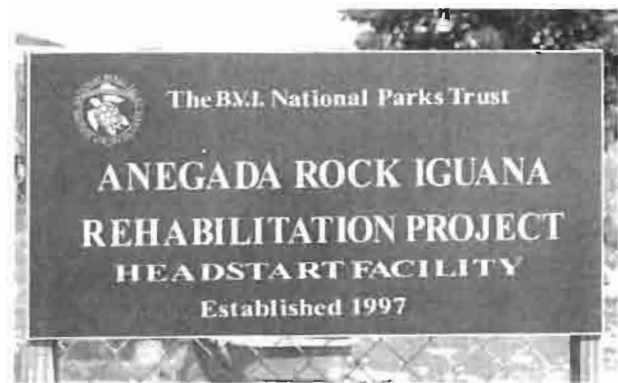
Aerial photograph of Bones and Windlass Bight, Anegada, BVI. This small stretch of land that lies between the ocean and salt ponds is the only core Stout Iguana habitat left on Anegada. Access cuts as well as the main road passing through the area are visible in the photograph.

concentration of iguanas at Bones Bight, which today remains one of the core areas for the species.

Carey's warning was reiterated by others, but efforts to fund the removal of livestock and feral predators remain mostly unsuccessful, despite some recent activity. In 1997, concrete efforts to secure the species' future materialized in the form of the Anegada Iguana Headstart Facility. In October 1997, at the request of BVINPT, West Indian Iguana Specialist Group (WIISG) members Rick Hudson (Fort Worth Zoo), Jeff Lemm (San Diego Zoo, CRES), and Rondel Smith (BVINPT) constructed a small facility to house three juvenile Stout Iguanas found floating in Manhead Pond. The facility provides a safe haven for collected



The Anegada Iguana Headstart Facilities currently hold about 80 captives. The two structures at the front left are new cages located close to the gate, allowing visitors to view these rare animals. The main cage system lies behind these new cages. Current keepers, Rondel Smith and Lee Vanterpool, have made substantial improvements and all animals are in good health.



The Anegada Iguana Headstart Facility's new sign is displayed proudly at the entrance.

hatchlings until they are large enough to reduce the threat of feral predators. A year later, a grant from the UK Foreign Commonwealth Office to the BVINPT and WIISG T-shirt and poster sales funded construction of the main complex by Rick Hudson and Jeff Lemm, joined this time by Mike Fouraker and Glenn Gerber. In August 2001, the International Reptile Conservation Foundation (IRCF) and the BVINPT funded an upgrade to the facilities to increase captive capacity. Team members for this project were John and Sandy Binns (IRCF), Alberto Alvarez (PR-DNRE), Juliann Sweet, Joel Friesch (IRCF), and Rondel Smith and Lee Vanterpool (BVINPT).

To date, none of these head-started captives have been released into the wild, but a limited release on Anegada, coupled with the relocation of a few captives to a neighboring island, has been discussed. In conjunction with this dialogue, a population assessment of Stout Iguanas is planned



This five-year-old captive Anegada Iguana is one of the older animals at the facility. Captive iguanas at the facility tend to be smaller than iguanas observed on Guana and Necker in the same age groups.



Fallen Jerusalem, BVI: this small island is a possible relocation site for some of the head-started animals on Anegada. This island, with no feral livestock, is well fortified with large rock boulders that offer a degree of protection during heavy storms and hurricanes.

during July 2003 to update the previously published estimate of fewer than 200 remaining in existence.

Controlling livestock or feral predators on Anegada is nearly impossible due to the island's remote location and the tens of thousands of dollars that would be required. So, in 1980, in light of the obviously rapid and apparently unchecked decline of the iguana population during the previous decade, Lazell and his colleagues believed that the species was headed for extinction — unless something was done immediately. Because a solution on Anegada was not feasible and Anegada was the only place where the species still existed, the obvious recourse was to establish a second population — but where and by what means?



Heavily degraded habitat on the East End of Anegada near Crasy Pond once supported subpopulations of Stout Iguanas. In 1984, the DOA converted a deep freshwater limestone solution hole called "The Fountain" to an above-ground watering hole, providing a permanent water source for feral livestock. Recent surveys in and around the East End suggest that Stout Iguanas have been extirpated.

Guana

Essentially all possible relocation sites in the British Virgin Islands were equally infested with feral predators and goats. However, in 1932, Chapman Grant had noted the presence of iguanas on Guana Island and had identified the species as *Iguana iguana* (Common or Green Iguana), but the presence of that species was never confirmed and none has been seen since. Sometime in the mid-1930s, Louis Bigelow, then owner of Guana Island, had extirpated goats and had banned woodcutting for making charcoal. This had left only a couple of domesticated burros and free-ranging sheep on the island. The latter are far less destructive than goats.



A Guana Island view to the north showcases its rich flora.

In 1974, Henry and Gloria Jarecki purchased Guana Island. Access to this small island (300 ha) is limited, although it lies only a few kilometers from Tortola. The exclusive Guana Island Club had been constructed in a location designed to



Guana Island's lush habitat clearly demonstrates the positive results of controlling feral animals.

minimize impact on the natural habitat, attributable to the foresight of Louis Bigelow, who chose the construction site of the main clubhouse in the 1930s. Hiking trails around the island also were conceived to protect and minimize destruction of the lush vegetation.

In 1980, Lazell initially approached Mary Randall, then Guana Island Club Manager, to determine if the owners would allow relocation of Stout Iguanas. Randall was very enthusiastic about the concept, but two years would pass before Lazell would meet the owners and take the next step.

In the interim, he continued working on a plan that would establish a second population of Stout Iguanas while promoting other conservation and restoration goals in the British Virgin Islands. An idea for an exchange of species came with the realization that the vast salt ponds of Anegada, which had supported large colonies of Greater Flamingos (*Phoenicopterus ruber*) in the 19th century, could be restored if funds could be found. The beauty of this plan was the mutual benefits to all parties involved: the British Virgin Islands and the residents of Anegada would benefit from the reintroduction of flamingos and, at the same time, the second population would provide some assurance for the long-term survival of Stout Iguanas.



Practically any view from Guana Island is breathtaking.

Lazell first discussed the plan with several Anegada residents. One of them was the late Clement Faulkner, who maintained a Stout Iguana feeding station adjacent to his home in Bones Bight. The plan next was presented to Robert Creque (DNRE), Lazell's boss at that time. Everyone agreed that the idea made eminently good sense.

In March 1982, Lazell finally discussed the possibility of relocating iguanas with the Jareckis, who were initially apprehensive. Would Stout Iguanas damage the island they had worked so hard to protect? Would they bite staff or visitors or destroy ornamental plants on the hotel grounds? These questions would take some time to answer. However, that meeting was instrumental in developing the long-term relationship between the Jareckis and The Conservation Agency (Lazell) that continues today.

During the remainder of March and April 1982, Lazell surveyed the island with the help of Lianna, Divonne, and Tom Jarecki (nieces and son of Henry and Gloria) and the late author, Gerald Durrell, who happened to be vacationing there.



"Hambone," one of the founding iguanas on Guana Island, frequents the vicinity of the Club. Photograph by Numi Mitchell.

Lazell visited Guana regularly over the next several years, conducting fieldwork with the aid of the managers, Mary Randall and her successor John Damron. Lazell also continued to build a portfolio of published papers and testimonials noting the disastrous effects of feral competitors and predators on Stout Iguanas and their habitat. Major contributors were the late Dr. William MacLean (University of the Virgin Islands), Walter Phillips of Water Island, USVI, Dr. Robert Chipley, and Nick Clarke, former Director of the National Parks Trust, BVI.

In 1984, the Jareckis agreed to rid their island of sheep, provide a sanctuary for Stout Iguanas, and fund the relocation of flamingos. Their decision certainly was influenced by Lazell's efforts, but they also were drawn into wildlife conservation

through the interest their sons and nieces had shown. Today, Eugene Jarecki remains interested in conservation. Tom Jarecki works for the Environmental Defense Fund, and Lianna Jarecki is teaching biology at H.L. Stouff Community College on Tortola, BVI and is finishing her Ph.D. with a thesis on salt pond ecology.

In July 1984, Lazell and four colleagues set off to Anegada in search of the first Stout Iguana destined for relocation to Guana Island. Lazell eventually captured a large, healthy, gravid female (SVL 46 cm) that was taken to Guana, where she was released on 29 July 1984. The other seven iguanas that comprised the founding stock (sex, SVL, and release date) were: male (41 cm; 19 July 1985), female (44 cm; 19 July 1986), female (22.4 cm, 27 July 1986), two females (33.5 and 43 cm, latter gravid) and two males (50.4 and 50.9 cm; 31 July 1986). Guana now had the foundation for a second population, but years would pass before the success of the relocation could be evaluated.

Lazell next set out to complete the species exchange plan. The Bermuda Aquarium, Museum, and Zoo (BAMZ) had both captive-bred and wild-stock flamingos and agreed to donate a number sufficient for establishing a population. Numi Mitchell (TCA) arranged the international transfer of the birds (BVI Agriculture and Fisheries Permit and veterinary certification of the birds' health, especially Newcastle's Disease). Numi and Glenn Mitchell (TCA) and James Conyers (BAMZ) transported the birds by jet from Bermuda to Tortola and then by boat to Anegada. The flamingos initially were released into a net holding pen at the salt ponds, allowing them to recuperate and

adjust to their new environment. On 7 March 1992, in a ceremony at the north end of the salt ponds, the Governor, the National Parks Trust, and the Anegada community celebrated the arrival of the first 18 birds. By 2002, the flock had multiplied to approximately 80 resident birds (Guana also supports six pinioned flamingos in a small salt pond, but they do not reproduce because the population density is too low).

Necker

Necker Island, like Guana, is privately owned and exclusive, with a single luxurious resort, the Balinese Great House, situated on the highest point and overlooking the coral reef-studded waters of the Caribbean. The island supports dense tropical vegetation, composed of both native and non-native plants and enhanced by irrigation. The other half of the island is more typical of the region, with rocky terrain and small clusters of hardy trees, low shrubs, and dense stands of cacti. Designated a bird sanctuary, Necker is home to pelicans, doves, and hummingbirds.



Necker Island, BVI: high atop the island is the Balinese Great House.



Greater Flamingos (*Phoenicopterus ruber*) in holding pens shortly after their arrival on Anegada. Photograph by Numi Mitchell.

In 1994, Richard Branson, owner of Necker Island (30 ha), expressed an interest in establishing a third population of Stout Iguanas. Because the iguanas on Guana had enhanced the natural setting of the island and were well received by visitors, Branson was eager to expand the conservation effort. Lazell had worked previously on Necker and knew the island to be free of feral livestock and rats.

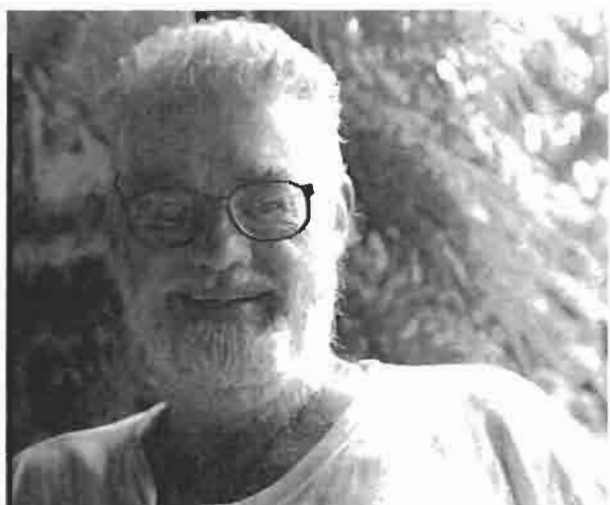
In October 1995, four hatchlings were taken to Necker and head-started for a year before being released. During that time, one female escaped, but was seen later and appeared to be gravid. In 2000, Lazell reported seeing the first hatchling and subsequent reports from the island indicated that Stout Iguana hatchlings were abundant. Although the population is still in its infancy, during the October 2002 population on Necker, founding stock, young adults, and hatchlings were recorded.



A Stout Iguana hatchling on Necker Island basking on the light sand walkway that leads to the beach. Small tail drags were numerous along these walkways.

Today

Long after these second and third populations were established, their existence is not commonly acknowledged, little pertinent information is available, and some controversy remains regarding the



Dr. James Lazell on Guana Island, 2002.

circumstances under which they were established. In 2002, I was invited to participate in an assessment of the Guana and Necker populations. That survey, directed by Lazell and Mitchell, was conducted during "Scientists Month" from 4–29 October (each year, Guana hosts a large contingent of scientists who conduct research on the island).

After 14 hours of travel and delays, Guana was a little piece of paradise. At the dock, my gear was loaded into the Club's pickup and we proceeded up the steep, twisting road to the clubhouse. The Club overlooks the dense tropical vegetation of the island's southern end, the salt pond — home to the six flamingos, and the white beach of a little cove that merges imperceptibly with the crystalline waters of the Caribbean.



A southerly view of Guana Island from the Club. The salt pond with the six flamingos is located in the lower left and the beach and docking area in the center.

When I arrived at the patio, which overlooks the equally picturesque northern end of the island, it was alive with more scientific dialog than I could begin to imagine — scientists, some 20 of them, at lunch. After brief introductions, focus quickly returned to the population survey that was already in progress.

That same afternoon, we were issued several 2-oz syringe barrels loaded with white latex paint and began a survey of the Club's wooded perimeter and nearby support structures. Many Stout Iguanas, including the founders, live in close proximity to the Club. The weather was cloudy and damp from the morning's rain, which kept iguanas from venturing far to bask or forage.

The first sighting was somewhat unusual. We came upon four workmen digging a ditch next to a small structure while talking loudly to be heard over the radio playing in the background. Above them on a rock ledge, a large iguana lay casually, as if supervising their work. We marked the animal with paint, which did not appear to disturb it, and it remained nearby, seemingly unaffected by the intrusion. The remainder of the day included marking or sightings of younger adults and juveniles, but the weather was clearly hampering our efforts. The founding iguanas and other older adults were nowhere to be found.

The next day, Mitchell and I explored the area west of the main facility, accessed from the "Iguana Trail," while another team surveyed the southern area. The weather had improved, but remained partly cloudy and cool compared to typ-



This subadult Stout Iguana was foraging casually along the hillside near the Iguana Trail and allowed us to approach within 3 m. This animal was marked after the photograph was taken.



A hatchling Stout Iguana on Guana Island seeks refuge among the branches of a bush, reducing the likelihood of falling prey to a Racer, but increasing the chances of being spotted by a Kestrel.



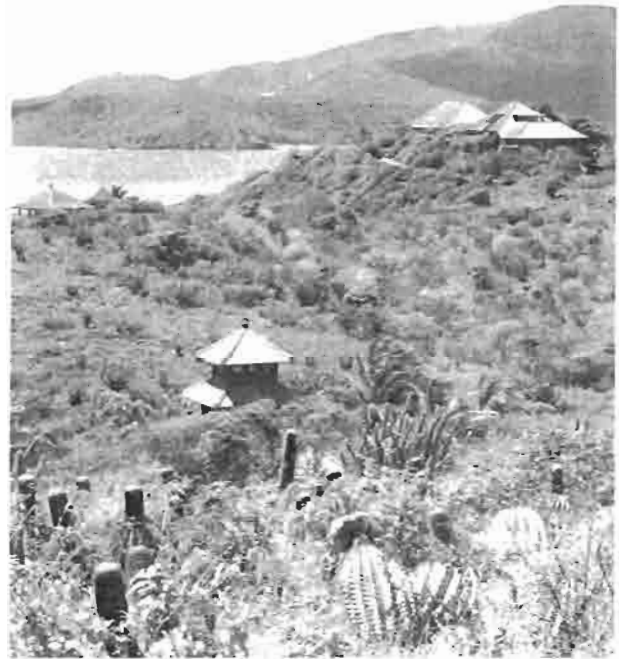
Iguana Trail: a path originating at the lower Guana Club level and leading leisurely to the salt pond and beach below.



Guana Island's North Trail was created to minimize impact on the habitat, yet it provides hikers with fabulous views of the surrounding natural features. About 300 m beyond this point, an adult Stout Iguana was sighted thundering off into a cactus thicket.

ical conditions. Our first marking was a subadult on a steep wooded slope not 50 m from the trail's entry point. Like our first iguana on the previous afternoon, it was rather nonchalant about our presence.

That afternoon, we focused our attention on the northern section of the island where iguanas were not known to occur. Tail-drags are common on trails in the area south of North Beach, but they abruptly disappear to the north of a line roughly parallel with Crab Cove. The trail eventually splits into two routes, and Mitchell and I separated to cover more ground. About halfway between Crab Cove and Chicken Rock Steps, I observed one large, unmarked adult, who, unlike others we had observed, responded to the intrusion by quickly thundering off into a cactus



A southwesterly view of Necker Island showing the Balinese Great House (upper right) and the retreat quarters in the pagoda styled structure (foreground). Stout Iguanas were sighted within this area.



A southerly view from the north side of Necker Island reveals habitat more typical of the region, with rocky terrain and small clusters of hardy trees, low shrubs, and dense stands of cacti.

thicket. We saw no other iguanas or tail-drags, but did see some scat.

The survey continued and the weather improved each day, as did the frequency of iguana sightings. In addition to the population size estimate (see "Assessment" on p. 49), we recorded three incidents of predation on juvenile Stout Iguanas, two by Racers (*Alsophis portoricensis*) and the other by a female Kestrel (*Falco sparverius*).

Early on the morning of 14 October, ten of us left Guana by boat for Necker Island to assess the third population of Stout Iguanas, only seven years after the initial four hatchlings were released. The survey was limited to two days, and the team members quickly dispersed upon arrival.

Mitchell and I began our survey at a location near the main facilities where iguanas are fed twice a day. The ground and trails showed many signs of tail-drags clearly produced by individuals of vastly different sizes. We saw several iguanas in the thick shrubs around this area. From there, I worked the very dry northern section of the island and saw

only one drag and one scat. Mitchell sighted a few animals as she worked an area near where the iguanas are fed.

Others on the survey team successfully marked several individuals and recorded sightings of hatchlings along the pathways around the maintenance and support facilities. Two Racers also were observed in the same area.



Racers on Necker Island commonly feed on juvenile Stout Iguanas.

The next day, starting where the iguanas are offered food, we saw two of the founding iguanas. A conservative estimate placed these animals at about 47 cm SVL and well over 5 kg. Both appeared in excellent health, alert, and with coloration of rich brown above blending into turquoise flanks. We spent our remaining time around the nursery and beach facilities and saw several iguanas, including a subadult and hatchlings. As on Guana, the Necker iguanas appeared to concentrate near the developed areas.

In stark contrast to the boisterous excitement that characterized the boat ride to Necker, we quietly sought a comfortable spot for the return trip. Although tired from the day's hard work in blaz-



One of the four founding Stout Iguanas on Necker Island (shown near the feeding area) was hiding behind a clump of debris, straining to see if his morning serving had arrived.

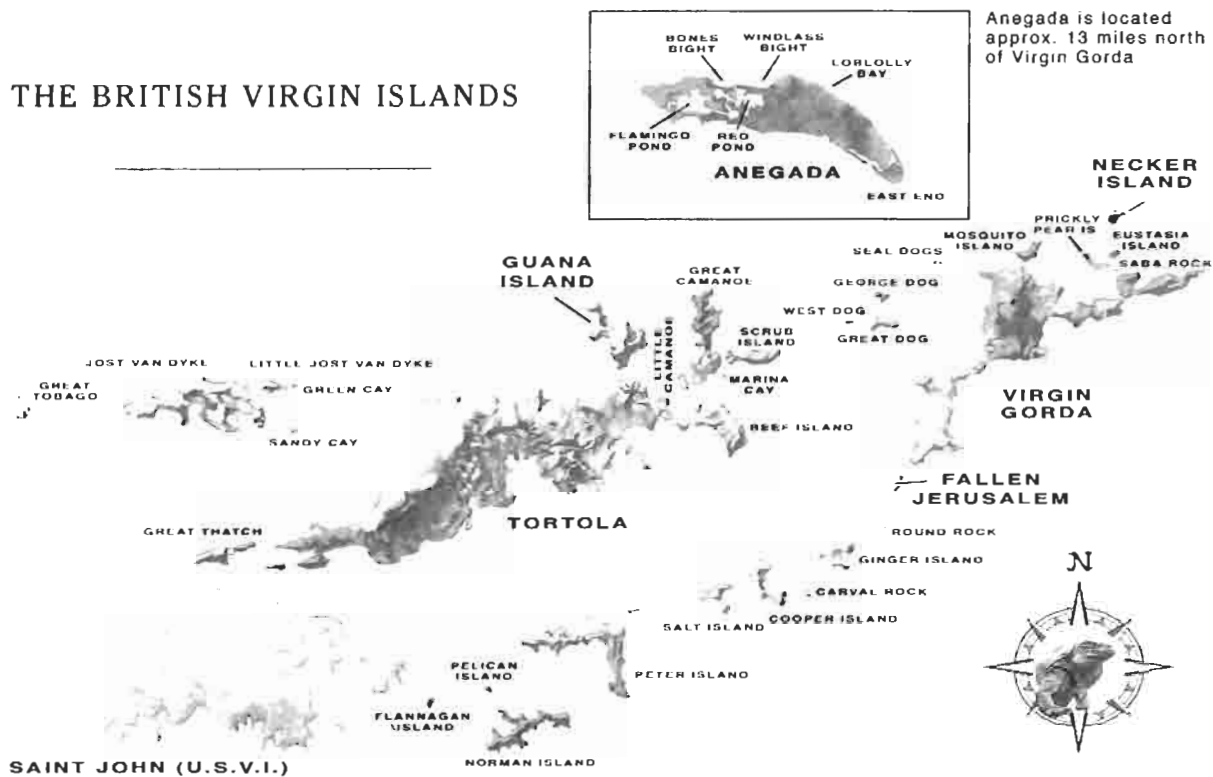
ing sun, we had time to reflect on events that had led us to this point in time and space.

The absence of committed, long-term funding continues to impede efforts to secure the species' survival on Anegada. Compounding loss of habitat is ongoing development. Consequently, Stout Iguanas are fighting for survival, suffering simultaneously from habitat degradation and predation on juveniles. Some fear that the upcoming assessment will determine that the Anegada population has declined to critically low numbers and may be functionally extinct in the wild. However, I believe we all shared a warm feeling knowing that the outlook for Stout Iguanas had improved considerably through the efforts of a few very special people.



This lightly wooded area near a salt pond on Anegada shows vegetation heavily damaged by feral animals seeking shelter from the sun or areas to rest. Habitat such as this has no chance of recovery while feral animals are allowed to roam free.

THE BRITISH VIRGIN ISLANDS



Anegada is located approx. 13 miles north of Virgin Gorda

Acknowledgements

I thank James Lazell and Numi Mitchell for the invitation to participate in the Guana and Necker island population assessments, and Henry and Gloria Jarecki and Richard Branson for their hospitality and enduring commitment to ensuring the survival of Stout Iguanas. Allison Alberts, Rick Hudson, and Glenn Gerber have been instrumental in all my conservation efforts, and my wife Sandy has her sleeves rolled up right beside me. This article has benefited from comments by Gad Perry and Robert Powell.



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Guana and Necker Island Population Assessments 2002

Gad Perry and Numi Mitchell
The Conservation Agency

Only rarely is a population so thoroughly known that every member is individually recognized and a full census possible. Because of this, a variety of statistical methods, some of them extremely sophisticated, are normally employed to estimate population sizes. As with all statistical methods, population estimates have limitations. The amount of available data is one crucial factor: the more, the better. In addition, certain assumptions, some of them unique to one set of estimators or another, apply.

Unfortunately, studies on critically endangered species tend to run afoul of one or both issues, making reliable population estimates difficult. This is the case with Stout Iguanas. Not only are the populations small, they are unreliable subjects (a captured adult iguana may retreat into its burrow for up to three weeks in response to the stress), hard to spot in the field (the terrain is rough and the animals are cryptically colored), and often not accessible (work on Guana normally can be conducted only during the month of October). These limitations render any estimate of population size less reliable than one would like and therefore much less satisfying to a wildlife manager. Nonetheless, work with endangered species requires that their population sizes be estimated, so that one can determine if the population is stable, growing, or — in a worst-case scenario — declining. A preliminary estimate, known to be imperfect, is better than none, as long as the limitations of the estimate are kept firmly in mind when management decisions are being made.

Several attempts to monitor the Guana iguana population were made over the years. Combined with the evidently growing numbers of hatchlings every year, they suggested that the population was doing well and growing at a steady pace. In October 2002, a more concerted effort was made by marking several individuals with water-based, white, exterior latex paint (which quickly dries and is waterproof) squirted from a two-ounce (60 cc) syringe barrel. Marking began on 4 October and continued until 13 October. Twenty-three individuals were marked, but on most days some sighted iguanas escaped unmarked. Beginning on 15 October, we did six

“round-up” counts of marked and unmarked individuals, finishing on 29 October. These provided six population estimates, based on the Petersen Index: 69, 115, 138, 138, 138, and 207. The numbers are relatively close to one another, suggesting that they probably represent a fairly robust estimate. A calculated mean (134) is probably not too far from the real number. A calculated standard deviation (45 in this case) allows us to say that we are 95% confident that the true population size is between 44 and 224: two standard deviations from the mean in each direction. Unfortunately, this method does not meet all of the assumptions of the test, which renders the numbers uncertain.

A second method for calculating population sizes was proposed by Z.E. Schnabel in 1938. Using this method, we can add to the six Petersen Index tallies the data from 4–13 October. This method generates remarkably similar numbers, estimating the population size at 95 individuals and the 95% confidence interval at 58–185. Once again, not all of the assumptions are met, but the fact that two very different methods with different assumptions led to similar estimates gives us more confidence that the population size really is about 100 individuals.

We arrived on Necker Island on the afternoon of 14 October 2002 and quickly marked five Stout Iguanas. The next day before our departure, we saw six iguanas, only one of which was marked. The implication is that one-sixth of the population was marked; so five times six is 30. No statistics can be done on a single estimate, but this observation conforms remarkably well with the opinion of resident naturalist and caretaker, Brian Andrews, who believes that about 20 individuals are present, not counting the current year's hatchlings.

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**Meeting with Skip Lazell (Conservation Agency) and Gad Perry (Texas Tech):
Issues and Points of Discussion relating to Anegada iguana conservation**

December 9, 2004

Fort Worth Zoo

Preface: Presently two “camps” are working along parallel lines to conserve the Anegada, or Stout, iguana in the BVI. The IUCN Iguana Specialist Group (ISG) is focused on trying to restore the population in its remaining natural habitat on Anegada, and is bound by an MOU agreement with the BVI National Parks Trust (NPT). The Conservation Agency/Guana Island Group is working to expand the species’ range in the BVI, and throughout the greater Puerto Rican Bank, and has successfully established wild populations on Guana and Necker, and moved and introduced iguanas to Norman and Little Thatch.

This meeting was initiated by Lazell and Perry and discussions centered on the following themes: *What can be done to reduce the current animosity between the two camps and integrate the programs for the benefit of the iguana?*

I. Species Recovery Plan: last drafted in April 2004 in Miami. Funds are being sought to compile the document into publishable format and Joseph has agreed to allocate time to Nancy Woodfield to complete.

Questions: 1) Where does this process stand now?
2) Is this SRP specific for the Anegada population? If not, shouldn't a SRP include other island populations throughout the species range?

II. Integrating the programs and populations: *Can we consider periodic genetic exchanges between the isolated populations in the future?*

Skip and Gad suggested moving hatchling iguanas from Guana back to Anegada in October 2005. This would be a “show of good faith” gesture, a gift with no strings attached.

Other suggestions:

- Genetic exchange between the US captive group at San Diego Zoo and Guana
- Sending SDZ stock to Puerto Rico to establish colonies on satellite islands
- Sending Guana stock to Puerto Rico to establish colonies on satellite islands

Question: can we begin discussions again on expanding *pinguis* populations to Puerto Rican offshore cays from sources other than Anegada since moving specimens from there is so contentious?

Currently SDZ has the following holdings of *Cyclura pinguis* and has successfully reproduced them four times from 2001 – 2004: 1.0 hatch 2001 (0.2 hatch 2001 are at Miami Metrozoo), 1.0 hatch 2002, 1.2 hatch 2003 and 0.0.5 hatch 2004 (18 total specimens, 16 at SDZ and 2 at Miami). Fort Worth Zoo will be building an iguana conservation and research center in 2005 and we would like to target *pinguis* for work. FWZoo could take two cohorts of juveniles from San Diego, ideally 9 hatchlings each from 2005 and 2006. Research on nutrition and the effects of social groupings on stress hormones and growth are being discussed.

III. Funding issues that ISG needs assistance with on Anegada: the ISG's perception is that if you are rich and own an island in the BVI, you can get iguanas without contributing to their conservation other than activities on the receiving islands. This needs to change. Funds from "well-heeled" sources in the BVI should be available to assist with conservation on Anegada, as this population is not a lost cause. Hudson suggested that funding for Anegada from Henry Jarecki, Richard Branson and John Maynard could go a long way as a unifying gesture and help alleviate the divisiveness. Suggested projects:

- **Island Conservation (IC) predator eradication feasibility study:** Skip will approach Jarecki about funding this. He stated that Henry was very result-driven and that if funds were spent with no results, it would have negative consequences for future funding
- **Genetic Study:** currently Glenn Gerber is holding a lot of DNA samples collected from Anegada and we are looking for someone to analyze these data. Skip suggested that it would be beneficial to compare the genetics on Anegada with the introduced populations on Guana and Necker. Has there been a significant founder effect, and corresponding loss of gene diversity in the sub-populations? Skip will approach potential donors about funding such a project. If funds were available would we consider combining the data for a comparative study? Who do we have in mind to undertake this project, and is Catherine Malone still interested? Is SDZ planning another IMLS grant for this?
- **Field research vehicle:** the IIF has put up \$4,000 toward the purchase of a small truck to be used on Anegada by the field research teams, contingent on matching funds. Perhaps private donors would be willing to match this.

IV. Growth data and Body Size: Gad has a manuscript that he intends to submit to Journal of Herpetology on *Reproduction and size in the endangered stout iguana*. His study is limited to Guana, Necker and Little Thatch iguanas, but includes some old Carey and Mitchell data for comparison. He is interested in collaborating and including recent data from Anegada which Gerber and Bradley own.

Conservation of the Extremely Endangered Stout Iguana

Gad Perry and James Lazell

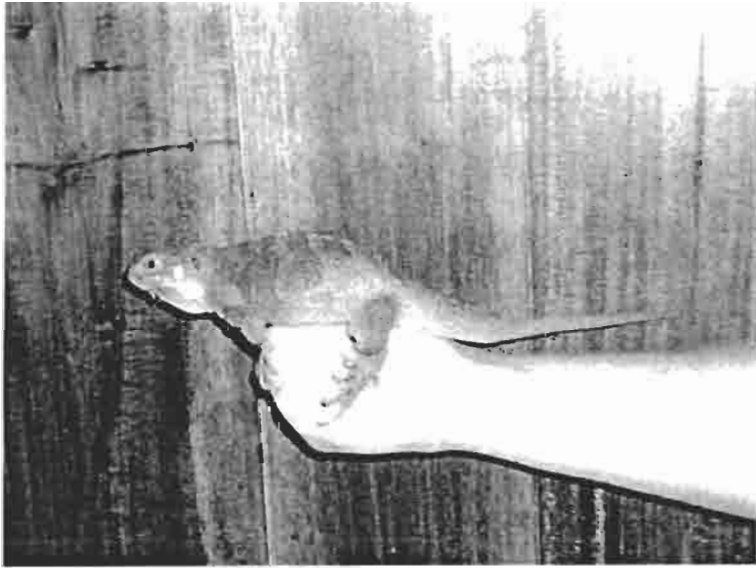
The stout iguana was originally found throughout the Greater Puerto-Rico Bank, but today survives only in the British Virgin Islands. With only about 200 individuals remaining, it is one of the most critically endangered species in the world. Until recently, the only surviving population existed on the island of Anegada, where increasing development and introduced herbivores and predators greatly degraded conditions and caused major population declines. To increase its chances of survival, the iguana has been reintroduced to a number of islands. The population on Guana Island appears to be flourishing, and the Necker Island population is also expanding. The severe threat currently facing the species makes detailed information about its biology essential to successful conservation and restoration efforts. We have been working to address this need by studying the natural history of the iguana and its reproduction.

Our findings are encouraging. The Guana Island population is consistently producing a large number of juveniles, with egg-laying occurring on sandy beaches in the summer and hatchlings dispersing into the interior of the island in the fall. Juvenile numbers are high enough that they are once again becoming part of the food cycle, and we have observed predation events by the native snakes and kestrels. During 2003 and 2004, we have captured, measured, and released nearly 50 juveniles, and have discovered that they begin growing almost immediately; weight gain is measurable even within the

To: Dr. Gad Perry

57

first few weeks of life. We hope to be able to track some of these individuals throughout their lives, documenting their ecology, growth patterns, and long-term survival.



A hatchling who survived a failed predation attempt showing tail damage/ and regeneration.
Picture by Gad Perry

^

Otherwise lovely!

Email:

>>> "Perry, Gad" <

> 01/13/05 8:56 AM >>>

Dear Dr. Gerber,

Rick Hudson tells me you were interested in providing input on our manuscript, which he circulated some weeks ago. I left a message on your machine a week ago, saying we'd like to submit the manuscript as soon as we can but will hold off for a bit to allow you to do so. Since I haven't heard back, I assume you are out of the country, so I thought I'd contact you by e-mail. While I'm doing so, let me also say that I would love it if you wanted to contribute related Anegada data to the paper (in exchange for authorship, of course). I think the paper would be both stronger and of greater value if it covered all free-ranging populations, and I am sure that your work on Anegada has resulted in collection of additional datapoints that could serve to complement what we currently have.

Sincerely,

Gad Perry

-----Original Message-----

From: Glenn Gerber [mailto:ggerber@sandiegozoo.org]

Sent: Thursday, January 13, 2005 11:15 AM

To: Perry, Gad

Subject: Re: Anegada iguanas

Ili Gad,

Yes, Rick did share your ms with me and I would like be happy to provide some feedback if you can wait a bit longer. My father died last week and I'm in NY with my mother at the moment. I'll be returning to San Diego early next week and so should be able to get to it not long after that. If you need to send it off sooner, no problem.

I appreciate your offer to include my Anegada data and extend authorship also. However, I'm already working on another ms that includes all my Agegada data so I'm going to pass on that. I would appreciate your comments on this ms down the road though. Kelly Bradley and I also have some growth data for headstarted animals that have been released but this will form part of her MS thesis, which is still in progress.

Best Wishes,

Glenn

Glenn Gerber, Ph.D.

Applied Conservation Division

Conservation and Research for Endangered Species

Zoological Society of San Diego

Dear Glenn,

My condolences on the death of your father. I can certainly wait a little bit longer. In fact, I'll be in Costa Rica 19-24 Jan, so you might as well wait until the 25th or so to respond, if you need to. I'd be more than happy to look at your MS when it is ready for that, and to collaborate on future work to the extent that the political situation allows.

Cheers,

Gad

Cuban Treefrog

09 December 2004

Skip,

About a month ago I told you that I was interested in making a brochure to distribute in the BVI with facts about the Cuban tree frog. Please take a moment of your time to look over what I have designed as well as the reasoning and motivation behind it. You mentioned previously that you might be able to find money to fund the printing if it seemed worthwhile. Please consider what I have designed and let me know if you might be of some assistance to me in this matter. Thank you for your time and consideration.

How the idea came about: I was meeting with Mr. Carnell Smith and Mr. Menchington Israel of the BVI Environmental Health Department and they expressed to me a need for a document that would provide facts on the Cuban tree frog in the BVI. Mr. Smith said that the department receives a lot of calls about the frogs and would like to direct the BVI residents with accurate, easy to understand information. He asked if I could put together something for them to use and distribute and I told them that I would at least produce something that can be copied and distributed by their office (This is always an option if funding is not available).

Currently the following people/organizations are interested in distributing facts on the Cuban tree frog:

- Environmental Health Department
- H. Lavity Stoutt Community College
- Aragorn's Studio
- Trellis Bay Cyber Café
- D Best Cup coffee shop
- Little Secrets Nature Gallery
- BVI Pest Control

Clive Petrovic mentioned that the local newspaper is always looking for information to print and would most likely love to have something like this brochure.

I would also like to get a copy to the manager's of each of the resorts/islands so they know what to be aware of with shipments and such.

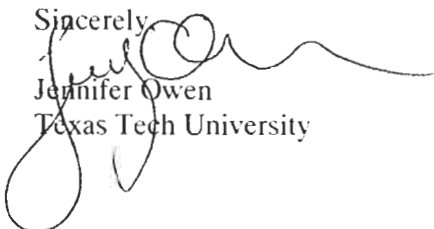
Please take a look at what I have produced and let me know if you are interested in helping in the search for funding. If not, I would still appreciate your input as I will probably still make copies to distribute on a smaller scale (50 or so).

I am currently working on pricing and will give you an estimated cost of production as soon as possible.

Once again, thank you for your time and consideration and please do not hesitate to contact me if you have any questions or comments.

Sincerely,

Jennifer Owen
Texas Tech University





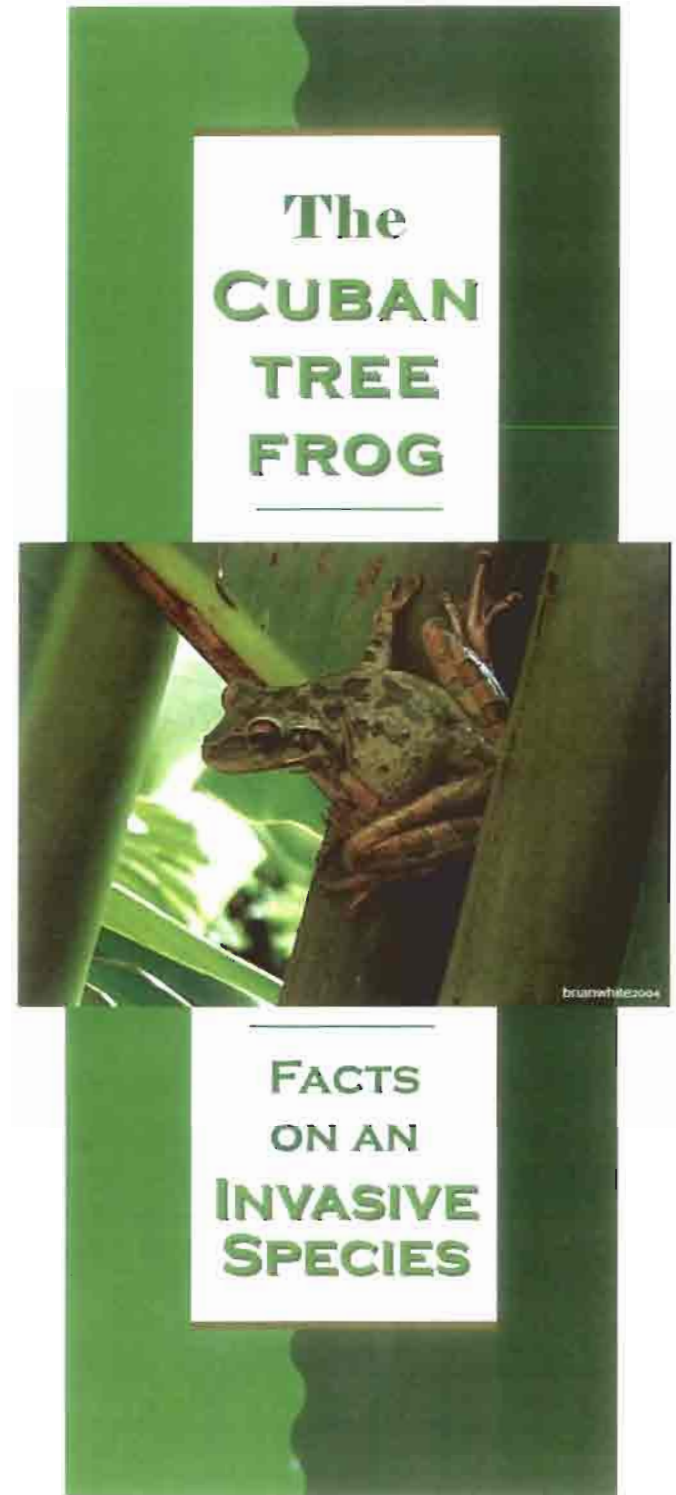
Produced by:

Jennifer Owen and Gad Perry

*Texas Tech University, Dept. of Range,
Wildlife and Fisheries Management*

The Conservation Agency

The Falconwood Foundation



The Cuban tree frog



Cuban tree frogs are **NATIVE** to Cuba, the Cayman Islands, and the Bahamas. They have been **INTRODUCED** in Florida, Hawaii, Puerto Rico, Anguilla, Bonaire, the USVI and the BVI.

You can usually tell the sex of a Cuban tree frog by its size. **MALES** are **SMALLER** with an average body length of 50mm, and **FEMALES** are **LARGER** with an average body length of 80mm.

Cuban tree frogs eat many different types of **INSECTS** and **SPIDERS** as well as the native **FROGS** (bo-peeps) and **LIZARDS** (anoles and geckos).

Cuban tree frogs have two ways of protecting themselves. First is a **MILDLY TOXIC SKIN SECRETION** that the frog produces when it feels threatened. This toxin is not harmful to humans, however if it **gets** in your eyes, nose or mouth it will **cause** a burning sensation. The second way Cuban tree frogs protect themselves is by emitting a **DISTRESS CALL** or screaming when they are grabbed by a predator such as a snake.



How did they get here?

Cuban tree frogs **came** from Florida and Puerto Rico. There are two main ways that Cuban tree frogs move from island to island.

They are:



**IN
UNFUMIGATED
PLANT
SHIPMENTS**



**IN
CONSTRUCTION
MATERIALS**



What is an INVASIVE SPECIES?

An **INVASIVE SPECIES** is a plant or animal that establishes itself in an area outside its normal home area and may cause damage to the native plants and animals.

Cuban tree frogs are an invasive species in the BVI, USVI, Puerto Rico, Florida, Anguilla, Bonaire and Hawaii. They cause damage to the local animals by: eating native insects and spiders, taking food away from native lizards and frogs and even eating native lizards and frogs.

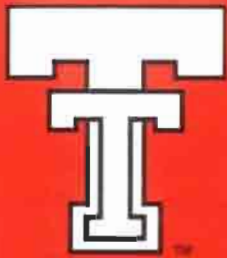


What *you* can do

1. REMOVE any Cuban tree frogs from your CISTERN and SCREEN your CISTERN, including any downspouts—Cuban tree frogs need fresh water to live and lay their eggs.
2. EMPTY any **STANDING WATER** such as in buckets and old tires or boats.
3. Put FISH in garden **PONDS**—fish will eat Cuban tree frog eggs and tadpoles but will not affect native frogs like the bo-peep which lay their eggs in bromeliads and have no tadpole stage.
4. INSPECT items being shipped, especially plants and construction materials.



A cistern in the BVI filled with over 200 Cuban tree frogs.



Research Highlights - 2003
Range, Wildlife, & Fisheries Management

63



**COLLEGE OF AGRICULTURAL SCIENCES
AND NATURAL RESOURCES**

**TEXAS TECH UNIVERSITY
LUBBOCK, TEXAS**

VOLUME 34

Cool lizards stay warm

*Adrian Andrei, Joydeep Bhattachargee,
Dana Ghioca, Kerry Nicholson, Jennifer Owen,
Nikki Radke, Shannon Torrence, and Gad Perry*



Crested Anole eating

Reptiles and amphibians are often called “cold blooded” because, unlike humans, they rely on outside sources of heat to bring their body temperature up to normal activity temperature. The problem is, heating up also means losing water to evaporation – and the British Virgin Islands (BVI), although tropical, often have short supplies of drinking water. To look at this dilemma, several researchers have studied the Crested Anole, a common and highly visible species in the BVI. Previous work has shown that populations on dry islands are

better at conserving water than lizards from wet locations.

In 2003, a tropical ecology graduate class revisited this issue by studying the importance of behavior in allowing the lizards to balance the conflicting demands of keeping warm and avoiding desiccation. The group discovered that body temperature was related to both time of day and relative humidity. Because conditions in the Caribbean are almost constant and temperatures are fairly high, lizards can maintain the body temperature they need without direct exposure to sunlight. Instead, lizards spend over 90% of their time sitting in one place, and that the perch site is usually located in the shade. However, lizards are sensitive to environmental conditions. Because of their smaller body size, juvenile lizards are especially sensitive to water loss. Their activity pattern reflects this vulnerability: smaller animals were significantly less likely to be active during the warmer parts of the day than were larger individuals. This study augments previous work by creating a more complete picture of the problems and solutions pertinent to the daily life of this species in particular and to similar taxa in general.



Identifying stomach contents

Effects of the Invasive Cuban Tree Frog in the British Virgin Islands

Jennifer Owen and Gad Perry

Non-native species are now present in every nation's ecosystems and their economic impact is estimated at over \$100 billion/year in the United States alone. They are also the second leading cause of extinctions, and thus of concern for conservationists. The Cuban Tree Frog (CTF) is currently recorded as invasive in Florida, Puerto Rico, Hawaii and the US Virgin Islands. Our research focuses on the spread of the CTF in the British Virgin Islands (BVI), where it was first seen a decade ago. To determine impacts in the BVI, we are documenting the CTF's distribution, determining its diet, and examining its reproductive output.

Including the latest set of animals, collected during an October 2003 trip, we now have almost 250 preserved specimens at the Natural Science Research Laboratory at the Museum of Texas Tech University. All preserved specimens have been dissected with stomach and intestinal tracts removed and preserved. Work on dietary analysis has begun, and preliminary analysis has identified invertebrates such as spiders, roaches, beetles, and ants. However, native vertebrates such as frogs and snakes were also found in the stomachs, confirming the possible impacts to the local fauna.

Two additional trips to the BVI are planned for July and October 2004, during which further research will be conducted on CTF distribution. Data collected in this study will be used to make informed management decisions regarding current populations and efforts to prevent future spread throughout the United States and the Caribbean.

Tracking the Invasive Agave Weevil in the British Virgin Islands

Gad Perry



Damaged, dying plant

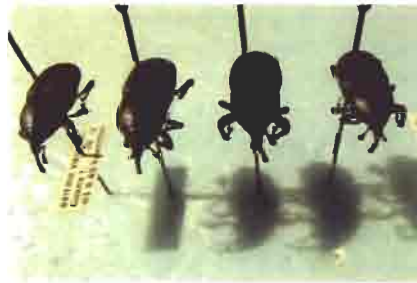


Dead husk

Agaves (also known as century plants) are an important plant in the British Virgin Islands (BVI). The plant is important both as a food source for native insects, birds, and bats, and culturally: the locals use the flower stalk as their Christmas tree. Because of that, it was alarming when a massive die-off was first noted in 2001. With the aid of entomologists Barry and Buena Valentine from Ohio State University and regional expert James Lazell from The Conservation Agency, the cause was quickly identified as the Agave Weevil. In its native range (the Southern

US, Mexico, and parts of South America), this beetle is not normally a problem for native agave species, which are attacked after they flower, when they are dying anyway. However, it is a major pest of agricultural species, such as sisal. It has become invasive at many locations in Asia, Africa, Europe, and Australia. The first beetles were seen in the US Virgin Islands in the 1990s, and may have spread to the BVI that same decade.

Work has focused on two objectives. First, to find out how widespread the impact of the beetle is and to try to identify means of preventing beetle impacts. Second, using information on the present weevil distribution and rate of spread to identify how they got to the BVI in the first place and how they are still spreading, so that invasion by similar pests can be blocked. The data show that the beetle has already killed over 75% of the plant population on some islands, and that on many islands, the impacts are still on the rise. They indicate that the beetle can spread actively over short distances, jumping from island to island and within islands using the wind and their wings. However, long-distance dispersal appears dependent on human assistance in the form of commercial transport of live plants. If additional data bear this tentative conclusion out, the indication is that careful inspection and fumigation can have a major impact on the spread of such costly pests. Despite the short-term inconvenience and cost, biosanitary measures are highly desirable and, in the mid- and long-term, the preferred economical choice.



The Agave weevil, *Scyphophorus acupunctatus*

Jumping Spider

Richman, D. A. 1989. A revision of *Hentzia* (Araneae, Salticidae). J. Arachnol. 17:285-346.

A REVISION OF THE GENUS *HENTZIA* (ARANEAE, SALTICIDAE)

David B. Richman

Department of Entomology, Plant Pathology and Weed Science
New Mexico State University
Las Cruces, New Mexico 88003 USA

ABSTRACT

The genus *Hentzia* belongs in the subfamily Dendryphantinae of the family Salticidae. It appears to be closely related to "*Beata*" *wickhami* and the genus *Anobius*. Twenty species are recognized in this revision, occurring from Nova Scotia and Quebec in the north to northern South America in the south. The genus ranges along the coastal areas of Mexico on both sides of the continent north to Arizona in the west and through central Texas to Mississippi. Six new species are described. These are *H. calypso* from Jamaica, *H. chekika* from Florida, the Bahamas and Cuba, *H. cubana* from Cuba, *H. pima* from Arizona, *H. whitcombii* from Guadeloupe, Puerto Rico and a few other Caribbean islands, and *H. zombia* from Hispaniola. The genera *Parahentzia* Bryant 1943, and *Moebiabeata* Caporaccio 1947, are here made junior synonyms of *Hentzia*. *Parahentzia insignita* Chickering 1946, is made a junior synonym of *Anoka parallela* Peckham and Peckham 1894. *Anoka peckhami* Cockerell 1893, and *Wala albovittata* Keyserling 1885, become junior synonyms of *Ictus vittatus* Keyserling 1885. All of these are placed in the genus *Hentzia*. *Balmaceda peckhami* Bryant 1940 is found to be the female of *H. tibialis* Bryant 1940. The female paratype of *Hentzia tibialis* Bryant 1940, is found to be the female of *Hentzia chekika* n. sp. Finally *Wala noda* Chamberlin 1976, is transferred from *Hentzia* to *Corythalia*.

INTRODUCTION

The genus *Hentzia* is composed of somewhat elongate jumping spiders with a primarily circum-Caribbean distribution. The genus was erected by Marx (1883), with *Epiblemum palmarum* Hentz 1832 as the type species. *H. mitrata* was described by Hentz as an *Attus* in 1846, the Peckhams erected the genus *Anoka* for *H. vernalis* in 1893 and Cockerell described *Anoka peckhami* from Jamaica in the same year. Roewer (1954) listed 14 species in the genus, including *antillana* Bryant, *audax* Bryant, *fibriata* (F. O. Pickard-Cambridge), *footei* (Petrunkévitch), *grenada* (Peckham and Peckham), *noda* (Chamberlin), *parallela* (Peckham and Peckham), *peckhami* (Cockerell), *poenitens* (Chamberlin), *squamata* (Petrunkévitch), *tibialis* Bryant, *vernalis* (Peckham and Peckham), *mitrata* (Hentz), and *palmarum* (Hentz). Of these, "*Hentzia*" *noda* was found during the current study not to belong to the genus at all, belonging instead to the genus *Corythalia*, and *H. peckhami* was discovered to be a junior synonym of *Ictus vittatus* Keyserling (now *Hentzia vittata*). Examination of material in the collections of the Museum of Comparative Zoology, the American Museum of Natural History, the Florida State Collection of Arthropods, and the United States National Museum of Natural History, has produced a total of six undescribed species, four represented by both sexes and two only by the female. In addition, the two species of

Henizia antillana Bryant

Figs. 102-108, Map 3

Hala vernalis Petrankewitch 1930:139 (misidentification)*Henizia antillana* Bryant, 1940:494 (holotype male and allotype female from Antigua in MCZ examined).

Diagnosis.—Males can be distinguished from all other members of the genus except *H. whitcombi* n. sp. and some specimens of *H. footei* by the presence of a curved, truncated retromarginal tooth on the chelicerae. It can be distinguished from *H. whitcombi* by the pattern of promarginal teeth in relationship to the retromarginal tooth and from *H. footei* by the general structure of the chelicerae (Fig. 104). The female epigynal structure has characteristic trumpet-shaped tubes leading to the spermathecae (Fig. 108).

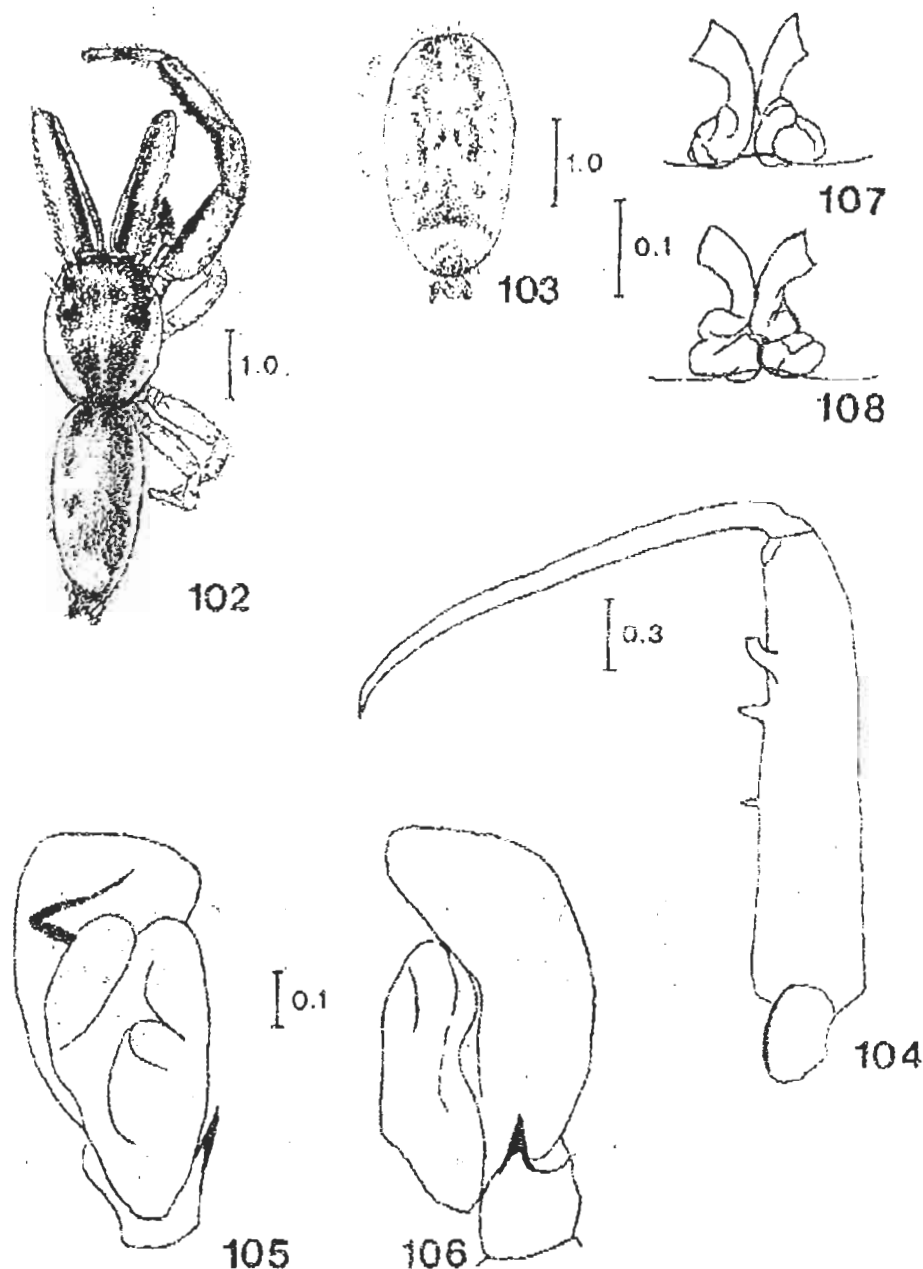
Male.—Total length 3.60-5.00. Carapace 1.50-2.00 long, 1.30-1.70 wide, 0.70-1.00 high at PLE. Ocular area 0.70-0.90 long, 1.00-1.25 wide anteriorly, 1.15-1.40 wide posteriorly. Chelicerae 1.10-2.00 long, 0.30-0.43 wide (10 males from Virgin Gorda, British Virgin Islands). PME slightly closer to ALE than to PLE. Leg formula 1423. Carapace red-brown with white hairs laterally. Dark around eyes. Clypeus with white hairs. Chelicerae yellow brown, promargin red-brown; tang darker. Endites red-brown with lighter inner edge. Labium dark brown. Sternum yellow-brown. Abdomen golden brown, slightly metallic. Venter and lateral areas yellow-gray. First legs yellow-brown; darker under prolateral femora, patellae and tibiae. Indistinct bands on distal patellae, tibiae and metatarsi. Other legs yellow. Pedipalpi red-brown, cymbium and bulb darker.

Female.—Total length 4.05-5.50. Carapace 1.50-2.10 long, 1.25-1.70 wide, 0.60-0.90 high at PLE. Ocular area 0.70-0.80 long, 1.00-1.30 wide anteriorly and 1.10-1.45 wide posteriorly. Chelicerae 0.45-0.80 long, 0.30-0.50 wide (10 females from Virgin Gorda, British Virgin Islands). PME closer to ALE than to PLE. Leg formula 1423. Carapace red-brown with lateral white hairs. Eyes dark. Clypeus with white hairs. Chelicerae red-brown. Endites red-brown with yellow prolateral tip. Labium red-brown. Sternum yellow-brown. Abdomen yellow with red brown markings. A posterior dark band (also seen in *H. vernalis* and *H. squamata* females) is almost always present. First legs red-brown. Other legs yellow. Pedipalpi yellow; annulate at proximal joints.

Distribution.—West Indies from Dominica to Cuba (Map 3).

Natural history.—Males and females have been collected in every month but December. It is probably found in all months as adults. In Puerto Rico the species was common in citrus groves in May and was also occasionally swept from tall grass. In Guadeloupe they were abundant in citrus in February. It is sympatric with *H. whitcombi* over much of its range.

Specimens examined.—ANTIGUA: Antigua (MCZ, USNMNH), Crosbys (MCZ), St. Johns (AMNH), Shirley Heights (MCZ). BARBUDA: Codrington (AMNH). BRITISH VIRGIN ISLANDS: Arnegada (AMNH, USNMNH), Beef Island (AMNH), George Dog Island (AMNH), Ginger Island (AMNH), Greater Thatch Island (AMNH), Green Cay (AMNH), Guana Island (AMNH, USNMNH), Little Comonoe (AMNH), Little Thatch Island (AMNH), Little Tobago (AMNH), Sandy Key (AMNH), Tortola (AMNH, MCZ, USNMNH), Virgin Gorda (AMNH, MCZ). BRITISH WEST INDIES: St. Kitts (MCZ), St. Lucia (MCZ), St. Nevis (MCZ). CUBA: Ceiba (AMNH). DOMINICA: country record (MCZ), Fond Sophie (AMNH), Roseau (AMNH). GUADELOUPE: Mairie Galant (FSCA), Petit Bourg (FSCA), Pointe-a-Pitre (AMNH). HAITI: Port-au-Prince (MCZ). LEEWARD ISLANDS: Saint Maarten (AMNH), Saba (MCZ). MARTINIQUE:



Figures 102-108.—*Hentzia entillana* Bryant: 102, 103, from Isabela, Puerto Rico; 102, male, dorsal view; 103, female, dorsal view of abdomen; 104-106, holotype male from Antigua; 104, left chelicera, ventral view; 105, 106, palp; 105, ventral view; 106, retrolateral view; 107, 108, epigynum of female from Virgin Gorda, British Virgin Islands; 107, ventral view; 108, dorsal view.

Fond la Haye (AMNH), Pointe Ferret (AMNH) Trois Ilets (AMNH). MONTISERRAT: Plymouth (AMNH). PUERTO RICO: Aibonito (AMNH), Arecibo (AMNH), Barros (AMNH), Blanquilla (AMNH), Cabeza de Pairo Island (AMNH), Camalache Forest (AMNH), Camuy (AMNH), Caña Gorda (DBR), Cayo Abogado (AMNH), Cayo Caracoles (AMNH), Cayo San Cristobal (AMNH), Chicken Island (AMNH), Coarao Springs (AMNH), Corozal (AMNH), Desecheo Island (AMNH), Isabela (DBR), Isla Palomirens (MCZ), Isla Ramos (AMNH), Isleta Marina (AMNH), Laguna

Cartagena (MCZ), La Parquera (MCZ), Loma Tinaja (AMNH), Luquillo Mountains (MCZ), Manatí (AMNH), Maricao Bosque National (MCZ), Mayaguez (AMNH, DBR, MCZ), Muertes Island (AMNH), Nicacos Island (MCZ), Quebradilla (AMNH), Pico Atalaya (AMNH), Pineros Island (AMNH), Ratones Island (AMNH), Rio Piedras (MCZ), San Juan (AMNH, MCZ), Vega Baja (AMNH), Vivevero de Catalina (AMNH). UNITED STATES VIRGIN ISLANDS: Anegada (AMNH), Hassel Is. (AMNH), St. Croix (MCZ, USNMNH), St. John (FSCA, MCZ, USNMNH), St. Thomas (MCZ).

Hentzia whitcombi, new species

Figs. 109-113, Map 5

Types.—Holotype male and allotype female from Petit Bourg, Basse Terre, Guadeloupe (25 February 1977, W. H. Whitcomb) deposited in the FSCA.

Etymology.—The species is named for Dr. W. H. Whitcomb, Professor Emeritus, University of Florida, who collected the type series during his study on the natural enemies of citrus pests.

Diagnosis.—Males differ from all other *Hentzia* except *H. antillana* in having long chelicerae with a curved truncated retromarginal tooth. They differ from *H. antillana* males in the arrangement of the cheliceral teeth (Fig. 109). The female epigynum differs from that of *H. antillana* by having round openings (Figs. 112, 113).

Males.—Total length 3.20-4.90. Carapace 1.50-1.90 long, 1.20-1.50 wide, 6.20-8.50 high at PLE. Ocular area 0.70-0.92 long, 1.00-1.22 wide anteriorly and 1.00-1.28 wide posteriorly. Chelicerae 0.65-1.70 long, 2.40-4.00 wide (10 males from Guadeloupe). PME closer to ALE than to PLE. Leg formula 1423. Carapace red-brown with central dorsal spearhead-like light marking with point toward posterior. Lateral areas with white scales. Black around eyes except dark brown around AME. Carapace with scattered iridescent scales. Clypeus brown with white hairs. Chelicerae red brown, darker prolaterally, with fringe of white hairs. Distal 1/5 of fang yellowish. Endites dark brown, tip pale. Labium dark brown, tip pale. Sternum orange. Abdomen dark brown with darker markings, similar to those of *H. antillana*. Dorsum with iridescent scales. Lateral area with pattern of white and brown stripes. Venter light brown. First legs yellow; dark brown prolaterally and ventrally. Other legs yellow. All legs with iridescent scales. Pedipalpi yellow; bulb and cymbium brown.

Female.—Total length 3.80-5.40. Carapace 1.70-2.00 long, 1.30-1.60 wide, 0.70-0.80 high at PLE. Ocular area 0.70-0.85 long, 1.15-1.30 wide anteriorly and 1.20-1.40 wide posteriorly. Chelicerae 0.40-0.60 long, 0.30-0.45 wide (10 females from Guadeloupe). PME closer to ALE than to PLE. Leg formula 1423. Carapace orange; white scales laterally. Black around eyes except brown around AME. Clypeus with white hairs. Chelicerae orange-brown. Endites dark brown, prolateral tip pale. Labium dark brown with pale tip. Sternum yellow. Abdomen yellow with brown markings like *H. antillana*. Venter yellow. First legs yellow with light brown markings on prolateral distal femora, patellae and tibiae, and retrolateral femora. Other legs yellow. Pedipalpi yellow with brown dorsal proximal markings on patellae, tibiae and tarsi.

Natural history.—Males have been collected in January-April and June-July. Females have been collected from January-March and May-August. They probably occur throughout the year.

Termites

29 Nov. '04

Skip -- Us federal employees really work hard to get information to our constituents.

I know that there is a bunch of chemical stuff in the paper that is about as much fun to read as a patent, but there are some aspects of the paper that are fun. The title is cute, you have to admit. The introduction is entertaining. The figures really tell the story.

We just submitted the paper on Friday and it is already out for review. Keep your fingers crossed. Glad we can still contribute to the Guana Island research projects. Lori and I just wish there were other projects for us to work on there. Maybe we should branch out and work on ants of the BVI.

In Brisbane it was good to see that you haven't aged in the 5 or so years since I saw you last. After I recovered from the flight home, I began to miss Australia again. I really do like that place.

Mike

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Journal of Chemical Ecology

Send Galley Proofs to:

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IDENTIFICATION OF TERMITE SPECIES
BY THE HYDROCARBONS IN THEIR FECES

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(Received , 2004; accepted 2005)

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Abstract – Blends of abundant cuticular hydrocarbons are species-specific and can be used to identify a given taxon without the diagnostic castes of the termites (Isoptera), the soldiers or imagoes. We demonstrate that hydrocarbon extracts of termite fecal pellets from damaged wood can also be characterized and used to identify the termites responsible for the damage, even though termites are no longer present or cannot be easily recovered. For example, in structures infested by drywood termites, it is common to find fecal pellets, but difficult to extract termites from the finished wood in service. Nine species of termites belonging to two families (Kalotermitidae and Termopsidae) were examined to compare the hydrocarbon composition of the termites and their fecal pellets. The Kalotermitidae were represented by *Neotermes connexus* Snyder, *Incisitermes immigrans* Snyder, *Cryptotermes brevis* (Walker), *Cryptotermes cynocephalus* Light, *Incisitermes minor* (Hagen), *Procryptotermes corniceps* (Snyder), *Pterotermes occidentis* (Walker), and *Marginitermes hubbardi* (Banks); *Zootermopsis nevadensis nuttingi* Haverty and Thorne was the sole representative of the Termopsidae. Diversity of the hydrocarbon mixtures was extensive: at least one half of the amount of the hydrocarbons from *N. connexus*, *I. immigrans*, *C. brevis*, *C. cynocephalus*, *P. corniceps*, and *Z. n. nuttingi* were olefins. *I. minor* and *P. occidentis* incorporated only small amounts of olefins in their cuticular hydrocarbons; *M. hubbardi* had no detectable olefins. The hydrocarbons extracted from fecal pellets were qualitatively and quantitatively similar to cuticular extracts and can be used to diagnose the termite species responsible without the termites



present.

Key Words -- Cuticular hydrocarbons, chemotaxonomy, dampwood termites, drywood termites, fecal pellets, frass, Kalotermitidae, Isoptera, species identification, Termopsidae.

INTRODUCTION

The cryptic nature of drywood and dampwood termites often precludes their collection for purposes of identification. Because they make their homes within wood, it is often not possible to collect termites without destroying the wooden structure. A commonly utilized sign for determining the presence of wood-inhabiting termites is the associated occurrence of fecal pellets, which are ejected from the galleries within. These pellets are diagnostic for drywood and dampwood termites and can be used to distinguish their damage from other wood-destroying insects (Ebeling, 1975; Moore, 1992).

Drywood and dampwood termites excrete feces in the form of hard, evenly shaped fecal pellets. While collecting drywood termites in a survey of the termites of the Hawaiian Islands (Haverty et al., 2000, unpublished data), we also gathered fecal pellets while removing termites from wood. Rather than simply signaling the general presence of termites, we wondered whether these pellets could be used for more precise diagnosis of the species of termite inhabiting the wood. We hypothesized that termite fecal pellets would contain the same mixture of hydrocarbons as the insects that produced them, and because cuticular hydrocarbons are species specific in termites (Page et al., 2002), we further hypothesized that we could identify termite species by these chemicals in their feces.

The cuticle that covers the outside surface of the termite also lines the inside of the rectum and likely also has a covering of wax composed

mostly of hydrocarbons. Fecal pellets of termites are formed in the elongate, bulbous rectum that is used for the temporary storage of undigested food particles (Child, 1934). Pellets are elongate and have six flattened sides that coincide with the rectal papillae. The six surfaces are a result of pressure applied by the six plates within the rectal epithelium. The hindgut, including the rectum, is ectodermal in origin, an invagination of the ectoderm of the embryo (Snodgrass, 1935; Romoser and Stoffolano, 1998). The hindgut is lined with chitinous intima which is continuous through the anus with the chitinous exoskeleton; the epithelial layer of the rectum is enormously thickened and contains a heavily chitinous intima (Child, 1934).

Fecal pellets must be dehydrated before expulsion; resorption of water represents an essential ecological adaptation for xeric conditions (Noirot and Noirot-Timothee, 1969). The function of the rectum is to press out and conserve the water content of material that enters from the colon. Water is absorbed through the rectal wall. During compression for removal of water, it is highly likely that fecal pellets acquire a hydrocarbon coating before extrusion. This may even facilitate discharge of pellets. Elimination of the fully formed pellet is accomplished by relaxation of the anal sphincter, and contraction of the radial and longitudinal rectal muscles (Child, 1934).

Characterization of the cuticular hydrocarbons of termite species supports the concept of species specificity of hydrocarbon mixtures (Haverty et al., 1988, 1996a, 1997, 1999, 2000; Watson et al., 1989; Kaib et

al., 1991; Brown et al., 1994, 1996; Haverty and Nelson, 1997; Takematsu and Yamaoka, 1999; Clément et al., 2001; Nelson et al., 2001; Page et al., 2002). Owing to the ontogenic origin of the insect hindgut, i.e., invaginated ectoderm, we hypothesized that external (cuticular) hydrocarbon might also be present internally and picked-up by expelled fecal material. Here we report another method of identifying species of drywood termites when the diagnostic castes are lacking or when termites are no longer present or difficult to extract from infested wood, but their leavings (i.e., damaged wood and fecal pellets) remain.

METHODS AND MATERIALS

Collection of Termites. Termites used in this study were gathered to document the cuticular hydrocarbons of termites from the British Virgin Islands (Haverty et al., 1997) and the Hawaiian Islands (Haverty et al., 2000). Collections of *Pterotermes occidentis* (Walker) and *Marginitermes hubbardi* (Banks) were also made in the vicinity of Tucson, Arizona, and collections of *Zootermopsis nevadensis nuttingi* Haverty and Thorne were made near Mt. Shasta, California. In total, nine species of termites belonging to two families were collected. The representatives of the Kalotermitidae included *Neotermes connexus* Snyder, *Incisitermes immigrans* Snyder, *Cryptotermes brevis* (Walker), *Cryptotermes cynocephalus* Light, *Incisitermes minor* (Hagen), *Procryptotermes corniceps* (Snyder), *Pterotermes occidentis* (Walker), and *Marginitermes hubbardi* (Banks); *Zootermopsis nevadensis nuttingi* Haverty and Thorne was the sole representative of the



becomes 2-meC27; 13,15-dimethylheptacosane becomes 13,15-dimeC27; and heptacosadiene becomes C27:2. Hydrocarbons are presented in the tables for each species and its feces in the order of elution on our GC/MS system.

Integration of the total ion chromatogram was performed using the HP Chemstation data analysis software. GC-MS peak areas were converted to percentages of the total hydrocarbon fraction. A summary of the relative amounts of each peak for termites and fecal pellets using representative chromatograms of each species was prepared and presented in table form.

Cluster Analyses of Hydrocarbon Mixtures from Termites and Fecal Pellets.

The percentage of each hydrocarbon was used as the response variable. The presence of co-eluting compounds precluded exact quantification of many individual hydrocarbons; the quantity of each hydrocarbon in each such peak was equal to $1/n$ of the value for the peak, with n = the number of hydrocarbons in the peak. The Euclidean Distance and Manhattan Distance for all 18 combinations of termite species by insect or fecal pellets were calculated using all hydrocarbons (R Statistical Language 2004). Results are displayed as a dendrogram.

RESULTS AND DISCUSSION

The cuticular hydrocarbons for five of these species (*Neotermes connexus* Snyder, *Cryptotermes brevis* (Walker), *Cryptotermes cynocephalus* Light, *Incisitermes immigrans* Snyder, and *Incisitermes minor* (Hagen)) from

Hawaii (Haverty et al., 2000) and one additional species (*Procryptotermes corniceps* (Snyder)) from the British Virgin Islands (Haverty et al., 1997) were previously characterized. In these papers, detailed discussions of the composition of the cuticular hydrocarbons of each species were presented. The composition of the hydrocarbon mixtures for these six species and the hydrocarbons from their fecal pellets are displayed in Figures 1-6 and summarized in Tables 1-6.

In this paper we also provide detail for the cuticular hydrocarbon mixtures of two additional drywood termite species, *Pterotermes occidentis* (Walker) and *Marginitermes hubbardi* (Banks), from Arizona, as well as the hydrocarbons from their fecal pellets, that have not been previously reported (Figures 7 and 8, Tables 7 and 8). We (MIH and LJJ) previously reported the composition of the cuticular hydrocarbons for frozen samples of *Z. nevadensis nuttingi* (*Zootermopsis* Phenotype III) (Haverty et al., 1988). In this paper we provide more detail and identify additional hydrocarbons not previously detected, as well as the hydrocarbons from fecal pellets (Figure 9, Table 9). The results of the method used in this paper are not equivalent to extracting live or freshly frozen termites, and demonstrate that there are quantitative differences in the composition of cuticular hydrocarbons extracted from dried specimens (Haverty et al., 1996b).

The cuticular hydrocarbon mixture of most drywood termite species examined thus far from the West Indies and Hawaii (Haverty et al., 1997, 2000) reflect a general pattern. Cuticular hydrocarbons occur in two

distinct groups: early eluting compounds (23 to 29 or 31 carbons in the parent chain) and late-eluting compounds (37 to 45 carbons in the parent chain). The hydrocarbon mixtures of *I. minor* and *M. hubbardi* are different in that hydrocarbons occur continuously from the early eluting hydrocarbons with 23 carbons in the parent chain to the late eluting hydrocarbons with 43 carbons in the parent chain (Figures 5 and 8). *Z. nevadensis nuttingi* displays a pattern similar to the general pattern for drywood termites with the addition of a few hydrocarbons with 31 carbons in the parent chain (Figure 9).

Hydrocarbons from Termites. *Neotermes connexus* is generally found in rotting wood or living trees in moist, forested areas in Hawaii between 200 and 2000 m in elevation (Zimmerman, 1948). The chromatograms of the cuticular hydrocarbons reflect the general pattern of drywood termites (Figure 1, Table 1). *n*-Alkanes comprised 21.8% of the total hydrocarbon; *n*-C23, *n*-C25, and *n*-C27 were the most abundant. Olefins were, by far, the most predominant hydrocarbons representing over 52% of the total hydrocarbon; dienes and trienes were the most abundant olefins. Terminally branched monomethylalkanes, mainly 2-; 3-meC23 and 2-meC24, accounted for 23.6% of the total hydrocarbon. Internally branched monomethylalkanes were rare; neither dimethylalkanes nor trimethylalkanes were detected.

Incisitermes immigrans is the predominant drywood termite in lowland xeric and coastal littoral forests, where it infests living and dead, standing trees, exclusive of man-made structures (Zimmerman, 1948). It is

hubbardi (see below) than that of *I. immigrans* (Figure 2), or other drywood termites from the tropics (Haverty et al., 1997, 2000). Hydrocarbons occurred in a continuous "series" from *n*-C23 to 13,17-dime-C43 without the unoccupied region from C29 to C33 (Table 5). *n*-Alkanes comprised 17.7% of the total hydrocarbon. The unsaturated components constituted only 19.7% of the total hydrocarbon, a proportion much lower than that of tropical kalotermitids. Late-eluting olefins predominated in this component. The terminally branched monomethylalkanes amounted to 6.7% of the total hydrocarbon, whereas internally branched monomethylalkanes totaled 6.9%. Dimethylalkanes were the predominant class of compounds, making up 42% of the total hydrocarbon. *I. minor* also made a homologous series of trimethylalkanes representing 7.0% of the total hydrocarbon.

Procryptotermes corniceps is found throughout most of the islands of the West Indies (Scheffrahn et al., 1994; Haverty et al., 1997). It can be found in dead wood of native vegetation, including fence posts, but has not yet been recorded from structures (Collins et al., 1997). The cuticular hydrocarbon mixture of *P. corniceps* (Figure 6) was very similar in gross comparison to that of *C. brevis* (Figure 3). The early eluting components were almost exclusively *n*-alkanes and terminally branched monomethylalkanes, and the late eluting compounds were primarily olefins (Table 6). *n*-Alkanes comprised 8.7% of the total hydrocarbon. As with *C. brevis*, the alkenes, alkadienes, and alkatrienes were the predominant class of cuticular hydrocarbons, totalling over 76% of the



total hydrocarbon. The terminally branched monomethylalkanes made up 12.2% of the total hydrocarbon.

Pterotermes occidentis occurs primarily within the general limits of the Sonoran Desert in southern Arizona and Baja California. *P. occidentis* has been found in very few tree species, most commonly in blue palo verde, *Parkinsonia florida* (Bentham ex A. Gray) S. Watson (Nutting, 1966). The cuticular hydrocarbon mixture of *P. occidentis* has never been published, therefore we will provide a detailed description here. Once again, cuticular hydrocarbons occurred in two distinct groups: early eluting compounds (25 to 31 carbons in the parent chain) and late-eluting compounds (41 to 43 carbons in the parent chain): the early eluting compounds predominated, representing over 92 percent of the total hydrocarbon (Figure 7, Table 7).

n-Alkanes were, by far, the most abundant hydrocarbons representing over 40% of the total (Table 7). *n*-C25, *n*-C27, and *n*-C29 comprised ca. 10.5%, 14.7%, and 9.1% of the total hydrocarbon, respectively. The other *n*-alkanes accounted for 6.6% of the total hydrocarbon (Table 7). In contrast to the tropical drywood termite species, olefins were not the predominant hydrocarbons, representing only 5.0% of the total (Table 7). Two monoenes, C41:1 and C43:1, made up the majority of these hydrocarbons.

Terminally branched monomethylalkanes were identified for C24 to C27 (Table 7). 2-MeC25 and 3-meC25 accounted for 2.8% and 2.6% of the total hydrocarbon, respectively. The remainder of these terminally

Hydrocarbons from Termite Fecal Pellets. In general, the hydrocarbons from whole-body extracts of drywood termites were represented qualitatively and quantitatively in extracts of fecal pellets from the same species. Extracts of fecal pellets were more similar to those of their producers than they were to extracts of any other termite species or their fecal pellets. Cluster analyses with all hydrocarbons, using either the Euclidean or Manhattan distance, consistently paired the hydrocarbon mixture from fecal pellets with the hydrocarbon mixture from termites of the species that produced the pellets (Figure 10).

The hydrocarbon mixtures from whole-body extracts and that of fecal pellets were not identical; minor differences did occur and were likely the result of one or more factors. For example, some termite/pellet pairs were not from the same colony or location (*N. connexus*, *I. immigrans*, and *C. brevis*); thus the minor qualitative and quantitative differences between termites and fecal pellets could simply reflect intraspecific variation. When certain hydrocarbons were found in the termites, but not in the fecal pellets, and *vice versa*, they often occurred in very small quantities, usually less than 1.0% of the total hydrocarbon component (Tables 1-9). Therefore, the lack of certain hydrocarbons could simply also be a function of the concentration of the extracts.

Paraffins, a series of *n*-alkanes, were found in both termite and fecal pellet extracts, but long-chain *n*-alkanes were found only in extracts of termite fecal pellets (Tables 1,2,7,8; Figure 1). *n*-Alkanes with more than 31 carbon atoms are not usually seen in insects; insects apparently cannot

synthesize *n*-alkanes containing more than 34 carbon atoms (Hadley, 1985). In plants, *n*-alkanes are the principal hydrocarbon fraction of the cuticular lipids, ranging in length from 21-37 carbon atoms (Hadley, 1981). It is possible that the long-chain *n*-alkanes from drywood termite fecal pellets were a contaminant from plant origin, from the ubiquitous Parafilm[®] used in most laboratories or even contamination from hand lotion. We (MIH & LNJ) occasionally see paraffin contamination in dried termite samples sent to our laboratory; such contamination complicated evaluation of chemotaxonomic characters of two species of Central American *Nasutitermes* (Howard et al., 1988).

Olefins comprised the majority of the hydrocarbon components in 6 of the 9 termites discussed in this paper. Olefins are the least stable and most reactive of the cuticular hydrocarbons. However, for some reason, they remain stable in or on the cuticles of insects. For example, when hydrocarbons were extracted from 70-year-old museum specimens of scolytid cone beetles, *Conophthorus ponderosae* Hopkins, the mixtures were qualitatively identical to those collected and extracted by Page et al. (1990a). To the contrary, once extracted, cuticular hydrocarbons of *Reticulitermes* spp. containing mono-, di- and trienes, lost much of the olefin component when dried and left in a vial for 24 hr, particularly the di- and trienes (Nelson and Haverty, unpublished observations). Thus, something prevents the oxidation of olefins while still in the cuticle. On or in fecal pellets, the olefins appeared to be as stable as they are within the cuticle of the termites.

The composition of the hydrocarbon mixture of insects is genetically controlled (Toolson and Kuper-Simbrón, 1989; Kaib et al., 1991; Page et al., 1991; Coyne et al., 1994). This composition can be slightly affected by diet and environmental conditions (Hadley, 1977; Espelie et al., 1994; Chapman et al., 1995; Howard, 1998; Woodrow et al., 2000). Because cuticular hydrocarbon mixtures are generally species-specific (see references in the introduction), we were somewhat surprised to observe qualitative differences in cuticular hydrocarbon mixtures between recently collected *Z. nevadensis nuttingi* and those (Phenotype III) described in Haverty et al. (1988). Sevala et al. (2000) found similar qualitative differences between recently collected *Z. nevadensis nevadensis* and those (Phenotype I) reported in Haverty et al. (1988). In the present study we extracted termites that had been dried, while Haverty et al. (1988) extracted freshly frozen (i.e. moist) termites. This could explain the difference, as drying termites first has been shown to enhance extraction of cuticular hydrocarbons, especially the late-eluting olefins (Haverty et al., 1996b). In addition, the olefin component of all four taxa reported by Haverty et al. (1988) was likely under-reported as samples were extracted, the extract dried under nitrogen, then sent to the University of Nevada for identification of the hydrocarbons by GC-MS. Therefore, many (or all) of the olefins could very well have oxidized and no longer been present in the sample for identification. Furthermore, the equipment used by Haverty et al. (1988) (Finnigan 4023 mass spectrometer) was much less sensitive than that used by Sevala et al. (2000) and in this study (HP5890

GC coupled with a HP5989 or 5970 MS, respectively). Thus, minor components and co-eluting isomers could have been missed by Haverty et al. (1988).

From where do the hydrocarbons in drywood termite fecal pellets come? The answer to this question could be as simple as contamination from the cuticles of the termites moving within the gallery system strewn with fecal pellets. Three other scenarios are more likely, however. First, controlled cannibalism is a key to the nitrogen economy of a termite colony. Exuviae, injured or dead individuals, and excess members of any caste are commonly eaten (Moore, 1969). The hydrocarbons ingested could pass through the gut undigested, only to be compacted in the fecal pellets, although this has not yet been tested. Second, the termites moving and storing fecal pellets could be secreting a mixture of hydrocarbons from the various glands (labral, mandibular, labial or salivary) associated with the mouthparts (Noirot, 1969). Third, and most likely, is that hydrocarbons are deposited onto the fecal pellets within the rectum during or after the fecal dehydration process. Oenocytes transmit hydrocarbons within the hemolymph to their epicuticular destinations (Schal et al., 1998; Sevala et al., 2000). Because the rectum is lined with cuticle (Child, 1934), hydrocarbons are likely transferred to the epicuticular cells of the rectum and then transferred to the surface, or lining, of the rectum.

What is the significance of fecal hydrocarbons that are similar to those found in termite cuticles? With more sampling across additional

taxa, diagnostic hydrocarbons could be identified (Haverty et al., 1997) and a key to species developed (Haverty et al., 2000) for either nondiagnostic castes, such as larvae, nymphs, and pseudergates or workers, or even fecal pellets alone. This knowledge could potentially have applications for quarantine operations to identify species or damage to wood products or solid wood packing material and contain the spread of invasive termite species. In addition, our findings open up the possibility of other chemicals, such as semiochemicals, being deposited on or within fecal pellets with the pellets functioning as a slow-release mechanism. The possibility also exists that other wood-destroying insects could also be identified to species according to the hydrocarbons in their feces.

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FIGURE CAPTIONS

FIG. 1. Total ion chromatogram of the cuticular hydrocarbons from nymphs of *Neotermes connexus* Snyder from Iao Valley Lookout, Maui, Hawaii, and from fecal pellets of *N. connexus* from junctions of Hwy 550 and 552, Kauai, Hawaii.

FIG. 2. Total ion chromatogram of cuticular hydrocarbons from pseudergates of *Incisitermes immigrans* Snyder from Poipu Beach, Kauai, Hawaii, and from fecal pellets of *I. immigrans* from Kualoa Beach, Oahu, Hawaii.

FIG. 3. Total ion chromatogram of the cuticular hydrocarbons from pseudergates of *Cryptotermes brevis* (Walker) from Honolulu, Oahu, Hawaii, and from fecal pellets of *C. brevis* from NOAA laboratory, Kewalo Basin, Oahu, Hawaii.

FIG. 4. Total ion chromatogram of the cuticular hydrocarbons from pseudergates of *Cryptotermes cynocephalus* Light from Waiahole Valley Road, Kamehameha Highway, Oahu, Hawaii, and from fecal pellets from the same collection.

FIG. 5. Total ion chromatogram of cuticular hydrocarbons from pseudergates of *Incisitermes minor* (Hagen) from Fresno, California, and from fecal pellets from the same collection.

FIG. 6. Total ion chromatogram of the cuticular hydrocarbons from pseudergates of *Procryptotermes corniceps* (Snyder) from Guana Island, British Virgin Islands, and fecal pellets from the same collection.

FIG. 7. Total ion chromatogram of the cuticular hydrocarbons from



pseudergates of *Pterotermes occidentis* (Walker) from the Santa Rita Experimental Range near Tucson, Arizona, and fecal pellets from the same collection.

FIG. 8. Total ion chromatogram of cuticular hydrocarbons from pseudergates of *Marginitermes hubbardi* (Banks) from the Saguaro National Monument southeast of Tucson, Arizona, and fecal pellets from the same collection.

FIG. 9. Total ion chromatogram of cuticular hydrocarbons from pseudergates of *Zootermopsis nevadensis nuttingi* Haverty and Thorne from the Klamath National Forest northeast of Mount Shasta, California, and fecal pellets from the same collection.

FIG. 10. Dendrogram from cluster analysis based on Euclidean Distance (A) and Manhattan Distance (B) of hydrocarbons extracted from eight species of drywood termites and one species of dampwood termite and their fecal pellets. N. con = *Neotermes connexus*, I. imm = *Incisitermes immigrans*, C. bre = *Cryptotermes brevis*, C. cyn = *Cryptotermes cynocephalus*, I. min = *Incisitermes minor*, P. cor = *Procryptotermes corniceps*, P. occ = *Pterotermes occidentis*, M. hub = *Marginitermes hubbardi*, and Z. nev = *Zootermopsis nevadensis nuttingi*.



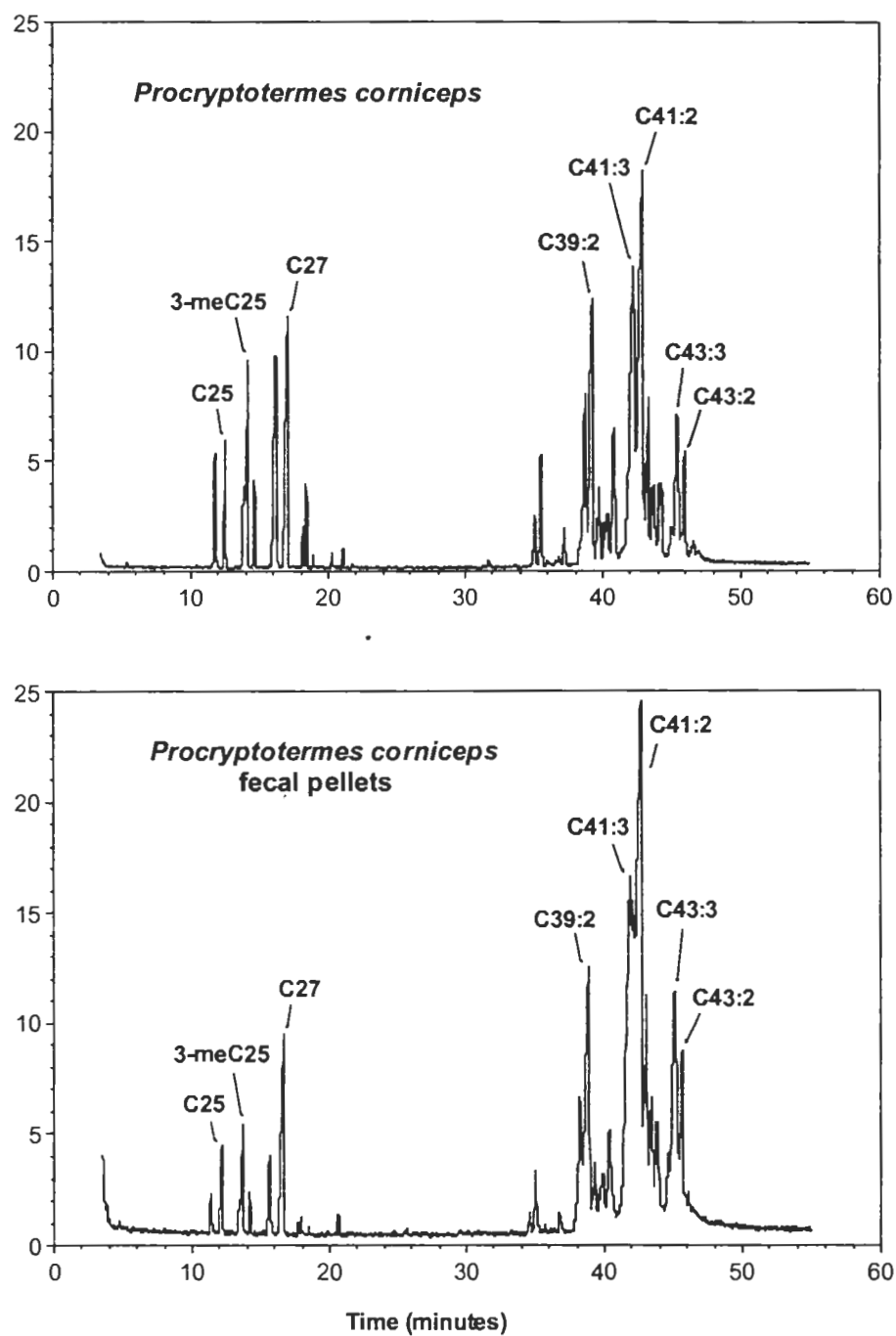


Figure 6

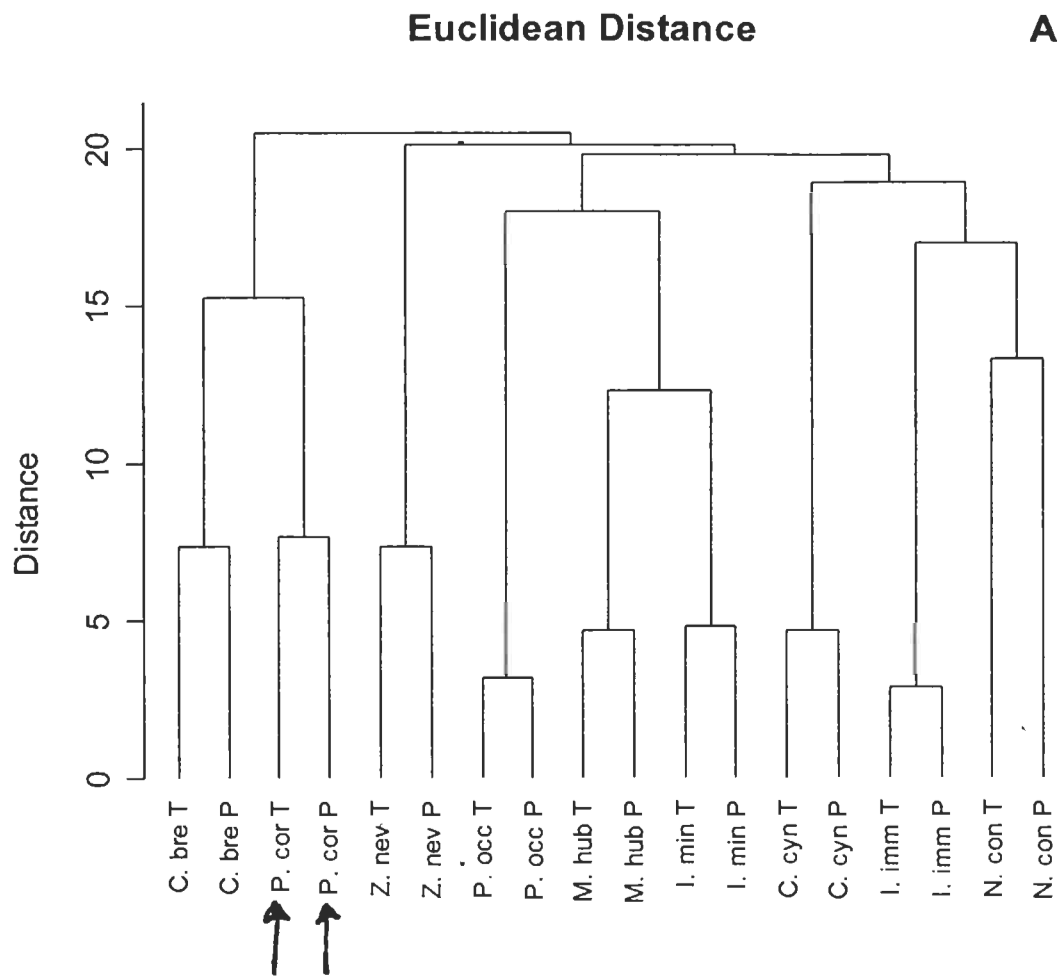


Figure 10 A

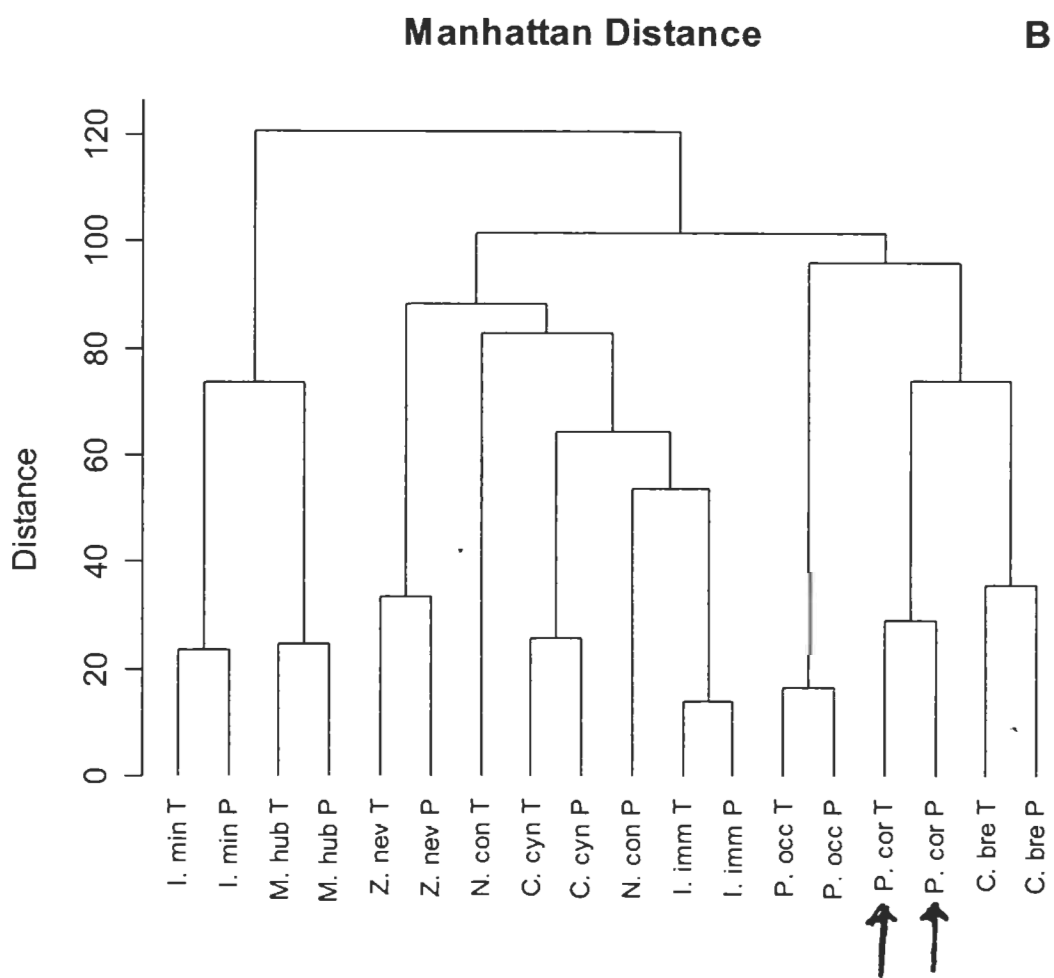


Figure 10 B

TABLE 6. RELATIVE ABUNDANCE^a OF HYDROCARBONS FROM
PSEUDERGATES AND FECAL PELLETS OF *Procryptotermes corniceps*
(Snyder)



Hydrocarbons	Termites	Fecal Pellets
2-meC24	1.52	0.68
3-meC24	0.06	0.00
<i>n</i> -C25	1.62	1.37
2-meC25	1.87	0.55
3-meC25	3.10	1.58
<i>n</i> -C26	0.87	0.47
2-meC26	4.18	1.55
3-meC26	0.27	0.00
<i>n</i> -C27	5.95	4.43
2-meC27	0.36	0.12
3-meC27	0.70	0.15
<i>n</i> -C28	0.11	0.09
2-meC28	0.17	0.27
<i>n</i> -C29	0.18	0.00
C35:2	0.09	0.00
C37:3	0.84	0.41
C37:2	1.65	1.02
C37:1	0.08	0.06
C38:3	0.14	0.00
C38:2	0.65	0.43
C39:3	4.88	4.04
C39:2	8.10	8.63

C39:1	13.63	1.62
C40:X ^c	0.58	0.48
C40:3	1.32	1.53
C40:2; 15-; 13-meC39 ^b	3.53	3.31
C41:3	13.35	22.83
C41:2	15.11	20.27
C41:1	0.96	1.23
C41:1	2.65	3.62
C42:X ^c	0.97	1.39
C42:3	1.46	2.24
15-; 13-meC41 ^b	1.26	1.68
C42:2	0.82	1.03
C43:4	0.80	1.47
C43:3	4.04	8.08
C43:2	1.79	3.09
C43:1	0.37	0.29

^a Percent of total hydrocarbon composition.

^b An isomeric mixture or two or more compounds co-elute in this peak.

^c This peak appears to be a mixture of unsaturated compounds, their exact identities are undetermined.

A Catalogue of West Indies Anthribidae (Coleoptera)

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Abstract. This is a catalogue of 23 described and 6 undescribed genera, and 48 described and 157 undescribed species of West Indian Anthribidae distributed from the Bahamas to Grenada. Each described genus has author, date, page, type species and how designated, World distribution, number of World species, and synonyms. Each described species has author, date, page, original generic name if a transfer has occurred, type locality, sex and location of type(s) if known, synonyms, and island-by-island distribution. New taxa are numbered, with data on museum location and island distribution. There are brief comments on New World distributions as they relate to the Antilles, and on missing Suffrian and Wolfrum types.

Introduction

The Antilles fauna is rich in biological interest, containing a diverse biota ranging from old endemics to modern tramps. Percentages vary greatly from one group of organisms to another, among the Anthribidae, 35% of the genera and 95% of the species are confined to the West Indies. This high degree of endemism is characteristic of isolated oceanic islands which were either never connected to the mainland, or which became separated before arrival of the present biota.

The difficulties inherent in crossing marine gaps (at least for anthribids) are clearly demonstrated by the absence of numerous widespread mainland lineages. Of 80 New World genera, 52 are absent from the West Indies; the absentees include 5 tribes and hundreds of species. Some missing genera and the number of mainland species known to me (described and undescribed) are listed in Table 1.

Other mainland genera have barely reached the Antilles. *Ischnocerus* Sch. has 14 species, one of which has reached the Bahamas from Florida. *Trigonorhinus* has 16 species with a single specimen of a common eastern U. S. species seen from Cuba. *Piesocorynus* has 54 species, two of which are Antillean, one in the Bahamas and Cuba, the other on Hispaniola. *Eusphyrus* Lec. has at least 110 species one of

which occurs in south Florida and Cuba. A total of eight species occur in Florida and either the Bahamas and/or Cuba, plus the cosmopolitan *Araecerus fasciculatus* (DeG.). No other islands share species with the mainland. Shared taxa are shown in Table 2.

In the above table, etc. indicates mainland distribution beyond Florida, *Ischnocerus infuscatus* ranges from the District of Columbia to Honduras. *Phoenicobiella chamaeropsis* from South Carolina to Louisiana along the coast, and *Trigonorhinus rotundatus* from Canada to Mexico.

In addition, several mainland genera, after reaching the Antilles have diversified within and between islands to form the endemic complexes characteristic of archipelago speciation and adaptive radiation (see discussion in Quammen, 1996:217-222, 627). Examples (includes undescribed species) are in Table 3.

Identification of West Indies Anthribidae is complicated by numerous new species. Three quarters of the 194 known to me are undescribed and of 28 genera, 6 are undescribed. Among the new species, three quarters are in *Ormiscus*, the only genus present on every island from which anthribids are known.

A second complication is non-availability of some Suffrian and Wolfrum holotypes. Suffrian (1870) described 16 new species of Anthribidae from Cuba. His collection (also Germar's) is in the Martin Luther Universität in Halle, Germany, but apparently con-

Table 1. Mainland genera not represented in the West Indies and the number of mainland species.

<i>Stenocerus</i> Sch.	11 species	<i>Corrhecerus</i> complex	45 species
<i>Discotenes</i> Labram & Imhoff	16 species	<i>Phaenithon</i> Sch.	94 species
<i>Monocloeus</i> Jordan	17 species	<i>Euparius</i> Sch.	94 species
<i>Tribotropis</i> complex	18 species	<i>Goniocloeus</i> Jord.	99 species
<i>Eugonus</i> Sch.	37 species	<i>Gymnognathus</i> Sch.	192 species

Table 2. Species shared between Florida and the West Indies.

<i>Acaromimus americanus</i> (Mots.)	Florida, Bahamas
<i>Ischnocerus infuscatus</i> (Fahrs.)	Florida etc., Bahamas
<i>Brachycorynus distentus</i> (Fries.)	Florida, Cuba
<i>Phoenicobiella chamaeropsis</i> (Lec.)	Florida etc., Bahamas
<i>Toxonotus fascicularis</i> (Sch.)	Florida, Bahamas, Cuba
<i>Trigonorhinus rotundatus</i> (Lec.)	Florida, etc., Cuba
<i>Eusphyrus schwarzi</i> Pierce	Florida, Cuba
<i>Ormiscus floridanus</i> (Leng)	Florida, Cuba

tained types of only five of his species: *Tropideres* (now *Homocloeus*) *confusus* and *obsoletus*, *Tropideres* (now *Ormiscus*) *angulatus* and *parvulus*, and *Ptychoderes* (now *Eucloeus*) *angulatus*, all of which I have examined. My identifications of the other species are based on Suffrian's and Gundlach's descriptions and on a partial set of Cuban species sent to me by Paul Wolfrum, some 25 years after he examined the Suffrian material.

In 1989, at my request, 23 Wolfrum type series were hand carried from the Frey Museum in Germany to Basel, Switzerland, and there examined by me. Included was the holotype and five cotypes of *Phaenotheriopsis bierigi* Wolfrum, one cotype of *Homocloeus conspersus* Wolfrum, and two paratypes of *Neanthribus mendax* Wolfrum. "Cotype" vs. "paratype" was based on Wolfrum's red pin labels. These specimens (plus 40 specimens of 20 additional species from the Neotropics and Africa) were not in the Frey Museum five years later. I suspect they are still in Basel. The Wolfrum collection was donated to the G. Frey Museum, Tutzing, Germany in 1961, and when I re-examined it in 1993 and 1994, no West Indian anthribid types were present. Wolfrum's (1930) paper on Cuban and Puerto Rican anthribids also mentions specimens and/or types of 16 species in the Berlin

Museum. I examined that collection in 1997 and found no West Indian anthribids.

Type materials of Schonherr, Boheman, Gyllenhal, and Fahraeus were examined in Stockholm, of Fabricius in Copenhagen, Oliver and Chevrolat in Paris, Leconte in Cambridge, Jordan in London, Pierce in Washington, D.C., Frieser in Feldafing, Germany, and Valentine in Columbus, Ohio, New York, and London.

The checklist includes all undescribed taxa known to me. To omit them would result in a grossly incorrect picture of Antilles diversity and distribution. Including them is sure to frustrate future workers, so I have indicated the collections in which they are housed. Codons for the various collections are discussed below.

Collection Codons

Dozens of American and European Coleoptera collections in museums, universities, and private hands have been examined for Antillean anthribids, with surprisingly poor results. The West Indies have not been adequately sampled. The following list includes repositories with West Indies Anthribidae, but is incomplete. It will, I hope, stimulate and facilitate future studies.

<i>Brachycorynus</i> Val.	7 of 13 species
<i>Homocloeus</i> Jord.	38 of 54 species
<i>Toxonotus</i> Lacord.	8 of 35 species
<i>Ormiscus</i> G. R. Waterh.	75 of 180 species
<i>Phaenotheriopsis</i> Wolf.	13 of 13 species

Table 3. Mainland genera that have undergone adaptive radiation in the West Indies and the number of West Indian species compared to the total.

Family Anthribidae
Subfamily Choraginae
Tribe Araecerini

Araecerus Schonherr, 1823:1135. Type: *Anthribus coffeae* Fabricius, 1801:411, by monotypy. Indopacific with 86 described species, one of which is cosmopolitan.

=*Araecerus* Schonherr, 1839:273. This corrected spelling is preoccupied by Nordman, 1837, in Staphylinidae.

=*Araecorynus* Jekel, 1855:150. Type species: *Araecorynus cumingi* Jekel, 1855:157, by original designation and monotypy.

=*Doticus* Pascoe, 1882:27. Type species *Doticus palmaris* Pascoe, 1882:27, by monotypy.

=*Metadoticus* Olliff, 1890:75. Type species *Metadoticus pestilens* Olliff, 1890:75, by monotypy.

fasciculatus (DeGeer, 1775:276, pl. 16, fig. 2) (*Curculio*). Type locality: Surinam. Lectotype: male in NHRS, designated by Valentine in press.

Cosmopolitan; Cuba; Hispaniola;
Jamaica; Grenada; Bermuda

=*cacao* (Fabricius, 1775:64) (*Bruchus*). Type locality: not given; however Olivier, 1795:15, who worked closely with Fabricius, states: "Il se trouve á l'Amerique meridionale." Holotype: female in ZMUC.

=*peregrinus* (Herbst, 1797:168) (*Bruchus*). Type locality: "Amerika." Holotype not found.

=*capsinicola* (Fabricius, 1798:159) (*Bruchus*). Type locality: "in Cajennae seminibus." Lectotype male in ZMUC, designated by Valentine in press.

=*coffeae* (Fabricius, 1801:411) (*Anthribus*). Type locality: India. Holotype: male in NHRS.

=*alternans* (Germar, 1824:175) (*Anthribus*). Type locality: Brasilia. Lectotype: male in MLUS, designated by Valentine, in press.

=*griseus* (Stephens, 1831:211, pl. XXI, fig. 2) (*Phloeobius*). Type locality: London, Suffolk, and Devonshire. Cotypes not found.

=*parvirostris* (Thomson, 1858:113) (*Cratoparis?*). Type locality: Gabon. Type not found.

=*seminarius* Chevrolat, 1871:7, pl. 1, fig. 5. Type locality: France, Paris, but imported from Brasil. Holotype: female in MNHN.

=*mateui* (Cobos, 1954:41, fig. 1) (*Tropideres*, subgenus *Rhaphitropis*). Type locality: Spain, Prov. de Barcelona, Tiana. Holotype female in Instituto de Aclimatación, Almeira, Spain

Cyptoxenus Valentine, 1982:197. Type species: *Cyptoxenus sigillatus* Valentine, 1982:197, by original designation and monotypy. Antillean endemic; 1 species.

**sigillatus* Valentine, 1982:198, fig. 1. Type locality: Jamaica
Jamaica, St. Andrew Par., NW slope of Long Mt., near Mona,
800'. Holotype: male in BDVC. Jamaica

New Genus A, near *Cyptoxenus* Valentine, 1982:197. Antillean endemic; 2 species.

*n. sp. 1 in NHMB. Hispaniola

*n. sp. 2 in BDVC. Jamaica

Neoxenus Valentine, 1999:253. Type species: *Neoxenus versicolor* Valentine, 1999:254, by original designation. Neotropical Texas (possibly adventive), Mexico to Brasil; West Indies; 7 species.

**pallipes* (Suffrian, 1870:170) (*Notioxenus*). Type locality: Cuba
Cuba. Holotype not found; identity uncertain. Cuba

*n. sp. 1 in BDVC, USNM. Cuba; Jamaica

*n. sp. 2 in BDVC, MCZC. Cuba; Jamaica; Puerto Rico

New Genus B. Antillean endemic; 2 species.

**acanthoceroideus* (Wolfrum 1930:31) (*Euxenus*). Type locality: "Portorico". Holotype not found. Puerto Rico

*n. sp. 1 in MAIC, BDVC. US Virgin Is: St. John; British Virgin Is: Guana

Habroxenus Valentine, 1999:256. Type species: *Habroxenus politus* Valentine, 1999:256, by original designation. Eastern United States to Guatemala; West Indies; 6 or 7 species.

**sarmenticola* Valentine, 1999:257, fig. 1. Type locality: Hispaniola
Haiti, Morne Guimby, 22 km SE. Fond Verettes. 6000'. Forêt
des Pins, hardwood cloud forest. Holotype: male in BDVC.

*n.sp. 1 in CNCC. Jamaica

*n.sp. 2 in CNCC. Jamaica

*n.sp. 3 in MAIC. British Virgin Is: Tortola

* n.sp. 4 in MAIC. Puerto Rico

Acaromimus Jordan, 1907:381. Type species: *Acaromimus sharpi* Jordan, 1907:382, by original designation and monotypy. Mostly Neotropical, south Florida to Costa Rica, West Indies; 8 species.

=*Acaropsis* Jordan, 1907:832, pl. 14, fig. 31, *lapsus*.

americanus (Motschoulsky, 1873:251) (*Xenorchestes*). Type locality: [Alabama], Mobile. Holotype not seen, may be in Moscow. ^{NOTE:} Use of the name *americanus* is not clear. I do not know if the South Florida - Bahamas species is the same as Motschoulsky's from Alabama, and Leconte's (1884) from Texas. I have tried twice without success to borrow the Motschoulsky type.

Florida; Tortugas; Bahama Is: Andros,
New Providence

*n.sp. 1 in BDVC.

Cuba

*n.sp. 2 in CNCC.

Jamaica

*n.sp. 3 in BDVC.

Bahamas: New Providence

*n.sp. 4 in BDVC, MAIC.

US Virgin Is: St. Thomas, St. John, St.
Croix; British Virgin Is: Guana, Great
Camanoe, Virgin Gorda, Jost Van Dyke



Tribe Choragini

Melanopsacus Jordan, 1924b:608. Type species: *Melanopsacus fortis* Jordan, 1924b:609 by original designation. Essentially world-wide except Nearctic; 80 species.

*n.sp. 1 in USNM.

Cuba

*n.sp. 2 in CNCC.

Jamaica

Holostilpna Jordan, 1907:382. Type species: *Choragus nitens* Jordan, 1907:382, not Leconte, 1884:32, by original designation. This species is now *Holostilpna jordani* Valentine, 1991:303; 12 species.

=*Euxenus* Leconte, 1876:409. Type species: *Euxenus punctatus* Leconte, 1876:409, by monotypy. Nearctic and Neotropical. Preoccupied by *Euxenus* Gistel, 1856.

*n.sp. 1 in MCZC.

Cuba

*n.sp. 2 in BDVC.

Hispaniola

*n.sp. 3 in MCZC.

Hispaniola

*n.sp. 4 in BDVC, MAIC.

Hispaniola

*n.sp. 5 in BDVC, MAIC

British Virgin Is: Tortola

*n.sp. 6 in MAIC

Montserrat

Apteroxenus Valentine, 1979:21. Type species: *Apteroxenus globulosus* Valentine, 1979:24, by original designation and monotypy. Antilles endemic; 1 species.

**globulosus* Valentine, 1979:24, fig. 1-3. Type locality: Jamaica, Portland Par., Hardwar Gap 4,000'. Holotype: female in BMNH.

Jamaica

Euxenulus Valentine, 1960:48, 53. Type species: *Euxenus piceus* Leconte, 1878:434, by original designation and monotypy. Nearctic and West Indies; 5 species.

infuscatus Fahraeus, 1839:192. Type locality: Mexico.
Holotype in NHRS.

Maryland to Guatemala; Bahama Is.:
Andros, Abaco, Eleuthera

=*tuberculatus* Labram and Imhoff, 1839:Heft IV. Type
locality: Mexico. Holotype unknown.

Tribe Gymnognathini

New Genus E, near *Gymnognathus* Schönherr, 1826:37. Antillean endemic; 3 species.

**caniqui* de Zayas, 1988:151, fig. 135. Type locality: Cuba,
Matanzas, Cienga de Zapata. Holotype in de Zayas
collection, Havana.

Cuba

*n.sp. 1 in BDVC.

Bahamas

*n.sp. 2 in USNM. This is *Gymnognathus* sp. of Wolcott,
1936:289.

Puerto Rico

Tribe Rhinotropidini

Homocloeus Jordan, 1904:264. Type species: *Homocloeus vestitus* Jordan, 1904:265, by original designation.
Neotropical; 54 species.

**acerbus* (Boheman, 1833:149) (*Tropideres*). Type locality:
Cuba. Holotype: female in NHRS.

Cuba

**balteatus* (Gyllenhal, 1833:154) (*Tropideres*). Type locality:
Cuba. Holotype: male in NHRS.

Cuba

**caliginosus* (Boheman, 1833:149) (*Tropideres*). Type
locality: Cuba. Holotype: male in NHRS.

Cuba

=*modestus* (Suffrian, 1870:182) (*Tropideres*). Type
locality: Cuba. Holotype not found.

Cuba

**confusus* (Suffrian, 1870:198) (*Tropideres*). Type locality:
Cuba. Cotypes male and female in MLUS.

Cuba

**conspersus* Wolfrum, 1930:29. Type locality: "Portorico".
Holotype not found.

Puerto Rico; Hispaniola; British Virgin Is:
Tortola

**dermestoides* (Suffrian, 1870:176) (*Eugonus*). Type
locality: Cuba. Holotype not found.

Cuba

**feralis* (Boheman, 1833:148) (*Tropideres*). Type locality:
Cuba. Holotype: male in NHRS.

Cuba

**insularis* (Frieser, 1959:420) (*Piezocorynus*). Type locality:
Guadeloupe. Holotype in NHMW.

Guadeloupe; Dominica

**laetus* (Suffrian, 1870:195) (*Tropideres*). Type locality:
Cuba. Holotype not found.

Cuba

**luscus* (Fahraeus, 1839:209) (*Tropideres*). Type locality:
Cuba. Holotype female in NHRS.

Cuba

*n.sp. 28 in MAIC.

Montserrat

Monocloeus Jordan, 1904:255. Type species: *Monocloeus elaphrinus* Jordan, 1904:255, by original designation. Neotropical; 17 species.

*n.sp. 1 in BDVC.

Hispaniola

Tribe Piesocorynini

Piesocorynus Dejean, 1834:235. Type species: *Euparius dispar* Gyllenhal, 1833:140, by monotypy. Nearctic and neotropical; 54 species.

**suffriani* Valentine, new name for *Tropideres gracilicornis* Suffrian, 1870:186, a junior homonym of *Camptotropis gracilicornis* Jekel, 1855:138, both of which are now in *Piesocorynus*. Type locality: Cuba. Holotype not found.

Cuba; Bahamas: Andros

*n.sp. 1 in MAIC, BDVC.

Hispaniola

*n.sp. 2 in MAIC

Hispaniola

Brachycorynus Valentine, 1999:271. Type species: *Tropideres rectus* Leconte, 1876:395, by original designation. Nearctic and Neotropical south to Panama; 13 species.

distentus (Frieser, 1983:53) (*Homocloeus*). Type locality: Cuba, Prov. Havana, Playa Marianao. Holotype: male in R. F. Frieser collection, to be deposited in ZSMC.

Cuba; south Florida

*n.sp. 1 in CUIC

Hispaniola

*n.sp. 2 in MAIC, CUIC, BDVC

Hispaniola

*n.sp. 3 in MAIC, CUIC, BDVC

Hispaniola

*n.sp. 4 in BDVC

Hispaniola

*n.sp. 5 in BDVC, USNM

Puerto Rico

*n.sp. 6 in MAIC, BDVC, CMNH

Jamaica

Phaenotheriopsis Wolfrum, 1931:70. Type species: *Phaenotheriopsis bierigi* Wolfrum, 1931:70, by original designation and monotypy. Antillean endemic; 13 species. Some species flightless.

**bierigi* Wolfrum, 1931:70. Type locality: Cuba, Prov. Havana, Tapaste. Holotype: male in NHMB.

Cuba

**conciliatus* Valentine, 1991:332, fig. 1. Type locality: Puerto Rico, Carib. N. F., El Toro Negro D., Hwy. 143. Holotype: male in BDVC.

Puerto Rico

**tuberculatus* Valentine, 1991:334, fig. 2. Type locality: Dominican Republic, LaVega, 18 km. SE. Constanza. Holotype: male in BDVC.

Hispaniola

- *umbonatus* Valentine, 1991:338, fig. 4. Type locality: Hispaniola
Dominican Republic, La Vega, 53 km. SE. Constanza.
Holotype: male in BDVC.
- *vauriei* Valentine, 1955:5, fig. 1A, B. Type locality: Bahama
Is., South Bimini I. Holotype: female in AMNH. Bahamas: South Bimini, Andros, New
Providence
- *verrucosus* Valentine, 1991:336, fig. 3. Type locality: Hispaniola
Dominican Republic, La Vega, 18 km. SE. Constanza.
Holotype: male in BDVC.
- *n.sp. 1* in BDVC Cuba
- *n.sp. 2* in MAIC, USNM Jamaica
- *n.sp. 3* in USNM Jamaica
- *n.sp. 4* in USNM Jamaica
- *n.sp. 5* in BDVC Jamaica
- *n.sp. 6* in BDVC Jamaica
- *n.sp. 7* in BDVC Jamaica
- *n.sp. 8* in BDVC Jamaica
- *n.sp. 9* in MAIC US Virgin Is: St. John
- *n.sp. 10* in MAIC, BDVC US Virgin Is: St. John; British Virgin Is:
Great Camanoe
- *n.sp. 11* in MAIC Vieques

Tribe Platyrhinini

New Genus F, near *Goniocloeus* Jordan, 1904:260. Antilles endemic; 3 species.

- *tuberculatus* (Olivier, 1795:10, pl. 1, fig. 11) Hispaniola, Puerto Rico,
(*Macrocephalus*). Type locality: "Afrique", corrected to "Haity"
by Lacordaire, 1866:534. Holotype female in Paris; missing
head and prothorax. British Virgin Is: Tortola
- *n.sp. 1* in FSCA, BDVC, MAIC Hispaniola
- *n.sp. 2* in FSCA, BDVC Hispaniola

Eucloeus Wolfrum, 1930:26. Type species: *Ptychoderes angulatus* Suffrian, 1870:199, by original designation
and monotypy. Antilles endemic; 1 species.

- *angulatus* (Suffrian, 1870:199) (*Ptychoderes*). Type locality: Cuba
Cuba. Holotype female in MLUS.

Tribe Platystomini

Phoenicobiella Cockerell, 1906:243, replacement name for *Phoenicobius* Leconte, 1876:400 preoccupied in Mollusca. Type species: *Phoenicobius chamaeropsis* Leconte, 1876:401, by monotypy. Nearctic (south Atlantic and Gulf Coast) and Antilles; 3 species.

chamaeropsis Leconte, 1876:401. Type locality: Florida, South Carolina to Louisiana; Bahamas: restricted to Volusia Co., Enterprise, by Valentine, 1955:8. South Bimini, Eleuthera, Crooked Syntypes in MCZC.

**trituberculata* (Suffrian, 1870:172) (*Toxonotus*). Type Cuba
locality: Cuba. Holotype ? not found.

Toxonotus Lacordaire, 1866:575. Type species: *Anthribus fascicularis* Schoenherr, 1833:132, by monotypy. Nearctic and Neotropical; 35 species.

=*Neanthribus* Jordan, 1906:341. Type species: *Neanthribus championi* Jordan, 1906:342, by original designation.

=*Pseudanthribus* Pierce, 1930:22, 24. Type species: *Anthribus cornutus* Say, 1831:4, designated by Anderson, 1947:504.

**bidens* (Olivier, 1795:13, pl. 2, fig. 18a, b) (*Macrocephalus*). Hispaniola
Type locality: "Saint Domingue". Holotype not found.

fascicularis (Schoenherr, 1833:132) (*Anthribus*). Type locality: South Florida; Cuba; Bahamas: South
Cuba. Holotype male in NHRS. A second specimen, female, Bimini, North Bimini, New Providence,
is *Toxonotus mendax* (Wolfrum). Berry Is: Fraser's Hog Cay

**mendax* (Wolfrum, 1930:31) (*Neanthribus*). Type locality: Cuba; Bahamas: South Bimini, Cat,
Cuba. Holotype not found. Abaco, Acklins, Crooked, Great Inagua

*n.sp. 1 in MCZC Cuba

*n.sp. 2 in BDVC, CMNH, USNM. Listed as *Toxonotus* Jamaica; Cayman Is.
fascicularis by Gowdey 1926:25.

*n.sp. 3 in BDVC, USNM, NHMB Hispaniola; Mona

*n.sp. 4 in USNM, NHMB, BDVC, MAIC Hispaniola

*n.sp. 5 in BDVC, MAIC, USNM, HAHC Puerto Rico; US Virgin Is: St. Thomas, St.
John, St. Croix; British Virgin Is: Tortola, Guana, Virgin Gorda, Jost van Dyke, Great St. James, Norman

Tribe Trigonorhinini

Trigonorhinus Wollaston, 1861:102. Type species: *Trigonorhinus pardalis* Wollaston, 1861:103, by monotypy. Palearctic, Nearctic, and Neotropical; 16 species.

=*Brachytarsus* of many authors, not Schoenherr, 1823:1135.

=*Anthribulus* Leconte, 1876:406. Type species: *Anthribulus rotundatus* Leconte, 1876:407, by monotypy.

=*Brachytarsoides* Pierce, 1930:29, 30. Type species: *Brachytarsus griseus* Leconte, 1876:405, by original designation.

rotundatus (Leconte, 1876:407) (*Anthribulus*). Type locality: Maine to Florida, west to Illinois, Kansas, and Texas; northern Mexico; ?Cuba
"Massachusetts to Louisiana". Cotypes in MCZC.

NOTE: This species is widespread and common in eastern United States, and especially so in southern Florida. A specimen, labeled Cuba, Pinar del Rio Prov., Sierra del Rosario, San Vicente, 17-vi-1959, collected by M. W. Sanderson, #C59-31, may represent a stray from the United States.

Tribe Zygaenodini

Eusphyrus Leconte, 1876:399. Type species: *Eusphyrus walshi* Leconte, 1876:400, by monotypy. Nearctic, Neotropical, introduced into Hawaii and France; at least 110 species.

=*Opisthotropis* Hoffmann and Tempère, 1954:66. Type species: *Tropideres* (subgenus *Opisthotropis*) *vasconicus* Hoffmann and Tempère, 1954:66, by original designation and monotypy.

schwarzi Pierce, 1930:28, pl. 4, fig. 63. Type locality: Florida, South Florida; Cuba
Key West. Holotype female in USNM.

Eugonops Jordan 1904: 285. Type species: *Eugonops germaini* Jordan 1904: 285, by original designation. Neotropical, at least 5 species.

*n.sp. 1 in MAIC

Hispaniola

Ormiscus G. R. Waterhouse, 1845:37. Type species: *Ormiscus variegatus* G. R. Waterhouse, 1845:37, by monotypy. Nearctic, Neotropical, Galapagos, introduced in Hawaii; at least 250 species.

=*Hormiscus* Leconte, 1876:397 [sic].

=*Toxotropis* Leconte, 1876:397. Type species: *Toxotropis pusillus* Leconte, 1876:398, designated by Jordan, 1906:362.

=*Gonops* Leconte, 1876:398. Type species: *Gonops fissunguis* Leconte, 1876:398, by monotypy.

**angulatus* (Suffrian, 1870:187) (*Tropideres*). Type locality: Cuba; Hispaniola; Jamaica
Cuba. Holotype male in MLUS.

=*variolosus* (Suffrian, 1870:188) (*Tropideres*). Type locality: Cuba. Holotype not found.

**conis* Jordan, 1924a:240. Type locality: Guadeloupe. Guadeloupe; Dominica; Martinique.
Holotype female in BMNH.

floridanus (Leng, 1916:28) (*Toxotropis*). Type locality: Florida; Cuba
Florida, Volusia Co., Enterprise. Holotype in Brigham Young University, Provo, Utah.

**fuscipennis* (Suffrian, 1870:192) (*Tropideres*). Type Cuba
locality: Cuba. Holotype not found.

**griseus* (Suffrian, 1870:195) (*Tropideres*). Type locality: Cuba
Cuba. Holotype not found.

**lineicollis* (Chevrolat, 1880:198) (*Brachytarsus*). Type Martinique; St. Lucia
locality: Martinique. Cotypes in MNHN.

**micula* Jordan, 1924a:239. Type locality: Grenada and St. Trinidad; Grenada; Grenadines: Canouan,
Vincent, here restricted to Grenada. Holotype female in Maureau, Union; St. Vincent
BMNH.

*n.sp. 31 in BDVC	Hispaniola
*n.sp. 32 in BDVC	Hispaniola
*n.sp. 33 in NHMB	Hispaniola
*n.sp. 34 in NHMB	Hispaniola
*n.sp. 35 in NHMB	Hispaniola
*n.sp. 36 in NHMB	Hispaniola
*n.sp. 37 in NHMB	Hispaniola
*n.sp. 38 in NHMB	Hispaniola
*n.sp. 39 in NHMB	Hispaniola
*n.sp. 40 in NHMB	Hispaniola
*n.sp. 41 in NHMB	Hispaniola
*n.sp. 42 in BDVC	Bahamas: Andros, New Providence
*n.sp. 43 = <i>Brachytarsus</i> sp. (#138-23) of Wolcott, (1924:122 and 1936:288).	Puerto Rico
<p><small>NOTE:</small> A specimen identified as ?<i>Brachytarsus</i> sp. from the Wolcott collection, #138-1923, is in USNM; it is labeled from San German, P.R., but Wolcott states "from pods of <i>Acacia farnesiana</i> at Boquerón" in USNM, BDVC.</p>	
*n.sp. 44 includes Wolcott's #4463 and 4601 (1936:288) in USNM, BDVC	Puerto Rico
*n.sp. 45 includes Wolcott's #2574 and 4464 in USNM	Puerto Rico
*n.sp. 46 includes Wolcott's #5682 in USNM	Puerto Rico
*n.sp. 47 includes Wolcott's #3869 in USNM	Puerto Rico
*n.sp. 48 in USNM, BDVC	Puerto Rico
*n.sp. 49 in USNM, BDVC	Puerto Rico
*n.sp. 50 in MAIC, BDVC, AMNH	Puerto Rico; Desecheo; US Virgin Is: St. Thomas, Little St. James, St. John, St. Croix; British Virgin Is: Guana, Anegada, Virgin Gorda, Great Camano, Anguilla
*n.sp. 51 in MAIC, BDVC	Puerto Rico; Hispaniola; US Virgin Is: St. John, St. Thomas, Great St. James; British Virgin Is: Tortola, Little Thatch Is.
*n.sp. 52 in USNM, MAIC	Puerto Rico; US Virgin Is: St. John
*n.sp. 53 in USNM	St. Kitts
*n.sp. 54 in USNM, AMNH, BDVC	Antigua
*n.sp. 55 in CNCC, USNM	Jamaica
*n.sp. 56 in CNCC, BDVC	Jamaica



Invasive Species Specialist Group of the IUCN Species Survival Commission

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Why did the beetle cross the sea? The Search for Invasives in the British Virgin Islands

I have been working in the British Virgin Islands (BVI) since 1993. Like much of the Caribbean, there are many invasive species in the BVI, and a number of them are very damaging. Various islands are troubled by mongoose (*Herpestes auropunctatus*), goats, sheep, coralita (*Antigonon leptopus*), and other invaders. With funding from the Falconwood Foundation, most of my time in the BVI is spent on Guana Island. This is a remarkably diverse private reserve: more species are known from it than from any island of comparable size. Although it wasn't invasives that originally brought me here, I soon became concerned with several species. Most of the work on these issues is conducted with the help of Dr. Skip Lazell (The Conservation Agency) and Clive Petrovic (H. Lavity Stoutt Community College). A few years ago we noticed that the century plants (*Agave missionum*) on Guana were dying. Searching for the cause, our colleagues Barry and Buena Valentine (Ohio State University) discovered that a new species of beetle, the agave weevil (*Scyphophorus acupunctatus*), has recently arrived. Unlike in its native range, where it only attacks senescent plants, in the BVI the beetle attacks pre-flowering adults and even juveniles.

Since then, our main objective has been to document the impact of the beetle. Repeated surveys of multiple islands show that the invasion is still ongoing, and that at the height of the irruption, over 90% of the agave population may be dead or dying. Those that remain are primarily the juveniles, which may then be attacked as they grow. We are also trying to ascertain the method of spread and identify potential means of limiting additional range extensions, but both targets have proven hard to achieve.

Some other issues we've been looking at recently primarily involve reptiles and amphibians. We have now documented the spread of corn snakes (*Elaphe guttata*) in the US Virgin Islands and on Curaçao, and expect them to spread further in the Caribbean in the near future. A few years ago, we identified a population of red-eared sliders (*Trachemys scripta*) on Tortola, and earlier this year have found at least one other freshwater turtle (tentatively identified as *T. stejnegeri*) at the same site. Finally, Jennifer Owen is finishing a Master's project with me, studying the spread and ecology of the Cuban treefrog (*Osteopilus septentrionalis*) in the BVI. Unfortunately, we have been able to identify several new island infestations and have evidence that they have a negative impact on native wildlife, and especially native frogs.

CAB International recently summarized Caribbean invasive species issues for the Nature Conservancy. They catalogued some 550 invasive species from the region (available at http://www.issg.org/database/species/reference_files/Kairo%20et%20al.%202003.pdf), yet a number of the species and every single one of the populations mentioned above were not included. This illustrates the magnitude of the problem in the Caribbean: there are many islands, spread over a large area, governed by dozens of regimes and speaking multiple languages. Invasive species have not been a major concern for many of them, and the result is a multitude of poorly-documented and mostly un-addressed invasions.

Gad Perry
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A Benign Invader?

>>> "Wenhua Lu" <wenhua@etal.uri.edu> 11/11/04 03:54PM >>>

Dear Dr. Steiner, Scott kindly sent me a copy of your Soc Wash 106 (4) paper because of the Guana, BVI, specs; I run that project and like to keep track of all the emergent lit. The late Tom Farr was one of my earliest mentors, in Jamaica in 1957. I last saw him there in 1996. Stewart Peck and I went to grad school together, and I invited him to hunt my place in the FL Keys as far back as the 70s. So, on your p. 743, it should be "Lazell place" -- we call it "Snake Acres". Stewart should know we took the vowel off generations ago. It's a small and convoluted world!

Your title will appear on our website www.theconservationagency.org and, eventually, as part of my 2004 annual report, on www.guanascience.com. Best wishes -- and extend the same to Stewart, Skip Lazell (aka Dr. James...)

From: "Warren Steiner" <Steiner.Warren@NMNH.SI.EDU>
To: <wenhua@etal.uri.edu>
Cc: "Scott Miller" <Miller.Scott@NMNH.SI.EDU>
Sent: Friday, November 12, 2004 8:57 AM
Subject: Re: H. farri

Dear Wenhua,

Good to hear that this paper is of interest and use. I'll look at your websites. Thanks very much for these bits of small-world history---I never got to meet Tom, but his collections continue to get my attention. I visited the Institute of Jamiaca in May '03 and borrowed a few specimens.

On the spelling of "Lazelle"---this was specimen label data, quoted as is in the paper. All sorts of far worse typos get immortalized in this manner, including the coining of species names.

Another paper on a related topic was just published in Coleopterists' Bulletin 58:335-343---mentions VIs in a discussion of Trachyscelis distribution, no specific Guana records, but cites the VIBF website, etc.; if you want copies let me know.

Warren

NEW DISTRIBUTION RECORDS AND RECENT SPREAD OF *HYMENORUS FARRI* CAMPBELL (COLEOPTERA: TENEBRIONIDAE: ALLECULINAE) TO FLORIDA AND IN THE CARIBBEAN REGION

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Abstract.—*Hymenorus farri* Campbell (Coleoptera: Tenebrionidae: Alleculinae) appears to be spreading as a “weed species” in the Caribbean region. The beetle is diagnosed and illustrated. New country distribution records are reported for the Bahamas, Belize, Guatemala, Mexico, Puerto Rico, Turks and Caicos Islands, U.S.A. (Florida), and the Virgin Islands, and additional collections from the Cayman Islands are noted. The occurrences, habitats, biogeography, and uncertain origin of the insect are discussed.

Key Words: adventive insects, Antillean fauna, Caribbean biogeography, comb-clawed beetles, disturbed habitats

Species of *Hymenorus*, a large, monotonous genus of “comb-clawed beetles,” are difficult to identify, but males of *H. farri* Campbell (1971) are distinctive. The species was described and reported from Jamaica, Cuba, and the Cayman Islands (Campbell 1971, 1978) and appeared to be indigenous to those islands. While collecting Tenebrionidae on Grand Cayman in 1993, I became familiar with this beetle and was able to compare specimens with paratypes of *H. farri*. This led to the identification of this *Hymenorus* from earlier and more recent collections from widely scattered localities, reported and discussed below. The beetle is far more widespread than previous records have indicated, and evidence suggests that this species is adventive in some areas, spreading with the aid of anthropogenic activities.

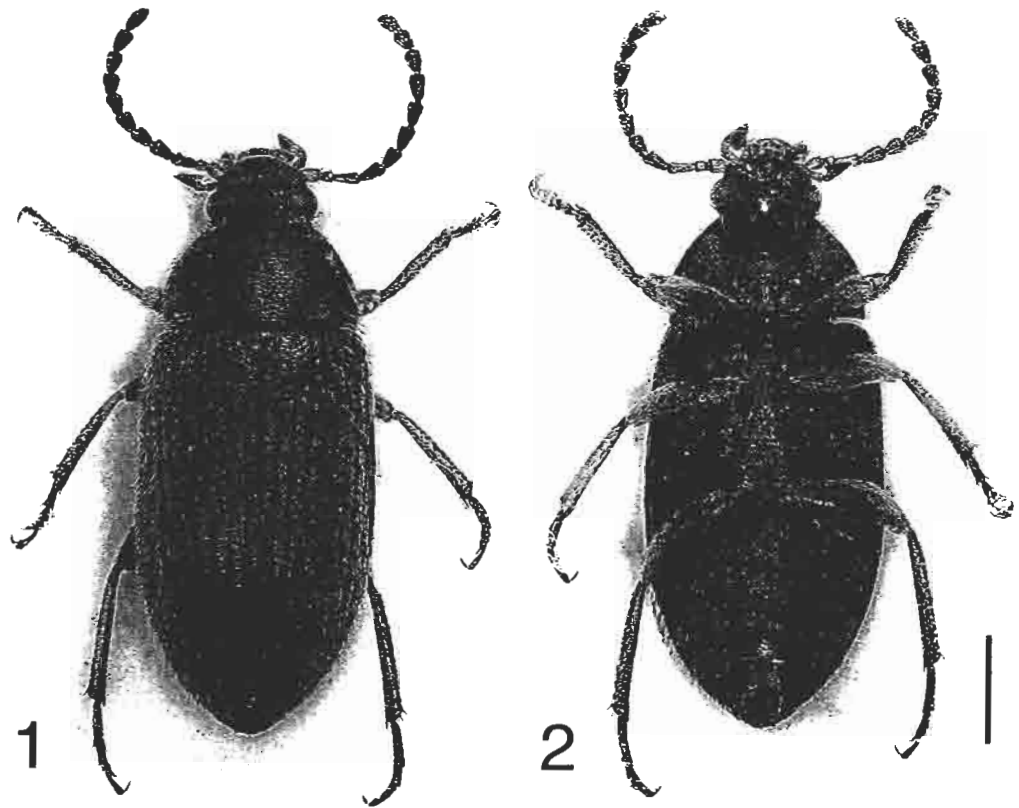
DIAGNOSIS

Hymenorus farri (Figs. 1, 2) is unique among its congeners in having dense median patches of fine setae and punctures on

basal abdominal sternites in males (Fig. 3). Other species have punctures more evenly distributed over these surfaces. This character and the combination of the relatively small and widely separated eyes, robust yellowish legs and tarsi, and finely, densely punctate pronotum with short, fine, erect pubescence, allow its separation from other species of similar size (4.5–5.5 mm). The apical two abdominal sternites are very dark brown, in contrast to the rest of the venter, which is reddish brown. The male genitalia are also distinct (Campbell 1971) and were of used to confirm the identifications made in this study. In the United States, the genus contains nearly 100 described species (Aalbu et al. 2002).

NEW MATERIAL AND COLLECTION RECORDS

All specimens reported here are deposited in the collection of the National Museum of Natural History, Smithsonian Institution, Washington, DC (USNM), except those listed as “SBPC,” which are in the collection of Stewart Peck, Ottawa, Canada,



Figs. 1–2. *Hymenorus farri*, dorsal and ventral views, respectively. Specimen from Key Largo, Florida. Scale line = 1 mm.

“MSU,” the collection of Montana State University, Bozeman, Montana, and “ABS,” the Archbold Biological Station, Lake Placid, Florida. I did not search other collections for additional records of *H. farri*; the purpose of this study is to simply call attention to the presence of this species in the United States and other new records at hand. Recently, however, I examined the Florida State Collection of Arthropods, Gainesville, and found no specimens of this species. Following the quoted label data for most collections, field observations and other information on the occurrences are given. Specimens in SBPC were identified by J. M. Campbell and S. B. Peck.

Central American and Mexico.—“BELIZE: Stann Creek Dist., Dangriga, 13–15 June 1981, W. E. Steiner (17); field notes describe (14 June) a series of “alleculines” taken at lights on walls of a hotel on the beach front; a few other specimens (13 and

15 June) were found near the building under leaf litter on sand during the day. These were identified by J. M. Campbell shortly thereafter. Because they represented the only known occurrence of *H. farri* in Middle American mainland, I then searched through several hundred undetermined *Hymenorus* in the USNM collection, finding only these additional two: “B. HONDURAS, Belize, ix 1959, N. L. H. Krauss” (1); “MEXICO, Veracruz, VI.1975” (1, no other data). Most recently, the following specimen was sent to the Systematic Entomology Laboratory, USDA, for urgent identification: “GUATEMALA (origin) at Long Beach, CA, USA, with bananas, 19 March 2003, P. Butsook, Inspector” (1).

Bahamas and Turks and Caicos Islands.—“Bahamas, Andros Island, Stafford Creek, Marks Place, 24.vii.1987, J. Browne, mangrove blk lt. 87-121J” (1, SBPC); same data except “BARC, 28.vii.1987, pasture

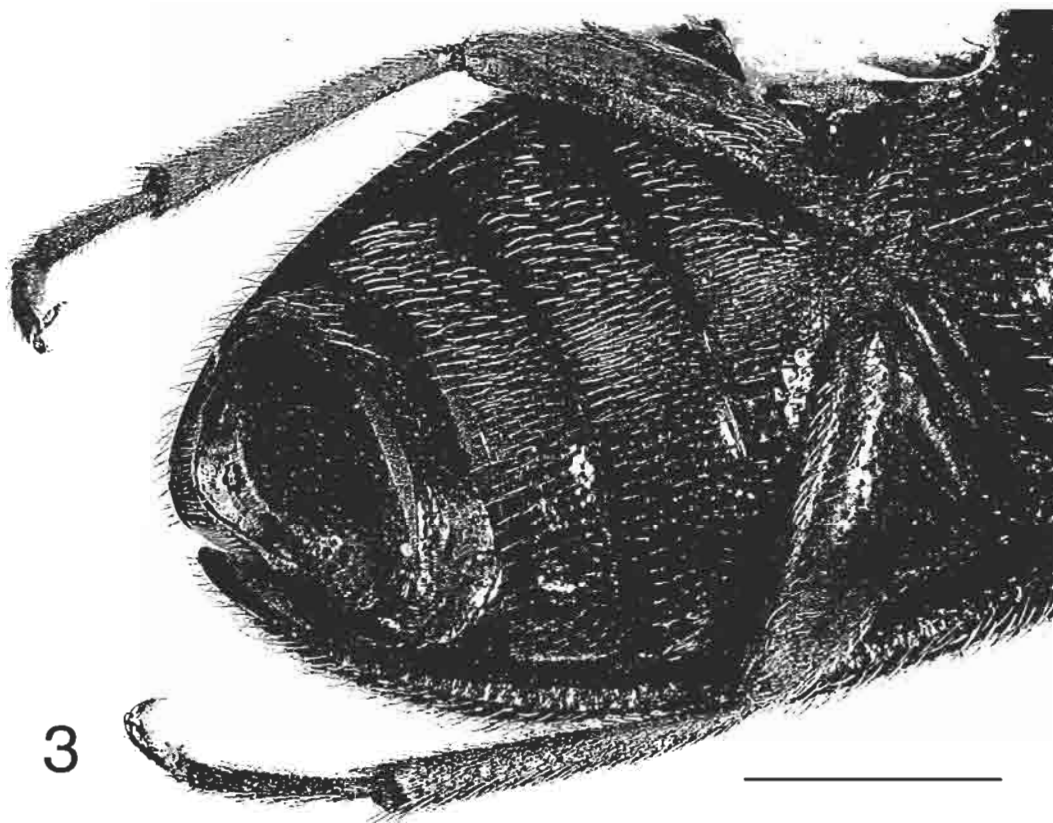


Fig. 3. *Hymenorus farri*, ventral surface of abdomen of male with median patches of setae. Scale line = 1 mm.

edge blk lt, 87-133J" (1, SBPC); same data except "Fresh Creek, Andros Twn, Androsia, 15-06.viii.1987, coppice interior, blk. lt, 87-163J" (1, SBPC); "GRAND BAHAMA ISLAND, Freeport, 20-26 June 1987, W. E. Steiner, M. J. & R. Molineaux" (9); "BAHAMA ISLS., San Salvador, Gerace Research Ctr., 24°07'N, 74°26'W, 20 June 2003, W. E. Steiner & J. M. Swearingen collectors" (1); same data except "21 June" (4) and "22 June" (3); "TURKS AND CAICOS ISLANDS, Providenciales, Grace Bay Beach, 21°48'N, 72°13'W, 26 January 1998/At light in sandy scrub forest; W. E. Steiner & J. M. Swearingen collectors" (1); same data except: "2 February 1998/specimen found dead when collected; in hotel room" (1); same data except: "Under leaf litter on sandy soil at edge of turf and garden" (15). Some of the specimens from Freeport were noted being taken "un-

der leaf litter on sandy loose soil under roadside shrubs" and others collected after dark at fluorescent lights on a building at the same locality. The most recent specimens (San Salvador) were found after dark on stone and concrete walls under mercury vapor lights in open sandy turf among buildings.

Cayman Islands.—"GRAND CAYMAN IS.: 2 mi N of Georgetown, flooded freshwater pond, 26 May 1975, P. J. Spangler" (1); "CAYMAN ISLANDS: Grand Cayman, 3 km W Colliers, 19°21'N, 81°07'W, 21 February 1993/At black light in cut-over forest near ponds; coll. W. E. Steiner & J. M. Swearingen" (12); same data except "On palm leaf at dusk" (1); "CAYMAN ISLANDS: Grand Cayman, Hell, 19°23'N, 81°24'W, 19 February 1993/W. E. Steiner & J. M. Swearingen collectors/Under leaf litter on sandy soil, weedy roadside" (1);

same data except "North Side, 19°21'N, 81°12'W, 22 February 1993/At black light in forest clearing near coast" (2); same data except "Rum Point, 19°22'N, 81°16'W, 22 February 1993/Under leaf litter beneath *Cakile* plants on sand, open edge of dune and pavement" (13) and "24 February 1993/Under dry palm fronds and litter on sandy soil, open mowed flat area near dune and beach" (1). These collections do not represent new island records, but associated notes on the captures add to the knowledge of the insect's habitat. *Hymenorus farri* was collected on all three of the Cayman Islands during a faunal survey in 1938 (Campbell 1978).

Puerto Rico.—"PUERTO RICO, Isla Verde, 27-II-63/A. B. Cochran, on walls & ceilings/San Juan 18388/63-6853" (6); "Isla Verde, P. R., host unknown, A. B. Cochran, 27 Feb. 1963/San Juan 18388, 63-6853" (4); "PUERTO RICO: Isla Verde Airport, 1-III-63, A. B. Cochran/San Juan 18458, 63-10499" (1); "P. R., San Juan, Airport, II-15-63, L. T. Sanders/On airport windows, San Juan # 18989, 63-19346" (1); "PUERTO RICO, Naguabo, Playa de Naguabo, 18°11'N, 65°43'W, 17 February 1996, collrs. W. E. Steiner & J. M. Swearingen" (3). Label data on the San Juan Airport collections, all made within a two-week period in 1963, suggest an artificial introduction. Except for the few specimens from Naguabo, no other records for Puerto Rico have been found; this is the only collection made "in the wild" on the island, but it indicates that the beetle is established or indigenous there. Notes made at the Naguabo site indicate specimens were found among beach strand vegetation, in dead leaves on sand among trailing vines in an open sunlit roadside area.

Virgin Islands.—"VIRGIN IS., St. Croix, Est. Mount Fancy, S.E. of Great Pond, 12 JAN 1993, D. S. Sikes, beating mangroves" (2, MSU); same data except "R. S. Miller, beating veget." (1, MSU); "BR. VIRGIN IS: Guana Is., The Flats, nr. Orchard, 13 July 1994, S. A. Bucklin colr.,

leaf & bark litter" (1, MSU); "BR. VIRGIN IS: Guana, Hotel to gardens, 16 OCT 2002, M. A. Ivie colr" (1, MSU); "BR. VIRGIN IS: Guana Is., White Beach, 18°29'N, 64°34'W, 01-17 JUL 1993, R. R. Snelling, Coccoloba coppice" (1, MSU).

United States.—"FLORIDA: Broward Co., Deerfield Beach, North 3rd St., November 5, 1990, Vince Golia, sweeping" [site described (V. Golia, personal communication) as a "vacant trashy lot"] (1, ABS); "FLORIDA: Broward Co., Fort Lauderdale, near Conference Ctr., 26°06'N, 80°07'W, 19 November 2002/W. E. Steiner, N. J. Vandenberg, J. M. Swearingen collectors" [in field notes: "... rough, trashy ground between a hedge & the asphalt, with scattered cabbage palms—bases of these had thick layers of coarse thatch from repeated mowing of weedy strip—more *Blapstinus fortis* under the matted debris, & a few *Hymenorus* sp. poss. *farri* ..."] (3); "FLORIDA: Dade County, Homestead/1 May 1986, W. E. Steiner & D. S. Bogar/Under leaf litter near sidewalk, open turf area" (1); "FLORIDA: Monroe County, Dry Tortugas, Garden Key, 13-15 February 1989/W. E. Steiner, J. M. Hill & J. M. Swearingen collectors" [in field notes (15 Feb. 1989): "Another *Blapstinus fortis*, series of the small pale *Phaleria*, & a few *Hymenorus* sp. under wind-deposited plant debris caught under spreading, isolated plants of the semi-succulent crucifer "sea rocket," *Cakile* sp."] (3); "FLORIDA: Monroe Co., Lower Matecumbe Key, 17 February 1989/W. E. Steiner, J. M. Hill & J. M. Swearingen collectors" [in field notes: "Series of *Hymenorus* under dry leaf litter under trailing 'ice plant' on loose sand beneath shrubs. Not much of a beach here in terms of sand build-up and almost no areas of elevated exposed sand. Probably semi-artificial anyway, being between tidal flats & bank of highway"] (6); "FLORIDA: Monroe County, Lower Matecumbe Key, ocean beach, 24°51'15"N, 80°44'10"W; 21 May 2000, coll. W. E. Steiner & J. M. Swearingen/Under leaf lit-

ter on sand beneath low shrubs of beach strand" (4); "FLORIDA: Monroe County, Key Largo, near Sunset Point, 25°02'45"N, 80°29'45"W, 15 May 2000, coll. W. E. Steiner & J. M. Swearingen/Under matted dry thatch on powdery soil, open mowed field among scattered trees" [in field notes: "... after dark ... big vacant park-like lot with isolated trees & groves, open mowed sandy flats with leaf litter deep & spongy in some areas—dug into & removed thick top layer to expose dry organic rich powdery soil beneath—got good series of a small *Hymenorus* prob. *farri* ..."] (41); "FL, Monroe Co., Middle Torch Key, Sec. 17, Lazelle Place, uv light trap, 10–19.viii.1992, S. & J. Peck, 92-315" [site described (S. Peck, personal communication) as "very disturbed, open, weedy, hot and dry"] (19, SBPC); "FLORIDA [Palm Beach Co.], Boynton Beach, 12-VI-1968, F. E. Wood, J. A. Davidson/Collected at black light" (3).

FURTHER OBSERVATIONS AND DISCUSSION

Habits and habitats.—The label data and noted observations show that the beetle occurs primarily at or near the coast in open weedy areas on sand or sandy soil. The larvae probably inhabit sandy substrates, as has been observed for some other species of the genus (Steiner 1995). Adults hide during the day under matted leaf litter, in open areas, but often shaded by shrubs, or at the base of trees. They were especially common in sites of human disturbance—near buildings, weedy roadsides, edges of garden plantings, and areas of coarse turf that receive occasional mowing and where layers of thatch accumulate.

Beetles are fully winged and rapidly take flight when exposed to sunlight on removal of plant debris cover. Nocturnal dispersal by flight is probably typical, however, as supported by the series collected at lights. Feeding has not been observed in *H. farri*, but a single Jamaican specimen is labeled "eating coccids on Agave" (Campbell 1971) with some question as to verity—no

predaceous habits have been observed in aleculines, and this needs further investigation. Adults and larvae are likely to be scavengers on dead plant material and probably fungi on its surfaces; adults of two Panamanian species apparently feed on lichens (Campbell 1962), and some eastern U.S. species chew at lichens on tree trunks at night (WES pers. obs.; in litt.).

Biogeography and detection.—"That the genus *Hymenorus* enjoys but a slight measure of popularity with collectors is undeniable" (Fall 1931). In the many localities newly added above, this may have contributed to the lack of detection of *H. farri* before now. In addition, it seems to "thrive" in habitats that are generally ignored and even avoided by collectors. The distribution of *H. farri* is much wider than originally reported, spanning the northwestern Caribbean and Bahamian regions. Campbell (1971) noted that the *Hymenorus* species of coastal areas tended to be more widespread. This species could be indigenous across its wide range, but because of the greater number of recent collections (very few records prior to 1960) and other characteristics considered here, I believe that the beetle is expanding its range.

Its appearance in Florida is especially telling: it is often common where found, but collection records are unknown prior to 1968. This rather distinct member of the genus likely would not have avoided detection until now, given the historical interest and work done on Florida Coleoptera, as summarized by Peck and Thomas (1998). Had the beetle been present much earlier, the diligent collecting of coleopterists such as E. A. Schwarz and W. S. Blatchley, when the Florida biota was in a pristine condition (Blatchley 1932), followed by the monographic works of Fall (1931) and Campbell (1971) on this genus, should have resulted in its detection. Therefore, it appears to be a recent addition to the U.S. fauna. However, determining native versus immigrant status for insects in southern Florida is particularly problematic (Whitehead and

Wheeler 1990), especially with a species of Antillean distribution. A similar situation involving several species of lygaeoid bugs that are probably recent arrivals to southern Florida in roadside habitats has been noted (Slater 1988). For the more vagile components of the circum-Caribbean lowland insect fauna, over-water dispersal from tropical America to Florida is most likely and accounts for the majority of such species in southern Florida (Peck 1989).

➔ Similarly, *H. farri* seems to be new to Puerto Rico, the Virgin Islands, and Bahamas. *Hymenorus wolcottii* Campbell (1971) has been the only *Hymenorus* species previously known on Puerto Rico; it is abundant in many coastal localities and habitats (Wolcott 1950). A continuing survey of the Coleoptera of the Virgin Islands (Ivie 1996) has accumulated specimens of *H. farri* only during the last decade. Also, no Bahamian specimens were found during Campbell's (1971) detailed study of material collected primarily from 1950 to 1965 on many islands, including the Turks and Caicos. The independent discoveries in 1987 on Andros and Grand Bahama, followed by other collections spanning the Bahamian archipelago, suggest a recent arrival and spread, possibly from Florida and/or Cuba.

The occurrence of *H. farri* on the Central American mainland raises several questions. Does this represent part of its natural range, or has it been recently introduced from the Greater Antilles, where it was first collected and recognized? The earliest collection record (Campbell 1971) is that of a specimen taken by E. A. Schwarz at Cayamas, Cuba; no year is given on Schwarz's specimen label, but his letters (Sherman 1929) indicate he worked there in 1903–1904. The few records from Belize, Guatemala, and Mexico are all based on relatively recent captures. That this species is often common, but not among those described by Champion (1885), suggests a possible spread from the Antilles to Central America in recent decades. However, with so few collection records, this suggestion is

tenuous. In addition, dispersal from islands to mainland is atypical—in fact, the opposite is a more likely scenario, with islands being colonized from mainland populations (Darlington 1938).

The genus *Hymenorus* is Holarctic (Campbell 1971, Papp 1958), but the numerous species treated by Champion (1885) and Fall (1931) indicate that its center of diversity and speciation is by far the arid parts of Mexico and the southwestern United States. A few species are known from Panama (Campbell 1962, 1982) and Brazil, but Campbell (1971) doubted that the latter were *Hymenorus*. Phylogeny among species is unknown; assuming that the genus is monophyletic, it displays mostly a "North American-Caribbean track" (Rosen 1976) of distribution, as does the known distribution of *H. farri* alone. Examples of other insect taxa that inhabit the soil surface also show this pattern, such as the carabid genus *Platynus* (Liebherr 1988) and many Lygaeoidea (Slater 1988). This perhaps supports the idea that *H. farri* is a mainland species that has spread to the Caribbean region. Two other species of *Hymenorus*, both of which also inhabit coastal sands, are nearly as widely distributed as *H. farri* and overlap with much of its range: *H. densus* LeConte, from North Carolina to Florida and the Bahamas (Campbell 1971) and Mexico (Champion 1885; recent collection records in USNM), and *H. convexus* Casey, from southern Florida, Bahamas, Turks and Caicos Islands, Cuba, and Cayman Islands (Campbell 1971, 1978). The latter, however, is not known from mainland Central America and appears to be of Antillean origin; Campbell (1971) stated that it "has spread into Florida from the Bahamas." Other *Hymenorus* species, including mainland ones, are known from relatively few records and appear to be more precinctive or endemic to one or a few islands (but this could be due to the "collectors' neglect" mentioned above). *Hymenorus farri* might be naturally widespread and has simply escaped detection across its range until now, but it ap-

appears more likely to be a "weed species" that is spreading (from an uncertain origin, possibly Cuba) with the aid of human activities.

In addition to being an active flier, *H. farri* has characteristics of insects that are likely to be introduced to new regions (Whitehead and Wheeler 1990). Some other adventive tenebrionids inhabit coastal sands and seem prone to accidental introduction (Steiner 1996, 2003, in press). *Hymenorus farri* lives in open, disturbed habitats and is found in the same microsites with other adventive or invasive species (e.g., turf weeds, imported fire ants). It also commonly co-occurs with *Blapstinus fortis* LeConte, a widespread native tenebrionid with a distribution (Davis 1970; WES unpublished data) similar to that of *H. farri*. Natural dispersal via flight and storm winds could have occurred, or, arrival at new lands via commerce, e.g., in soil with ornamental plant stock, is possible, as demonstrated by the recent U.S. port interception of the beetle in a fruit shipment from Central America.

Anthropogenically altered, maintained, open habitats are more easily colonized by species of coastal sandy localities and open scrub, regardless of dispersal method. Removal of native vegetation offers such a species a much greater chance of successful colonization, and the open ground of roadsides provides corridors of dispersal to other areas. Roadside habitats have provided corridors for fire ant dispersal (Taber 2000, Tschinkel 1986). Even some native, flightless species, e.g., the tenebrionid *Opatrinus minimus* (Beauv.), have "weedy" characteristics and may be spreading to new areas, where they are becoming more abundant than in their previous range (Steiner 1999). Future collecting and tracking of individual species in question will better define this continuing blending of biota.

ACKNOWLEDGMENTS

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imen records. Jonathan Bayless and R. B. Rodgers, U.S. National Park Service, facilitated work in the Dry Tortugas; material was collected under permit no. 890002. Fred Burton, National Trust for the Cayman Islands, provided help in many ways during a visit to Grand Cayman. Specimens from Belize were taken on an Earthwatch-supported expedition led by Don Messersmith, University of Maryland. In the Bahamas, research was facilitated by Eric Carey and Tanya Ferguson, Department of Agriculture, Nassau; Vincent Voegeli helped with fieldwork at the Gerace Research Center, San Salvador. Gary Hevel, Smithsonian Institution, helped with search of literature on the activities of E. A. Schwarz. Natalia Vandenberg, Systematic Entomology Laboratory, USDA, supplied information on the intercepted specimen. Lucrecia Rodriguez, Systematic Entomology Laboratory, USDA, assisted with imaging specimens and creating the figures. Michael Ivie, Montana State University, Bozeman, Montana, and Stewart Peck, Carleton University, Ottawa, Ontario, provided specimen data and helpful comments on early drafts of this study. The manuscript was greatly improved with editorial comments from Al Wheeler, Clemson University, Clemson, South Carolina. For access to study the collections in their care, I thank Michael Thomas, Florida State Collection of Arthropods, Gainesville, and Mark Deyrup, Archbold Biological Station, Lake Placid, Florida.

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Dragonflies

Wenhua Lu

From: "Fred Sibley" <fcsibley@empacc.net>
To: "wenhua Lu" <wenhua@etal.uri.edu>
Sent: Monday, November 22, 2004 3:43 PM
Subject: Florida, Guana, etc.

Dear Skip and Wenhau:

Takes a long time to readjust to the northern days and temperatures and then the election results were just too depressing to face up to. Thus a long delayed email.

Sent DNA material from dragonflies to two different researchers. Neither promised miracles but we'll see. May just find out that I need different preservation techniques.

Think I wrote that the red and magenta forms of *Orthemis ferruginea* appear to be different species and not sure either one matches up with a mainland name (would be the magenta form if it did). My mentor says the original description for a Caribbean form gives type locality as Guadeloupe, Jamaica, British Guinea and a few other places so a real taxonomic rats nest.

Caught *Tramea calverti* on Virgin Gorda and *Pantala hymenaea* on Beef Island - first time for each since 1997.

Not sure there's much more to do with dragonflies in BVI. Would like to chase down the large darner reported by two different ladies after my talk. Also, depending on DNA results, my want to do get more material for those studies. But basically, I chased down the odds and ends I wanted this last trip, managed to find places to make behavioral observation. Not sure this work needs to be padded with more specimens or observations.

Would love to come back again next year but hate to be a fifth wheel and not sure you want two people taking up space with a minimal project. Is Holly coming back? Does she need some assistants? Seems to have a tough time finding people who can stay with her. She's a tough worker. Another option would be to work with snake people, but not sure you need another person devoting large amounts of time to catching snakes. In any case will keep in touch.

The Spider Wasps of Puerto Rico and the British Virgin Islands (Hymenoptera: Pompilidae)

ROY R. SNELLING¹ AND JUAN A. TORRES^{2,3}

ABSTRACT: We record 16 species of spider wasps from Puerto Rico. One new species, *Auplopus taino* (Pepsinae), is described from a single female. The types of the long unrecognized *Pompilus cressoni* Dewitz, 1881 have been examined and found to be a species of *Episyron*, a genus not previously reported from Puerto Rico; *E. cressoni* is a senior synonym of *E. conterminus posterus* (W. Fox, 1893), a common North American species. *Batazonus hookeri* and *B. mundiformis*, now placed in *Poecilopompilus* and both described by Rohwer, 1915, are opposite sexes of a single taxon; *P. hookeri* has page priority. We here treat this wasp as a subspecies of the widespread Neotropical species, *P. flavopictus* (F. Smith, 1862).

Keys in both English and Spanish are provided for the separation of the known species, as are appropriate illustrations.

RESUMEN: Reportamos 16 especies de avispas cazadoras para Puerto Rico. Una nueva especie, *Auplopus taino* (Pepsinae), es descrita basado en una hembra. Los tipos de la ya no reconocida *Pompilus cressoni* Dewitz, 1881 fueron examinados encontrándose que son una especie de *Episyron*, un género no previamente conocido para Puerto Rico; *E. cressoni* es un antiguo sinónimo de *E. conterminus posterus* (W. Fox, 1893), una especie común en América del Norte. *Batazonus hookeri* y *B. mundiformis*, ahora colocados en *Poecilopompilus* y ambas descritas por Rohwer, 1915, son los sexos opuestos de un solo taxón; *P. hookeri* tiene prioridad de página. Nosotros aquí tratamos esta avispa como una subespecie de la especie de amplia distribución neotropical, *P. flavopictus* (F. Smith, 1862).

Claves en inglés y español se proveen para identificar las especies conocidas, así como las figuras apropiadas.

KEY WORDS: Hymenoptera, Pompilidae, Pepsinae, Pompilinae, spider wasps, systematics, Puerto Rico

The spider wasp fauna of the islands comprising the "Puerto Rico Bank" (Puerto Rico, the Virgin Islands, and their smaller satellite islands and cays) within the Greater Antilles, is poorly known. St. Croix, although administratively part of the American Virgin Islands, lies east of the Anegada Passage and is, thus, more nearly allied to the Lesser Antillean fauna.

The first published report dealing exclusively with the Hymenoptera of Puerto Rico is that of H. Dewitz (1881), followed soon after by a list of Puerto Rican insects by A. Stahl (1883). Gundlach (1888), although treating Cuban taxa, did include several known to be present in Puerto Rico. The first, relatively modern, listing of the Hymenoptera of Puerto Rico was that of Wolcott (1936), followed 12 years later by an updated list (Wolcott, 1948).

In all of these lists there were numerous misidentifications and questionable generic assignments, largely due to the chaotic nature of spider wasp systematics at the time. Dewitz (1881) included in his list "*Pompilus ferrugineus* Dahlborn" and Gundlach (1888) included also "*Pompilus flavus* Cresson"; neither has been confirmed to be present on Puerto Rico; it seems likely that each is based on a misidentification. Most of the

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Pepsis reaumuri Dahlbom, 1845:465; ♀.

Pepsis heros: Wolcott, 1936:565. [Misidentification]

Discussion. The bright orange to orange-brown wings, with sharply contrasting dark bases and apices are distinctive for this species within our fauna. This wasp appears to be less commonly encountered than either of our other species of *Pepsis*.

Pepsis species prey entirely on mygalomorph spiders (Theraphosidae) ("tarantulas"). According to Petrunkevich (1926), in Puerto Rico *P. marginata* preys only on *Cyrtopholis portoricae* Chamberlin.

Distribution. "Endemic to the West Indies and possibly southern Florida; up to 523 m in the Dominican Republic" (Vardy, 2002). Vardy also noted that all the records from Puerto Rico pertain to the eastern half of the island.

Specimens examined. PUERTO RICO: Humacao, 4 May 1983 (J. A. Torres; LACM) (1 ♀); Río Piedras, June 1983 (J. A. Torres; LACM) (3 ♀♀); Río Piedras, 16 June 1947 (Z. Bajandas; LACM) (1 ♀).

Pepsis rubra (Drury)

Fig. 7



Sphex rubra Drury, 1773:75; ♀.

Sphex rubripennis Christ, 1791:264. [Unnecessary replacement name for *S. rubra*.]

Sphex sanguitutta Christ, 1791:293; ♂.

Sphex papiliopennis Christ, 1791:297; ♂.

Sphex speciosa Fabricius, 1793:217; ♀.

Sphex stellata Fabricius, 1793:219; ♂.

Pepsis stellata: Fabricius, 1804:214.

Pepsis speciosa: Fabricius, 1804:216. Dewitz, 1881:203.

Pepsis quadrata Lepeletier, 1845:478.

Pepsis formosa: Wolcott, 1948:857–859. [Misidentification]

Discussion. As observed in the British Virgin Islands by the senior author, females of both *P. marginata* and *P. rubra* are commonly seen as they search in the forest litter for burrows of their prey. Males are more abundant and may sometimes be seen as they visit the flowers of various shrubs and trees; they are especially abundant at blossoms of *Coccoloba uvifera* (L.) L. (Polygonaceae) when that tree is in bloom. As with many other *Pepsis* species, males form sleeping aggregations; one such, collected on Guana Island on 25 May 1993 by the senior author, consisted of 18 males.

Pepsis rubra is the model for the wasp-mimicking moth, *Empyreuma pugione* (Linné) (Lepidoptera: Ctenuchidae) (pers. obs.).

The presumed prey for this species, and the following, is the local tarantula, *Cyrtopholis bartholmei* (Latreille). This spider is common and lives in ground burrows. Although one of us (RRS) has followed searching females of the wasp, an actual capture has not been observed.

Puerto Rican specimens recorded in earlier literature as *Pepsis coerulia* (Linné) by Wolcott (1936) and earlier authors such as Gundlach (1888) and Ashmead (1900) are misidentifications, but it is not clear to which of the species here recorded from Puerto Rico this name applies. The Linnean species (as well as another with the same name described by Fabricius) is not a species of *Pepsis* (Hurd, 1952).

"*Pepsis formosa* Say, listed by Dr. Gundlach as *Pepsis caerulia* L. in synonymy with *P. speciosa* F., as "rara en Puerto Rico," and by Drs. Dewitz and Ashmead, of which

specimens from Puerto Rico were subsequently identified by Mr. S. A. Rohwer as *Pepsis rubra* (Drury) and confirmed under this name by Prof. Nathan Banks . . ." (Wolcott, 1948).

Distribution. "West Indies, including the Bahamas, Cuba and Jamaica south to the Guadeloupe Passage only" (Vardy, 2000). Vardy further noted that this species occurs at elevations up to 1385 m in Haiti.

Specimens examined. BRITISH VIRGIN ISLANDS: Guana I.: April and October, various years (R. R. Snelling; LACM) (15 ♀♀, 38 ♂♂). PUERTO RICO: Caja de Muertos, 8 July 1983 (J. A. Torres; LACM) (2 ♂♂); Carolina, 20 June 1986 (J. A. Torres; LACM) (1 ♀); Fajardo, 8 June 1927 (LACM) (1 ♂); Río Piedras, 12 May 1948 (P. Zamora; LACM) (1 ♀).

Pepsis ruficornis (Fabricius)

Fig. 6

Sphex ruficornis Fabricius, 1781:450; ♂, ♀.

Pepsis ruficornis: Dewitz, 1881: 203.

Discussion. Although less common than *P. rubra*, *P. ruficornis* is often seen on Guana Island in the British Virgin Islands. The two species are similar in size, but are easily distinguished from one another. In *P. rubra* the wings are largely bright reddish and the antennae are black; in *P. ruficornis* the wings are uniformly blue and the antennae are mostly red beyond the scape in the females, but often only the middle segments are red in males.

Distribution. Greater Antilles to northern South America.

Specimens examined. BRITISH VIRGIN ISLANDS: Guana Island, various months and years (R. R. Snelling; LACM) (10 ♀♀, 22 ♂♂); Sage Mountain National Park, 460 m, Tortola Island, 13–15 July 1987 (S. E. Miller & V. O. Becker; BPBM, LACM) (5 ♂♂); Virgin Gorda Peak, ca. 380 m, Virgin Gorda Island, 17 July 1987 (S. E. Miller & V. O. Becker; BPBM, LACM) (4 ♂♂). PUERTO RICO: Cambalache, 31 Oct. 1991 (R. R. Snelling & J. A. Torres; LACM) (1 ♀); Laguna Tortuguero, 31 Oct. 1991 (R. R. Snelling & J. A. Torres; LACM) (1 ♀); Río Espíritu Santo, 25 July 1989 (R. R. Snelling & G. R. Camilo; LACM) (1 ♀, 7 ♂♂); Valle de Icacos, 650 m, 28 July 1989 (R. R. Snelling; LACM) (1 ♀, 8 ♂♂).

Priocnemis (P.) cornica (Say)

Fig. 3

Pompilus (Miscus) cornicus Say, 1836:305; ♀.

Pompilus (Miscus) conicus LeConte, 1859:746. [Emendation]

Pompilus (Priocnemis) pomilius Cresson, 1867:116; ♀.

Salius pompilius (sic!): Dalla Torre, 1897:237.

Ageniella eximia Banks, 1919a:83; ♂.

Priocnemis pompilus (sic!): Banks, 1919b:245.

Ageniella aludra Brimley, 1928:201; ♂.

Priocnemis (Priocnemis) cornica: Townes, 1957:99–101.

Discussion. This species has not been previously recorded from the Greater Antilles, and appears to represent a recent introduction from the United States, where it is transcontinental. According to Townes (1957) the usual habitat is open, sparsely covered ground, often in sandy areas. Females presumably nest in soil and provision their cells with a variety of spider species. It seems likely that this species may have been accidentally transported to Puerto Rico in the soil of live plant material.

Anoplius hispaniolae Evans

Fig. 14, 19

Pompilus Coruscus: Dewitz, 1881:203 [Not *Pompilus coruscus* F. Smith, 1855; **Misidentification**].

Psammochares (Pompilus) coruscus: Wolcott, 1936:566.

Anoplius (Pompilinus) coruscus: Evans, 1951a:273 [Not *Pompilus coruscus* F. Smith, 1855; **Misidentification**].

Anoplius (Pompilinus) hispaniolae Evans, 1966:324–325; ♂, ♀.

Discussion. This wasp has long been misidentified as *A. coruscus*; Evans (1966) recognized the error and described the species as *A. hispaniolae*. As the name implies, the type is from Hispaniola but Evans recorded additional type material from Santo Domingo and Mona Island. Nothing is known of the biology of *A. hispaniolae*. Our few specimens are from dry scrub forest, both on Puerto Rico proper and Mona Island.

Distribution. Known only from Hispaniola and Puerto Rico.

Specimens examined. PUERTO RICO: "Puerto Rico" (Klug; ZMBC) (2 ♀♀); Bosque Estatal de Guánica, 19–28 Sept. 1998 (R. R. Snelling; LACM); Mona I., 28–30 Oct. 1991 (R. R. Snelling & J. A. Torres; LACM) (1 ♀); Mona I., *Casuarina* plantation, 7–13 Nov. 1992, Malaise trap (R. R. Snelling & J. A. Torres; LACM) (1 ♂).

Aporus prolixus Bradley

Fig. 9

Aporus (Neoplaniceps) prolixus Bradley, 1944a:105–106; ♀.

Discussion. This species was described from a female collected at Christiansted, St. Croix, U. S. Virgin Islands. Its presence on Guana Island, British Virgin Islands suggests that it is likely to be found throughout the Virgin Islands, and perhaps in Puerto Rico, as well.

Nothing is known of the biology of this species. In October 2003, over a period of several days, RRS observed females running on the litter under a large tamarind tree (*Tamarindus indica* L., Caesalpiniaceae), apparently hunting for spiders; none were seen to capture prey, however. So far as currently known, all Aporini are predaceous on various species of trap-door spiders (Ctenizidae); an unidentified species of the genus *Ummidia* is fairly common on Guana Island. Females of this wasp vary greatly in size, suggesting that they may seek out immature spiders.

Distribution. Virgin Islands.

Specimens examined. BRITISH VIRGIN ISLANDS: Guana I., various sites, 24 Apr. to 30 Oct., various years, most ex Malaise traps (Liao Wei Ping, S. E. Miller & V. O. Becker, R. R. Snelling, B. & B. Valentine; BPBM, LACM, OHSU) (8 ♀♀, 12 ♂♂).

Aporus simulatrix (Bradley)

Fig. 10

Odontaporus simulatrix Bradley, 1944a:113; ♀.

Discussion. Originally described from a female from "Jayuya, Pichaco Mt., Areciba (sic!), Puerto Rico" (Bradley, 1944a); female paratypes, three in all, were from various localities in Cuba. The holotype is in the USNM and has been examined; the type locality data are incorrect and should read "Jayuya, Picacho Mt., Arecibo".

The biology of this species is unknown. Presumably the females provision their nests with some species of trap-door spider.

Distribution. Known only from Puerto Rico and Cuba.

Specimens examined. PUERTO RICO: El Verde, Luquillo Natl. Forest, 4–17 Dec. 1968 (USNM) (3 ♀♀, 22 ♂♂); El Verde Field Station, 4 Dec. 1968, ex Malaise trap (LACM) (1 ♀); Río Grande, 1 July 1986 (J. A. Torres; LACM, PRAS) (14 ♂♂); Río Grande, 8 July 1985 (J. A. Torres; LACM, PRAS).

Episyron conterminus cressoni (Dewitz) NEW COMBINATION

Fig. 17

Pompilus Cressoni Dewitz, 1881:203–204; ♀, ♂.

Pompilus posterus Fox, 1893:115; ♀. NEW SYNONYMY.

Pompilus exactus Cameron, 1893:202; ♀.

Pompilus temaxensis Cameron, 1893:208; ♂.

Pompilus porus Fox, 1894:98; ♀.

Episyron posterus: Banks, 1912:229. Evans, 1950:223–226.

Episyron exactus: Banks, 1931:133.

Psammochares (Pompilus) cressoni: Wolcott, 1936:566.

Episyron porus: Bradley, 1944b:11.

Episyron conterminus posterus: Evans, 1966:196–199.

Discussion. The type series of *Pompilus cressoni* Dewitz, described from two females and three males, collected by Klug at an unspecified Puerto Rican locality, has been examined. The better preserved of the two female specimens is here designated as the Lectotype; the remaining specimens are designated as paralectotypes. The types are conspecific with the common North and Central American *E. conterminus posterus* (Fox, 1893).

Evans (1966) treated *E. posterus* as a subspecies of *E. conterminus* (F. Smith, 1873), a South American species, and noted that "*E. conterminus* is virtually identical to *posterus* except that the spurs of the female are whitish and the antennae of the males ferruginous beneath."

Prey records for this species (all from the United States) consist of orb-weaver spiders of the family Araneidae. Nests are in soil and the egg is attached to the wall of the cell rather than to the spider as in most other Pompilidae (Evans, 1950).

This wasp is transcontinental across the southern United States and ranges south to Costa Rica. The nominotypical form occurs in Brazil, Peru, Bolivia, and Argentina.

Specimens examined. PUERTO RICO: "Puerto Rico" (Klug; ZMBC) (2 ♀♀, 3 ♂♂); Bosque Estatal de Guánica, 19–28 Sept. 1998, ex Malaise traps (R. R. Snelling; LACM; PRAS), (1 ♀, 14 ♂♂).

Poecilopompilus flavopictus hookeri (Rohwer) NEW STATUS

Fig. 12, 18



Pompilus flavopictus F. Smith, 1862b:396; ♀.

Pompilus concinnus: Dewitz, 1881:203. [Misidentification]

Batazonus flavopictus: Banks, 1925:338. Wolcott, 1936:566.

Batazonus hookeri Rohwer, 1915:237–238; ♀. Wolcott, 1936:566.

Batazonus mundiformis Rohwer, 1915:238–239; ♀, ♂. Wolcott, 1936:566. NEW SYNONYMY.

Batazonus mundus: Wolcott, 1936:566.

Poecilopompilus flavopictus: Bradley, 1944b:10.

Poecilopompilus interruptus flavopictus: Evans, 1951b:313–314.

Poecilopompilus flavopictus flavopictus: Evans, 1966:206, 214–218.

Discussion. *Poecilopompilus mundus* was described by Cresson (1865a) (as *Pompilus*) from Cuba. Whether or not specimens from Puerto Rico, determined by Wolcott as *P. mundus*, are conspecific has not been determined and Cresson's species is not here listed as a synonym. All the Wolcott specimens seen in PRAS are *P. flavopictus* as here identified.

Evans (1966) noted that the "... West Indian forms ... are at most subspecifically distinct from *flavopictus*." There does seem to be but a single species present in Puerto Rico and we consider *hookeri*, *mundiformis*, and *mundus* (as listed by Wolcott, 1936) to be conspecific with *flavopictus* (F. Smith, 1862). The types of both *B. hookeri* (female) and *B. mundiformis* (male), both in USNM, were examined and found to be the opposite sexes of a single species.

Because the Puerto Rican form is consistently different from the common Central American form, *P. flavopictus flavopictus*, we are here treating it as an insular subspecies. The color pattern of each sex was adequately described by Rohwer (1915) and it is sufficient to note that the insular form differs from the mainland form in the greatly reduced yellow markings on the mesosoma. In particular, the mesepisternum is largely black, with only an oblique yellow line, and the propodeum is black with two small sublateral yellow spots posteriorly.

Wolcott's reference (1936) citing "*Pycnopompilus mavus* [sic!] Ashmead" is in error. In the 1902 paper in which Ashmead described *Pycnopompilus*, the type and only included species, was *P. scelestus* Cresson, 1865b. The species *navus* appears on the prior page as the type species of *Poecilopompilus* Ashmead, 1902; *P. navus* Cresson, 1865a, is now regarded as a junior synonym of *P. interruptus* (Say, 1836).

Known prey records for species of *Poecilopompilus* include only spiders of the family Araneidae (orb-weavers) (Evans, 1950, 1966), of which several species occur in our area. The hunting female darts toward the spider on its web, causing it to drop toward the ground, where it then may be safely attacked by the wasp. Nests are in the soil.

Distribution. Northern South America through Central America to Jalisco and southern Texas; Puerto Rico and the Virgin Islands.

Specimens examined. BRITISH VIRGIN ISLANDS: Guana I., 26–27 Oct. 1992 (R. R. Snelling; LACM) (1 ♀). PUERTO RICO: Fortuna Agricultural Experiment Substation, 19 Nov. 1968, ex Malaise trap (PRAS) (1 ♂); Guánica, 22 Nov. 1979 (LACM) (1 ♂); Guayaba, Cabo Rojo, 13 Feb. 1987 (LACM) (1 ♀); Juana Díaz, 12 July 1990 (LACM, PRAS) (2 ♂♂); Toa Baja, 2 Aug. 1984 (J. A. Torres; LACM) (1 ♀); Toa Baja, 4 Aug. 1984 (J. A. Torres; LACM) (1 ♂); Vega Baja, 11 Sept. 1971 (PRAS) (1 ♀). Specimens have also been seen from Christiansted, St. Croix, in the American Virgin Islands.

Psorthaspis gloria Snelling

Fig. 11, 16

Psorthaspis gloria Snelling, 1995 (1992):103–107; ♀, ♂.

Discussion. This is certainly the most attractive of all the wasps found on Guana Island (Fig. 14) and is evidently related to the Central American species, *P. variegata* (F. Smith). In addition to Guana I. (the type locality), *P. gloria* has been collected on St. Croix and Puerto Rico; it probably occurs throughout the islands of the Puerto Rico Bank.

This species is considerably larger than *Aporus prolixus* and, therefore, likely is predaceous on the adults of the trap-door spiders.

Distribution. Puerto Rico and the Virgin Islands.

Specimens examined. BRITISH VIRGIN ISLANDS: Numerous males and 8 females from Guana Island, various dates and collectors (BPBM, LACM, OHSU, USNM). PUERTO RICO: Bosque Estatal de Guánica, 19–27 Sept. 1998, ex Malaise trap (R. R. Snelling; LACM, PRAS) (8 ♂♂); Desecheo I., 13 July 1968 (S. Medina Gaud; PRAS) (1 ♀).

Incertae Sedis

Gundlach (1888) listed "*Pompilus flavus* Cresson" and "*P. ferrugineus* Dahlbom" from Puerto Rico, but we know of no such species by either name as present in Puerto Rico, or elsewhere in the Greater Antilles.

Dedication

We respectfully dedicate this paper to the memory of Howard Evans, whose contributions and insights so greatly improved our understanding of the systematics of spider wasps.

Acknowledgments

We wish to thank the following for permitting us to study material in the collections in their care: S. Medina Gaud (PRAS), Frank Koch (ZMBC), Scott E. Miller (BPBM, USNM), and B. Valentine (OHSU). Julio Genaro located and made available a copy of the 1946 paper by J. C. Bradley, which we were unable to locate elsewhere. For the opportunity to visit and collect on Guana Island, British Virgin Islands, RRS is deeply indebted to Henry and Gloria Jarecki and James "Skip" Lazell. The color rendering of the female of *Psorthaspis gloria* is the work of the talented Marianne D. Wallace.

We are also indebted to those anonymous reviewers whose suggestions have improved this paper.

Dedication

This paper was originally written to commemorate Howard Evans, a greatly respected colleague. It is now also dedicated to the memory of Juan A. Torres Negrón, my co-author and friend, who died suddenly on 4 June 2004, at the age of 51. Roy R. Snelling.

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RED IMPORTED FIRE ANTS EXPAND THEIR RANGE ACROSS THE WEST INDIES

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The islands of the West Indies have long been home to fire ants (Mann 1920, Wheeler 1905, Wilson 1971), but until the last two decades, this meant only the tropical fire ant, *Solenopsis geminata* (Fabricius). A potentially more serious pest, the red imported fire ant, *Solenopsis invicta* Buren, is now expanding its range in this region. The expansion of *S. invicta*'s range outside the United States has received relatively little attention. Buren (1982) first reported it in Puerto Rico from three mounds in El Tuque, a seaside park near Ponce. It is now very common and widely distributed in Puerto Rico. We collected *S. invicta* at the following locations: Guayama (April 1992, SDP [Porter et al. 1997]), Mayaguez (October 1995, LRD), and Ponce (September 1997, LRD). Mounds were observed and disturbed but no specimens were taken from San Juan (November 1997, LRD), Luquillo Beach (November 1997, LRD), and the Caribbean National Forest (November 1997, LRD).

The red imported fire ant has been reported from several islands in the Bahamas (Fig. 1). In a recent review of Bahamian ant biogeography, Morrison (1998) found records of *S. invicta* from San Salvador (Deyrup 1994). This species has

since been discovered on New Providence and North Andros Islands (Deyrup et al. 1998). The following collections provide new records for *S. invicta* on other Bahamian islands (Fig. 1). Zach Prusak collected foraging *S. invicta* workers on Gorda Cay (= Castaway Cay, October 1997) as stray workers near a large resort construction site but he did not find nests. John Mangold collected *S. invicta* (May 2000) on Abaco Island (Marsh Harbor, Island Breeze) and Grand Bahama Island (Redwood Inn and Freeport airport).

The following are new records from other parts of the West Indies (Fig. 1). Barbara L. Thorne sent fire ants to us from the British Virgin Islands (Guana Island, October 1996) that we identified as *S. invicta*. The presence of this species on Guana Island is, apparently, a recent occurrence. Snelling (1993) spent the month of October 1992 collecting ants there and did not find *S. invicta*. Rudy G. O'Reilly, Jr. collected additional specimens containing alate males and females from four large colonies on the National Guard facility at Estate Fredensborg about 9 km west of Christiansted on the island of St. Croix, US Virgin Islands (November 1997). John Mangold collected specimens of *S. invicta* from a mound along highway 66, about 0.8 km east of highway 663, St. Croix, US Virgin Islands (November 2000).

John Mangold also collected specimens of *S. invicta* from 7 sites on the island of Providenciales, Turks & Caicos (May and June 2001).

Ron Barrow provided 4 samples of *S. invicta* from Antigua, collected at the following locations (January 2000): All Saints; Gambles Terrace, St. Johns; Paynter's Paradise, St. George; Buckley's Village. These constitute the first records from the eastern edge of the Lesser Antilles.

In June 2000, two large colonies containing alates were found in Trinidad near Caroni Swamp on the western coast of the island. Classical morphological identifications of these samples were supplemented with gas chromatographic analysis of cuticular hydrocarbons and venom alkaloids. (Vander Meer 1986; Vander Meer & Lofgren 1988). Because the western edge of Trinidad is only approximately 10 km from the Venezuela coast an invasion of northern South America by *S. invicta* might be expected. Established populations of *S. invicta* are also very likely on other islands in the Lesser Antilles. Improved quarantine efforts may slow the spread of this ant (Lockley & Collins 1990), but mated queens are known to disperse 20-32 km over the ocean (Banks et al. 1973; Wojcik

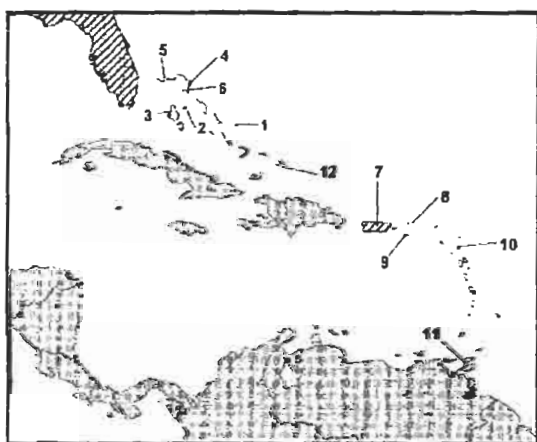


Fig. 1. Known distribution of the red imported fire ant, *Solenopsis invicta*, in the West Indies. The Bahama Islands: 1) San Salvador, 2) New Providence, 3) North Andros, 4) Abaco, 5) Grand Bahama, 6) Gorda Cay. Other Caribbean locations: 7) Puerto Rico, 8) British Virgin Islands, 9) U.S. Virgin Islands, 10) Antigua, 11) Trinidad, 12) The Turks and Caicos Islands; Providenciales Island. Puerto Rico and Florida are marked with bold hash marks because they are generally infested by *S. invicta*.

1983) so they may be able to jump between some of the islands. *Solenopsis invicta* is likely to invade Jamaica, Hispaniola, and Cuba, if indeed it is not already present on one or more of these islands.

Clearly, the red imported fire ant is spreading and becoming a threat throughout the West Indies and may require intensified local quarantine efforts. Resources committed to early detection and eradication of incipient infestations could also greatly delay ecological and economic problems caused by this highly aggressive invasive ant species (Lofgren 1986).

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SUMMARY

We present new records for *Solenopsis invicta* from the Bahama Islands (Abaco Island, Grand Bahama Island, and Gorda Cay) and the first records from the British Virgin Islands (Guana Island); the United States Virgin Islands (St. Croix, 2 sites); the Turks and Caicos Islands (Providenciales, 7 sites), Antigua (4 sites); and the island of Trinidad. These records indicate that this potentially damaging species is becoming widely distributed across the West Indies.

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A New Bee

Family Halictidae: The halictids are small to moderate-sized bees, often metallic, and can usually be recognized by the strongly arched basal vein (Figure 538 C). Most of them nest in burrows in the ground, either on level ground or in banks: the main tunnel is usually vertical, with lateral tunnels branching off from it and each terminating in a single cell. Larger numbers of these bees often nest close together, and many bees may use the same passageway to the outside. Nearly 500 species of halictids occur in our area.

Subfamily Halictinae: In *Agapostemon* (Figure 602 B), *Augochloropsis*, *Augochlorélla*, and *Augochlora*, the head and thorax are a brilliant metallic greenish; these bees are small, 14 mm in length or less, and some of the bees in the genus *Augochlora* are only a few millimeters in length. The other fairly common genera are *Halictus*, *Lasioglossum*, and *Sphecodes*; these usually have the head and thorax black (in some species of *Halictus* the head and thorax are metallic). In *Halictus* the abdomen has apical bands of pale pubescence; in *Lasioglossum* the abdomen lacks apical bands but often has basal bands of pale pubescence; and in *Sphecodes* the abdomen is red. The bees in the genus *Sphecodes* are rather wasplike in appearance, and are parasites (cleptoparasites) of other bees. Some members of the genus *Lasioglossum* are frequently attracted to people who are perspiring, and are called sweat bees.

From:

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Three new *Habralictellus* bee species from the Caribbean (Hymenoptera: Halictidae)

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ABSTRACT. Three new species of the endemic West Indian bee lineage *Habralictellus* are described. *Habralictellus rufopanticis* sp. nov. occurs on Puerto Rico, Mona Island and the British Virgin Islands while *H. eickwortellus* sp. nov. is known only from Puerto Rico. *Habralictellus eleutherensis* sp. nov. is described from the Bahamas and Cuba. Available floral records for *H. rufopanticis* are provided.

Key words: Bees, Halictidae, *Habralictellus*, new species, Puerto Rico, Mona Island, British Virgin Islands, Bahamas, Cuba..

INTRODUCTION

The endemic West Indian bee genus *Habralictellus* consists of two uncommonly encountered species (Moure and Hurd, 1982). Although originally proposed and tentatively retained herein as a distinct genus, *Habralictellus* is certainly a monophyletic derivative of the more widely distributed genus *Dialictus*. Once the relationships among subgroups of *Dialictus* have been resolved *Habralictellus* should be considered as a subgenus of the former (or even recognized as merely a species-group within *Dialictus*, if this group is placed within an expanded *Lasioglossum*: as has been done by Michener, 2000).

Herein I provide descriptions for three closely related species of *Habralictellus*. The species are described here to make their names available for use by other authors studying the Caribbean bee fauna. The format for the descriptions roughly follows that used by Engel *et al.*, (1997) and Engel (2000). Measurements were made using an ocular micrometer on a WILD-M5a microscope. Those values presented in the descriptions are for the holotype with ranges of variation given in parentheses. Sternum and tergum are abbreviated as "S" and "T" respectively.

SYSTEMATICS

Habralictellus rufopanticis, sp. nov.

(Fig. 1)

Diagnosis. Face brilliant metallic copper. Mesoscutum strongly shining, faintly imbricate, well-defined punctures scattered over central disc, punctures smaller and more tightly packed outside parapsidal lines. Two submarginal cells. Basal area of propodeum imbricate, without rugae. Female T2 without transverse medial band of brown, brown pigmentation restricted to lateral margins, metasoma rarely entirely brown.

Description. Female: Total body length 5.62 mm (5.10-5.94; n=5); forewing length 3.56 mm (3.36-3.56; n=5). Head broader than long, length 1.26 mm (1.22-1.30; n=5), width 1.44

mm (1.40-1.50; n=5). Mandible with weak subapical tooth. Lower half of clypeus extending below lower tangent of compound eyes. Epistomal sulcus obtuse. Ocelli above upper tangent of compound eyes. Eyes weakly emarginate above level of antennae; weakly convergent below. Mesoscutal anterior border broadly rounded. Intertegular distance 1.06 mm (0.98-1.20; n=5). Basal area of propodeum approximately as long as scutellum; metanotum approximately half length of scutellum. Basitibial plate with all borders well-defined; inner hind tibial spur pectinate. Two submarginal cells; distal wing venation weakened; distal hamuli arranged 2-1-2.

Labiomaxillary complex dark brown except palpi amber. Labrum reddish brown. Mandible black at base, apex reddish-brown, remainder amber. Clypeus dark brown on apical half, remainder brilliant metallic copper with strong metallic green highlights on lateral margins. Antennae brown except amber on basal third of scape, inner surface of scape, and inner surface of flagellomeres 3-10. Remainder of face brilliant metallic copper with metallic green highlights, blending to completely metallic green on vertex. Gena brilliant metallic green. Postgena mostly metallic copper. Mesosoma brilliant metallic green except pronotal lobe amber and integument near lobe dark brown. Tegula amber. Legs dark brown except amber on protibia, protarsus, and inner surface of mesotarsus; procoxa with some metallic green highlights. Wings hyaline; veins brown except pterostigma and Sc+R dark brown. Metasoma reddish-orange except on the following areas: dark brown on anterior surface of T1 excluding the basal margin, reddish brown on laterally on T2, reddish brown transverse band medially on T3, T4-6 dark brown; dark brown areas with strong metallic blue-green highlights. Sterna amber except brown on basal two-thirds of S5 and apical third of S6.

Clypeus and supraclypeal area with scattered weak punctures, integument between granular; punctures of supraclypeal are smaller than those on clypeus. Scape weakly punctured. Face more strongly granular with scattered faint punctures separated by 1-2 times puncture width. Granular integument becoming weaker towards ocelli, eventually blending to imbricate by vertex. Gena with small, well-defined punctures separated by puncture width, integument between smooth. Postgena imbricate. Pronotal dorsal surface smooth with minute punctures separated by more than 3 times puncture width except along border with mesoscutum punctures separated by less than puncture width, integument between smooth; lateral surface faintly imbricate and impunctate. Mesoscutum faintly imbricate with small, well-defined punctures separated by 2-4 times puncture width over central disc, punctures separated by 1-2 times puncture width outside parapsidal lines and somewhat smaller. Scutellum as on mesoscutum except punctures separated by 3-5 times puncture width over central disc, separated by 1-3 times puncture width on borders. Metanotum imbricate with small punctures separated by 1-3 times puncture width. Preepisternum imbricate with punctures separated by 1-3 times puncture width. Mesepisternum imbricate with punctures separated by 2-4 times puncture width except hypopimeron faintly imbricate and punctures along border with metepisternum punctures smaller and separated by 1-2 times puncture width. Metepisternum with transverse striae on upper half, lower half with faint punctures separated by less than puncture width. Basal area of propodeum imbricate; lateral and posterior surfaces imbricate, posterior surface slightly more faintly than lateral surface. Metasoma faintly imbricate.

Pubescence generally white to yellow. Face with scattered hairs, those at and below level of antennae with many minute branches, those above with relatively fewer minute branches and seeming less numerous. Gena with hairs like those of lower half of face. Postgena with widely scattered, long mostly simple hairs. Pronotal dorsal surface with appressed, short, branched hairs except along a transverse, medial band hairs absent. Mesoscutum with scattered hairs similar to those of vertex; hairs becoming nearly twice as long on scutellum

and metanotum. Pleura with hairs like scutellum and metanotum except metepisternum lacking long hairs instead with a few minute hairs. Propodeal lateral surface with hairs like metanotum on upper border, remainder of hairs simple but of same length; posterior surface with hairs like those of metanotum. Terga with scattered simple hairs, a few with minute branches; hairs becoming progressively more numerous and longer on more distal terga. Sternal hairs long and branched, confined to apical half to third of sterna.

Male: As for the female except as follows: Total body length 4.78 mm; forewing length 3.24 mm. Head length 1.18 mm, width 1.34 mm. Mandible simple. Intertergular distance 0.90 mm. Inner hind tibial spur serrate. Genital capsule as in Fig. 1.

Amber on inner surface of flagellum running from first flagellomere to distal flagellomere. Pronotal lobe dark brown. Legs dark brown except amber on protibia, tarsi, and inner apical half of mesotibia. Metasoma dark brown.

Aside from usual sex differences (e.g., absence of a scopa) pubescence as in the female except sternal hairs much shorter.

Types. **Holotype**, BRITISH VIRGIN ISLANDS: female, Guana Island, hotel area, 26-27.x.1992, R.R. Snelling, on flowers of *Schaefferia frutescens* [sic] (Celastraceae). Deposited in the Natural History Museum of Los Angeles County (NHMLAC). **Allotype**, PUERTO RICO: male, Mona Island, road above Uvero, 11.xi.1992, R. R. Snelling and J. A. Torres (NHMLAC). **Paratypes**. BRITISH VIRGIN ISLANDS: 14 females, same data as holotype. 4 females, same data as holotype except 7.x.1992 and collected on flowers of *Capparis cynophallophora* (Capparidaceae [sic]). 1 female, same data as previous specimens except 13-14.x.1992. 2 females, Guana Island, White Beach, 18°28.7'N 64°34.5'W, 2.vii.1993, R. R. Snelling, on flowers of *Casine xylocarpum* [sic]. 1 female, same data as previous specimen except 29.vi.1993. 1 female, same data as previous specimen except 30.vi.1993. PUERTO RICO: 3 females, Guanica, #120, 27.iv.1991, J.A. Torres. 1 female, Guanica Forest, Guanica, 27.x.1991, R. R. Snelling and J. A. Torres. All deposited in the NHMLAC.

Etymology. The specific epithet is derived from the Latin words *rufus* (meaning "reddish") and *pantex* (meaning "abdomen"), and is a reference to the mostly reddish-orange metasoma of this species.

Floral associations. CAPPARACEAE: *Capparis cynophallophora* L. CELASTRACEAE: *Schaefferia frutescens* Jacq. and *Casine xylocarpa* Vent. (probably variety *caribea* Urban). Two females are covered in pollen, but most specimens lack pollen.

Variation. The degree of coloration on the metasomal terga is variable. The darkness of the dark spots or bands on the reddish-orange terga can range from reddish-brown to dark brown. The size of these area also vary. In one female the terga are mostly brown.

Habralictellus eickwortellus, sp. nov.

Diagnosis. Head and mesosoma brilliant metallic blue. Mesoscutum granular with well-defined punctures closely packed. Pleura granular. Three submarginal cells. Basal area of propodeum with short rugae along anterior margin, remainder of basal area imbricate. Female T2 without transverse brown band.

Description. As for *Habralictellus rufopanticis* sp. nov. except as indicated. Female: Total body length 5.64 mm; forewing length 4.56 mm. Head length 1.32 mm, width 1.38 mm. Intertergular distance 1.10 mm. Three submarginal cells.

Labrum black. Mandible black with reddish-brown apex. Clypeus black on apical half, remainder brilliant metallic blue with a few weak copper highlights medially. Remainder of face brilliant metallic blue with a few faint purple highlights a metallic copper highlight surrounding frontal line. Antennae brown. Gena and postgena brilliant metallic blue-green

with a few metallic copper highlights. Mesosoma brilliant metallic blue with a few metallic purple highlights except dark brown on pronotal lobe. Tegula brown. Legs black except amber on distal tarsomeres. Wings hyaline; veins black. Metasoma dark brown except reddish-orange on T1-2, S1-2, and brown on S3-6; lacking metallic highlights.

Clypeus, supraclypeal area, and face granular with a few small punctures above level of antennae, separated by a puncture width; granular integument becoming weaker by vertex. Scape not punctured. Gena imbricate. Pronotal dorsal surface smooth with small punctures separated by a puncture width or less; lateral surface granular. Mesoscutum granular with small punctures separated by less than a puncture width. Scutellum granular. Metanotum minutely roughened. Pleura granular. Basal area of propodeum strongly imbricate with short rugae along anterior margin extending only one-third of basal area length; lateral and posterior surfaces strongly imbricate.

Face with scattered hairs some with a few minute branches, hairs most numerous along inner margins of compound eyes and bordering epistomal sulcus. Fuscous hairs on outer surfaces of mesotibia, metatibia, metabasitarsus, and metatarsomere 2. Propodeal posterior surface with minute hairs surrounding pit, with scattered long branched hairs.

Male unknown.

Holotype. PUERTO RICO: female, Toro Negro Division, Caribbean National Forest, Cerro de Punta, 6.v.1985, coll., G. C. Eickwort. Deposited in the Cornell University Insect Collection, New York.

Etymology. The specific epithet honors my late mentor and friend, Dr. George C. Eickwort who collected the only known specimen.

Habralictellus eleutherensis, sp. nov.

(Fig. 2)

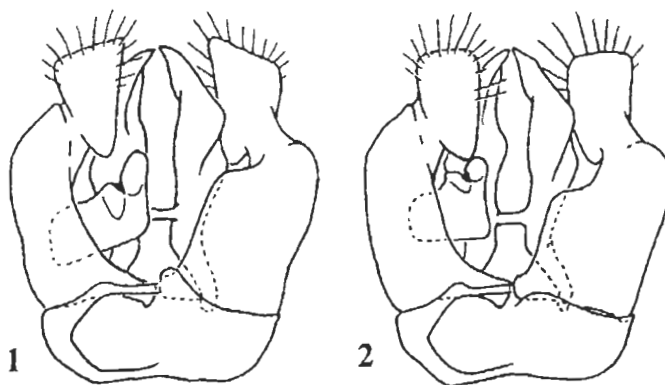
Diagnosis. Face brilliant metallic green. Mesoscutum strongly imbricate, faint punctures scattered over central disc, punctures not smaller nor tightly packed outside parapsidal lines. Two submarginal cells. Basal area of propodeum imbricate, without rugae. Female T2 with transverse medial band of brown; metasoma strongly banded.

Description. As for *H. rufopantis* sp. n. except as indicated. Female: Total body length 4.96 mm (4.54-4.96; n=7); forewing length 3.40 mm (3.20-3.40; n=7). Head length 1.16 mm (1.14-1.24; n=7), width 1.28 mm (1.20-1.32; n=7). Intertegular distance 0.96 mm (0.92-1.02; n=7).

Clypeus dark brown on apical half, remainder brilliant metallic green. Remainder of head brilliant metallic green. Legs dark brown except amber on protibia, protarsus, and inner surface of distal mesotarsomeres. Basal area of propodeum metallic blue. T1-4 reddish-orange with transverse, medial dark brown bands, bands with metallic blue highlights; T5-6 dark brown with metallic blue highlights. Sterna amber except apical margin of S6 dark brown.

Clypeus weakly imbricate. Integument of pronotal dorsal surface faintly imbricate. Mesoscutum strongly imbricate with faint punctures separated by 3-5 times puncture width, not closely packed outside parapsidal lines. Scutellum imbricate with punctures separated by 2-5 times puncture width, punctures primarily restricted to posterior half. Preepisternum strongly imbricate with faint punctures separated by 1-3 times puncture width. Mesepisternum strongly imbricate.

Male: As for the female except as follows: Total body length 4.62 mm; forewing length 3.04 mm. Head length 1.06 mm, width 1.12 mm. Mandible simple. Intertegular distance 0.90 mm. Inner hind tibial spur serrate. Genital capsule as in Fig. 2.



Figs. 1-2. Male genitalia of *Habralictellus* species. 1. *Habralictellus rufopanticis* sp. n. 2. *H. eleutherensis* sp. n. Left half of images is the ventral view; right half is the dorsal view.

Types. **Holotype**, BAHAMAS: female, Eleuthera, Rainbow Bay, 1 July 1987, D. B. and R.W. Wiley, Malaise trap. Deposited in the Florida State Collection of Arthropods (FSCA).

Allotype. BAHAMAS: male, same data as holotype (FSCA). **Paratypes**, BAHAMAS: 7 females, same data as holotype (FSCA). CUBA: 2 females, cayo Guillermo, Archipiélago Sabana-Camagüey, iv.1995, I. Fernández [No. 18.1695, Museo Nacional de Historia Natural de Cuba (MNHNCu)]; cayo Paredón, Archipiélago Sabana-Camagüey, v.1995, R. Rodríguez (No. 18.1696, MNHNCu).

Etymology. The specific epithet is derived from the type locality, Eleuthera Island, Bahamas.

Acknowledgments.— I am grateful to Roy R. Snelling, (NHMLAC), and James Wiley, (FSCA), for allowing me to study the above material. I am further thankful to Julio A. Genaro for assisting with the publication of this paper and for many kindnesses extended to me during my studies of West Indian sweat bees.

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Hi Skip and Wenhua:

I hope you got or will get my little package in the mail. I know you are looking for references to work that people who study at Guana have published etc., so I want to add a footnote to the material that I sent you:

Back in 1989, I gave a paper at the Society for Historical Archaeology Conference in Baltimore, Md. in which the small post-in-ground structure on the flats at Guana Island (the one by the burials near the beach) was described and discussed. The title of the paper was; "Post-in-Ground Construction: An Example of Acculturation in the Virgin Islands."

These papers are not published afterwards, but the paper was cited in: William Chapman, "Slave Villages in the Danish West Indies: Changes in the Late Eighteenth and Early Nineteenth Centuries." In: Perspectives in Vernacular Architecture IV, edited by Thomas Carter and Bernard L. Herman, Columbia University. Missoula Press, pp 108-120; Notes pp. 223-226. My note is Number 13 on page 224.

I plan also to give a paper in Trinidad this July at the IACA conference, to introduce the work at Guana. Happy new year to you both. Best wishes, Holly

October 27, 2004

PREHISTORIC MIDDENS: A RECORD OF NATURAL HISTORY

BY ELIZABETH RIGHTER

Introduction

My talk tonight is about the natural resources that may be found in prehistoric middens and how they can help us to identify the plants and animals that were present in a given area in the past. In the New World, a prehistoric midden is a waste dump left by people, sometimes called “Indians”, who lived there before the arrival of Christopher Columbus. By analyzing the materials found in these prehistoric waste deposits we can learn not only about the Indian way of life, but also about the animals and plants that were present in a given area and in its surrounding waters before European introduction of new species. Recovery of data from prehistoric middens, found on Guana Island, in the British Virgin Islands, should provide much information about the natural history of the island. One goal of Skip Lazell’s biological research on Guana Island is to restore to the island many of the plants and animals that were originally present. The Indian middens on Guana are a valuable source of information to assist in achieving this goal.

Background

For years, prehistoric pottery and a few shell celts had been turning up in the garden area at the Guana Island resort. In 1988, at Guana, we made a preliminary shovel testing survey of the flat land inland from White Bay and generally delimited the distribution of prehistoric material there. In 2003, we set up a grid over the site; starting with a base line, and laying out transects every five meters. We also conducted additional shovel tests at the edges of the grid to try to find the limits of the site, and extended the grid into a rich midden which was in a future donkey pen area. In this area we found a thick intact midden with refuse material in place, where it had been thrown in the prehistoric past.

In 2003 also, we excavated a number of units in this prehistoric midden. At some sites, like Tutu in St. Thomas, several layers or strata are present in the soil indicating that the site was occupied for many generations and sometimes thousands of years. In such cases, it is possible to chart cultural changes as well as changes in the plant and animal species that were present. Our findings so far in the Guana midden, however, indicate a single time period during which refuse was either thrown out during a single occupation or disposed of repeatedly during short stays on the island. As we do more investigating and perhaps find other midden areas, it may be that there was more than one occupation of the island and that there is horizontal differentiation in the distribution of prehistoric material. But we do not know this yet.

During the 2003 excavations, each level was cleaned off and photographed, and artifacts

were mapped in place and then collected and stored in labeled bags. Soils were collected from each level and from certain locations in the midden also. Such soils may contain tiny microscopic plants residues and tiny bones that would be recovered from fine screening in the lab.

In the midden the soils are very dense, and, because we could not determine soil or level changes, we excavated the prehistoric stratum, which was about 25-40 cm thick, in arbitrary 10-cm intervals so that we could keep track of artifact locations in the soil. Analysis of the ceramic types and distributions in the soil, supported by carbon-14 dates, should reveal 1) the extent of disturbance, if any, from gardening; and 2) whether there was one or a series of occupations on the island.

We have not yet been able to recover an adequate charcoal sample from the midden, but we have recovered a good sample of the prehistoric ceramics from Guana, and these are undergoing analysis to compare their attributes with ceramics from other sites in the region (which includes the Greater Antilles and the British and US Virgin Islands (Richter, Wild and Lundberg, 2004). So far, comparative typology indicates similarities between the Guana island pottery and some pottery from Magens Bay in St Thomas. The Guana pottery also shares some characteristics with pottery from sites in St. John. Based on this preliminary comparison, it would seem that the Guana midden ceramics date to a period between about AD 700 and AD 1200. As Skip Lazell has noted, this is a time period that is not represented at the Tutu site in St. Thomas.

In the Greater Antilles and USVI, ceramics, (which are often used by archaeologists as indicators of cultural change), gradually undergo transformation from the classic Saladoid pottery which contained many highly decorated items in White on Red (W-O-R) painting to a plainer ware with sophisticated shapes, known as Cuevas in Puerto Rico and Coral Bay-Longford in the US Virgin Islands. In Puerto Rico and the US Virgin Islands, early or Elenan Ostionoid pottery followed the Saladoid series (Rouse, 1992: fig 14) and is very different from it.

Early Ostionoid, and possibly some late or epi-Saladoid pottery* is found in the Guana midden. The pottery is relatively crude, with traces of coils left on the necks of some vessels. Exteriors are lumpy and poorly smoothed and certain diagnostic decorative features are often present. Shapes tend toward bowls with incurving rims.

The pre-Columbian human utilization of Guana Island appears to have occurred after the initial Ceramic Age settlement of many Caribbean islands by Saladoid people (sometimes called farmers because they were the first known Caribbean islanders to practice agriculture). A prehistoric human presence on Guana ended before the rise of Taino chiefdoms which have been identified in the Greater Antilles, including the USVI, Puerto Rico and Dominican Republic

* Note 1. The existence of an epi-Saladoid ware is currently under debate and we are hoping that pottery found in the Guana midden will assist in clarification of the situation.

(Richter et al, 2004). The Guana Island ceramics are representative of a very interesting time period of apparently rapid cultural change in the Greater Antilles. However, there is much to learn about the reasons for, and mechanisms of such change. The site at Guana Island, because it apparently is a single component, promises to shed light on some important questions regarding this period of prehistory.

Flora

Among the remains that may be recovered from the Guana prehistoric midden are plant remains, some microscopic, that do not deteriorate over time. These include pollen, phytoliths and charred plant remains. Plant pollen is a durable and useful source of information about plants that were present at a collection site and its environs. Because it is windborn, pollen from some distance away may be present in a midden. Pollen frequently leaches out of sandy soils; but, because the soils of the Gauna prehistoric midden are dense and moist, there is a good possibility that pollen is preserved in them. Such pollens might assist in identification of the types of trees, herbaceous plants and grasses that were present prehistorically; and might indicate whether or not fresh water ponds and marshes were extant in the vicinity. With the assistance of a pollen analyst, it may be possible to analyze soils collected from the midden to find pollen that will identify some of the plants that were present a thousand or more years ago on Guana. From knowledge of the identified plants, we may be able to reconstruct some information about the vegetation, climate and general ecology of the island.

Another microscopic plant part that can provide more locally specific botanical information is a phytolith. Phytoliths are microscopic bodies of silica deposited in the cells of living plants and then released into the soil when the plant dies and decays. Because phytoliths are mineralized, they survive in soils over long periods of time, even in the tropics. These are often diagnostic of individual plant families and genera. Because phytoliths are residues of plants that decayed in place, they are sometimes more useful than pollen for identifying those plants that were directly associated with a human occupation site and, consequently, a localized area.

While most soft plant parts deteriorate, charring preserves plant remains, and these, including seeds, can be analyzed to either confirm the results of phytolithic and pollen analysis or add more information about the flora of an area. Charred plant remains are recovered from bulk soil samples by a process known as flotation. This season (2004), we constructed a flotation device and recovered many charred plant remains that were present in the soil samples collected from the Guana midden.

Fauna

As well as plants, Indian middens also often contain evidence of animals that, although not a food source today, were in the environment and utilized for food by prehistoric people. Some of these animals are found on Guana, or in its waters, today. For example, from the Tutu middens in St. Thomas, evidence of white crowned pigeons was recovered; while, from the Indian midden at

Magens Bay, St Thomas, Theodoor deBooy excavated mammals, birds, reptiles and mollusks that included sea turtles and manatees (or sea cows).

Middens also can provide information about animals that once lived on an island and are no longer present. For example, in the Magens Bay midden, DeBooy also found the bones of a small rodent or hutia that is now extinct. It is believed that the prehistoric people brought the animals from Puerto Rico to the US Virgin Islands. Dr. Elizabeth Wing has found supporting evidence for an hypothesis that at some prehistoric sites the hutia were raised in pens for food. At Tutu, however, we did not find hutia bones in sufficient numbers to believe that the Indians there were indeed raising the animals at that site. DeBooy also found bones of a flightless rail bird that had not been identified previously. Both the hutia and the flightless rail also were found in middens on St Croix. The hutia has been identified in the Guana midden, and there is a good possibility that the flightless rail was present also.

At Tutu, we recovered the tooth of a monk seal, another animal that is now extinct in the region. Monk seal jaws and teeth have been recovered from other sites in the Antilles and were verbally reported to have been found in the Guana material from 1988. However, in the present investigations, we are hoping to find more conclusive evidence of this animal's presence in the Guana refuse.

During 2003, we collected a number of animal bones, mostly fish, which were taken for analysis to Dr. David Steadman, Department Chair and ornithologist at the University of Florida in Gainesville. According to his findings, so far, we have found evidence of birds such as shearwaters, pigeons and boobies; iguana, fish, crab, hutia and sea turtle. Dr. Steadman is compiling a more comprehensive report which will be available soon.

Summary

In summary, prehistoric middens are extremely valuable sources of biological information that often is not utilized by non-archaeologists. Middens contain, in concentrated form, not only evidence of flora and fauna that were present in an area and utilized as human food, but also the remains of many other plants and animals that were utilized in economic, religious, medicinal, and other ways by a site's inhabitants.

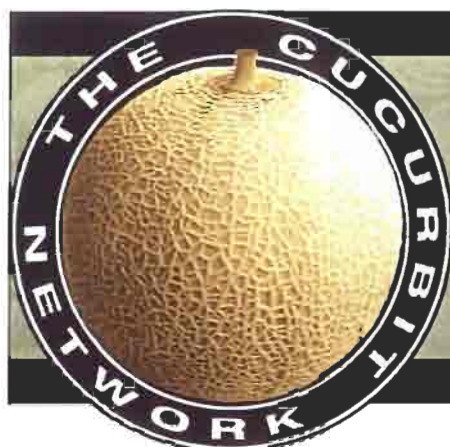
Because we can usually date midden deposits, and identify items introduced by trade or exchange, carefully excavated and analyzed midden deposits can give us a time frame for when certain animals and plants were present. Guana's prehistoric middens potentially may provide evidence of animals and plants that lived on Guana Island; or were hunted, fished and collected by prehistoric people from nearby marine environments, between about 800 and 1300 years ago.

From identification of plant and animal remains in middens we can reconstruct the natural history of an area when prehistoric humans were present. The prehistoric middens on Guana Island, because of the remarkable information that they contain, are deserving of careful

protection. Ultimately, with the assistance of analytical specialists, these middens can provide undeniable proof of the flora and fauna that were a part of the island's ecology as many as 1300 years ago.

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A semiannual newsletter for The Cucurbit Network

The Cucurbit Network News

Volume 12, Issue 1 — Spring 2005

Cucurbitorial—

Moving Pains

The Spring 2005 issue of our newsletter is out early this year because TCN Editor Deena Decker-Walters and her husband, Terrence, are in the process of moving to Fort Collins, Colorado. Thus, the headquarters of The Cucurbit Network will be leaving the sunny shores of southern Florida and entering the world of fragrant pines and snowy peaks. There are not a lot of native cucurbits in the montane West, nor is it the best climate for growing these cold-sensitive vines. So Deena will have to satisfy her cucurbit-lust by continuing to communicate with those of you who are blessed with warm-weather gardens or travels to tropical locales. Keep sending in your articles so that your experiences can be shared by all readers of TCN News.

Our other editor, Tom Andres, has been on recent adventures to South America. He will share some of his cucurbit encounters (e.g., tales of *Fevillea* necklaces and unusual tropical squashes) in the Fall 2005 newsletter.

→ TCN member Angela Davis continues her

explorations of Caribbean natives with an article in this issue on *Doyerea emetocathartica* and an article in the fall issue on *Cayaponia americana*. We'd like to hear from more of you concerning your cucurbit experiences. An easy way to communicate and send both articles and digital photographs is to use our e-mail address—CucurbitNetwork@netscape.net. And, even though Deena is in the midst of moving, mail will be forwarded from our

Miami P.O. box to Colorado for the next year. So, you can still send letters and snapshots by regular mail. We will, of course, send out the new Colorado address for The Cucurbit Network in the next issue of the newsletter. Finally, if you have cucurbit photographs that you would like to contribute to our website (www.cucurbit.org), Tom, who manages the site, can be reached at Tom@Andres.com.

—The Editors: DDW and TCA.



Caribbean Coralfruit ←

by Angela R. Davis & Rudy G. O'Reilly, Jr.

In 1864, Dr. Renato de Grosourdy named a New World cucurbit species *Doyerea emetocathartica*. Subsequently, the species had several synonyms, such as *Corallocarpus emetocatharticus*, *Corallocarpus glomeratus*, and *Anguria glomerata*. In fact, this species has at least seven synonyms. However, Grosourdy's scientific name appears to be the most widely accepted and is still used today.

This cucurbit not only has a handful of scientific names, it also has many common names, including coralfruit, batata de burro, batata zandumbia, batata zambomba, kis kaan (meaning snake stink), kuum ak (pumpkin vine), tuch tunich (belly raising among the stones), xkabax kaax (plant from the forest), xmakal kaan (vine with a yam), xput kaan (papaya vine), xta kaan (stinky vine), ya'ax kani (wild vine), and xmuk kaan (buried vine). The least flattering of its common names is probably diarrhea plant. The scientific name *emetocathartica* actually refers to vomiting (emetic) and purgation (cathartic). We guess Grosourdy was having some fun with his nomenclature.

As its name suggests, this woody perennial vine has been employed as an emetic. It has also been prescribed by Latino healers in New York for treatment of uterine fibroid cysts. In Yucatán, Mexico, coralfruit is reportedly used by the Mayan people as a remedy for snake bite, ulcers, rheumatism, and as an analgesic. Although often grown by cucurbit or succulent fanciers, there is little commercial use for coralfruit, except as a folk medicine.

This species prefers thickets at low to middle elevations. It does well in the understory, climbing on bushes, trees, and other vines, and can often be found in coastal scrub. Coralfruit survives in rocky, tropical, arid zones because the plant stores water in its fleshy subterranean roots and woody stems.

The tendriled vine branches from a tuberous base with nearly cylindrical stems of up to 10 m long. The smooth grayish-green color of the mature stems contrasts with the light green pubescent leaves. The undersides of the often-lobed leaves are pubescent; the upper surfaces are rough. The leaves vary in size, up to 10 × 15 cm, and shape, from lobed wide-ovate to

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Rudy G. O'Reilly, Jr., U.S.D.A. District Conservationist

Rudy received his masters in Botany from the University of Puerto Rico in Mayaguez. Since that time, he has worked in St. Croix for the University of the Virgin Islands' Cooperative Extension Service as a Resource Specialist, then for the Natural Resources Conservation Service of the U.S. Department of Agriculture (U.S.D.A.) as a Soil Conservationist and currently as the District Conservationist. A native of St. Croix, Rudy enjoys hiking the trails of his and the surrounding islands, collecting both herbarium and living material for conservation. His own collection of native plants and local bonsai keeps him busy and serves as a personal conservation effort. Rudy specializes in *Ficus* and many of his bonsai are of species collected from various islands in the Caribbean. At one time his bonsai collection even included a corallfruit (*Doyerea emetocathartica*). Since that specimen was lost in a hurricane, the only cucurbits you can find in his collection these days are those in his refrigerator. Along with his green thumb, Rudy finds time to entertain his two dogs Bucho and Ginga. He also loves keeping aquariums and practices the Afro-Brazilian martial art called capoeira. To contact Rudy, e-mail him at Rudy.O'Reilly@pr.usda.gov.



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rounded-cordate, giving some of the leaves a heart-shaped appearance. The diversity of leaf size and shape on the same vine gives the plant a mismatched look.

Corallfruit vines are dioecious, having male or female flowers, but not both. Therefore, it takes at least two plants to set fruit. The small flowers are not showy. The male blossoms are about 4 mm long and are borne in short racemose clusters. Female blossoms are larger (ca. 8 mm long) and have elongated, densely pubescent ovaries. The flowers have green sepals and five white or greenish-yellow petals. The asymmetrically ellipsoid fruit is a little over 1–2 cm long and fleshy. The smooth surface becomes rugose as the pepo dries out. The light green rind, decorated with dark green spots and broken whitish lines, turns orange or red with fruit maturity. The thick pear-shaped seeds are mottled brown and measure about 4 mm long.

Corallfruit is native to various islands of the Caribbean, including Hispaniola, Puerto Rico, U.S. Virgin Islands, Lesser Antilles, Trinidad, and Margarita. On the

mainland, it ranges from Mexico through Central America to Colombia and Venezuela. The corallfruit photos shown here were taken on Guana Island, a little slice of paradise in the British Virgin Islands. We were looking for this and other cucurbits on the island to collect seed for germplasm conservation. We were excited to find this species since it had not been documented here, even though a fairly thorough compilation of the island's flora had been made. Conservation of this and other species is of increasing importance for the British Virgin Islands since the natural habitat is being destroyed by feral sheep and goats at an astonishing rate. Even though some control measures have been undertaken on Guana Island, sheep defoliate the forest floor, leaving little chance for seedling survival. We were only able to locate two corallfruit plants after a week

of searching the 300-hectare island. And, unfortunately, we found no seed for collecting. Perhaps on our next trip.



Two corallfruit stems winding around each other for support.

Suggested Reading

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Above: Three leaves of corallfruit.



Left: Woody vine of *Doyerea emetocathartica*.

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