All members of the SSAR are entitled to vote by mail the secure online ZenScientist website via this link: http://www.ssarherps.org/pages/membership.php. To join SSAR or to renew your membership, please visit www.ssarherps.org. 

The Society for the Study of Amphibians and Reptiles, the largest international herpetological society, is a not-for-profit organization established to advance research, conservation, and education concerning amphibians and reptiles. Founded in 1958, SSAR is widely recognized today as having the most diverse society-sponsored program of services and publications for herpetologists. Membership is open to anyone with an interest in herpetology—professionals and serious amateurs alike—who wish to join with us to advance the goals of the Society.

All members of the SSAR are entitled to vote by mail ballot for Society officers, which allows overseas members to participate in determining the Society’s activities; also, many international members attend the annual meetings and serve on editorial boards and committees.

All members and institutions receive the Society’s primary technical publication, the Journal of Herpetology, and its bulletin, Herpetological Review; both are published four times per year. Members also receive pre-publication discounts on other Society publications, which are advertised in Herpetological Review. To join SSAR or to renew your membership, please visit the secure online ZenScientist website via this link: http://www.ssarherps.org/pages/membership.php.

Future Annual Meetings
2014 — Chattanooga, Tennessee, 30 July–3 August (JMIH with ASIH, HL, and AES)
2015 — Lawrence, Kansas 30 July–3 August (SSAR with PARC and KHS)

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and it seems likely that turtles are capable of traversing steep slopes. Diet is presumed to include insects and fruits. Courtship and oviposition are thought to occur near the start of the rainy season, with females producing clutches of 1–4 eggs (Milstead and Tinkle 1967. Copeia 1967:180–187), although reproductive ecology remains unstudied in the wild.

Our cover depicts an adult Spotted Box Turtle in situ near the east bank of the Río Aros, Sonora, Mexico, discovered by Robert A. Villa. Here, at the point where the Aros meets the Río Bavispe to form the headwaters of the Río Yaqui, *T. nelsoni* approaches its northern boundary. The habitat is characterized by plants whose northward expansion is thwarted by sensitivity to frost; other neotropical reptiles whose northern range limits are nearby include Central American Indigo Snakes (*Drymarchon melanurus*), Mexican Brown Snakes (*Storeria storerioides*), Mexican Black-bellied Garter Snakes (*Thamnophis melanogaster*), Beaded Lizards (*Heloderma horridum*), and Clouded Anoles (*Anolis nebulosus*) (Enderson et al. 2009. Check List 5[3]:632–672).

Villa recorded the image using a Fujifilm FinePix S4500 using fill flash. He is a Tucson, Arizona-based field biologist whose primary interests are in monitoring biodiversity of the Sky Island region. He is a past president of the Tucson Herpetological Society, as well as an accomplished violinist.

**ABOUT OUR COVER: Terrapene nelsoni**


_Terrapene nelsoni_ (Spotted Box Turtle), depicted on our cover, remains the least known of the box turtle species. It occupies the Pacific versant of the Sierra Madre Occidental on Mexico’s west coast from Sonora and Chihuahua south to Nayarit and Jalisco. However, the vast majority of records are from the northern part of the range (Sonora) and elsewhere it remains a rarely recorded species (Buskirk and Ponce-Campos 2011. In Rhodin et al. [eds.], Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs No. 5, pp. 060.1–060.9, doi: 10.3854/crm.5.060.nelsoni.v1.2011, http://www.iucn-tftsg.org/cbftt/).

This is a turtle of thornscrub and pine-oak forest in the Sierra Madre Occidental. Thornscrub, in particular, is a plant community that has a stark appearance for much of the year until the arrival of summer monsoons, when the region is quickly transformed into a luxuriantly green landscape. This is when box turtles become active. The terrain is often rugged, and it seems likely that turtles are capable of traversing steep slopes.

**Dean E. Metter Memorial Award, 2013**

The Metter Memorial Award honors the legacy of Dean E. (Doc) Metter, long-time biology faculty member at the University of Missouri-Columbia. The award is designed to encourage students to pursue field research in herpetology.

The 2013 Metter Memorial Award goes to Mitch Tucker, a PhD student in the Division of Biological Sciences at the University of Missouri. His major professor is Carl Gerhardt. Mitch’s proposal was entitled “Behavioral Consequences of Polyploidy in Gray Treefrogs, _Hyla chrysoscelis._” A key component of the proposal hinges upon being able to generate autopolyploid frogs in the lab which Tucker is able to do with a “cold-shock” treatment developed by he and Gerhardt. Tucker’s proposal was especially innovative and experimental and takes an approach involving field work as well as laboratory work to provide insight to a particularly interesting biological system. Congratulations to Mitch Tucker.

**SSAR Student Poster Award Winners for 2013 Announced**

The third annual SSAR Student Poster Awards were presented at the 56th Annual Meeting of the SSAR in Albuquerque, New Mexico, 10–15 July 2013. This year there were 40 eligible posters. In recognition of outstanding student poster presentations at the annual meeting, a single award was given in each of the following categories: Evolution, Genetics, & Systematics (6 presentations), Ecology, Natural History, Distribution, & Behavior (23 presentations), and Conservation & Management (11 presentations). Because few students entered the Physiology & Morphology category, those students were placed in other categories and no award was given in that category. All awardees received a check for US $100 and a book from University of California Press.

This year’s judges were Tiffany Doan (Chair, State College of Florida, Manatee-Sarasota), Marina Gerson (California State
Biology of the Reptilia

This celebrated series, now complete in 22 volumes, has been widely acclaimed as the definitive resource on reptilian biology. From the first volume in 1969, the distinguished contributors to this series have included an international group of almost 170 experts in their respective fields under the general editorship of Carl Gans. Each volume consists of multiple chapters summarizing the state of our knowledge, laying groundwork for future research, and providing an in-depth guide to the relevant literature. All volumes are fully illustrated with figures, graphs, and extensive tables of information. Each text volume has both subject/species and author indices, and is bound in sturdy cloth covers.


- **Volume 22 (Comprehensive Literature of the Reptilia)** 1366 pages. Cross-indexed list of the 22,652 titles cited in volumes 1 to 21, compiled by Ernest Linder.

**Note:** Previous volumes in this series were issued by other publishers in the UK and USA.

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Reduced Prices for Individual Volumes and Additional Discount on Sets of Four Volumes

- Volume 19 $20 (reg. $88)
- Volume 20 $30 (reg. $70)
- Volume 21 $30 (reg. $70)
- Volume 22 $45 (reg. $130)
- Special price for all four volumes $110 (reg. $338)
- Shipping: $5 per volume in USA; overseas at cost.

Send orders to: Breck Bartholomew, SSAR Publications Secretary, P. O. Box 58517, Salt Lake City, Utah 84158-0517, USA (telephone: area code 801, 562-2660; e-mail: ssar@herpnet.com). Make checks payable to “SSAR.” Overseas customers may make payment in USA funds using a draft drawn on American banks or by International Money Order. All persons may charge to MasterCard, American Express, Discover Card, or Visa (please provide account number and expiration date). SSAR membership details and a complete list of all Society publications can be obtained on request to the Publications Secretary (address above). For details, check the Society’s website at www.ssarherps.org.
SSAR Roger Conant Grants-In-Herpetology: Award Winners for 2013

An award in the amount of US $500 was made to each of the following individuals:

Conservation.—Todd Pierson, University of Georgia, “Monitoring Appalachian Plethodontidae using “environmental DNA.” Advisor: Travis Glenn

Education.—Tiffany Vanderwerf, Buffalo Zoo, “Save your backyard: a local herpetological conservation education outreach program.”

The Andrew H. Price Field Research Grant In Herpetology.—Mark Oliva, California State University-Northridge, “Call complexity of an Ecuadorian treefrog, Dendropsophus carnifer: mate call recognition and female choice.” Advisor: David Gray

Laboratory Research.—Schyler Nunziata, University of Kentucky, “Microevolutionary response of two salamander species to climate change in an isolated seasonal wetland.” Advisor: David Weisrock

Travel.—Justin Lawrence, The University of Mississippi, “The effect of color and pattern on predator generalizations in a polymorphic poison frog.” Advisor: Brice Noonan

International.—Jessica Hacking, Flinders University, Australia, “Honest signals of fitness? Analysis of immune gene variation, parasite loads, and male colouration in the tawny dragon lizard (Ctenophorus decresii).” Advisor: Mike Gardner

SSAR thanks Committee Chair, Joshua M. Kapfer (University of Wisconsin-Whitewater), and the following reviewers: Robert Brodman (St. Joseph’s College), Kyle Barrett (Clemson University), Michael Clifford (Virginia Herpetological Society), Gary Fellers (USGS-Western Ecological Research Center), Lee Grismer (La Sierra University), Jeffery Lorch (University of Wisconsin-Madison), Malcolm McCallum (University of Missouri at Kansas City), Melissa Pilgrimm (University of South Carolina Upstate), David Steen (Virginia Tech), Steve Sullivan (Peggy Notebaert Museum, Chicago).

Roger Conant Grants-in-Herpetology Program 2014

Proposals will be accepted for the 2014 SSAR Grants-in-Herpetology Program starting on 15 September 2013. This program is intended to provide financial support for deserving individuals or organizations involved in herpetological research, education, or conservation. In keeping with the Society’s goal of encouraging participation by the broadest possible community of applicants, preference may be given to individuals who might not have access to other funding sources. Applications must be submitted by individuals only (but see special considerations for education category below).

Grant proposals will be considered in the following categories:

1. CONSERVATION OF AMPHIBIANS AND REPTILES. Proposals should outline a conservation-oriented research project. This project may focus on species endangered or threatened at the state, national, or international level, or address research on potentially threatened habitats or species, or on introduced injurious species.

2. THE ANDREW H. PRICE FIELD RESEARCH GRANT IN HERPETOLOGY. Proposals may address needs for field station fees or equipment and materials in field oriented projects, or the field work portions of broader studies. This might include in situ behavioral studies, ecological, life history, or sexual selection studies. Survey work by individuals or regional societies may be submitted here or in TRAVEL below depending on how the funds are to be used.

3. LABORATORY RESEARCH. Proposals may address needs for equipment or materials in laboratory projects or laboratory portions of broader projects. This might include studies in behavior, biochemistry, molecular biology, biomechanics, or physiology.

4. HERPETOLOGICAL EDUCATION. Proposals may address an educational project or start up support for an educational program in a zoo, museum, park, nature center, regional herpetological society, etc. The project must focus on a herpetological topic. Note: Although proposals for institutional projects are accepted, education proposals must be submitted by an individual (either sole applicant or principle contact person for the project). Applicants need not be students or SSAR member.

5. TRAVEL. Proposals may address support for travel to field study sites near or far, or to utilize distant collections or facilities. If funding is sought to get from one place to another, proposals should be submitted in the TRAVEL category. Proposals normally submitted in the CONSERVATION or FIELD RESEARCH categories should be submitted here if travel funding is being sought.

6. INTERNATIONAL. Proposals may address needs in any of the above five categories. The applicant must be a student, but not necessarily a SSAR member. Preference will be given to students with limited access to research funds and in countries where herpetological research has historically been under-funded. Note Regarding Eligibility in the International Category: In late 2011, the current President of SSAR, the Grants-In-Herpetology Chair, and several members of the SSAR Board of Directors decided that proposals in this category would only be accepted if they were submitted from institutions OUTSIDE of the United States. Proposals from students

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who are primarily affiliated with United States institutions are not eligible for this category.

Submitting your proposal: All proposals must be submitted electronically to Joshua Kapfer (e-mail: kapferj@uww.edu) as a single PDF file named “lastname-category.pdf” no later than 15 December 2013 to be considered (letter of support may be included with the proposal or sent separately). Exceptions to electronic submission and file format may be allowed for special cases with prior approval by SSAR-GIH Chair. Full details about the GIH program and proposal requirements are available on the SSAR website:

http://www.ssarherps.org/pages/GIH.php

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NEWSNOTES

Collections Codes Updated

Standard Symbolic Codes for Institutional Resource Collections in Herpetology and Ichthyology, edited by Mark Sabaj Pérez, has been updated. Version 4.0, dated 28 July 2013, can be downloaded in pdf or Excel format from http://www.asih.org/ (select the Resources tab).

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New Version of Reptile Database Released

The Reptile Database (http://www.reptile-database.org/), edited by Peter Uetz as a service to the herpetological community, released a new version in July 2013. The Database now contains 9831 species and 31,756 literature references. For full details of this update, please visit: http://www.reptile-database.org/db-info/news.html.

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David J. Morafka Memorial Research Award - 2014

In honor and memory of Prof. David J. Morafka, distinguished herpetologist and authority on North American gopher tortoises, the Desert Tortoise Council, with the aid of several donors, has established a monetary award to help support research that contributes to the understanding, management, and conservation of tortoises of the genus *Gopherus* in the southwestern United States and/or Mexico: *G. agassizii*, *G. morafkai*, *G. berlandieri*, and/or *G. flavomarginatus*.

Award Amount: US $2,000 to be awarded at the Desert Tortoise Council’s Annual Symposium, depending on the availability of funding and an appropriate recipient.

Eligibility: Applicants must be associated with a recognized institution (e.g., university, museum, government agency, non-governmental organization) and may be graduate students, post-doctoral students, or other researchers. They must agree to present a report on the results of the research in which award funds were used at a future symposium of the Desert Tortoise Council.

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Grants In Herpetology Donor Information

Financial contributions by SSAR members, institutions, and other benefactors support this program significantly, and can increase the number and/or size of awards. Your tax-deductible contribution (US citizens) to this program will directly benefit meritorious research and education in herpetology. Contact the SSAR Treasurer (Ann Paterson; distichus@hotmail.com) for additional information about contributing to the Grants-in-Herpetology program. If you are employed by an organization that will match donations made to nonprofit organizations, please notify your employer that you have made a donation to the Grants-in-Herpetology program.

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Evaluation Criteria: Applications will be evaluated on the basis of the potential of the research to contribute to the biological knowledge of one or more of the above gopher tortoise species, and to their management and conservation. Important considerations are the significance and originality of the research problem, design of sampling and analysis, preliminary data supporting the feasibility of the research, and the likelihood of successful completion and publication.

Application Procedure:

1. Download and open an application form from the Desert Tortoise Council’s website www.deserttortoise.org. The form is electronically interactive.

2. Provide all information requested on the application, including a description of the research project in no more than 1,200 words.

3. Submit the completed application to grstewart@csupomona.edu as a pdf attachment.

4. Applications must be supported by three letters of recommendation, one of which must be from the applicant’s research advisor, supervisor, or a knowledgeable colleague. Instruct the recommenders to submit their letters to grstewart@csupomona.edu as pdf attachments.

5. Completed applications and letters of recommendation must be received by **December 2, 2013**. They will be evaluated by a committee of gopher tortoise biologists appointed by the Desert Tortoise Council Board of Directors.

The research award recipient will be notified of his/her selection by **January 17, 2014** and the award will be presented at the 2014 Desert Tortoise Council Symposium, February 21–23, 2014.

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The Herpetologists’ League

EE Williams Research Grant

The Herpetologists’ League is pleased to announce competitive grants for graduate student research for 2014. These awards
are named in honor of the late Ernest E. Williams, HL’s first Distinguished Herpetologist. Cash awards (US $1,000) will be presented to one winner in each category: Behavior, Conservation, Ecology, Physiology. Morphology/Systematics. The application deadline is 15 December 2013. Full details, as well as an application form, may be downloaded from the HL website:

http://www.herpetologistsleague.org/dox/eewilliamsgrant.pdf

Amphibian Ark Surplus Animal Service for Researchers

Amphibian Ark represents a global network of amphibian captive breeding programs as part of the global IUCN Amphibian Conservation Action Plan (ACAP). The ACAP emphasizes the primary importance of basic research in fields such as climate-change, ecotoxicology, or disease ecology in order to inform appropriate conservation programs. Much of this research takes place in the realm of academic labs around the globe, and this research often requires the use of living animals (per institutional IACUC guidelines). Some amphibian breeding programs produce surplus progeny that are not needed to ensure the appropriate genetic integrity of a particular survival-assurance breeding program. Amphibian Ark can help potential partners at breeding institutions and research labs to direct surplus animals to the research programs where they can really contribute towards the research needed to inform amphibian conservation.

While many ex situ partners have disposition policies that cannot support this activity, many do not and surplus animals often are available for qualified IACUC-approved research. Interested institutions should check the “Animals for ACAP” page on the Amphibian Ark website:

http://www.amphibianark.org/mailman/listinfo/animalsforacap_amphibianark.org

IHS Grants Available

The International Herpetological Symposium has established a grant program to provide financial assistance to individuals or organizations conducting herpetological research, conservation, and education. Proposals are accepted January through May of each year and grants are awarded in August. Grants are in the amount of up to US $500 and will be awarded to applicants whose projects represent a significant contribution to herpetoculture in one of the following categories: herpetological natural history, herpetological conservation biology, captive propagation, or herpetological education. For details on the application process, please visit the IHS website at <http://internationalherpetologicalsymposium.com/grant.html>

MEETINGS

Meetings Calendar

Meeting announcement information should be sent directly to the Editor (HerpReview@gmail.com) well in advance of the event.


4–7 June 2014—Biology of the Pitvipers 2, Tulsa, Oklahoma, USA. Information: http://www.biologyofthepitvipers.com

30 July–3 August 2014—Joint Meeting of Ichthyologists and Herpetologists (SSAR, HL, ASIH), Chattanooga, Tennessee, USA. Information: http://www.dce.k-state.edu/conf/jointmeeting/
Among the published works in herpetology over the last five centuries, only two can be said to cover all known species of amphibians and reptiles comprehensively and scientifically. One, in English, was by George A. Boulenger and based on the collections of the British Museum in London (9 volumes, 1882–1896). These books were reprinted in 1961–1966 and, despite their age, remain among the most frequently consulted references in herpetology. The other, in French, was by Constant Duméril, Gabriel Bibron, and the senior author’s son, Auguste Duméril, and based on the collections of the Muséum d’Histoire Naturelle in Paris (9 volumes plus an atlas of colored plates, 1834–1854). This latter work, generally known as “D & B,” had never been reprinted until now. It remains of continuing value to a broad community of academic zoologists, museum and zoo curators, and conservationists, and especially to herpetologists working in developing countries. D & B is, in fact, more comprehensive than its English counterpart, for in addition to having more detailed descriptions of genera and species, it also covers the internal anatomy, physiology, and the associated literature. Paris was then the epicenter of world science and its museum boasted the greatest naturalists: Buffon, Geoffroy Saint-Hilaire, Lacépède, Lamarck, and the greatest of them all, Georges Cuvier. Also among them was Constant Duméril, who trained as a physician and became one of Cuvier’s closest colleagues. The Paris museum then possessed the largest natural history collections in the world. D & B was the first work in which a natural arrangement of genera was attempted, and many of the genera and species were first described in it.

This full-size facsimile is complete and carefully edited for clarity. The 120 finely executed plates are reprinted in both uncolored and colored states because the original coloring sometimes obscures details of scutellation. The nine text volumes, which total nearly 7,000 pages, and the atlas of 240 plates are sturdily bound in library-grade cloth and printed on durable, acid-free paper. The new introduction by Roger Bour (Paris) is an in-depth review of the book (including exact publication dates) with new biographies of the three authors. A comprehensive index to the scientific names, missing in the original book, has been added. The original book was issued in fewer than 500 sets; a colored set, rarely offered today, costs about US$15,000. Only 400 new sets have been reprinted. (This reprint is being offered at an affordable price because of a generous subsidy from Ronald A. Javich of Montréal.)
The purpose of Current Research is to present brief summaries and citations for selected papers from journals other than those published by the American Society of Ichthyologists and Herpetologists, The Herpetologists’ League, and the Society for the Study of Amphibians and Reptiles. Limited space prohibits comprehensive coverage of the literature, but an effort will be made to cover a variety of taxa and topics. To ensure that the coverage is as broad and current as possible, authors are invited to send reprints to the Current Research section editors, Beck Wehrle or Ben Lowe; e-mail addresses may be found on the inside front cover.

Current Research

Venom Proteins in Non-Venomous Squamates

In recent years, phylogenetic and toxicological studies have greatly increased our understanding of the origins and extent of venom production in Squamata. We now know that several of the toxin-associated proteins found in squamates originated as gene-duplications along the branch leading to Toxicofera, the clade containing Iguania, Anguimorpha, and Serpentes. However, though researchers have made great strides in revealing the variation in the gross morphology of squamate oral glands, it has remained largely unknown how histology and genetic control varies among gland types and taxa. To further our understanding of venom evolution, the authors of this study investigated the oral glands of 23 taxa including representatives of all major squamate lineages using sectioned heads, excised glands, and magnetic resonance imaging of whole heads. Furthermore, they generated transcriptomes for these species by isolating and reverse transcribing RNA from glands and sequencing the resulting cDNA libraries. The recovered sequences identified as toxin genes in BLAST searches were subsequently included in phylogenetic analyses and subjected to tests for selection. These investigations led to some very interesting discoveries. The red-tailed pipe snake Cylindrophis raffus (Uropeltidae) was found to possess large rictal glands, paired and poorly studied organs of snakes occurring in the corner of the mouth posterior to the better-known maxillary and mandibular glands. These rictal glands are strictly composed of serous cells (indicating a digestive or venom function), while the mandibular and maxillary glands of C. raffus are a mix of serous and mucosal cells. Alternatively, the oral glands of the examined boid and python snakes are largely composed of mucosal cells, likely functioning to aid in the ingestion of large prey. Iguanian lizards possess oral glands of mixed cell types, with herbivorous species tending to have predominately mucosal cells while those that regularly consume vertebrate prey have a greater proportion of serous cells. Non-toxicoferan squamates exhibit mucosal mandibular glands (maxillary glands are highly reduced or absent). Interestingly, despite histological variation among the various types of oral glands of a particular species, the glands all possess the same RNA transcripts, indicating they are under the same genetic control. The transcriptome sequences also added to the list of proteins occurring in iguanians, boids, uropleptids, and pythons that are homologous with venom proteins known from anguimorph and caenophidian squamates. Two iguanian transcripts that were found to be highly expressed and under diversifying selection have been hypothesized to have an antimicrobial function, a possible precursor function of venom proteins. A second group of proteins were found to be shared by the clades Anguimorpha and Serpentes, lending support to the hypothesis that these taxa form a clade (a hypothesis lacking support from traditional molecular phylogenetic analyses). A third burst of protein recruitment occurred along the branch leading to Caenophidia.


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Sticky Secretions of Amphibians Strikingly Similar to Those of an Invertebrate

Amphibians of widely disparate families have the capacity to produce a remarkably sticky adhesive. The function of this ability has been studied in some taxa; for instance, some members of the genera Plethodon and Limnodynastes use their extreme stickiness as a predation deterrent. The sticky secretions of another species, Notaden bennetti (Myobatrachidae) of Australia, have been studied in some detail. Interestingly, the characteristics of this substance are remarkably similar to sticky substances produced by velvet worms (Onychophora) for use in prey apprehension. Previous work has indicated that the secretions of N. bennetti and the onychophoran Euperipatoides rowelli contain large polypeptides lacking protein structure. To further explore the potential similarities of these two substances, the authors collected secretion samples from both N. bennetti and E. rowelli. To detect and characterize any carbohydrates present, samples from N. bennetti were subjected to protein- and carbohydrate-degrading enzymes as well as Schiff staining. Samples from both species were subjected to SDS-polyacrylamide gel electrophoresis (PAGE) to visualize and isolate proteins. The isolated proteins were then analyzed for their amino acid composition and sequenced using in-line tandem mass spectrometry. Some stretched and dried secretion was also investigated for protein structure using wide-angle X-ray scattering (WAXS). When treated with protease K (an enzyme that breaks bonds between adjacent amino acids), clumps of N. bennetti secretion broke apart and formed a slurry, confirming the substance was largely composed of amino acids. Alternatively, when a protein denaturant was administered, long filaments could be plucked out. Staining for various carbohydrates in the N. bennetti secretions revealed the presence of hexose sugars. When these sugars are enzymatically removed, the proteins tended to irreversibly clump (and were resistant to denaturation even when boiled), signifying a potential function of the sugars. The SDS-PAGE experiments demonstrated that the constituent polypeptides of the adhesive were large, as large as 350 KiloDaltons (kDa) in E. rowelli and 500 kDa in N. bennetti. When these large-molecular-weight polypeptides were analyzed for amino acid composition, they were both found to contain high proportions of the amino acids Glycine, Proline, and Hydroxyproline and a low proportion of Methionine. Both the amino acid sequence
and the WAXS analysis suggest an unstructured polypeptide. The deep phylogenetic divergence between these two taxa prohibits a hypothesis of homology and instead indicates a fascinating case of convergent evolution. However, the authors posit that future research may reveal the secretion of \textit{N. bennetti} is homologous with similar secretions found in other amphibians.


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New Insights into the Morphological Evolution of Turtles

Recently, the discovery and investigation of an ancient member of the turtle lineage, the Triassic \textit{Odontochelys semitestacea}, has greatly expanded our understanding of turtle evolution. The shell of \textit{O. semitestacea} was transitional relative to extant turtles, with a well-developed plastron but a carapace consisting only of expanded ribs, revealing the pathway of turtle shell evolution. However, whether turtle shells are derived exclusively from rib bones or possess contributions from dermal bone remained uncertain. Phylogenetic analyses including \textit{O. semitestacea} also aided in placing the enigmatic Permian fossil reptile \textit{Eu-notosaurus africanus} as an even older member of the turtle lineage. The authors of this paper examined undescribed material of \textit{E. africanus} with particular attention paid to whether the specimen supported the dermal-bone-contribution hypothesis. They discovered that \textit{E. africanus} represents an intermediate stage in turtle shell evolution, with a distinct broadening of the ribs but no shell contribution from the neural spines of the vertebrae as seen in \textit{O. semitestacea}. Instead of dermal bone contributing to the broadening of the ribs, their microanatomical investigations revealed that the expansion occurred within the perichondral membrane of the ribs. Furthermore, these investigations demonstrated that the intercostal muscles had already been lost in \textit{E. africanus} and that the respiratory muscles had migrated to the ventral surface of the ribs. Neither \textit{O. semitestacea} nor \textit{E. africanus} exhibited the modern turtle condition of the pectoral girdle being contained within the ribcage, indicating this occurred after the axial skeleton and musculature modifications. The authors suggest that microanatomical investigations of \textit{Milleretia rubidgei}, a Permian taxon proposed by previous researchers to be a successively more ancient relative of turtles, may shed further light on the morphological evolution of turtles.


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Local Adaptation in “Meso-Predators” Has a Buffering Effect on Prey Diversity

Ecologists have sometimes encountered difficulty trying to explain community dynamics through biotic and abiotic factors alone. Though rarely accounted for, local adaptation may be an important component of community dynamics. The author of this paper presents findings from his research into this phenomenon. Larvae of the Marbled Salamander (\textit{Ambystoma opacum}) are both a competitor (for zooplankton prey) and predator of Spotted Salamander larvae (\textit{Ambystoma maculatum}). Interestingly, because they hatch in the fall and require ponds that do not freeze solid over the winter, \textit{A. opacum} abundance varies considerably between breeding sites of \textit{A. maculatum} (a spring breeder). Previous work has demonstrated that \textit{A. opacum} exerts a strong selective pressure on \textit{A. maculatum}. This is evidenced as \textit{A. maculatum} from ponds with high \textit{A. opacum} densities forage more aggressively (and therefore grow large enough to avoid predation faster) than those from ponds with low \textit{A. opacum} density. In this study, three experiments were conducted to determine if this local adaptation works to increase or decrease prey (zooplankton) abundance and diversity. In a laboratory experiment, \textit{A. maculatum} larvae from ponds with different densities of \textit{A. opacum} were placed in a container with an identical prey base (including the four most abundant zooplankton species) and \textit{A. opacum} chemicals cues and after 24 hours, the prey abundance and diversity were determined. This experiment confirmed that \textit{A. maculatum} from \textit{A. opacum}-dense ponds exhibit an increased rate of feeding, though prey preference did not vary. In a subsequent outdoor experiment, \textit{A. maculatum} larvae reared from eggs collected from ponds of varying \textit{A. opacum} density were placed in tubs designed to emulate natural, closed-canopy pond conditions. Identical zooplankton prey allotments were added to all tubs, and to half of these tubs, \textit{A. opacum} larvae were added. Zooplankton density and diversity were then estimated at regular intervals starting prior to adding larval \textit{A. maculatum} and continued through metamorphosis. Over these experiments, \textit{A. maculatum} densities declined by 80% when \textit{A. opacum} were present, with no significant effect of \textit{A. maculatum} source pond. Still, source pond did have the same effect on zooplankton biomass as seen in the previous experiment. Strangely, in treatments with \textit{A. maculatum} from high \textit{A. opacum} density pools, zooplankton diversity increased when \textit{A. opacum} was present and decreased when not. Indeed, a multivariate analysis indicated that \textit{A. maculatum} predation history had a significant effect on zooplankton diversity. This seems to be a result of the two salamanders preferring different zooplankton types. These findings were confirmed in zooplankton diversity and abundance sampling of natural ponds with and without \textit{A. opacum} present. The author concludes that while top predators have a negative effect on prey diversity, local adaptation in “meso-predators” works to counteract this effect.


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Can Tortoises Distinguish Between Real Food and Pictures of Food?

Recent work has revealed some interesting insights into the cognitive abilities of tortoises. For instance, other new research has demonstrated that tortoises can learn from watching other tortoises. The authors of this study set out to determine if tortoises can distinguish between real food and photographic representations of food. In the first part of the study, five Red-footed Tortoises (*Chelonoidis carbonaria*) were first subjected to training trials where they were presented an item of food and a non-food item (objects they had previously been exposed to such as a pebble, a piece of paper, or a bottle cap). The tortoises took an average of 12.8 trials to reliably identify the food item. Once they had achieved this, the tortoises were subjected to trials wherein they were presented photographs of a food item and a non-food item. Their performance in these photograph trials did not differ from their performance in the real object trials, implying that the tortoises were able to make a connection between an object and a photograph of that object. In the second part of the study, the tortoises were presented a real food item and a photograph of that food type. The researchers found that the tortoises chose the photograph as frequently as they chose the real food item. As the tortoises were not allowed to eat the food when they chose correctly (and therefore the outcome was the same regardless of their choice), an additional set of trials was performed wherein correct choices were rewarded. In these test trials, the tortoises chose correctly 58% of the time, significantly more than chance. However, a repeated-measures ANOVA revealed that rewards for correct choices did not improve the tortoises’ performance relative to the no-reward trials. These experiments provide further evidence that vision is the primary sense employed by turtles, as the olfactory cues of the real food failed to influence the tortoises’ decision making.


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New Neotropical Palm-Pitviper from Honduras

The Chortis Highlands region, the mountainous area effectively spanning Honduras, boasts one of the richest and most endemic herpetofaunas of the Neotropics. Indeed, Honduras has 101 described endemic reptiles and amphibians, the vast majority of which occur in the Chortis Highlands. The authors of this paper announce the discovery of Honduras’ 102nd endemic herp. While conducting the first herpetological surveys of the wildlife preserve Refugio de Vida Silvestre Texiguat (within the northern “Cordillera Nombre de Dios” region of the Chortis Highlands), they collected a series of palm-pitvipers (*Bothriechis*). These specimens morphologically conform to the species *B. marchi*, which is known from montane regions to the west and south of the Cordillera Nombre de Dios. The authors sequenced four mitochondrial genes for nine Texiguat preserve *Bothriechis* specimens and four other viper specimens from the region, and together with previously published data from eleven other specimens, compiled and analyzed a multi-taxon molecular dataset with the goal of elucidating the phylogenetic relationships of *Bothriechis*. The resulting phylogeny revealed four well-supported clades within *Bothriechis*. A clade consisting of the eyelash vipers (*B. schlegelii* and *B. supraciliaris*) is sister to the rest of the genus. Within this crown clade, the Texiguat preserve snakes form a well-supported clade sister to *B. lateralis*, a species whose closest populations occur over 500km to the south in Costa Rica, while the remaining northern species form a separate, more distantly related clade. Another southern species, *B. nigroviridis*, is molecularly divergent from other *Bothriechis* and its affinities are uncertain. Subsequent morphological analyses uncovered subtle differences between *B. marchi* and the Texiguat preserve *Bothriechis*, and similarities between the latter and *Bothriechis* specimens from Parque Nacional Pico Bonito (farther east in the Cordillera Nombre de Dios and for which no tissue samples exist). Of particular diagnostic importance is the condition of the prelacunal and second supralabial scales (fused or separate). These findings imply that the Texiguat preserve *Bothriechis* may be a relictual species, more closely related to *Bothriechis* from much farther south than to proximal species. This pattern is repeated in other taxa, such as the salamander genus *Nototriton* and the frog genus *Isthmohyla*, indicating the Cordillera Nombre de Dios region may be a paleo-refugium, allowing old lineages to persist that have gone extinct elsewhere. The authors describe the new species as *B. guifarroi* and conclude that populations attributed to *B. marchi* in the region south of Cordillera Nombre de Dios (and for which genetic tissue samples are not currently available) should be included in future analyses.


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Herbivorous Lizard King of Eocene Community

Although living herbivorous squamates are significantly smaller than sympatric mammal herbivores, ancient plant-eating squamates may have been closer in size to their contemporary mammal competitors. The authors of this paper describe a new fossil lizard from central Myanmar and with estimates of total size, analyze and discuss its place in its historical ecological community. The lizard, named *Barbaturex morrisoni*, was excavated from a geologic horizon dating back to the late Eocene (about 37 million years ago [mya]) and exhibits characteristics consistent with the family Agamidae. Phylogenetic analyses confirm that *B. morrisoni* is closely related to and possibly a member of Agamidae. This new species possesses several traits characteristic of living agamids and absent in more distant fossil relatives, as well as some features possessed by lizards of the agamid subgenus Uromastycinae, possibly indicative of the fossil’s phylogenetic affinity. As the uromastycine fossil record dates back to the early Eocene (54 mya) and molecular clock estimates of the timing of early Agamidae diversification range from 70 to 100
mya, the time when *B. morrisoni* diverged from extant lineages is open to speculation. Though only represented by fragmentary craniofacial material, the authors were able to identify the species as an herbivore. Using measurements from extant agamids, they created a jaw length-body length curve with which to extrapolate the total body length of *B. morrisoni*. This method predicted a snout-vent length of almost one meter and a body mass of 26.7 kg, making *B. morrisoni* twice as large as the largest extant agamid, *Hydrosaurus ambioensis*. When compared with perissodactyl and artiodactyl mammals known from the same fossil deposit, *B. morrisoni* fell out in the middle of the size distribution. In contrast, in three modern communities containing herbivorous iguanians (*Uromastyx aegyptius*, *Hydrosaurus ambioensis*, and *Ctenosaura similis*) the lizards are distinctly smaller than the smallest perissodactyl or artiodactyl. The authors argue that these results signify that competition with mammals did not exclude herbivorous Eocene squamates from attaining large size and that instead Cenozoic climate change may instead have given mammals their present ecological advantage.


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**Black Velvet Snake Coloration Achieved through Structural Coloration**

Some squamates possess microscopic ornamentations on their scales. These structures have been hypothesized to function in aiding with locomotor ability and altering visual appearance in different taxa. For instance, the iridescent color of indigo snakes (*Drymarchon*) and the bright colors of shield-tailed snakes (*Uropeltidae*) are obtained through epidermal microornamentation. In this study, shed skins of the West African Gaboon viper (*Bitis rhinoceros*) were investigated for scale microornamentation form and function. This species presents a high contrast dorsal patterning consisting of light and remarkably dark, “velvet-like” regions. Scanning electron microscopy (SEM) was employed to reveal the dimensions and morphology of the microornamentation of both light and dark scales. Reflectance measurements were taken for light and dark dorsal scales, ventral scales, and a white reflectance standard with which to compare the scales. To control for the effect of scale transparency and therefore measure the effect of epidermal microornamentation alone, the authors analyzed the reflectance of light and dark scales coated with a gold-palladium alloy. Additionally, the researchers measured transmittance of each scale type. The SEM revealed the light and dark dorsal scales to have radically different microornamentation. The dark scale surfaces are densely packed with thin, wedge-shaped structures roughly 20 µm tall. In turn, the surfaces of these structures are covered with reticulating ridges a fraction of a micrometer in height (“nanoridges”). These ridges are connected by still thinner, shallower ridges and punctuated by small pits and spine-like projections. The microornamentation of the light scales was similar, however the structure at all levels is compressed vertically, resulting in much flatter surfaces. The reflectance values (percentage of white reflectance standard) for all surfaces varied more or less across the visible spectrum, but the dark scales reflected less than the light scales at every wavelength (with the reduction ranging from five to 20%). Remarkably, the gold-palladium had opposite effects on the two scale types: light scales exhibited 20 to 40% increased reflectance over non-coated scales, while coated dark scales reflected less light across the spectrum (zero to 15% of the white reflectance standard). Furthermore, metal coating on light scales reduced transmittance across the spectrum by more than half, however coated dark scales showed no reduction relative to uncoated.


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**Genomic Insights into *Bd* Evolution and Biogeography**

In recent years, studies have tried to elucidate the genetic diversity and biogeographic history of *Batrachochytrium dendrobatidis* (*Bd*), with particular interest in determining if *Bd* was historically present worldwide or if it is a recent arrival in regions of amphibian declines (the “endemic” and “emergent pathogen” hypotheses, respectively). Previous studies have generally come to the conclusion that *Bd* fits the pattern of an emergent pathogen that has spread around the globe within the last century as evidenced by high genetic diversity in hypothesized regions of origin and little to no diversity elsewhere. The authors of this study aimed to reveal patterns of *Bd* genetic diversity in the New World using genomic data. Samples containing *Bd* were taken from 26 North, Central, and South American amphibians (and from one African, Asian, and Australian amphibian); from these samples, a single strain was isolated and cultured in the laboratory. These cultures were then subjected to next-generation genome sequencing, after which the recovered sequences were compiled and single-nucleotide polymorphisms (SNPs) were identified and extracted. Importantly, they also sequenced a relative of *Bd* to serve as an outgroup. These procedures resulted in 101,931 SNPs, which were then concatenated into a single dataset and subjected to a phylogenetic analysis under the Maximum Parsimony criterion. Additionally, these data were merged with previously published data on an additional 20 isolates, fifteen of which were from the Old World. In this larger dataset, 76,515 SNPs met the criterion for retention, and were analyzed in a similar fashion. As in previous studies, the authors identified a widespread *Bd* clade, the global panzootic lineage (GPL). However, these analyses revealed more genetic diversity within the GPL than previously appreciated, and found the biogeographic scenario to be much more complicated than previously suspected. While in previous studies non/GPL strains were only found in Europe and Africa, this study identified two in Brazil and one
in the USA. The authors state that there is little evidence for any geographic region being the origin of Bd. Using a standard rate of evolution, they derived a wide confidence interval for the timing of the origin of the GPL, the lower end of which (500 years ago) is considerably older than previous estimates. If these estimates are reliable, this indicates that either the global spread of Bd began earlier than previously thought, or that we cannot trace the global spread of Bd to a single strain. Additionally, the inbreeding coefficient was calculated for the GPL, and the low value was indicative of either sexual reproduction or mitotic recombination. To determine which of these two factors is at play, the authors determined how chromosome heterozygosity correlates with chromosome size. They found that larger chromosomes have less heterozygosity than smaller ones, consistent with mitotic recombination. The authors conclude that Bd is endemic in some regions and novel in others, and previous attempts to cast Bd as either an emergent or endemic pathogen amount to a false dilemma.


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New Pesticides Found to be Accumulating in Frogs of Pristine, Montane Environments

Along with fungal pathogens, invasive species, and habitat destruction, pesticides are recognized as an agent of amphibian declines. The high elevations of western North America’s Sierra Nevada seem pristine and beyond the reach of pesticides, but previous research has shown that prevailing winds transport pesticides from California’s Central Valley to the tops of the mountains. The authors of this paper sampled high-elevation populations of the Pacific Chorus Frog (Hylidae: Pseudacris regilla) to determine if contemporary pesticides are accumulating in Sierra Nevada frogs. Water, sediment, and P. regilla samples were collected from seven sites spanning the Sierra Nevada during the breeding seasons of 2009 and 2010. Additional water samples were taken 10–12 weeks later (coinciding with peak pesticide usage). Using gas chromatography, the authors evaluated these samples for the presence of 98 pesticides and pesticide degradates. Pesticide concentrations were analyzed between years and sampling sites, and sites differing in pesticide diversity and prevalence were identified. Twelve pesticides or pesticide degradates were detected in frog tissues across the study area, none of which were detected at all sites. Two fungicides, pyraclostrobin and tebuconazole, were detected from tissues taken at all but one site: the relatively pesticide-free Summit Meadow of Yosemite National Park. Dichlorodiphenyl dichloroethylene (DDE; a degrade of the long-banned insecticide DDT) was also detected in frogs at six of the seven sites, which is not surprising given its high environmental persistence. DDE and the insecticide diazinon were the only compounds of the twelve that had ever been recovered from anuran tissue before this study. Overall, the water and sediment samples poorly reflected the compounds seen in the tissue samples. The water and sediment samples turned up fewer pesticide compounds, and the compounds identified in them were quite different from those found in the frog tissues (86% and 43% different, respectively). Giant Sequoia National Monument, the southernmost sampled site, exhibited the highest concentrations of pesticides, while the site with the highest number of pesticides (10) was in the Stanislaus National Forest in the central Sierra Nevada. These findings demonstrate that currently used pesticides applied as much as a 100 km away are finding their way into frogs. This should be an impetus for further studies, as we know little of the effects of these chemicals on amphibians.


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Herb Dessauer (30 December 1921–8 February 2013), clearly one of the nicest and most generous people in herpetology, died with a respiratory illness. He had served as a meteorologist in the Air Force in World War II, being among the first “hurricane hunters” in the Pacific with his lab in the nose-gunner position of a B-24 bomber, then entered medical school at LSU where he realized that the thrill of discovery in biochemistry and nature were his primary interests. His wife, Frances Jane Moffat (1926–2005; they married on 10 December 1949), entertained and enjoyed his graduate students, visitors, and their families as much as Herb did, throughout his long career at the LSU Medical Center, New Orleans. The Dessauers especially loved to expose visitors to the real New Or-leans, Herb’s home town, and various nature reserves in south-ern Louisiana. Herb also loved literature of every kind (Fig. 1). However, it is not our intent to do a traditional-style obituary on Herb here. For such personal history see the Historical Perspec-tive (Liner and Cole 2003. Copeia 2003:195–199). Our intent here is to pay tribute to Herb’s joy of life; thrill of discovery; love of family, colleagues, and friends; and his accomplishments and productivity in science. Our world would be a lesser place if Herb Dessauer had not been here.

As a graduate student in the 1950s, Herb Dessauer began to wonder whether there was biochemical evidence bearing on the theory of evolution. Consequently, he merged his interests in nature and state-of-the-art research laboratories. After a few discoveries he was thoroughly hooked and went on to influence the following (citing examples from his Bibliography, below): nontraditional animal models (1950–1953); proteins, especially electrophoresis with amphibians and reptiles and attempts to find correlations with phylogeny (1955–1957); use of protein electrophoresis to study genetics of hybrid zones (1961–1962); importance of long-term management of research resources for the broader scientific community (1975, 1984); discovery of multiple paternity in kingsnakes (1983) and alligators (2001); parthenogenetic cloning in unisexual species (1986); the hybrid origins of tropical unisexual species and use of molecules to predict the existence of unknown species (1989, 1990); descriptions of new species (1993, 1997); and use of molecular probes to efficiently screen large samples of reptiles from nature (1996). His diverse research subjects included amphibians, reptiles (including birds), and mammals (including humans). Herb was creative and proficient as a laboratory experimentalist, and when the budget was stressed, he made his own potato starch, starting with whole potatoes from the grocery store. Molecular specialists have called Herb “one of the fathers of Molecular Systematics” (Liner and Cole 2003. Copeia:197).

Comments from Colleagues

The Boy Scout Law states that a scout is “Trustworthy, Loyal, Helpful, Friendly, Courteous, Kind, Obedient, Cheerful, Thrifty, Brave, Clean, Reverent”…a pretty high standard, yet it well describes Herb Dessauer. OK, not Reverent, in fact decidedly irre-verent, but 11 for 12 is a great batting average.

In the 1960s I was a graduate student working on anole behavior on Trinidad. I suspected that two species were hybridizing and understood the important implications of the biochemical/ge-netic work Herb was publishing, often with his friend Wade Fox. When I wrote Herb to ask if I could send some lizards for analysis, he responded by inviting me to work in his lab in the summer of 1964 and learn first-hand. Working with Herb and his associates at the LSU Medical Center in New Orleans, where I was treated as a colleague, kick-started my scientific career. I soon realized that beyond the scout law, Herb was Welcoming, Enthusiastic, Patient, and Supportive. He also completely lacked pretension, and that was one of the most endearing parts of his personality.

An inestimable added bonus to my visit was to be completely embraced by the entire Dessauer clan as a virtual family member. Consequently, I benefitted from many fine meals at their home, generally prepared by Fran. I last saw the Dessauers during a short visit in 2002, when Herb led me and my wife Amy to the Barataria Preserve of the Jean Lafitte National Historical Park, where he enthusiastically pointed out water moccasins and anoles.

George Gorman
Herb Dessauer was the mentor of my father and a huge figure in my New Orleans childhood, starting at age 4. I practically grew up in his lab. He was a wonderful grandfather figure to me with a mischievous smile and a love for Halloween that made me question whether he was an adult or just a really big kid. My father always discussed him in tones of awe and adoration, which only confirmed that my initial gut feelings were correct and his family welcomed our new immigrant family into their home in a deep and honest way I have tried to emulate since. You never knew what mysteries lay in their labs. Once I had to use the bathroom and pants down at the bowl I looked over at the bathtub and starring back at me was a gaggle of very excited baby alligators. Even for a feral lizard-catching little boy, that was heart attack material. I credit his group of dedicated but fun-loving scientists with inspiring me to study science in turn.

Guy Shochat (son of Dan and Edna)  
UCSF Medicine

Thanks to an introduction through George Gorman, Herb Dessauer invited Dan to join his lab as a graduate student in 1971. We depleted our savings account to purchase trans-Atlantic, one-way air tickets from Israel and arrived in New Orleans with two young children. Herb and Fran were instrumental in softening the culture shock and sense of loneliness associated with the transition from a foreign country for a young and cash-strapped graduate student family. Forty-two years later we look back at Herb and Fran as ones who changed the course of our lives for generations to come. Every Thanksgiving we remember the Dessauers for taking us under their wings, for their love and hospitality, and for important help in settling into our adoptive homeland.

Edna and Dan Shochat,  
Agama Inc., Biopharmaceutical Consulting

The typical day in the Dessauer lab started with the ritual of drinking coffee and chicory. Herb had a white porcelain-looking drip unit that he never washed. Yesterday’s grounds were simply dumped out the following morning. Most people drank cafe au lait, a few cafe noir. The most telling aspect of this morning ritual was an inevitable race to the bathroom, however subtle it appeared, as Herb’s coffee was one of the great laxatives never sold on the open market.

Another ritual was the weekly trek on Fridays to get a lunch of gumbo at a local restaurant off Canal Street. The gumbo was fantastic, and discussions ranged from hypotheses about why an experiment did or did not work to New Orleans politics (always a fascinating topic) to when the next music festival, Mardi Gras, or other holiday would occur. They do know how to party in New Orleans. One Friday in late 1979 most members of my graduate committee came over with the “regulars” to get gumbo. Herb surprised me by asking if I could name to genus everything in New Orleans. After stammering a bit, I actually named 5 of the genera (*Penaeus, Callinectes, Crassostrea, Sassafras, Oryza*). Herb later told me that was the first part of my qualifying exam; those biochemists and molecular biologists were so impressed that I probably passed my orals on the spot (of course they still put me through the wringer two weeks later).

The most important thing that I remember about Herb and daily laboratory life was that he was so willing to come into the lab and help. Here was the man who had published a starch gel electrophoresis study of lizard allozymes a full four years before Lewontin and Hubby’s classic *Drosophila* allozyme paper appeared in 1966, was a Full Professor and recently the President of the American Society of Ichthyologists and Herpetologists, and he was still willing to jump right in to help bleed a snake, run a micro-complement fixation reaction or a gel, or even do the dishes. It was an object lesson that I never forgot.

Some of my most enjoyable times as a graduate student were spent with Herb, Miss Frances and their children Danny, Becky, and Bryan, at their A-frame cabin and extensive wooded property near St. Francisville, LA, the same area where young Audubon lived for a while teaching the children of wealthy plantation owners and painting so many of his famous bird prints. We would sit around drinking beer, eating crawfish, and enjoying each other’s company, oh yes and “telling lies.” I have modeled my own interactions with our lab’s graduate students after Herb and I often think about him when I am at the Rockefeller Wildlife Refuge or some wilderness locality in Texas surrounded by my students and family and enjoying a good meal and a cold beer.

Herb Dessauer was a very special human being who loved his family, loved his students, and loved life and he knew how to get the most out of it. He also loved his science, and his enthusiasm and dedication spread infectiously among those with whom he worked. Herb was a great friend, wonderful mentor, and an outstanding role model for me and many others. We should all be so fortunate to have a life as full as Herbert C. Dessauer had (Fig. 2).

Llewellyn (Lou) Densmore

F Harvey Pough, the undergraduate mentor at Cornell who steered me toward Herb Dessauer’s lab for graduate school, called Herb “the kindest man you will ever meet.” Truer words were never spoken. I was to see Herb prove Pough right time after
time in his interactions with students, colleagues, family, friends, and even strangers on the streets of New Orleans. Herb absolutely adored children (Fig. 3)—watching them, teasing them, challenging their minds, getting down on the floor and rolling around with them. In many ways his love of science was childlike too—full of wonder, enthusiasm, and awe. Herb and Fran did not yet have grandchildren when I joined the lab in 1977, so they immediately became surrogate grandparents when our daughter Jessica was born. Herb constantly volunteered to babysit, and often asked if I would be taking my wife out on a Friday or Saturday night (so he and Fran could have Jessica). Later he reveled in showing her herps and insects that we encountered on outings. There were few other kids in the lab family at the time, so Jessica often became the center of attention. As her third birthday approached, my wife Kirsten and I asked her who she wanted to invite to her party, expecting her to name classmates from preschool. Her response: “I want Uncle Herb, Aunt Frances, Toby (Bradshaw) and Moira, Lou (Densmore) and Sandy…”—all the adults from Herb’s lab group! It worked out well for Jessica, as she got better presents than would have come from a houseful of three-year-olds.

In the lab, Herb was a dyed-in-the-wool experimentalist. Even though he was awed by good literature of every kind, and we worked in a high tech biochemistry department with sophisticated, state-of-the-art equipment, he had no interest in users’ manuals. It was a personal challenge to figure out how something worked by tinkering with it, no matter how complicated. He often said that the first thing he did with a new piece of equipment was to discard the user’s manual. We did not know how serious he was until a large and expensive piece of equipment arrived for a new faculty member who was outfitting her lab nearby. It was something like an ultracentrifuge or laminar flow hood, and a small crowd of graduate students and junior faculty gathered to help uncrate and admire the sophisticated equipment. When the users’ manual appeared in the packaging, I held it up and said “You know what Herb Dessauer would do with this?” while tossing it into a wastepaper bin with feigned disgust. I retrieved the manual as the laughter subsided, and Herb appeared in the doorway, attracted to the mirth and crowd. “What’s this?” he said, “A new toy?” as he admired the shiny machine. Suddenly Herb saw the manual in my hand, grabbed it, and turned to the new owner. “Now, you know what to do with this, don’t you?” he said dramatically as he tossed it right back into the same wastepaper bin! Everybody cracked up and Lou Densmore literally fell to the floor doubled over. Herb laughed also, but I do not think he ever knew why his demonstration was so entertaining.

Mike Braun

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Herb had a helluva run, making his mark big-time as a scientist and remaining a thoroughly decent and life-loving human along the way.

Harry Greene
Cornell University

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In the late 1970s I also received a wonderful invitation for an extended visit to Herb’s lab in New Orleans. I asked him when I should arrive to best fit his busy schedule, and he said “I’ll have to check the calendar and get back to you.” The morning after my arrival we were working feverishly in the lab and had gels running by 1:00 p.m. Then Herb announced “It’s time for a parade, let’s go!” as he whisked me out the door. In no time, Herb and Fran were down in the gutter scrambling for plastic beads and candies thrown off the parade floats, and Herb was making a mental note on how long it took for this visiting introvert from New York to do the same. Suddenly I realized that checking his calendar to plan the date of my arrival had nothing to do with his lab schedule. It depended on the dates for Mardi Gras parades! The same scheduling happened year after year, and my wife and I enjoyed all the special pleasures of being enveloped in the Dessauer family as have been described above.

Jay Cole

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My first visit to the Dessauers occurred during the year Jay and I were married (1978–1979). When Herb and Fran learned that we had been married at City Hall in New York City they decided we needed a real wedding, which was quickly organized in their back yard. Local wild flowers provided the bouquet and candies thrown off the parade floats, and Herb was making a mental note on how long it took for this visiting introvert from New York to do the same. Suddenly I realized that checking his calendar to plan the date of my arrival had nothing to do with his lab schedule. It depended on the dates for Mardi Gras parades! The same scheduling happened year after year, and my wife and I enjoyed all the special pleasures of being enveloped in the Dessauer family as have been described above.

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The publications are listed chronologically, consistent with development of Herb’s career, rather than alphabetically by lead author and then chronologically.

Bibliography
(excluding abstracts)

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Miriam Heyer and I interviewed Vanzolini at his home in the Cambuci neighborhood of São Paulo in order to compose a historical perspective for the journal *Copeia* (2004:184–189). The following reminiscences about Vanzolini slightly duplicate material in the *Copeia* article.

Vanzo was initially appointed as Director of the museum within the Departamento de Zoologia da Secretaria de Agricultura do Estado de São Paulo. Shortly thereafter, he successfully transferred the museum to the Museu de Zoologia da Universidade de São Paulo (MZUSP). The scientific staff was small and Vanzo was the only staff member who had a PhD (from Harvard University, Alfred Romer was his Major Professor). Vanzo brought together biology students from the University of São Paulo and provided either “internships” or educational opportunities for them. Naercio Menezes was a USP student at the time Vanzo became Director of MZUSP. Vanzo brokered Naercio to get a PhD (fishes) from Harvard University. Vanzo took it upon himself to be the major professor for other MZUSP zoologists to obtain their PhDs from the University of São Paulo. In the decade 1970–1979, 15 curators obtained their PhDs; from 1980–1989, 7 curators obtained their PhDs, and Vanzo’s last PhD student was in 1990. Vanzo’s PhD students’ dissertations covered the whole field of zoology—6 insects, 1 nematode, 2 gastropods, 5 fish, 3 frogs, 2 lizards, 2 bats, and 1 primate. (I have not included USP Masters degrees or non-biological PhDs). Vanzo’s efforts resulted in the MZUSP having the most robust natural history scientists in all of Brazil. This core of high quality scientists established a firm foundation for the Museum during the entire term of Vanzo’s directorship (when Vanzo was appointed to be Director of the MZUSP, the term was for life, with mandatory retirement at the age of 70).

The following illustrates, in part, Vanzo’s approach to science and scientists. When I was an Assistant Professor of Biology at Pacific Lutheran University (1970–1973, Tacoma, Washington, USA), I obtained a National Science Foundation award to underwrite the museum to the Museu de Zoologia da Universidade de São Paulo (MZUSP). The scientific staff was small and Vanzo was the only staff member who had a PhD (from Harvard University, Alfred Romer was his Major Professor). Vanzo brought together biology students from the University of São Paulo and provided either “internships” or educational opportunities for them. Naercio Menezes was a USP student at the time Vanzo became Director of MZUSP. Vanzo brokered Naercio to get a PhD (fishes) from Harvard University. Vanzo took it upon himself to be the major professor for other MZUSP zoologists to obtain their PhDs from the University of São Paulo. In the decade 1970–1979, 15 curators obtained their PhDs; from 1980–1989, 7 curators obtained their PhDs, and Vanzo’s last PhD student was in 1990. Vanzo’s PhD students’ dissertations covered the whole field of zoology—6 insects, 1 nematode, 2 gastropods, 5 fish, 3 frogs, 2 lizards, 2 bats, and 1 primate. (I have not included USP Masters degrees or non-biological PhDs). Vanzo’s efforts resulted in the MZUSP having the most robust natural history scientists in all of Brazil. This core of high quality scientists established a firm foundation for the Museum during the entire term of Vanzo’s directorship (when Vanzo was appointed to be Director of the MZUSP, the term was for life, with mandatory retirement at the age of 70).

The following illustrates, in part, Vanzo’s approach to science and scientists. When I was an Assistant Professor of Biology at Pacific Lutheran University (1970–1973, Tacoma, Washington, USA), I obtained a National Science Foundation award to undertake research on *Adenomera* and *Leptodactylus* species in South America. On one of the trips to South America, I collected frogs in northern Argentina and then went to São Paulo to introduce myself to Vanzo and to take some data on the MZUSP *Adenomera* and *Leptodactylus* species. When I arrived at the MZUSP, I was told that Vanzo was on an Amazonian expedition; I was disappointed that I was not able to meet him. In 1973 I obtained a Curator position at the Smithsonian Institution. About a few months after my arrival at the Smithsonian, I received a telephone call from the front desk indicating that a visitor wanted to see me. I walked to the front desk and there was Vanzo! As soon as we reached my office, he asked me about my research. I told him that I had just undertaken research on *Leptodactylus* at Limoncocha, Ecuador, near the Brazilian border, and I was curious about the distribution of *Leptodactylus* in adjacent Brazil. I had a large map of South America in my office and I pointed to the general region in which I would like to pursue fieldwork on Brazilian leptodactylids. Vanzo indicated that he was organizing an expedition to the Rio Purus and if I wished to join him, I could do so. I enthusiastically confirmed my desire to join his expedition from December 1974 to January 1975. Vanzo hired a river boat with a captain and crew. The captain told Vanzo that because of the length of time for the expedition, he would only undertake the trip if he could bring his family along (a wife and three relatively young children) and that the captain’s wife would serve as the cook. Vanzo had no other option at the time, so he agreed with the captain’s terms. Vanzo invited his nephew, Roberto Brandão, to join the expedition. Beto (as he is known) was finishing college and Vanzo thought that Beto’s experiences on the trip might help him determine whether he would go to graduate school in some aspect of zoology. Beto wound up undertaking entomology in graduate school (Universidade de São Paulo), worked on ants, and was hired at MZUSP where he still continues his entomological studies. Vanzo, Beto, and I flew to the town of Rio Branco (on the Rio Acre), where we met the boat and crew. It was after this first trip with Vanzo and my subsequent times at the Museum that I realized that Vanzo managed things differently on the river than at the museum. On the Rio Purus expedition, Vanzo took disasters with a grain of salt. The first potential blow-up occurred when we met the boat and crew and found out there was an additional person who would make the trip. Vanzo had contracted for the three children, wife, captain, engine man, Beto, Vanzo, and myself. The boat was not large. Vanzo asked the captain about the additional person and the captain said he was an old family friend who wanted to go to Manaus before he died. Vanzo suggested that there was no room for the friend and the captain countered by saying he would not undertake the trip without the old family friend. Vanzo calmly deferred. We departed to the city of Boca do Acre which had a naval customs house for inspecting boats going upstream from the town of Boca do Acre. There were three documents that had to be approved by the customs inspector: paperwork for the captain, the engine itself, and the engine man. The captain had appropriate paperwork. Neither the engine man nor the engine had appropriate paperwork. Additionally, there was no toilet on the boat nor were there working lights on the boat. The boat, the engine, and engine man failed the inspection. The only solution...
was for the boat and crew to go to the captain's home town of Xapuri. Vanzo was told that the captain's brother had appropriate engine paperwork and that they would install a toilet on the boat at Xapuri. Vanzo accepted the situation very calmly. When the boat and crew returned to Boca do Acre, Vanzo learned that the captain's brother had appropriate engine paperwork and swapped the engines. Fortunately, the inspector did not ask to have the lights turned on. None of the engine-powered lights worked. Only a kerosene lamp provided light at night. Consequently, there was very little night boat travel. One night when Vanzo, Beto, and I were collecting specimens at Boca do Acre while we were awaiting the return of the boat from Xapuri, Vanzo happened to see a house that had a party going full blast. Vanzo saw the customs inspector exhibiting some sort of inappropriate behavior and the inspector noticed that Vanzo was looking in at the party. When Vanzo went to have the boat inspected, he asked the inspector if there was some way of certifying the engine man. The customs official wrote an official note that the engine man had approval for the trip to Manaus as if there were no other licensed engine men in Porto Velho. I don't think the boat would have been approved if Vanzo hadn't seen the customs official partying. The boat and crew returned to Boca do Acre one week later. Again, Vanzo took the information about the changes made on the boat very calmly. This calm personality on Vanzo's river trips was in stark contrast to Vanzo's role as museum director. At MZUSP, Vanzo was THE BOSS! There was no give-and-take regarding how the museum was to be administered. On this trip, Vanzolini told me that he did not drink cachaça or pinga on the river trips, to convince himself that he was not an alcoholic (although he certainly downed quite a bit of cachaça in São Paulo). Vanzo underwent mandatory retirement at 70 years. After Vanzo's retirement, USP initiated four-year terms for MZUSP Directors.

Vanzo often mentioned that he much enjoyed the fellowship of practitioners of "plastic arts." I recently learned that the Brazilian term translates to visual arts, embracing artists, photographers, and film makers. (Vanzo also published a book of his poetry.) Vanzo invited me to join an expedition the following year on the Rio Madeira (October–December 1975). Vanzo had received funding from FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) to purchase two boats for his subsequent Amazonian trips. The two boats were lashed side-by-side. The crew slept on the boat with the engine. The other boat lacked an engine and was used by scientists and guests for work, dining, and sleeping. All specimen preparations were performed on the motorless boat so that specimen preservation did not endure vibrations that would otherwise cause distortion of the specimens. Vanzo had the crew catch fish that provided food on the trip as well as several carboys of fish specimens for the MZUSP ichthyologists to study. The Rio Madeira trip included Miriam Heyer, the entomologist Francisca Carolina do Val (Chica, short for Francisca) who focused on drosophilid flies, and the artist José Claudio da Silva to document his impressions of the expedition. José Claudio produced just over 100 oil paintings on the trip, at least one painting per day as well as numerous sketches. José Claudio didn't appreciate the forests in which we collected. He never set foot in the forest except for once to observe our night collecting. Otherwise, he only got off the boat when we stopped at towns to obtain supplies. All of the paintings that José Claudio executed on the Madeira river trip are now in the collection of the State of São Paulo's Governor's Palace in the city of São Paulo. José Claudio also kept a daily log on the expedition, which he subsequently published both as newspaper articles and as a book (Silva 2009). After our return from the Rio Madeira, Vanzo received a message from the director of FAPESP that the Rio Madeira expedition would be the last trip for which Vanzo would receive FAPESP funding. The FAPESP director and Vanzo had some disagreements that resulted in Vanzo being cut off from further
FAPESP funding for use of the boats. Vanzo was livid when he received the telephone call from the FAPESP director and that was a sore spot for several years afterwards. There was some sort of bureaucratic problem involving funding for the boat crew members who were residents in the State of Amazonas and were illegally being paid from São Paulo funds. According to Vanzo, “his boats” sat stagnant at Manaus and finally deteriorated. The irony of this fracas was that Vanzo was part of the committee that established FAPESP. Vanzo was proud of his contribution to the founding committee of FAPESP. In 1959 one of Vanzo’s friends was appointed Secretary of Agriculture for the State of São Paulo. For the next four years, Vanzo served as a cabinet advisor to the Secretary of Agriculture. Vanzo was given the assignment of writing the legislation for creating FAPESP. Vanzo was proudest of his role in obtaining an inflation-resistant funding source for FAPESP. The initial 0.5% of state sales tax was later raised to 1%. To this day, FAPESP is able to support the State of São Paulo scientists on the basis of sound research and never have to worry about funding ups and downs. After the FAPESP fracas, Vanzo later found other boats to continue his river collecting trips. As far as I am aware, there were only two additional Amazon river expeditions that he undertook. In addition, one of Vanzo’s film director friends made a movie about Vanzo’s boat trips describing the nature of the kind of research that Vanzo undertook. The film was completed and shown commercially in Brazil. FAPESP and Editora Beca recently published Vanzo’s collection of all of his scientific papers (Vanzolini 2010).

Vanzo lived in an uncompromising positive or negative environment—there was no gray in his life. As an example, Werner Bokermann was a protégé of Vanzo. Werner was raised in Campinas and was a self-taught taxidermist. He went to MZUSP to inquire if there was a taxidermist position available. Vanzo mentored Werner on how to curate and study frogs. Werner’s frog articles were well done. Unfortunately, Werner crossed a line. When Vanzo was working on his PhD under Alfred Romer at the Museum of Comparative Zoology at Harvard, Vanzo was personally providing Werner with funds to complete high school so that he could start getting a college education in zoology. Werner decided that going to school was a waste of his time and stopped attending. Werner did not inform Vanzo about his decision, but word got around to Vanzo, who stopped all support for Werner’s classes. Vanzo was instrumental in obtaining a position for Werner at the São Paulo zoo, so that Vanzo would no longer have to interact with Werner. Werner was not the only person who crossed Vanzo. When Vanzo was at Harvard getting his PhD, Carl Gans often studied amphibiaenids at Harvard. Upon completion of his PhD at Harvard, Vanzo invited Carl to study amphibiaenids at MZUSP. Carl became friends with a MZUSP staff member. Vanzo did not approve of the situation and a rift developed. Vanzo was not on speaking terms with Carl for the rest of his life. I came dangerously close to crossing the line with Vanzo. The editor of Papéis Avulsos de Zoologia sent me a manuscript on amphibiaenids authored by one of Vanzo’s colleagues. I reviewed the manuscript and made several minor suggestions for improving it. I received a terse message from Vanzo in the mail telling me that he had fully approved of the manuscript as it was and he was furious at the suggested changes. I thought that I had crossed the Vanzolini line. Miraculously, as far as I was concerned, the manuscript was submitted to another journal. Vanzo subsequently wrote to me that the other journal accepted the manuscript with the same text as initially submitted to Papéis Avulsos de Zoologia and that he was not pleased with me and my review!

Through most of Vanzo’s tenure as Director of MZUSP, a driver would pick him up at his residence at 7:30 am. He worked in the Director’s office in the morning, taking care of museum administration and museum-wide research and collections activities. He spent the rest of the day after lunch in his research offices. He had a drink or two of cachaça or pinga after 6 pm and often invited one or two colleagues to join him. He then went to a restaurant for dinner and visited a night club or two to listen to (and often participate in) Brazilian sambas. Ernest Williams was Vanzo’s house guest in Brazil when the two of them worked on joint research projects. When Ernest retired from the MCZ, Vanzo lobbied Ernest to spend the rest of his years in São Paulo so that the two of them could continue their research collaboration. Vanzo was unsuccessful in getting Ernest to live out the rest of his life in São Paulo. By the time I met Vanzo, he was estranged from his wife. His parents had owned a set of five townhouses in the Cambuí neighborhood that were close to MZUSP. Vanzo moved to one of the Cambuí houses after first spending some time in a rental apartment. Samba singer Ana Bernardo moved in with him after a few years. During his last decade or so, Vanzo and Ana produced compact discs of Vanzo’s music and produced samba “shows.” Ana sang with two or more instrumentalists while Vanzo sat on the stage providing commentary on aspects of his sambas. Within Brazil, Vanzo was a famous “pop star” known and appreciated for his sambas. Outside of Brazil, he was an internationally known herpetologist. Vanzo was very frustrated to be more recognized as a musician/composer than as a scientist within Brazil. Reporter Leila Kiyomura (Jornal da USP, Ano XXVIII, number 997, p. 16) quoted Vanzo “You cannot want to be the owner of an idea. A scientist has to be generous to divide the investigation with the world. It is necessary to know how to share. This I learned in the United States from the American scientists.” Kotomura also pointed out Vanzo’s generosity of donating his private library to the University of São Paulo that he bought with the money he made from his songs.

Paulo Emilio Vanzolini was indeed a complicated, intelligent, fascinating, and at times, a frustrating person. I miss him.

There is a substantial amount of Vanzolini correspondence that is now deposited in the Smithsonian Archives and available to the public.

PHOTO BY W. R. HEYER
Unlike most of his peers in academia and in the field of herpetology, Hobart Smith had a problematic childhood characterized by events that both consciously and subconsciously proved to be important elements in his lengthy life. He was not born with a silver spoon in his mouth—in fact, he was not born as Hobart Smith.

In Stanwood, a small town east of Cedar Rapids, Iowa, on September 26, 1912, a child was born to Harry M. Stouffer and Blanche M. Hawk Stouffer; he was christened Frederick William Stouffer, the fifth child of his parents, who had been married in May 1904 in Chambersburg, Pennsylvania. The family eventually settled in Ohio, where a sixth child was born in 1914. For unknown reasons, Harry Stouffer left his family and enlisted in the army to fight in the Great War. He was killed in combat on July 18, 1918 and was buried in the Aisne-Marne American Cemetery, Belleau Wood, near Paris, France. Meanwhile, the family was destitute, and all six children were farmed out or placed in an orphanage. By early 1915, Frederick was living with three siblings in the Huron County Children’s Home in Norwalk, Ohio. So far as known, Blanche Stouffer surrendered all of her children for adoption, never saw her children again, and remarried to become Blanche Hawk Stouffer Burr. Frederick grew up believing that he had been orphaned.

When Frederick was somewhat disobedient at the orphanage, he was punished by being placed in a scary dark basement room. Nevertheless, he survived two years in an orphanage that allegedly had a history of mistreating children. In the summer of 1916, a childless couple, Charles Henry Smith and Frances Muir Smith, who had been vacationing in Michigan, visited the orphanage and later adopted Frederick in Oklahoma on May 10, 1917. Frederick was renamed Hobart Muir Smith. The Smiths resided in the small agricultural town, Shawnee, Oklahoma, where Charles was a postal clerk and Frances had been a schoolteacher. Early in his childhood, the family moved to Okmulgee, Oklahoma, where they lived in a house with gas lights instead of kerosene lanterns that had been their sources of light in Shawnee.

Hobart’s parents were strict disciplinarians, who seemed to have had little insight as to how to raise a child; however, his mother is to be credited for having initiated his education prior to his entering school. In fact, on entering grade school, Hobart was placed in the second grade. Although he met the academic challenges, he was small in size and frequently bullied; nonetheless, Hobart was reasonably well muscled and survived by running away. In 1925, the family moved to Bentonville, Arkansas, where they enjoyed electric lights. Hobart skipped the first year of high school, and became active in physical education. Unfortunately, he was stricken with an unknown disease that resulted in tachycardia, which necessitated his slowing his physical pace. While he was in high school his adoptive mother died of tuberculosis.

Hobart held various low-income summer jobs in Bentonville. He greatly enjoyed the woods and streams in the Bentonville area, and developed a fascination with insects. Having no books on insects, Hobart knew nothing of their classification and relationships. One of his high school teachers suggested that if he wished to pursue a career in entomology he should go to Kansas State College. Consequently, in the early fall of 1928 at the age of 15, a socially inexperienced Hobart Smith found himself on the campus of Kansas State University. There he came to know Professor Reginald H. Painter, an insect taxonomist, who proved to be an important influence on Hobart’s life.

Shortly after Hobart became established in College at Manhattan, Kansas, his adoptive father came for a brief visit and inopportunistely, died there. Again Hobart was an orphan. Once the immediate arrangements were taken care of, Hobart faced a new problem—he was underage and had no parents, although he had inherited funds sufficient to see him through his undergraduate education. Fortunately, Professor Painter agreed to be his guardian. Hobart never lived with the Painter family, but he did accompany them on field trips to collect insects. Painter greatly influenced his orientation toward a career in taxonomy, but taxonomy of what?

Painter introduced Hobart to a young assistant professor in the Department of Zoology, Howard K. Gloyd, who maintained quite a herpetological menagerie. Gloyd “allowed” Hobart to take care of the live amphibians and reptiles, mostly rattlesnakes, and introduced him to scientific names and classification. Hobart

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**In Memory of Hobart Muir Smith (1912–2013): From Humble Beginnings to Worldwide Recognition**

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accompanied Gloyd on three field trips to southeastern Kansas, Utah, and Arizona, and familiarized himself with the habitats and behavior of many species. Initially, Hobart was a mediocre student, but once he developed some basic studying techniques along with an interest in biology, he became an all "A" student.

One day Gloyd introduced Hobart to a visitor from the University of Kansas—Professor Edward H. Taylor. Over the next two years, Hobart joined Taylor on short collecting trips in Kansas. Perhaps because of their different personalities, the domineering Taylor and the comparatively meek Smith worked well together in the field. On one or more of these field trips they must have discussed plans to invade Mexico (herpetologically speaking). On June 4, 1932, 19-year-old Hobart Smith graduated from Kansas State University with three short herpetological publications to his credit. As he shed his cap and gown, Taylor was waiting for him, and they drove south to Mexico. Thus was born one of the greatest herpetological achievements of all time. [A detailed account of Hobart Smith's childhood and collegiate career can be found in Smith, 2001].

In 1932, roads in Mexico were few and still fewer were paved. Smith and Taylor went everywhere they could in Taylor's aging car; the many times they were stuck in deeply rutted roads, they had to be pulled to drier ground by oxen. Flat tires were common; once they even dropped their gas tank. Early in the trip, individual responsibilities were sorted out. Both men spent all available time collecting. Hobart preserved and cataloged specimens, and Taylor drove and prepared meals—most rice, sugar, and canned evaporated milk—three times a day! Occasionally this diet was supplemented with bread and rarely by a chicken. Taylor, who personally was financing the trip, sometimes would buy each of them a meal and a beer in town. Taylor had set a goal of 50 specimens per day. Most specimens were caught by hand, but a .22 caliber single-shot rifle with dust-shot cartridges was used for many lizards. At night, they each carried a Coleman lantern for finding frogs and occasional snakes. They exceeded Taylor's goal by collecting 5500 specimens in three months. These specimens formed the EHT-HMS collection maintained by Taylor at the University of Kansas.

The relationship between Edward H. Taylor and Hobart M. Smith was sometimes tenuous. This is best expressed in a letter to WED from Smith dated April 16, 2011: "Although Taylor made me what I am, quite definitely, what I am is not Ed Taylor. He was forever an enigma to me, and at times I hated him. Certainly some of his actions deserve hate. I can say this and still recognize that he was gifted to an unparalleled or at least remarkable degree in some respects, but was deficient in some humanitarian ways. He seemed to be aware of this (witness his elaborate soirées, erratic displays of generosity) but never really changed."

Upon returning to Kansas in September 1932, Hobart began graduate studies at the University of Kansas. During his first year, he scrounged for funds for support; subsequently, he was the teaching assistant in comparative anatomy, a rather famous course taught by Taylor. Hobart was itching to go back to Mexico, especially to gather more material for his research on lizards of the genus *Sceloporus*. Eventually, a trip was organized with a fellow graduate student, David Dunkle. They scraped together $250 for the trip in the summer of 1934 and traveled in Dunkle's 1923 Model T-Ford coupe. They spent three months in northern Mexico as far south as Zacatecas and collected about 1500 specimens. They were plagued with nearly constant car trouble of one kind or another and the car finally was abandoned in southwestern Kansas. Both men, stricken with malaria, returned to Lawrence by train. In 1936, Taylor financed four months of fieldwork in Mexico. During part of the trip Hobart travelled with Henry D. Thornas, a graduate student working on aquatic insects. Off and on Hobart encountered Taylor in Mexico, who was travelling alone in his car and collecting hundreds of specimens. Part of the summer they were in the Yucatan Peninsula, and Hobart, who was fascinated with a fauna previously unknown to him, spent several weeks in the rainforest at the base of the peninsula.

Once back in Lawrence, Hobart worked feverishly on completing his doctoral dissertation, “The Lizards of the torquatus Group of the Genus *Sceloporus* Wiegmann, 1828,” and successfully defended it in June 1936. Hobart was extremely fortunate to receive a National Research Council Fellowship, which supported the research for the completion of his monographic study of *Sceloporus* while at the Museum of Zoology at the University of Michigan (1936–1937). Times were tough in the late 1930s, but Hobart persevered by working briefly as a research assistant for Howard K. Gloyd, who was then Director of the Chicago Academy of Sciences, and subsequently as a WPA (Works Progress Administration) employee under Karl P Schmidt at the Field Museum of Natural History, also in Chicago. He submitted his lengthy manuscript on Mexican and Central American *Sceloporus* to Schmidt for publication by the Field Museum, but Schmidt was reluctant to allocate a large part of the publication budget for this one publication until Taylor presented him with large synoptic collection (about 1500 specimens of 57 species, including 9 holotypes) of Mexican *Sceloporus*. Schmidt had to reallocate a large part of the publication budget to publish the monograph (Smith 1939).

Obviously, Edward H. Taylor played a significant role in Hobart Smith's developing career and continued to do so in the late 1930s. He influenced former Kansas student Alexander Wetmore, then Director of the United States National Museum (USNM), to support Smith for continued fieldwork in Mexico. In the summer of 1938, Smith was awarded a Walter Rathbone Bacon Travelling Fellowship for two years of investigations in Mexico. But Hobart would not be travelling alone. While a graduate student at Kansas, he had dated Rozella Blood, who was a graduate student in the Department of Anatomy in the School of Medicine. In the summer of 1938 he proposed to Rozella, and they were married in Chicago on August 26; Howard K. Gloyd and Karl P. Schmidt witnessed their union.
The newlyweds spent a month in Washington D.C. preparing for their trip to Mexico and in October 1938, their lengthy honeymoon began. They travelled in a 1936 half-ton panel truck and entered Mexico on October 3. Until August 24, 1940, they drove throughout Mexico exclusive of the two peninsulas—Baja California and Yucatan. Sometimes they travelled by train or river steamers to get to places not reachable by roads. Although their “cuisine” seldom included rice and evaporated milk, they survived on a tight budget; Hobart’s frugality was continued from earlier expeditions. Taylor joined them for about a month in 1940. As usual, he began to take charge of the operation; Hobart complied as he had in earlier expeditions, but Rozella stood up to Taylor. This was the beginning of a life-long dislike of one another.

The fieldwork in Mexico was extremely productive; they collected slightly more than 20,000 specimens that were to be deposited in the USNM. Wetmore arranged for a third year of support on the fellowship, so that Hobart could study the specimens and properly add them to the USNM collections. By the time that Smith left the USNM in August 1941, he had published 42 papers (961 pages) on Mexican amphibians and reptiles; two papers were coauthored with Edward H. Taylor, one with Bryce C. Brown, and one with David Dunkle. Twenty-seven of these publications dealt with lizards (14 on Sceloporus), and 14 pertained to snakes. Amphibians were included in two faunal papers, and one paper contained the description of a new species of frog (Eleutherodactylus spatulatus). Most papers focused on descriptions of new taxa from Mexico—one genus, 20 species, and 12 subspecies of lizards, and 1 genus, 12 species, and 6 subspecies of snakes.

While Hobart was at the USNM, Roger Conant urged him to write a checklist of the amphibians and reptiles of Mexico. Somewhat later, Hobart and Ed Taylor agreed to write the checklist and, more importantly, keys to the Mexican herpetofauna. Smith immediately undertook a volume on the snakes, while Taylor prepared a volume on the amphibians. Taylor’s influence with Wetmore again paid off; the USNM would publish the volumes. Smith prepared most of the checklists on the reptiles, whereas Taylor wrote most of the volume on the amphibians. Smith suggested that Hobart should be the first author on the amphibian volume, but Taylor generously argued that they should keep the same authorship throughout the series. The volume on the snakes was written primarily by Hobart when he was at the University of Rochester (Smith and Taylor, 1945). The next volumes were delayed, because Hobart did not want to submit the manuscripts before Taylor could add the finishing touches, and Hobart dared to do so. Taylor was active in Southeast Asia as an officer with the OSS (forerunner of the CIA) from 1944 until January 1946. The volume on amphibians finally appeared after Hobart joined the faculty at the University of Illinois, and a volume on reptiles exclusive of snakes followed two years later (Smith and Taylor, 1948, 1950).

Completion of the fellowship at the USNM was a major turning point in Hobart’s life. Before his 29th birthday he had an enviable publication record and became recognized as the authority on the Mexican herpetofauna. This is especially amazing in that he had spent nearly three years in the field, but fieldwork was coming to an end, as pointed out in a letter to WED from Hobart dated August 23, 2010: “The 2 years that Rozella were with me in Mexico were all she wanted of field work. After that it was Best Western [motel] or nothing.” In one respect, Hobart was fortunate; most men his age were being drafted for military service, but because of his tachycardia he was not accepted.

Late in the summer of 1941, Doris Cochran recommended Smith for a position at the University of Rochester, where for three and a half years he taught comparative anatomy to navy premed students; his salary for this temporary assistant professor position was $2,200 per year. While at Rochester, Hobart maintained his constant production of scientific publications—58 papers mainly dealing with Mexican reptiles and amphibians. Perhaps it is a coincidence that Sherman C. Bishop, who was a Professor of Vertebrate Zoology at the University of Rochester, published his book on salamanders (Bishop 1943) while Smith was in residence at Rochester, and he must have begun his work on a handbook of lizards in the same series (Smith 1946).

Being kicked out (Smith’s own words) of Rochester at the end of the fall semester in December 1944 could have been catastrophic for the family (Bruce D. Smith was born in Rochester on January 22, 1943). Fortunately, at the University of Kansas, E. Raymond Hall, who was awaiting Edward H. Taylor’s return from service in Southeast Asia, needed someone to teach comparative anatomy in the spring semester; he hired Smith for one semester. Hall also arranged for Smith to write a book on the amphibians and reptiles of Kansas; Hall would edit the manuscript and
be a coauthor. Taylor, who had returned to campus in January 1946, was furious that Hall should be a coauthor. Hobart was caught in the middle of this dispute, which resulted in Smith's being the sole author (Smith 1950). This incident apparently was the origin of the nasty, life-long feud between Hall and Taylor. Despite the situation, Hall continued to support Smith and recommended him for a position at Texas A&M College (now Texas A&M University). In the fall of 1946 with a newborn daughter (Sally, August 30, 1946) the Smith family moved to College Station, Texas, where Hobart spent a year teaching various courses in the Department of Wildlife Management.

In the post-war years with thousands of former GIs enrolling in colleges and universities, classes were swelling, and there was a need for more professors. In the spring of 1947 the University of Illinois advertised for an Assistant Professor of Zoology to teach comparative anatomy. Hobart applied and soon was elated when he was offered the position. At last, a tenure-track position in herpetology. Hobart hit his stride at the University of Illinois, where he rapidly rose through the ranks to full professor. He was a popular teacher as evidenced by having as many as 200 students (most premed hopefuls) in his comparative anatomy course. Whether in his office, eating lunch, or walking across campus, he always seemed to have time to converse with his students, undergraduates and graduate students alike. The latter were a mixture of morphologists and herpetologists. Among the morphologists, two became leaders in their fields of specialization—Karel L. Liem in functional morphology at Harvard University and R. Glenn Northcutt as a neuroanatomist at Scripps Institution of Oceanography. Among the many PhD students mainly engaged in herpetology were Philip W. Smith (1953) at the Illinois Natural History Survey, James C. List (1956) at Ball State University, Ronald A. Brandon (1972) at Southern Illinois University, to have been the construction of a tree house in a large tree in the yard in St. Joseph; it was a favorite place not only for Bruce and Sally but numerous neighborhood kids. After Rozella obtained a Master’s degree in library science in 1963 from the University of Illinois, she became less involved in family activities. From that time on, the Smiths were an academic family. While Hobart continued his herpetological work, Rozella explored new horizons, especially the use of computers in library automation. She applied her skills not only at the University of Illinois, but also at the National Center for Atmospheric Research in Boulder, Colorado, and the University of Kansas Medical Center in Kansas City. Rozella was a renaissance woman—a needle-point perfectionist, science and medical librarian, writer, Shakespearean scholar, and a Sherlock Holmes enthusiast; both she and Hobart were members of the Baker Street Irregulars.

While working in Colorado, Rozella discovered Coors beer, and it became a favorite beverage for both her and Hobart. But in the 1960s, Coors beer was not sold east of Kansas; so periodically, Rozella would show up in Lawrence, driving her huge Chevrole-Impala station wagon. She would take Duellman and Linda Trub to lunch, but they had to drive, too. Why? Because after lunch they all would go to a liquor store and fill that huge station wagon with cases of beer, even on the floor and the seat beside her. She would take off for Urbana with several months’ supply of their favorite beverage. Coors beer was made in Colorado. One might suspect that this was one reason for their move to Boulder in 1968, but by that time, neither one drank beer.

The organizational arrangements between the Department of Zoology and the Museum of Natural History were like those at Kansas. Hobart was an Assistant Professor in the department and the unpaid curator of the herpetological collection in the museum. These units were administered by Donald F. Hoffmeister, a mammalogist and former student of E. Raymond Hall at the University of Kansas. Hoffy, as he was called behind his back, emulated Hall in many ways by being somewhat dictatorial and making sure that mammalogy was first in line for available space, funds, and student help. Smith adapted well to the arrangement. He convinced the administration to provide $10,000 for the purchase of 10,000 specimens (roughly one third of the total) from the EHT-HMS collection. In this way, he had a diverse collection of Mexican amphibians and reptiles for study. These collections were augmented by many expeditions to Mexico by graduate students and funded by the Natural History Museum. Hobart was fortunate to have the continued assistance of Dorothy M. Smith; she catalogued specimens in the collection and maintained Hobart’s ever-increasing card file on Mexican herpetology.

Hobart hit his stride at the University of Illinois, where he rapidly rose through the ranks to full professor. He was a popular teacher as evidenced by having as many as 200 students (most premed hopefuls) in his comparative anatomy course. Whether in his office, eating lunch, or walking across campus, he always seemed to have time to converse with his students, undergraduates and graduate students alike. The latter were a mixture of morphologists and herpetologists. Among the morphologists, two became leaders in their fields of specialization—Karel L. Liem in functional morphology at Harvard University and R. Glenn Northcutt as a neuroanatomist at Scripps Institution of Oceanography. Among the many PhD students mainly engaged in herpetology were Philip W. Smith (1953) at the Illinois Natural History Survey, James C. List (1956) at Ball State University, Ronald A. Brandon (1972) at Southern Illinois University,
and Peters S. Chrapliwy (1964) at University of Texas at El Paso. He also mentored several Master’s Degree students and undergraduates who went elsewhere for their PhDs; among these are Kenneth L. Williams and Larry David Wilson who received their PhDs in 1968 and 1970, respectively, under the tutelage of Douglass A. Rossman at Louisiana State University, and John D. Lynch and Thomas H. Fritts who received their PhDs in 1970 and 1972, respectively, under the mentorship of William E. Duellman at the University of Kansas.

Hobart continued his extraordinary rate of publication, usually publishing more than a dozen papers per year (39 in 1963). He published textbooks on comparative anatomy (Smith 1954, 1957, 1964) and various papers on diverse aspects of vertebrate anatomy. However, many publications dealt with Mexican herpetology. From the beginning of their fieldwork in Mexico in 1932 through the time of the publication of their last checklist in 1950 Smith and Taylor wrote 195 papers dealing with the amphibians and reptiles of Mexico; only 10 of these were jointly authored by the two of them. In these papers they proposed 266 new scientific names. These included three genera and 39 species of salamanders and one genus and 67 species of frogs. Among the reptiles, they named six genera of snakes and one of lizards, while proposing names for 88 species and subspecies of snakes and 72 of lizards. It is no wonder that they were considered to be the modern initiators of Mexican herpetology. (Alfredo Dugès is nominally considered to be the father of Mexican herpetology.)

At the University of Illinois, Hobart had his shirt pocket stuffed with a row of pens (in a plastic envelope) and index cards; thusly, he was prepared to scribble notes wherever he might be; later many of these were expanded into publications. While at the University of Illinois, he published 380 papers and books; most of the papers were coauthored, usually with students. Of the 380 publications, a minority of 87 dealt with Mexico, whereas 57 were proposals or opinions published in the *Bulletin of Zoological Nomenclature*. During this period Smith introduced several terms, e.g., herpesian and herpetogeny (Smith 1949), and herpetozoa (Grant and Smith 1960); most of these terms were short lived in the herpetological community. Also, during this period, he published scores of short popular papers in such outlets as *All-Pets Magazine* and *Turtox News* as well as popular books (e.g., Smith and Zim 1953).

Rozella was employed as a librarian at the National Center for Atmospheric Research in Boulder, Colorado, even before they moved to Boulder. Hobart had taught comparative anatomy during summer sessions at the University of Colorado and was offered a full-time professorship there. In the summer of 1968, he bade farewell to the large herpetological collection that he had assembled at the University of Illinois and moved with his extensive library to Boulder. This was the end of the herpetological program at Illinois that had produced so many graduate students and research on amphibians and reptiles.

Hobart’s library was amazing. He had accumulated throughout his professional life every publication that he could find that pertained to amphibians and reptiles in Mexico. For originals that he did not own, he had photocopies or microfilms; some even were typewritten. While he was a graduate student he began a card file on names of, and references to, Mexican amphibians and reptiles. This grew to tens of thousands of cards. The checklists that Smith and Taylor wrote in the 1940s were woefully out of date. Hobart was lucky to have Rozella at hand. She had begun getting involved with computers in the early 1960s. As Hobart wrote (Smith, 1988), “…her claim to fame in herpetology and, more importantly, in general scientific endeavor came from her captivation with the intricacies and potentials of computer applications to fixed-field data manipulation and graphics.” In a herculean attempt to bring the bibliography of Mexican herpetology up to date, husband and wife set to work in 1968. Rozella worked with programmers with the CDC 6400 mainframe computer at the University of Colorado. Her input device was an Oliveti terminal. Data were on punch cards. Hobart provided the source material and Rozella handled the computerization. They planned to produce nine volumes. The first was the literature on the axolotl; it contained 3311 references (Smith and Smith, 1971).
Hobart's card file contained published erroneous spellings of scientific names and he insisted that these be included, thereby greatly increasing the number of entries. Furthermore, he was a true believer in subspecies—producing still more entries. Sometimes, not all was rosy in Colorado, as emphasized in a long letter from Rozella to Duellman dated January 25, 1979: “Bill, is it really necessary to include ALL of the ‘erroneous subsequent spellings without nomenclatural status’ names? OHMYGOD. Only Smitty with his half a century of tight indexing would ever have found them. Some are so obvious. Alvarez del Toro … had a bad type-setter. Well, WHO CARES? Smitty's excuse is 'Mertens and Woodward did ... Stejneger did …’ I bet that they didn't have as many as you have, ’I whine. ‘They didn't find them all,’ he concedes. ‘I'll bet by God they didn't.’ I tell him.

‘I understand that there are people in the world who would do away with all subspecies. I am one of them. For my own reasons, naturally. Dissolution of subspecies would do away with a hell of a lot of underlining. Underlining is a pain in the ass. It has always been. BUT there is something different any more in the picture than the inconvenience of little underpaid girls who sweat over the typing. The COMPUTER hates to underline. My Olivetti doesn't like to underline and neither do the CDC 6400's. With computers coming more and more into the picture perhaps we can make a break for it. What would happen to the world of systematics if instead of underlining, we put scientific names in CAPS?

“I would appreciate any comment you would care to make. At least if it is necessary to include all of those ‘erroneous subsequent spellings …’ and if one must underline, I'll feel better if you say I have to.”

How Rozella would have loved a modern desktop computer and Microsoft Word®! She worked in the “dark ages” of electronic data management and word processing.

The comments by Rozella were made at the time she was finishing Volume VI (1044 pages on the turtles), published in 1979. In recognition of her collaboration with Hobart and especially for her pioneering work using the computer to compile and edit bibliographies, the University of Colorado awarded Rozella an honorary doctorate in August 1983. Linda Trueb and I visited the Smiths in Boulder in the summer of 1985. After dinner one evening the conversation drifted to the “Synopsis,” and I queried them when the next volume would appear. After a few words …' and if one must underline. I'll feel better if you say I have to.”

Despite the trauma of losing Rozella and not finishing the “Synopsis,” Hobart maintained an active academic life at Colorado. For 15 years he enthusiastically taught comparative anatomy, vertebrate morphology (e.g., Jonathan Oldham, 1975) and reptilian systematics (e.g., Harry L. Taylor, 1983). He also influenced many undergraduates, some of who went elsewhere to graduate school (e.g., Alan H. Savitzky, PhD, University of Kansas, 1979). Hobart was especially proud of Richard L. Holland, one of his undergraduate protégés, who became an outstanding biology teacher in Boulder, Colorado. Hobart was named Chair of the Department of Environmental, Population, and Organismic Biology in 1974 and held that position for three years, plus an additional year as co-chair with Carl Bock. All the while he delegated social duties to others. Hobart was not comfortable in large social gatherings; moreover, his hearing was waning. He continued teaching until his retirement at the age of 70 in 1983. At his last lecture in comparative anatomy his teaching assistants wore tuxedos; they provided him with a golden probe that he faithfully carried in his shirt pocket along with used IBM cards, a fringe benefit from the “Synopsis.”

Once Hobart was established at the University of Colorado his production of publications exploded. In the 42-year period of 1969–2010 he had 1119 publications, an average of 26.6 per year. In 1993 he had 68 publications! Nearly all of these were co-authored (67 with Rozella, including seven volumes of the “Synopsis”). Hobart's deep concern for nomenclature is revealed by his 47 proposals and opinions published in the Bulletin of Zoological Nomenclature. He became disgusted with the review processes of the leading journals and submitted most of his herpetological papers to non-refereed outlets, his favorites being the Bulletin of the Maryland Herpetological Society and the Bulletin of the Chicago Herpetological Society. During this time, he published two books on anatomy (Oldham et al. 1970; Smith 1976). Smith, as sole author, had several publications dealing with philosophical issues (e.g., “Evolution by premeditation,” Smith, 1970). He and co-authors published several papers dealing with reptiles and amphibians on coins and stamps. Also, many papers were reviews of books; in many of these and in obituaries he waxed eloquently (e.g., Smith 1971).

Many of Smith's publications during this time still dealt with the Mexican herpetofauna—descriptions of new species and subspecies, notable range extensions, noteworthy collections, and nomenclatural problems. Most importantly, he collaborated with several Mexican herpetologists. Although Hobart knew and had contact with Rafael Martin del Campo, they never collaborated together. Miguel Alvarez del Toro was the first Mexican collaborating with Hobart; together they described several taxa in the 1950s–1970s. After the 1970s, many Mexican biologists became interested in amphibians and reptiles. Many of these communicated by letter with Hobart to ask for help, including requests for literature difficult to obtain in Mexico and personal inquires on certain groups of Mexican amphibians and reptiles. Hobart answered all of them and sent advice and photocopies of publications. The list of Mexicans who coauthored papers with Hobart is long, but most notable are Gustavo Casas, Aurelio Ramírez, Oscar Sanchez, Oscar Flores, and Julio Lemos. Many other Mexican students sent copies of their unpublished theses to Hobart, now these are back in Mexico, in his library at UNAM. He was ecstatic about the increasing interest of Mexicans in their herpetofauna. Thus, while in his 80s and 90s, he was subconsciously still collecting in Mexico. And he actually did collect again in Mexico. After 57 years since he had set foot in Mexico, he and David Chiszar spent a week in 1993 collecting in Chihuahua, an experience that was repeated in 1997.

Hobart was seriously concerned about his library on Mexican herpetology. After several diversions and numerous communications with Oscar Flores-Villéla, he donated his library to the Museo de Zoología at the Universidad Nacional Autónoma de México (UNAM). Oscar rounded up funds in Mexico to cover the costs of packing and transporting the library from Boulder to Mexico City. In October 2006, he and two helpers spent a hectic week in Boulder (Flores-Villéla, 2006). They finally got the boxes...
of books and cabinets of reprints, files of index cards, and maps to UNAM, where personnel have undertaken the chore of placing the bibliography on a website. The finest library on Mexico herpetology is where it should be—in Mexico, thanks to Hobart Smith's generosity. Its contents are being made available on the web at: http://repositorio.fciencias.unam.mx:8080/xmlui/handle/11154/139840.

Although Hobart obviously spent most of his time on herpetology, he did have one major hobby—lapidary. In 1966 his son, Bruce, gave him some rocks; Hobart got books on the subject and set up a small shop at home. Soon he was producing bolo ties. He must have made hundreds that he gave to his colleagues. Although even in his 80s, he was active outdoors, weather permitting. At home he had an exercise bicycle that he used while reading or watching sports on TV.

Hobart rarely attended national meetings, but he and Rozella had to attend one in 1983. The Society for the Study of Amphibians and Reptiles held its annual meeting in 1983 at the University of Utah in Salt Lake City. The featured symposium, “Biogeography of the herpetofauna of Mexico: perspectives and approaches,” was organized by Larry David Wilson in honor of Hobart and Rozella Smith, who were amazed by the presence of Carlos and Miguel Ceron, brothers who had helped them so much at Cuahtlaplan, Veracruz, more than 40 years previously; also they were enchanted by the roaming mariachis during the outdoor picnic lunches. Furthermore, they were happy to hear presentations by three Mexican herpetologists.

Shortly after joining the faculty at Colorado, Hobart met a young assistant professor in the Department of Psychology, David A. Chiszar, whose research at the time focused on strike behavior of rattlesnakes. Quickly the two became almost inseparable friends and colleagues. After Rozella’s death, David took care of Hobart in many ways—foremost was transportation and hearing as Hobart became more and more deaf. Chiszar was an opposite of Hobart; he was robust in size and persona. He was an avid numismatist, fisherman, and weight lifter. Chiszar took Hobart for his first motorcycle ride (at the age of 88); he enjoyed sitting on the back seat, but Chiszar soon made Hobart more comfortable by adding a sidecar. Rozella had ridden on the motorcycle sometime before Hobart rode.

Chiszar and Smith collaborated on a diversity of publications involving snake and turtle behavior, reptile taxonomy, and various other aspects of herpetology. Whenever time permitted and the weather was suitable the two of them traveled throughout Colorado and adjacent Nebraska searching for range extensions or new county records for “herps.” Hobart also collected at the Research Ranch, a sanctuary of the National Audubon Society in southeastern Arizona, where he got a scare, as related to me in a letter from Carl Bock dated March 31, 2013: “But on the first occasion he was alone and one evening we were driving to a local restaurant when he spotted a Mojave rattlesnake (Crotalus scutulatus) on the road, got out to collect it, and got bitten in the hand. It was a wet bite, though only one fang, from what I am sure you know is a very dangerous beast. You can imagine what raced through my mind as we raced to the nearest hospital (about 40 miles away): that the world’s most famous herpetologist was going to die on my watch. They got him into emergency, then tested him for sensitivity to the anti-venom and found he had a positive allergic reaction to the serum. So, they decided not to administer unless he became critical. Fortunately that was not the case. He spent only one additional night in the hospital, and was back collecting again the next day—albeit with one arm swollen to twice the diameter of the other. Hobart was highly embarrassed by the whole thing and swore me to secrecy.”

In the period from 1975 to 2010, Smith and Chiszar authored 402 publications, of which 102 were one-paragraph notes on geographic distribution in Herpetological Review. David Chiszar retired in 2011 and their collaboration terminated, although David was a frequent visitor to Hobart, who then lived in an efficiency apartment at the Villas at the Atrium, a senior living facility in Boulder. Hobart had a computer and communicated with colleagues in Mexico and the USA by e-mail. Hobart’s eyesight was declining, so communications were in 24-point type. However, the amazing thing about corresponding with him, even when he was 98 and 99 years old, was his mental acuity. He was sharp as a tack, and his memory was nearly infallible.

Unfortunately, gathering communications between Hobart and other persons must depend on the other persons, because as written to me by Hobart on 16 April 2011: “When Ed [Taylor] was putting together his material for the KU archives, he asked me whether I would like to have our correspondence for my own archives. I told him yes, so he gave it to me. However, it was bulkier than I thought, and since I had thrown out my own correspondence with other colleagues at various times, in the process of successive moves, I decided not to bother with it. I have no archives, here or elsewhere. I never even looked at what he sent to me.”

Beginning in 2012, Chiszar’s visits to Hobart became erratic because Chiszar was undergoing treatment for cancer. David Chiszar passed away just two months before Hobart’s own life ended. However, they did have in a way an important last collaboration. The editors of Herpetological Conservation & Biology asked Hobart to reflect on the field of herpetology. Hobart engaged David Chiszar to “interview” him for three things: “(1) to look backward and identify seminal developments in herpetology during my watch, (2) to peer forward and speculate about the future developments in the field, and (3) to provide advice to young people about how to prepare for careers in herpetology.” This nostalgic and provocative article (Smith 2012) was published just a few days before his 100th birthday and should be read by all of us. This was Hobart’s last publication (number 1635) while he was alive.

In the spring and summer of 2012, I worked with Bob Hansen and Smith's children (Bruce Smith and Sally Nadvornik) on celebration of Hobart’s 100th birthday. Bruce was against any party for him at his residence; he said that Hobart would be uncomfortable with a crowd and embarrassed because he could not hear. Thus, I encouraged several former students to send written comments to Hansen, who arranged them and several photos into an article “Hobart Muir Smith turns 100,” which was a feature article in the September 2012 issue of Herpetological Review published on Hobart’s birthday. Meanwhile, Duellman invited scores of colleagues and former students to write congratulatory electronic letters; these were printed in at least 24-point type and together with numerous photographs placed in plastic sheaths in two thick loose-leaf notebooks. The issue of Herpetological Review and the notebooks were taken to Hobart by Bruce and Sally, who reported that he was absolutely flabbergasted. However, I felt that there one letter lacking and sent it separately by e-mail:

SEPTEMBER 26, 2012

SMITTY, DAMMIT! I NEVER GOT THAT FAR. CONGRATS ON REACHING 100.

—Edward H. Taylor (in absentia)
On 15 February 2013, Hobart was admitted to the emergency room in a hospital in Boulder, where he was treated for bronchitis. He returned to his apartment at Villas at the Atrium in a weakened condition and informed his son, Bruce, that “he did not have the interest in continuing to live and had lost interest in making a come back. He does not want to go to the hospital or an assisted care facility. I have talked with him about this and am comfortable with his decision” (letter from Bruce Smith to WED dated 25 February 2013). Bruce arranged for hospice care, which continued until March 4, when Hobart passed away peacefully at the age of 100 years, 5 months, and 6 days.

What a legacy! The trail from an orphanage in Ohio to Professor Emeritus in Colorado had many stepping stones, some slippery, others encouraging. Serendipitously, these steps led to Mexico, a country and its herpetofauna that became Hobart’s lifelong obsession. Hobart wrote prodigiously; it is unlikely that his record of 1637 publications, including 30 books, will ever be surpassed; one paper (Murphy and Smith 2013) and one book (Lemos Espinal et al. 2013) were published posthumously. But his publications are all that most young herpetologists know about “Smitty.” They did not have the good fortune to know him personally, as did I for six decades, beginning in 1952. And here I can only repeat what I wrote in Herpetological Review last September—viz., that his perspicacity, kindness, and generosity were exceeded only by his modesty.


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Literature Cited


HERPETOLOGICAL NOMENCLATURE

News from the ICZN

Perhaps the most contentious case ever considered by the International Commission on Zoological Nomenclature (ICZN) is Case 3463 relating to the name Testudo gigantea Schweigger, 1812 which for many years had been applied to the Giant Tortoise of the Aldabra Atoll. The application in the Bulletin of Zoological Nomenclature (BZN, vol. 66, 2009) asked the Commission to conserve Schweigger’s name through maintenance of a previous designation of a neotype. The case had broad implications including the standing of the genus-group name Aldabrachelys, and the species-group name Testudo dussumieri. In 1831, applied by some to the Giant Aldabra Tortoise. An all-time record of 83 comments on the case was received by the ICZN from both supporters and those antagonistic to the proposal. In Opinion 2316 (BZN 70[1]:61, 2013) the ICZN ruled under its plenary power that all previous fixations of a type of Testudo gigantea be set aside and that National Museum of Natural History turtle (USNM 269962) as designated and described by Frazier (2006) is to be retained as the name-bearing type. In addition, the name Testudo dussumieri, 1831 was suppressed for the purposes of The Principle of Priority but not for the Principle of Homonymy. Further, the generic name Aldabrachelys Loveridge and Williams, 1957 of which Testudo gigantea is the type species was placed on the Official List of Generic Names in Zoology and Testudo gigantea was placed on the Official List of Specific Names in Zoology. Finally, Testudo dussumieri was placed on the Official List of Rejected and Invalid Specific Names in Zoology.

The Aldabra Giant Tortoise is probably best cited as Geochelone gigantea (Schweigger, 1812) or Geochelone (Aldabrachelys) gigantea (Schweigger, 1812). I take the opportunity provided by the resolution of this case to briefly review the history of the plenary power of the ICZN and some broader nomenclatural issues.

In the end of the 18th and the early 19th century the Linnean binominal system of nomenclature had been widely accepted. However, there was no consistency in how it was applied to previously published names. Frequently, authors simply proposed new generic or specific names for already named taxa because they thought the old name was not descriptive, not good Latin, or for other reasons. It was also common practice when shifting a previously proposed species name to a new or different genus to claim authorship of the name as new. Such names today are considered new combinations. Gradually, the notion of priority as a way to provide some stability to nomenclature crept into the system (Melville 1995). Strict priority meant that the chronologically first name of two or more names applied to the same taxon had precedence for use. As the numbers of taxa and names increased exponentially by the mid-19th century the ideal of stability and universality of zoological names was seriously undermined. As a consequence, a number of scientific bodies and individuals developed sets of nomenclatural rules to provide a framework for dealing with priority and other issues in the years between 1843 and 1905 (Melville 1995). Two of the most influential were the British Association for the Advancement of Science Code and the American Ornithologists Union Code. The former is often referred to as the Strickland Code as it was the brainchild of H. E. Strickland, a naturalist with broad interests in zoology, or the British Association Code. This set of rules was adopted by the Association in 1843 and revised in 1866. The AOU Code was first published in 1896.

Finally, at the International Congress of Zoology in Berlin (1901) the Règles Internationales de la Nomenclature Zoologie was adopted by the Congress and published in 1905. It soon became apparent that several of the rather stringent rules, especially the adoption of absolute priority, were not universally acceptable. The application of the priority rule soon led to major discontent among many systematists because increasingly in-depth studies of the older literature required replacement of long used names by younger ones. Especially upsetting was the replacement of names in the medical and agricultural literature. This concern and other difficulties in the rigid application of the Règles resulted in the 9th Congress of Zoology at Monaco (1915) giving the ICZN the plenary power to suspend any part of the Code in any case where the Commission thought that its application would disturb stability or universality or result in confusion. It was through use of that power that the name Testudo gigantea was stabilized.

In due course many of the applications to the Commission over the next decades involved the suppression of an older forgotten name in favor of a long used younger one. Consideration of these applications became an increasing burden on the Commission in terms of the volume of applications. During this period use of the plenary power was, in the case of priority, gradually expanded to preserve well-established names of taxa prominent in ecology, physiology, and genetics in addition to those of medical or agricultural importance. However, there was also a gradual increase in applications to preserve younger names over new found senior synonyms where the taxon in question was of interest to only a small number of specialists. After several trials at providing a method whereby these kinds of cases need not go to the Commission, a solution was provided in the 4th edition of the International Code of Zoological Nomenclature (Art. 23.9).

Art. 23.9.1 provides that a name not used as a valid name after 1899 may not be used in preference to a younger synonym or homonym used as the presumed valid name in at least 25 works published by 10 authors in the immediate preceding 50 years and occupying a space of at least ten years. Art. 23.9.2 requires that an author who discovers that the conditions above are met must present evidence and explicitly state that the younger name is valid. From the date of such a published statement the younger name (nomen protectum) is to be used and the older becomes a nomen oblitum. A number of systematists, myself included, have argued for a less rigorous set of requirements. One suggestion being that citation of material in the Zoological Record instead of detailing the required references would expedite the process and place the onus for retention of the older unused name on those who might seek to retain its precedence.

The decision to use the plenary powers to validate the use of Geochelone gigantea remains noteworthy. Perhaps more important than the actual details of this case is the Commission’s response to comments from conservationists, conservation organizations, and government officials, almost all favoring the
retention of the name *Geochelone gigantea* for the Aldabra species. In the past most comments on cases of this nature have been by dueling systematists. It is refreshing to see in the remarks various Commissioners made with their votes that this time the user community had significant influence.

**Recent Rulings on Herpetological Names**

*BZN = Bulletin of Zoological Nomenclature*

Opinion 2313 (Case 3510): *Cyclodina aenea* Girard, 1857 (currently *Oligosoma aeneum*; Reptilia, Squamata, Scincidae) and *Tiliqua ornata* Gray, 1843 (currently *Oligosoma ornatum*): specific names conserved and neotype designated. BZN 69(4):308–309. Action was required in this case to preserve current usage of the New Zealand skink species names when it was discovered that the holotype of *Tiliqua ornata* was a specimen of *Oligosoma aeneum*. By action of this opinion a neotype was selected for *Tiliqua ornata* and the name was placed on the Official List of Specific Names in Zoology.

Opinion 2315 (Case 3351): *Chelodina rugosa* Ogilby, 1890 (currently *Macrochelodina rugosa*; Reptilia, Testudines): precedence not granted over *Chelodina oblonga* Gray, 1841. An alternate proposal to set aside all previous designations of the type species for *Chelodina oblonga* and to designate as its neotype the lectotype of *Chelodina colliei* Gray, 1856 also was not granted. BZN 70(1):57–60. The issue in this case is that the name *Chelodina oblonga*, usually applied to a southwestern Australian turtle was recently found to be a subjective senior synonym of *Chelodina rugosa*, a name long used for a northern Australian species. As neither proposal was approved by the Commission the name *Macrochelodina oblonga* must be used for the Northern Long-necked Turtle instead of *Macrochelodina rugosa*. The southwestern Australian turtle remains *Macrochelodina colliei* Gray, 1856.

Opinion 2316 (Case 3463): *Testudo gigantea* Schweigger, 1812 (currently *Geochelone (Aldabrachelys) gigantea*; Reptilia, Testudines): usage of the specific name conserved by maintenance of a designated neotype, and suppression of *Testudo dussumieri* Gray, 1831 (currently *Dipsocelh dyssumieri*). BZN 70(1):61–65.

Opinion 2320 (Case 3536): *Stegosaurus* Marsh, 1877 (Dinosauria, Ornithischia) type species replaced with *Stegosaurus stenops* Marsh, 1887. BZN 70(2):129–130. The generic name *Stegosaurus* was originally based on a specimen described as *Stegosaurus armata* by Marsh in 1877. That specimen has proved to be unidentifiable so to establish the stability of the widely used and recognized generic name a neotype designation was necessary.

**Pending Cases of Herpetological Interest**


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—*Jay M. Savage, Section Editor*
ZOO VIEW

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Deadly Encounters By and Upon Crocodilians Depicted in Historical Illustrations and Accounts. Part II. Assaults Upon Crocodilians

To return to reptile “training,” the most common variety of this in the Vest is a “Fakir Act” in which the trainer “hypnotises” crocodiles. A remarkable and convincing act it can be, but training it is not. It depends on exactly the same deception as I have explained in the case of the Indian who “charms” the cobras. It depends on timing—in apparently commanding an activity which is, in fact, about to happen in any case.

Here in retrospect is how it looked once to the audience in the old Círcus Renz off the Praterstrasse in Vienna. The ringmaster’s voice brought a hush of heightened expectation to the audience. “Ladies and gentlemen.... The Great Labero, master of man and beast, will now perform his most sensational and astounding feat....” They had already say spellbound while “The Great Labero” had done most of the tricks and stunts usual in what we call a “Fakir Act.” They had watched him “hypnotise” a lioness so that she allowed him to take a hunk of meat away from her jaws. They had seen him “hypnotise” small animals and birds. Now apparently something even more startling was coming.

Labero, a good-looking young man in evening dress, advanced on an oblong black box about fourteen feet long. As he lifted the sliding trap which served as an end to the crate, a deep, loud hissing came from the interior—a sound somehow suggestive of the power behind a steam engine. From the box there emerged a tremendous crocodile. Labero raised his hand and the Beast immediately stopped.

The audience shuddered. A few more and the creature sank slowly down on to the sawdust and settled into complete immobility. The audience relaxed slightly. The performer now began a series of short passes with his hands—over the head of the monster across its neck, from the base of the skull between the eyes forward to the nose, then a slight tap at the point of the upper jaw.

Suddenly the monster’s jaws gaped hugely and the sinister, spiked teeth shone in the spotlight. Then a gasp of horror from the audience. The man was actually passing his hand and forearm between the jaws of the monster; pausing actually with his hand held rigid between the twin decks of these terrible teeth, turning his hand slowly palm-upward in the creature’s mouth.... A quick withdrawal, a slap of his hand on the snout, and the jaws crashed shut with a sound that could be heard in the farthest row of seats.

Hans Brick, The Nature of the Beast, 1960

Although habitat alteration and other threats are a serious concern in efforts to preserve crocodilians, this important question must be asked: Why do humans have such a primal fear and hatred toward snakes and crocodilians? There have been studies on ophiophobia (see Burghardt et al. 2009) but the literature on apprehension, trepidation, and panic toward the latter is less complete. At the Dallas Zoo years ago, large American Alligators had to be removed from their outdoor exhibit after one was killed and several others were injured by zoo-goers. At this zoo and others, visitors threw an astounding variety of missiles at them: children’s toys, cans of all types and descriptions, coins, batteries, bullets, arrows, bamboo and metal spears, keys, lighted cigarettes and cigars, tree branches, hunting and pocket knives, crayons, pens and pencils, garbage, Frisbees, chunks of concrete, cardboard and Styrofoam boxes, sticks, rocks, sunglasses, baseball caps, plastic and glass bottles, bottle caps, hand tools, soiled baby diapers, and human food. In one case, there was a shoe in the enclosure but unfortunately no foot was inside! In some cases, one would surmise that the patrons planned beforehand to bring the items, such as spears with pointed tips, into the zoo for the expressed purpose of killing the reptiles.

Incredibly, alligators are being used for swimming pool parties with children in Florida. The alligator’s mouth is taped shut and the reptile swims, likely in chlorinated water, among the attendees. I suspect that renting an alligator might cost an arm and a leg! As is to be expected, the Florida Fish and Wildlife Conservation Commission has received many complaints about this practice and is now investigating the legality of using alligators in this manner.

“If one visits the famous Café el-Fishawy in Cairo, one might notice, among the more conventional objects of interior decoration such as mirrors and chandeliers, a large stuffed crocodile suspended over the doorway. This is not a unique phenomenon: there are other houses in Cairo and many more in Upper Egypt, especially between Aswan and Luxor, that boast crocodiles over their doors, or above the entrance to a hāra, or neighborhood. In Cairo, the builders of a nineteenth century house even went so far as to carve a limestone crocodile into the lintel over the main entrance. These crocodiles (from kroke meaning pebble and dri-los meaning worm, describing the animal’s skin), both real and imitation, are intended to have an apotropaic function: placed above the door they avert the evil eye and safeguard the house’s residents.” (Ikram 2010, pers. comm.). She found that crocodiles, or parts thereof, were also commonly used in ancient Egyptian medicines, and are still used in some folk-medicines today: leg pains, cramps and stiffness, and balding; dung was used as part of the cure for river blindness caused by the parasitic roundworm (Onchocerca) and to test pregnancy in women. Burning
Sculptors find battles between crocodilians and other animals irresistible for developing their artwork. There are many statues showing epic struggles with tigers, lions, leopards, sharks, giant snakes, and elephants; the crocodilians almost always appear to be the losers. Two stand out as particularly tense and violent—Antoine-Louis Barye’s bronze statues called Tigre dévorant (Tiger Devouring a Gavial) and Jaguar dévorant un crocodile (Jaguar Devouring a Crocodile) in the 1830s. Man versus crocodilian is a favorite theme. One of the most striking renderings is “The Crocodile Hunter” by Arthur Bourgeois in front of the Reptile Menagerie at the Jardin des Plantes in Paris. There is even a recent one called “Batman vs Killer Croc DC Classic Confrontations statue” available for purchase; every home should have at least one!

In The Economist (May 18, 2010), a portrait of the late crocodilian biologist John Thorbjarnarson provides a hint:

**“The rippling fire of the tiger, the cuddliness of the panda, the viridian flash of the green-cheeked parrot, all argue that these most-endangered species should be saved. It’s harder to make the case for crocodilians. That bony, hideous head, with its unblinking yellow eye; those huge teeth, smelly with fish-debris, overhanging the long, cruel, curling smile; the slogging slide of the white underside down a muddy slope, into the water where those jaws, the strongest in nature, will smash round the leg of a man and pull him under, thrashing and screaming.”**

John Thorbjarnarson knew he could not end men’s fear of crocodilians, hard-wired since hominids first ventured down from the trees into swamps that seethed with them. But in his 20-odd years working for the Wildlife Conservation Society he did more than anyone else to try. He commended the grace of their straight, silent swimming, their camouflage mottlings of yellow, grey and olive green, and the jewelled beauty of new, damp hatchlings no bigger than the span of his hand.

Clearly, crocodilian conservationists have a major challenge ahead in trying to protect a group of reptiles with such bad—sensationalized, inaccurate, and misguided—press. Zoo and aquarium biologists, especially in temperate regions where the creatures need to be maintained indoors in cold weather, are faced with a daunting challenge: how to create sustainable captive breeding groups for these animals when so many species are at risk. There are many critical issues. These include the lack of space, especially for many of the larger taxa; the need to have large colonies to ensure genetic diversity; space to allow the separation of sexes for controlling breeding or limiting aggression; the desire by administrators to show the biggest and the more spectacular (for example, Nile and Saltwater Crocodiles) at expense to some of the smaller but more endangered forms; aberrant behavior patterns toward humans; and, generally, the need for suitable enclosures where crocodilians can be handled safely. There were roughly 1500 American Alligators in US zoos and aquariums in 2010, occupying valuable space, space better used for critically endangered forms (AZA Crocodilian Advisory Group—The Future of Crocodilians in North American Institutions, Colette Adams, pers. comm.).

In the US, there are relatively few formalized AZA programs for crocodilians—Cuban, Orinoco, Philippine, Siamese, Slender-Snouted crocodiles, and Gharial—and all are faced with the captive challenges listed above. As an example, the number of holdings for Cuban Crocodiles is not adequate so breeding must necessarily be curtailed (Bill McMahan, pers. comm.) To complicate the problem, zoos are generally not directing resources to the construction of expanded facilities or programs. Further, there are limited funds available for supporting in situ initiatives that are critical supplements to captive programs. Zoo development officers focus fund-raising efforts on the charismatic mammals at the expense of reptiles, including crocodilians. What is
needed here is a total shift in priorities, elevating crocodilian conservation to the level of support as elephants, giant pandas, tigers, cheetahs, rhinos, and other critically endangered mammals receive.

This leads to one potentially workable solution: concentrate efforts to maintain these reptiles in southern climates where indoor space is not a problem. As there are not enough zoos in these areas to accomplish the goals, private organizations and foundations would need to help with this effort. Further, zoos would be asked to help defray expenses if the private sector is involved, and it goes without saying that most zoos are dealing with serious budget issues; they would likely not have discretionary monies available. If crocodilians at risk go south for the winter and reproduce successfully, will there be suitable wild homes for the young reptiles to be safely reintroduced? A conundrum to be sure!

However, taking a broader view as one looks at the shift of captive elephants to places deemed to have more appropriate space and climate, this move of captive crocodilian programs to the south would just be another way of saying that zoos and aquariums are not fit to have animals. It would be another step in the direction of the elimination of zoos and aquariums.

While all animal managers face the same issues of space and other competition for captive resources, it is unconscionable to give up the fight to protect crocodilians. I am skeptical that protection of any taxon will successfully happen in a sustainable way over the next few decades and so I am preparing myself to watch many of these majestic animals disappear from our planet. But it is too soon to give up the effort and crocodilians deserve to be numbered among the groups that garner attention.

Acknowledgments.—This contribution is dedicated to Peter Brazaits and his wife Myrna Watanabe, who have spent a lifetime trying to save crocodilians.

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Books and Other Publications on Interactions between Crocodilians and Humans


Natural History Cabinets of Curiosity and Operating Theaters of Anatomy


These forms may be called, collectively, “crocodilians.” In all, there are twenty known living species and many more fossil forms. They are often of great size, ugly and vicious in appearance, and wholly carnivorous. They inhabit fresh water swamps, lakes and rivers in tropical or subtropical countries, though two species, the Nile Crocodile (which is found throughout Africa), and the East Indian Crocodile, are known to swim boldly out to sea. These two species are also notable as the most seriously dangerous to human beings. They are all excellent and powerful swimmers and secure their food either in the water or from the neighboring banks. They are by no means exclusively aquatic, however, the true crocodiles, especially, being capable of active motion on land. All come ashore to sun themselves and to deposit their eggs. In size, the crocodilians are the largest of living reptiles. Some of the existing forms reach an occasional length of thirty feet, while the largest fossil forms are estimated at about fifty feet. The American alligator with a maximum adult size of about sixteen feet is intermediate between these monsters and the smallest forms. One of the South American caimans is not known to reach a length of more than four feet.

Karl P. Schmidt (1922) *The American Alligator*
Crocodiles were often found in cabinets of curiosities and apothecary shops, usually hanging from the ceiling. Illustration from Ferrante Imperato’s *Dell’istoria naturale, di Ferrante Imperato ... libri XXVIII* in 1599.

A word in regard to shooting saurians. Go prepared to hunt and kill whatever specimens you require, for the chances are you will not get any save what are brought to bag with your own trusty (or rusty) rifle. To kill a crocodile, proceed as follows: Find where he is in the habit of coming out on the bank for his daily sun-bath; then, at precisely the right time,

‘Come where my love lies dreaming.’

Sneak up as close to him as you can, get a position so that you can attack him broadside on, and post a couple of natives close by, primed beforehand with instructions to rush forward and grab the scaly monster by the tail as soon as you fire. Estimate the distance carefully, wipe the perspiration out of your eyes, aim at the neck-bone, or the vertebral column anywhere in front of the shoulders, and let drive. If the reptile’s body lies still and his jaws fly wide open, run for him like a quarter horse, for you have hit his spine, and he is your meat if you only get to him in time to lay hold of his tail. Take your rifle along, for you might need it again, particularly if the crocodile is more than ten feet long. If he requires a coup de grâce, give him another bullet in one of his cervical vertebrae, and the subsequent proceedings will interest him no more.


Medieval bestiaries described the Hydrus, the enemy of the crocodile living in the Nile River, which it kills from the inside. The root of the word refers to water and the description is based on its habit of finding a sleeping crocodile, rolling in the mud, crawling into the reptile’s mouth, eating the internal organs, and emerging from the body which causes death is rather vivid, even if fanciful.
One of the earliest printed images of the hippo/croc battle is in Pierre Belon’s works on aquatic animals *Histoire naturelle des estranges poissons marins* (Paris, 1551, a woodcut, hand-colored. There is also a black & white image in his *De aquatilibus* (Paris, 1553). In the French version Belon seems to say that this is an image from an ancient Roman statue or carving on stone, possibly depicted in ancient Egypt. Several Egyptian tomb scenes show a crocodile seizing a baby hippopotamus as it emerged from its mother during birth.

Conrad Gesner used the same image (reversed when it was copied) in his *Nomenclator aquatilium animantium...* (Tiguri [=Zurich], 1560. The same cut was probably in his slightly earlier *Historia animalium. Liber III: De piscium et aquatilium animantium* (Tiguri [=Zurich], 1558).

The same image appears again—the croc is a bit smaller this time—in Ulysse Aldrovandi’s *De quadrupedibus digitatis viviparis...et...oviparis* (Bononiae [=Bologna], 1637). The subject seems to drop out of the picture after the 1500s.

Copying images from earlier works was not considered plagiarism because some authors and artists felt that altering or changing texts or illustrations was inappropriate since the world created by God was already perfect.
This illustration (left) shows a human subduing a crocodile from River God, Crocodile and Hippopotamus by Jean Temporal, Historiale Description de l’Afrique in 16th century. The other one is called Capturing a Crocodile using a Goat as Bait. These images were taken from Roman coins.

But such discussions take us away from the real reason for men’s curiosity about crocodile diet. Eating is a highly evocative subject to humans, full of sexual and above all cannibalistic symbolism. In the associative processes of our unconscious thinking little distinction is drawn between a man eating a man and an animal eating a man: they both connote cannibalism. Opening up a croc always raises the possibility of finding human remains inside – something bound to excite any human. This lends a juicy, macabre air to poking around inside a croc’s gut. And from time to time the inquisitive have indeed found “anklets, wristlets and other lugubrious objects inside crocodiles.

A. D. Graham (1973) Eyelids of Morning; The Mingled Destinies of Crocodiles and Men
Illustration From *Bücher und Schrifften, von der Natur* in 1565 by Pliny the Elder. (Haines, Slithy Toves, SSAR 2000).

It is a curse on four legs, and equally pernicious on land and in the river. Its teeth are set close together like a comb, it has no tongue, and it bites down with its mobile upper jaw, unlike other land animals. It also has claws, and its hide is impervious to blows. It foreknows to lay its eggs above the point where the river will rise during the next flood. To stay warm, it stays on land during the day and in the water at night. It allows a small bird to enter its mouth to clean its teeth; if it falls asleep with its jaws open while this is happening, the ichneumon jumps down its throat and gnaws its way out through the belly. Dolphins also attack crocodiles, using the sharp fin on their backs to cut open the crocodile’s soft belly.

*Natural History, Book 8, 37–38*


...the ichneumon, or Egyptian mongoose, like other mongooses an important enemy of young crocodiles and a raider of nests, was said by Pliny the Elder to kill the adults as they basked with their mouths open:

Now that he is lulled as it were fast asleep with this pleasure...the rat of India or ichneumon spith his vantage and seeing him lie thus broad gaping, whippeth into his mouth and shooteth himself down his throat as quick as an arrow, and then gnaweth his bowels, eateth a hole through his side, and so killeth him...

Pliny also said that dolphins attacked crocodiles and killed them by slicing the thin belly skin with their fins. This may have some factual basis in that combats between crocodiles and sharks do sometimes occur. The battle here may go either way, for there is one report of a shark found in a crocodile’s stomach.

*Sherman A. Minton Jr. and Madge Rutherford Minton* (1973) *Giant Reptiles*
Illustration and quote from Edward Topsell.

There be many who in the hunting and prosecuting of these Crocodiles, doe neither give themselves to runne away from them, nor once to turne aside out of their common path or roade, but in a foolish hardinesse, give themselves to combat with the beast, when they might very well avoid the danger, but many times it happeneth that they pay decrely for their rashnes, and repent too late the too much reputation of their owne man-hood: for whiles with their speares and sharpe weapons they thinke to pierce his fides, they are deceived, for there is no part of him penetrable except his belly, and that he keepeth safe enough from his enemies, blunting vpon his soales (no leefe hard then plates of yron) all the violence of them blowes and sharpeffe of weapons, but clubsbes, beetles, and such like weapons, are more irksome to him, when they be sette on with strength, battering the scales to his body, and giving him such knocks as doth dismay and astonish him. Indeede there is no great vse of the taking of this Serpent, nor profit of merchandise commeth thereby, his skinne and flesh yeelding no great respect in the world.

Landing the crocodile is still a matter of some difficulty. Specimens more than ten feet in length can not be towed with the canoe. One of us, therefore, stripped and waded in the breast-deep water, hauling steadily on the long rope. With a hundred feet of rope, even the largest specimens are rather easily managed in this way. The unfortunate beast makes a few struggles and rushes about at the surface with open jaws, but it is surprising that so powerful an animal make so little effectual resistance. It is important to choose a rocky shore on which to reach the crocodile as he may otherwise become deeply buried in the mud. Once hauled out, a large crocodile is a savage customer, snapping viciously at his captors and at the rope.

Karl P. Schmidt (1952) describing the capturing of crocodiles for display in the Chicago Natural History Museum in his book Crocodile Hunting in Central America.
Alligators are losing this particular battle as depicted by engraver Theodor de Bry in 1591. Humans are really tiny or alligators are really big! Illustration from Theodor de Bry’s *Dritte Buch Americae, darinn Brasilia / / durch Johann Staden ...* and account from *Narrative of Le Moyne: an artist who accompanied the French expedition to Florida under Laudonnière, 1564 / / translated from the Latin of De Bry; with heliotypes of the engravings taken from the artist’s original drawings in 1875.

Illustration from Peter Pindar’s *Peter’s Prophecy... or, An Important Epistle to Sir J. Banks, on the Approaching Election of a President of the Royal Society* in 1788. (Haines, Slithy Toves, SSAR 2000).


The recipe for Bayou Alligator Sauce Piquant calls for 50 lbs cubed alligator meat and serves 100+. It starts off, “Get a big, really big pot.”

**Preparation**—Chances are slim that you will be processing an alligator (or crocodile) from a live specimen so I will give a few pointers, based on my experience, on processing the carcass after it has been skinned for its hide. Be sure to have plenty of free time.

Alligators are losing this particular battle as depicted by engraver Theodor de Bry in 1591. Humans are really tiny or alligators are really big! Illustration from Theodor de Bry’s *Dritte Buch Americae, darinn Brasilia / / durch Johann Staden ...* and account from *Narrative of Le Moyne: an artist who accompanied the French expedition to Florida under Laudonnière, 1564 / / translated from the Latin of De Bry; with heliotypes of the engravings taken from the artist’s original drawings in 1875.

**Killing crocodiles**

Their way of attacking crocodiles is as follows: They put up, near a river, a little hut full of cracks and holes, and in this they station a watchman so that he can see the crocodiles, and hear them, a good way off; for, when driven by hunger, they come out of the rivers, and crawl about on the islands after prey, and if they find none, they make such a frightful noise that it can be heard for half a mile. Then the watchman calls the rest of the watch, who are in readiness; and, taking a portion, ten or twelve feet long, of the stem of a tree, they go out to find the monster, who is crawling along with his mouth wide open, all ready to catch one of them if he can; and with the greatest quickness they push the pole, small end first, as deep as possible down his throat, so that the roughness and irregularity of the bark may hold it from being got out again. Then they turn the crocodile over on his back and, with clibs and arrows pound and pierce his belly, which is softer; for his back, especially if he is an old one, is impenetrable, being protected by hard scales. This is their way of hunting crocodiles; by which they are, nevertheless, so much annoyed that they have to keep up a regular watch against them both day and night, as we should do against the most dangerous enemy.
In 1885, Léon Vaillant & Guillaume Grandidier published this exquisite color plate of the Nile Crocodile found in Madagascar in Histoire Naturelle des Reptiles. Première Partie: Crocodiles et Tortue. Vol. XVII. Many of the reptiles pictured in this volume are near extinction, due to poaching and habitat loss.

The fights among crocodilians during mating season, which sometimes cause significant mutilations, can lead to the death of an animal... On crocodile farms, where a large number of crocodilians are often kept under cramped conditions, missing limbs, tails, and jaw fractures are not rare.

Ludwig Trunau and Ralf Sommerlad (2006) Crocodilians; Their Natural History & Captive Husbandry


The flesh is delicately white, but has so perfumed a taste and smell that I could never relish it with pleasure.


The Natural History by Mark Catesby in 1771.
Caimans are heavily hunted for their skins throughout the range. Illustration of Black Caiman (Melanosuchus niger) [left] and Dwarf Caiman or Cuvier’s Smooth Fronted Caiman (Paleosuchus palpebrosus) from Johann Baptist von Spix (1824–1825) Animalia nova, sive, Species novae lacertarum [serpentes, testudinum et ranarum] : quas in itinere per Brasiliam annis MDCCCXVII-MDCCCXX jussu et auspicis Maximiliani Josephi I. Bavariae regis suscepto / / collegit et descriptis dr. J.B. de Spix.

Native tribes hunt crocodilians with harpoons, hooks, traps, and nets. In the Amazon Basin, many caimans are beaten to death with clubs when the bodies of water dried out. The simple hunting method of the natives did not endanger the overall crocodilian populations. Only when the Europeans with their modern weapons invaded the tropical countries, the number of crocodilians declined drastically.

Ludwig Trützmuller and Ralf Sommerlad (2006) Crocodilians; Their Natural History & Captive Husbandry

Vaughn Glasgow tells us that threats to Alligators were endless even in the early days: Native Americans used skins for tribal instruments, Indian basketry used alligator entrails for baskets, early colonists used tail fat to help produce indigo, and in the middle of the 19th century, alligators’ teeth were sold by jewelers for babies’ pacifiers.

The draining of swamps and marshes, the damming of almost all the major southern rivers, and the clearing and removal of wetland vegetation have all contributed to reducing the alligator’s natural habitat. The full impact is often not recognized because of the alligator’s ability to adapt to artificial lakes, ponds, and canals, as well as its capacity to persist in areas heavily populated by people. Their obvious presence in such unnatural aquatic systems gives an illusion that alligators are coping with the human alteration of wetland habitat. And they probably are doing so more effectively than most wetland species they normally coexist with.

J. Whitfield Gibbons (1997)

John James Audubon reported on 16 April 1822 that a group of nine Whooping Cranes was killing a band of young alligators. He added the gators in April and painted the background some years later.

Robert Havell Jr was an English engraver hired for Audubon’s monumental double-elephant folios of prints [Audubon Plate 8]; Havell number CCXXVI (measured 29.5 × 39.5 inches (untrimmed), drawing traced on copper plates and hand-colored).
Leitch and Catania (2012) asked what the purpose was for the thousands of microscopic pigmented bumps found on crocodiles’ bodies and the minute dome organs restricted to the faces of alligators. Using scanning electron microscopy, they discovered that each dome was surrounded by a hinge depression. The authors located sensory receptor structures beneath the domes with sensitive free nerve endings near the dome surface, and laminated corpuscle structures responding to sustained pressure in the lowest skin layer. A delicate network of nerves infiltrated the entire jaw. Remarkably, the domes around the animals’ teeth and jaws were more touch sensitive than human finger-tips. The conclusion: this sensitivity allows the crocodilians to distinguish rapidly between inedible debris and prey and aids females during extraction of hatchlings from eggs with their jaws.

Hatchling crocodilians face an array of dangerous predators, including larger crocodilians, during their first few years of life. Drawing from Albertus Seba’s *Locupletissimi rerum naturalium thesauri* in 1734–1765.

Hatchling crocodilians face an array of dangerous predators, including larger crocodilians, during their first few years of life. Drawing from Albertus Seba’s *Locupletissimi rerum naturalium thesauri* in 1734–1765.

***The absurd story that alligators eat their own young, cannot be believed for a moment. A gentleman informed me, that one of his negroes having caught a young alligator, which whined like a young puppy, the parent came towards the negro with a rapidity he had never witnessed on other occasions—a kind of jumping motion, which caused the boy to run, after dropping his captive. I have been assured, when danger is imminent, that very young alligators run into the parent’s mouth for safety. I have this statement from a highly respectable physician.***

**Bennet Dowler (1846) Contributions to the natural history of the alligator (*Crocodilus mississippiensis*); with a microscopic addendum.**
Conservation of crocodilian populations is highly dependent upon management practices that allow people and crocodiles to coexist. Successful programs have focused on incentives to maintain crocodiles and their habitats in a relatively undisturbed state. Sustainable use has become a key element in recent conservation efforts, based on more than two decades of experience with different management schemes in Papua New Guinea, Venezuela, Zimbabwe, the USA, and Australia. In each case, crocodilian populations in the wild have increased or remained stable while supporting economically viable levels of harvest.

Tim Halliday and Kraig Adler (eds.)

The recovery of the American alligator is a striking conservation success story, and one that demonstrates the resilience of crocodilian populations to hunting pressures... Despite the large number of hunters after their skins, breeding groups of alligators remained in many areas and became a foundation that allowed a rapid recovery once hunting stopped. The key factor here was the fact that American alligator habitat remained abundant throughout the entire species range. A similar situation is seen for a variety of other species including the black caiman and the Morelet’s crocodile. Once widespread commercial hunting was controlled, populations entered a period of recovery. Species like the Chinese alligator, with little or no remaining habitat, represents a very different conservation challenge.

The Chinese Alligator...
Drawing of False Gavial (*Tomistoma schlegeli*) in *Verhandelingen over de natuurlijke geschiedenis der Nederlandsche overzeese bezittingen*... by Salomon Müller and Hermann Schlegel in 1839-44. This taxon is endangered, due to human activities. This species was assumed to have a predominantly fish diet but recent evidence has shown these reptiles to prey on larger vertebrates including humans, Proboscis monkeys, long-tailed macaques, deer and fruit bats (Rachmawan, D., Brend, S. 2009. *Human-Tomistoma interactions in central Kalimantan, Indonesian Borneo* Crocodile Specialist Group Newsletter January 2009 – March 2009. Volume 28 No. 1: 9–11). (Haines, Slithy Toves, SSAR 2000).

Illustration and quote from Davy Crockett’s Almanack of Wild Sports in the West, Life in the Backwoods, Sketch of Texas, and Rows on the Mississippi (1837, v. 1, no. 3). Crockett’s wife and daughters are mentioned: “The women then slacked the rope a little and made it fast round a hickory stump, when my oldest darter took the tongs and jumped on (the alligator’s) back, when she beat up the ‘devil’s tattoo’ on it, and gave his hide a real ‘rub a dub...’ My wife threw a bucket of scalding suds down his throat, which made him thrash round as though he was sent for. She then cut his throat with a big butcher knife. He measured thirty seven feet in length.” I am curious as to where he found his ruler. At least she is riding side-saddle as a proper lady should.
Herpetological Surveys of the Serra Jeci and Namuli Massifs, Mozambique, and an Annotated Checklist of the Southern Afromontane Archipelago

The reptiles and amphibians of northern Mozambique are among the least studied in all of Africa. This lack of study stems in part from the combined effects of limited infrastructure and Mozambique’s extended civil war (1977–1992), making access notoriously difficult. While much of Mozambique south of the Zambezi River has historically been included as part of the southern African region in field guides and herpetofaunal summaries (Alexander and Marais 2007; Branch 1998; Carruthers 2001; du Preez and Carruthers 2009), the provinces of Cabo Delgado, Nampula, Niassa, and Zambézia are poorly studied in a biological context, with large regions lacking even preliminary surveys (Poynton and Broadley 1991; Schneider et al. 2005). The most significant contribution to the herpetofauna of northern Mozambique was made by Branch et al. (2005a), who recorded 57 species of reptiles occurring in Niassa Game Reserve (NGR). The NGR spans the northern limits of both Niassa and Cabo Delgado Provinces, with the Rovuma (or Ruvuma) River forming the northern border of the Reserve, and border with Tanzania. While much of the Reserve is low elevation woodland or savannah, the Serra Mecula Plateau sits between 800–1000 m elevation, with the Serra Jeci massif rising to 1300–1800 m elevation. The vegetation is characterized by grasslands, miombo woodland and evergreen moist forest, the latter containing species commonly associated with Afromontane forests. On the Serra Mecula Plateau, Branch et al. (2005a) discovered a new species of cordylid lizard (Branch et al. 2005b), identified several taxa of equivocal status, and uncovered many faunal elements linked to other Afromontane isolates in Zimbabwe (Eastern Highlands), Malawi (Mt. Mulanje), and Tanzania (Eastern Arc Mountains). Branch et al. (2005a) established the Serra Mecula Plateau and surrounding region as having the highest reptile diversity in all of Mozambique, thereby highlighting the importance of surveying additional inselbergs across Mozambique.

Northern and central Mozambique are dotted with inselbergs, several of which have been explored recently as part of the Royal Botanic Gardens Kew Darwin Initiative to catalogue biodiversity in montane systems (Bayliss et al. 2010; Timberlake et al. 2007; Timberlake et al. 2009). These montane areas are located in Zambézia Province, Mozambique, adjacent to Mt. Mulanje, Malawi, and include Mt. Chiperone, Mt. Inago, Mt. Mabu, and Mt. Namuli (Fig. 1). These four inselbergs each rise to over 1500 m elevation, and support unique habitats not found in surrounding lowlands, including areas of Afromontane vegetation. Formal biodiversity surveys were conducted to catalogue plant, bird, and invertebrate diversity, and although not targeted specifically, reptiles and amphibians were collected opportunistically. The limited herpetological sampling of these inselbergs has already resulted in the discovery of several new species (Branch 2005b; Branch and Bayliss 2009; Branch and Tolley 2010), and these regions await focused herpetological surveys.

Further north are other largely unexplored inselbergs, including the Serra Jeci massif, situated on the Lichinga Plateau in Niassa Province (Fig. 1). The Lichinga Plateau sits between 900–1300 m elevation, with the Serra Jeci massif rising to 1300–1800 m elevation. The vegetation is characterized by grasslands, miombo woodlands, riparian forest patches, and limited evergreen montane forest patches (Ryan and Spottiswoode 2003). The Serra Jeci massif was first identified as supporting a diverse community of forest-dependent birds, including an endemic subspecies, in 1945 (Benson 1945, 1946). However, due to extremely difficult access it has only been visited twice in the last 67 years, once for a two-day avifaunal survey (Ryan and Spottiswoode 2003), and once for a brief scouting expedition by the Royal Botanical Gardens in 2009. Nothing has been reported about the herpetofauna of this area, which represents a critical biogeographic link between the Serra Mecula Plateau and inselbergs further south and west.

During July–August of 2011, we conducted herpetological and avian surveys on and near the Lichinga Plateau and Gurué...
highlands, and our primary survey areas were the Serra Jeci massif (29 July–5 August) and Mt. Namuli (7–11 August). Overall, all conditions were cool and dry, as these months represent the end of the winter period before seasonal rains begin. In each area, combinations of sites were sampled to maximize the types of habitat surveyed. Sites surveyed in the Namuli region include localities on the massif and in the nearby town of Gurué, and ranged in elevation from 700–1720 m. Sites surveyed at the Lichinga Plateau include the Serra Jeci massif and the nearby town of Lichinga, and ranged in elevation from 1300–1770 m. Specimens were hand-captured during diurnal and nocturnal visual surveys. Time limitations precluded the use of pitfall traps or other systematic techniques. Voucher specimens and tissue samples are deposited in the Museum of Vertebrate Zoology (MVZ) at the University of California, Berkeley, with a subset of voucher specimens deposited at the Natural History Museum of Maputo. Morphological identification of bufonids and hyperoliid frogs were confirmed through DNA barcoding, using the mitochondrial gene 16S (DMF, unpubl. data).

The following species accounts, including locality and voucher details and relevant natural history information, are given for animals collected during our surveys. We present an annotated checklist (Table 1) of the herpetofauna of the southern Afromontane archipelago based on: 1) this study; 2) the targeted herpetological surveys of Mt. Mulanje, Malawi (Branch and Cunningham 2006) and Niassa Game Reserve, Mozambique (reptiles only, Branch et al. 2005a); 3) the opportunistic collections made by the Royal Botanic Gardens Kew Darwin Initiative across three Mozambican inselbergs (Bayliss et al. 2010; Timberlake et al. 2007; Timberlake et al. 2009); and 4) a brief survey of the Lichinga Plateau that followed our work in the area (Branch 2012).

**ANURA**

*Arthroleptidae*

*Arthroleptis xenodactyloides* (Fig. 2A–C). Niassa Province: Serra Jeci forest drainages, 2–4 August, 12.8512°S, 35.1777°E, MVZ 265868; 12.8492°S, 35.1810°E, MVZ 265869–71; 12.8438°S, 35.1781°E, MVZ 265871–904. This species was found only in moist leaf litter at the edges or in elevated portions of small streams within Afromontane forest, at 1668–1723 m elevation. This species was not found in permanent pools or marshy areas in open grassland below the montane forest (<1450 m).

*Brevicipitidae*

*Breviceps mossambicus* (Fig. 2D). Zambezia Province: Gurué, 7 August, 15.4639°S, 36.9778°E, MVZ 266110. Found at night on surface of compacted sandy soil after rain showers, 730 m elevation.

*Bufonidae*

*Amietophrynus gutturalis* (Fig. 3A). Niassa Province: Lichinga, 27 July, 13.3010°S, 35.2456°E, MVZ 265843–44; Serra Jeci grassland, end of Malulo–Cal Road, 29 July, 12.8674°S, 35.1850°E, MVZ 265846–53; Zambezia Province: Gurué, 23 July, 15.4687°S, 36.9939°E, MVZ 265840; 7 August, 15.4639°S, 36.9778°E, MVZ 265856–57; Village adjacent to Mt. Namuli, bridge overpass, 9 August, 15.3875°S, 37.0731°E, MVZ 265864. This species was often found in sympathy with *A. gutturalis*, and was active during daytime hours.

*Hyperoliidae*

*Afrixalus brachycnemis* (Fig. 2E, F). Niassa Province: Serra Jeci grasslands, 2 August, 12.8673°S, 35.1733°E, MVZ 265820–23; Zambezia Province: Grasslands below Ukaliní Forest, Mt. Namuli, 11 August, 15.3842°S, 37.0719°E, MVZ 265824–26. This species was found sheltering diurnally in banana plants, sugarcane leaves, and sedges near flowing water outside of the montane forests, at 1200–1400 m elevation.

*Hyperolius marmoratus* (Fig. 2G). Zambezia Province: Mt. Namuli grasslands, 11 August, 15.3842°S, 37.0719°E, MVZ 266048, 266051. Two juveniles were captured sheltering in banana plants in an agricultural plot adjacent to a stream in otherwise open grassland habitat.

*Hyperolius cf. spinigularis* (Fig. 2H). Zambezia Province: Mt. Namuli grasslands, 11 August, 15.3842°S, 37.0719°E, MVZ 266050. A single juvenile was captured sheltering in a banana plant in an agricultural plot adjacent to a stream.

*Hyperolius substratus* (Fig. 4A–H). Niassa Province: Serra Jeci Peak Forest, 1 August, 12.8401°S, 35.1845°E, MVZ 265976–86; Grassland agricultural drainage, 2 August, 12.8618°S, 35.1732°E, mass and tadpoles were sometimes found in the same water sources as adults.

*Amietophrynus maculatus*. Niassa Province: Serra Jeci grassland, end of Malulo–Cal Road, 29 July, 12.8674°S, 35.1850°E, MVZ 265845; Zambezia Province: Gurué, 23 July, 15.4687°S, 36.9939°E, MVZ 265841; Village adjacent to Mt. Namuli, bridge overpass, 9 August, 15.3875°S, 37.0731°E, MVZ 265864. This species was often found in sympathy with *A. gutturalis*, and was active during daytime hours.
MVZ 265987–90; Grassland farmbush pond, 2 August, 12.8767°S, 35.1845°E, MVZ 265991–6004; Grassland irrigation ditch, 2 August, 12.8680°S, 35.1841°E, MVZ 266005–14; Serra Jeci Forest Camp, 2 August, 12.8512°S, 35.1818°E, MVZ 266015–18; Serra Jeci Drainage Forest, 4 August, 12.8438°S, 35.1781°E, MVZ 266019–24; Zambézia Province: Mt. Namuli grasslands, 11 August, 15.3842°S, 37.0719°E, MVZ 266026–47, 266049, 266052–107. Specimens at Serra Jeci were found at 1360–1770 m elevation, whereas specimens at Mt. Namuli were found at 1200–1420 m elevation. There is substantially more variation in adult color pattern in the Serra Jeci population as compared to the population at Mt. Namuli, which exhibits a more typical adult form of this species (Fig. 4). This was the most abundant hyperoliid species encountered, and it was found in a variety of habitats including streamside vegetation inside the montane forests (Serra Jeci only), drainages and seeps in open grasslands, grassland ponds and marshes, and in agricultural areas close to moving water.

Fig 2. Photographs of voucher specimens in life: (A) *Arthroleptis xenodactyloides* (MVZ 265885), Serra Jeci; (B) *Arthroleptis xenodactyloides* (MVZ 265869), Serra Jeci; (C) *Arthroleptis xenodactyloides* (MVZ 265870), Serra Jeci; (D) *Breviceps mossambicus* (MVZ 265910), Gurué; (E) *Afrixalus brachycnemis* (MVZ 265820), Mt. Namuli; (F) *Afrixalus brachycnemis* (MVZ 265826), Serra Jeci; (G) juvenile *Hyperolius marmoratus* (MVZ 266048), Serra Jeci; (H) juvenile *Hyperolius cf. spinigularis* (MVZ 266050), Mt. Namuli.

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Ptichadidae


Pyxicephalidae

Amietia angolensis. Zambézia Province: Ukalini Forest on Mt. Namuli, 9–10 August, 15.3689°S, 37.0615°E, MVZ 265829–30, MVZ 265834; 15.3677°S, 37.0587°E, MVZ 265833; Mt. Namuli riparian patch, 10–11 August, 15.3745°S, 37.0649°E, MVZ 265831–32, MVZ 265835; 15.3875°S, 37.0732°E, MVZ 265836. Found in streams and pools in Ukalini forest and the riparian patch below nocturnally, at 1200–1700 m elevation. Pickersgill (2007) recently elevated three subspecies of *A. angolensis* (*A. lubrica*, *A. tenuoplicata*, and *A. viridireticulata*, distributed across Uganda, Tanzania, and Tanzania and Malawi respectively) to species. The phylogenetic affinities of this newly sampled population are unknown, and additional work will be necessary to clarify its taxonomic status.

Fig. 3. Photographs of voucher specimens in life: (A) Amietophrynus gutturalis (MVZ 265863), Mt. Namuli; (B) Amietia sp. (MVZ 266166), Serra Jeci; (C) Rhampoleon sp. (MVZ 266165), Mt. Namuli; (D) Rhampoleon sp. (MVZ 266161), Mt. Namuli; (E) Acanthocercus atricollis (MVZ 265813), Serra Jeci (F) Panaspis wahlbergii (MVZ 266148), Serra Jeci; (G) Trachylepis margaritifer (MVZ 266172), Mt. Namuli; (H) Trachylepis varia, Lichinga.
Amietia sp. (Fig. 3B). Niassa Province: Serra Jeci grasslands, 2 August, 12.8680°S, 35.1841°E, MVZ 266166. A single specimen was collected diurnally next to a shaded irrigation ditch in the grasslands.

Testudinidae
Kinixys belliana (Fig. 5A). Niassa Province: Serra Jeci grasslands, 3 August, 12.8694°S, 35.1829°E, MVZ 266166. A total of seven live animals were observed over the course of three days following the fires, three of which were collected as voucher specimens.

Testudinidae
Kinixys belliana (Fig. 5A). Niassa Province: Serra Jeci grasslands, 3 August, 12.8694°S, 35.1829°E, MVZ 266166. This species was encountered sheltering around rock outcrops after being driven out of the grasslands by a large fire, at 1300–1400 m elevation. A total of seven live animals were observed over the course of three days following the fires, three of which were collected as voucher specimens.

Squamata — Lizards

Agamidae
Acanthocercus atricollis (Fig. 3E). Niassa Province: Serra Jeci grasslands, 3–4 August, 12.8674°S, 35.1850°E, MVZ 265813–19. Specimens were collected on large trees in grasslands and were
often found under bark at night. This species is common and widespread, and can be found in eastern South Africa, eastern Botswana, Zimbabwe, Mozambique, Malawi, Zambia, with scattered populations in Tanzania, Uganda, and Kenya. This species has previously been recorded from Niassa Game Reserve, Niassa Province (Branch et al. 2005a), however these records fill in a large distributional gap in northwestern Mozambique.

*Agama kirkii.* Niassa Province: Serra Jeci grasslands, 3 August, 12.8674°S, 35.1850°E MVZ 265827–28; Zambézia Province: Mt. Namuli grasslands, 11 August, 15.3875°S, 37.0732°E, MVZ 265806–12. Juveniles and adults were found basking on large rock outcrops present in open grassland habitat, 1280–1380 m elevation.

*Chamaeleonidae*


*Rhampholeon* sp. (Fig. 3C, D). Zambézia Province: Ukalini Forest, Mt. Namuli, 8–9 August, 15.3693°S, 37.0613°E, MVZ 265935–42. This common, widespread species was found in disturbed areas on mainly artificial structures at night.

*Gekkonidae*

*Hemidactylus mabouia.* Niassa Province: Lichinga, 26 July, 15.3103°S, 35.2498°E, MVZ 265931–34; Zambézia Province: Gurué, 7 August, 15.4639°S, 36.9778°E, MVZ 265935–42. Specimens found active on shrubs and trees in urban areas during the day, 1320 m elevation.

36.9778°E, MVZ 266129–34. This widespread species was commonly found diurnally active in low to mid-elevation (<730 m) disturbed habitat.

Lycodactylus sp. Zambézia Province: Mt. Namuli grasslands, 10 August, 15.3745°S, 37.0649°E, MVZ 266137–38. This species was found on wooden debris near a village residence in open grassland habitat on Mt. Namuli, at 1200–1420 m elevation. This species is most similar morphologically to Lycodactylus rex, known only from Mt. Mulanje, Malawi.

Sciuridae

Panaspis wahlbergii (Fig. 3F). Niassa Province: Serra Jeci grasslands, 29 July, 12.8674°S, 35.1850°E, MVZ 266148. The specimen collected is consistent with the coloration described for P. wahlbergii, rather than P. maculicollis, both of which have been recorded from central Mozambique (Jacobsen and Broadley 2000). The specimen exhibits a uniform olive-brown dorsal color but lacks longitudinal stripes, which are sometimes present in P. wahlbergii. A pale yellowish-brown dorsolateral stripe begins at the nostrils but becomes faint past the shoulder. Below this, beginning at the nostrils, is a broad dark brown band that extends to the base of the tail. A white strip is present below this band (absent in P. maculicollis), which begins on the upper labials and terminates past the shoulder. There are no alternating dark markings on the upper and lower labials, a pattern typical of P. maculicollis. Schmitz et al. (2005) assigned Panaspis wahlbergii to the revived genus Afroablepharus, however this assignment seems premature as their study focused mainly on West African species. Branch et al. (2005a) also report P. wahlbergii from Niassa Game Reserve.

Trachylepis margaritifer (Fig. 3G). Niassa Province: Serra Jeci grasslands, 4 August, 12.8674°S, 35.1850°E, sight records; Zambézia Province: Guruê, 7 August, 15.4639°S, 36.9778°E, MVZ 266171; Mt. Namuli grasslands, 11 August, 15.3875°S, 37.0732°E, MVZ 266172–79. This species was found on large rock outcrops in open grassland habitat.

Trachylepis striata. Niassa Province: Lichinga, 27 July, 13.3010°S, 35.2456°E, MVZ 266188–89; Serra Jeci grasslands, 3 August, 12.8674°S, 35.1850°E, MVZ 266190; Zambézia Province: Guruê, 7 August, 15.4639°S, 36.9778°E, MVZ 266191–92; Mt. Namuli grasslands, 11 August, 15.3875°S, 37.0732°E, MVZ 266193–200. All specimens exhibit a red-brown dorsal color with a pair of well-defined yellow dorsolateral stripes, consistent with the coloration of typical T. striata as described by Broadley (2000). A closely allied form, T. wahlbergii, has been recorded from western Mozambique, but exhibits grey-brown to olive-brown dorsal color with poorly defined pale dorsolateral stripes (Broadley 2000). On most specimens the subocular contacts the lip, a condition that varies geographically in T. striata, with this particular character state being most common along the coastal plains of Kenya, Tanzania, and northern Mozambique (Broadley 2000).

Trachylepis varia (Fig. 3H). Niassa Province: Lichinga, 27 July, 13.3010°S, 35.2456°E, MVZ 266201–06; Serra Jeci grasslands, 2 August, 12.8672°S, 35.1736°E, MVZ 266207; Zambézia Province: Mt. Namuli grasslands, 11 August, 15.3875°S, 37.0732°E, MVZ 266208–27. Broadley (2000) reports T. varia is quite variable throughout its range, which extends from Somalia to South Africa, but that montane populations tend to be smaller in size, more slender, and darker in coloration. Additionally, lowland populations of T. varia tend to have 30–34 midbody scale rows, 19–25 lamellae beneath the 4th toe, and fewer supraciliaries (<5), whereas montane populations tend to have higher counts of midbody scale rows (34–38), shorter toes (17–22), and five supraciliaries (Broadley 2000). The specimens collected at the Lichinga Plateau exhibit 34–35 midbody scale rows, 20–25 lamellae beneath the 4th toe, 5–6 supraciliaries, and range from 55–65.5 mm SVL (n = 7). The specimens collected at Mt. Namuli exhibit 31–36 (average 33) midbody scale rows, 18–23 lamellae beneath the 4th toe, 4–5 supraciliaries, and range from 46.5–68.0 mm SVL (n = 20). Given the large geographic range, broad elevational distribution (sea level to 3500 m a.s.l.), morphological variation, and bimodal reproductive mode of T. varia, this species is an appealing candidate for phylogeographic study.

Squamata — Snakes

Colubridae

Thelotornis mossambicanus. (Fig. 5C) Niassa Province: Serra Jeci grasslands, 4 and 5 August, 12.8674°S, 35.1850°E, MVZ 266167–70.

Elapidae

Naja melanoleuca. (Fig. 5D). Zambézia Province: Guruê, 24 July, 15.4451°S, 36.8975°E, MVZ 266146. Juvenile found basking in large bamboo grove near roadside.

Lamprophiidae

Lamprophis capensis. (Fig. 5B). Niassa Province: Serra Jeci grasslands, 5 August, 12.8674°S, 35.1850°E, MVZ 266111; Zambézia Province: Guruê, 7 August, 15.4639°S, 36.9778°E, MVZ 266112. The two specimens collected have two broad pale stripes occurring on the head, one on the upper labials and the other running from the snout, through the upper eye, and extending to a variable distance onto the side of the body. The bodies are light brown with light tan vernication on the forebody. This coloration is consistent with that described for L. capensis, rather than L. fuliginosus, which replaces L. capensis in northern Zambia and Tanzania (Broadley et al. 2003). Branch et al. (2005a) report L. capensis, rather than L. fuliginosus, is also present in Niassa Game Reserve.

Psammophis mossambicus. Niassa Province: Serra Jeci grasslands, 4 August, 12.8674°S, 35.1850°E, MVZ 266149.

Viperidae

Bitis arietans (Fig. 5E, F). Niassa Province: Serra Jeci grasslands, 5 August, 12.8674°S, 35.1850°E, MVZ 265905; Zambézia Province: Mt. Namuli grasslands, 11 August, 15.3875°S, 37.0732°E, MVZ 265906–07. Branch et al. (2005a) noted the puff adders in northern Mozambique display an unusual and complicated color pattern, with the hind body resembling a pattern more typical of Bitis gabonica. The puff adders collected at Serra Jeci and Mt. Namuli also display this unusual pattern (Fig. 5E, F). A recent molecular study by Barlow et al. (2013) illustrates the complex relationships of Mozambican puff adders, as a single individual sequenced from the coastline of central Mozambique appears to be highly divergent from all other lineages in central and southern Africa. Branch et al. (2005a) noted the puff adders at this locality (Moébase Region, Zambézia Province) also exhibit the unusual coloration described above, and even suggested...
Table 1. Initial checklist of species present in the southern Afromontane Archipelago, consisting of surveyed inselbergs and surrounding lowland regions in southern Malawi and northern Mozambique.

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<td>Family</td>
<td>Species</td>
<td>Mt. Mulanje, (Branch and Cunningham 2005)\textsuperscript{a}</td>
<td>Mt. Namuli, present study</td>
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<td>Mt. Chiperone, (Timberlake et al. 2007)\textsuperscript{b}</td>
<td>Mt. Inago, (Bayliss et al. 2010)\textsuperscript{b}</td>
<td>Lichinga Plateau, present study</td>
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Note: \(^a\) Branch and Cunningham (2005) \(^b\) Timberlake et al. (2007) \(^c\) Bayliss et al. (2010)
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Presence of species is indicated by an 'X'. The Niassa Game Reserve column includes species found on the Serra Mecula Plateau, which are indicated by an 'X', and species found in the surrounding lowlands (< 800 m elevation), which are denoted by an 'L'.

a Surveys specifically targeting herpetofauna.
b General surveys reporting opportunistic encounters or sampling of herpetofauna.
c Survey does not include reports on amphibian fauna.
behavioral differences may exist. Given the occurrence of the odd color pattern at Serra Jeci, Mt. Namuli, and Niassa Game Reserve, these populations may form a clade with the Moebase Region, although their phylogenetic affinities remain untested.

**Discussion.**—We conducted the first targeted herpetological surveys at both the Lichinga Plateau and Mt. Namuli, two poorly studied regions in northern Mozambique. During our work on the Lichinga Plateau, we recorded 7 amphibian and 14 reptile species. Following this, Branch (2012) recorded an additional 10 species, thereby producing a total of 32 species documented for the Lichinga Plateau (13 amphibians, 1 tortoise, 12 lizards, and 6 snakes; Table 1).

Timberlake et al. (2009) initially recorded 11 species occurring at the Namuli massif, based entirely on opportunistic sampling. During our survey we recorded 22 species, 16 of which represent new records for the area. There are now 27 species documented for the Mt. Namuli region (13 amphibians, 10 lizards, and 4 snakes; Table 1).

Several significant discoveries were made during our surveys, including range extensions and taxonomic novelties. Two hyperoliid frog species, *Afrixalus brachycnemis* and *Hyperolius cf. spinigularis*, represent new country records for Mozambique. The former was collected at both Mt. Namuli and the Lichinga Plateau, and was previously only known to occur in Malawi and eastern Zambia, and the latter, previously known from Malawi and Tanzania, was recorded from Mt. Namuli. The species of *Rhampoleon* occurring on Mt. Namuli has been previously reported as an undescribed new lineage (Branch et al., in prep; Branch and Bayliss 2009; Timberlake et al. 2009), and shows affinities to *Rhampoleon platyceps*, which is known from Mt. Mulanje, Malawi. The species of *Lygodactylus* collected on Mt. Namuli is most similar to *Lygodactylus rex*, also known from Mt. Mulanje, but it is morphologically and genetically distinct and represents a new species (Portik et al., in press). Other taxa require further investigation to clarify evolutionary and taxonomic relationships, including *Anietia angolensis* from Mt. Namuli, as well as *Lygodactylus angularis* and the species of *Anietia* collected on the Lichinga Plateau.

As survey work in the southern Afromontane archipelago progresses, the biogeographic links between montane isolates in northern Mozambique and other Afromontane regions continue to emerge. We provide a preliminary checklist of the herpetofauna of the southern Afromontane archipelago based on our results and all available literature in Table 1. The ties between Mt. Mulanje and Mt. Namuli are readily apparent, as several species described from Mt. Mulanje have a cryptic sister taxon present at Mt. Namuli, including *Rhampoleon platyceps* (Branch et al., in prep.), *Lygodactylus rex* (Portik et al., in press), and *Notophryne broadleyi* (Werner Conradie, pers. comm.). However, only limited herpetofaunal information is available from several nearby inselbergs, such as Mt. Chiporone, Mt. Mabu, and Mt. Inago (Table 1), and additional species closely related to those present at Mt. Mulanje and Mt. Namuli may be uncovered with future work. Beyond geographically proximate inselbergs, more broad-scale patterns can be inferred from the presence of numerous taxa found in northern Mozambique. Several frog species detected in our surveys have distributions following the Afromontane archipelago in Tanzania and Malawi, including the hyperoliid species *Afrixalus brachycnemis, Hyperolius cf. spinigularis*, and *Hyperolius substratiatus*, as well as the arthroleptid species *Arthroleptis xenodactyloides*. The discovery of these species at Mt. Namuli or Serra Jeci illustrates the connection of Mozambican Afromontane inselbergs to the larger Afromontane archipelago, and these isolated Mozambican regions likely represent the southern distributional limit for many of these East African forms. The presence of distinct *Rhampoleon* species across the Eastern Arc Mountains of Tanzania, the Eastern Highlands of Zimbabwe, Mt. Mulanje of Malawi, and several Mozambican inselbergs (including Mt. Namuli, Mt. Chiporone, Mt. Mabu, Mt. Inago, and Gorongosa Mountain) supports a biogeographic connection between these areas, with the genus *Rhampoleon* also reaching its southern distributional limit in Mozambique (Gorongosa Mountain). Other forest species which link Mozambican montane isolates with central and East African Afromontane regions include two species of viper: *Bitis gabonica* found at Mt. Chiporone (Timberlake et al. 2007), and the discovery of a new species of *Atheris, A. mabuensis*, at Mt. Namuli and Mt. Mabu (Branch and Bayliss 2009). Together these findings highlight the unique herpetofaunal diversity present in northern Mozambique, which is a complex admixture of Afromontane species, East African lowland forms, and southern African species, and demonstrate the clear need for continued work in this poorly studied region.

**Acknowledgments.**—All specimens were collected under the regulations of a research permit administered by the Universidade Eduardo Mondlane Natural History Museum of Maputo (No. 04/2011 and 05/2011) and a credential administered by the Ministry of Agriculture. Herpetological specimens were exported under CITES Permit No. MZ-0354/2011 provided by the Ministry for the Coordination of Environmental Action. We thank Lucilia Chiquela (Director of the Natural History Museum), Mandrate Oreste Nakala (Deputy National Director of the Ministry of Agriculture), Marcelino Poloma (National Directorate of Lands and Forests), Emilia Veronica Lazoro Polana (Department of Environmental Management), and the Ministry of Tourism National Directorate of Conservation Areas for granting permits and for logistical assistance. This research was funded by a Mohamed bin Zayed Species Conservation Fund awarded to J.P.M. (Project #11251846) and by the Museum of Vertebrate Zoology (University of California, Berkeley). We thank William R. Branch and Werner Conradie for providing unpublished technical reports, information, and discussion. We thank H. Cristoph Liedtke for establishing toad identifications through DNA barcoding, Lucinda P. Lawson for discussion of hyperoliid frog identifications, Sean Maher for generating our map figure, and Sean M. Rovito, Sarah M. Hykin, Theodore J. Papenfuss, and two anonymous reviewers for commenting on the manuscript.

**Literature Cited**


Co-Occurrence of Invasive Cuban Treefrogs and Native Treefrogs in PVC Pipe Refugia

The Cuban Treefrog (Osteopilus septentrionalis) was first introduced to Florida at Key West (Barbour 1931). Since this introduction, Cuban Treefrogs have spread first to Miami (Schwartz 1952), and are now established throughout most of peninsular Florida (Meshaka 2001). Cuban Treefrogs can become very abundant in areas they colonize (Meshaka 2001; Townsend et al. 2003), all species of treefrog become a popular method for sampling hylid anurans (Barbour 1931; Boughton et al. 2000; Campbell et al. 2010). This method has been shown to be effective at sampling both native and introduced Cuban Treefrogs (Bartareau 2004; Boughton et al. 2000; Campbell et al. 2010). This method has been shown to be effective at sampling both native and introduced Cuban Treefrogs (Bartareau 2004). While some variability may exist in the use of PVC pipe refugia by different species (Zacharow et al. 2003), all species of treefrog occurring in southern Florida will use these pipes. Cuban Treefrogs may pose problems for the use of PVC pipes in monitoring frog populations in two ways. If native treefrogs avoid PVC pipe refugia in use by Cuban Treefrogs, then bias is introduced into the sampling process.

Cuban Treefrogs may contribute to the decline of native treefrogs (Allen and Nell 1953; Knight et al. 2008; Meshaka 2001) through both competition and predation. Cuban Treefrogs grow to a larger maximum size than treefrogs native to Florida, have broad dietary niche overlap, and inhabit the same retreat sites, potentially increasing competition between species (Meshaka 1996, 2001). Cuban treefrog larvae can consume larvae of Squirrel Treefrogs (Hyla squirella) (Smith 2005b) and adversely affect the development of Green Treefrogs (Hyla cinerea) (Smith 2006a). Adult Cuban Treefrogs are known to prey upon several species of native anurans including both Green and Squirrel Treefrogs (Glorioso et al. 2012; Meshaka, 2001).

In recent years, polyvinyl chloride (PVC) pipe refugia have become a popular method for sampling hylid anurans (Bartareau 2004; Boughton et al. 2000; Campbell et al. 2010). This method has been shown to be effective at sampling both native species and introduced Cuban Treefrogs (Bartareau 2004). While some variability may exist in the use of PVC pipe refugia by different species (Zacharow et al. 2003), all species of treefrog occurring in southern Florida will use these pipes. Cuban Treefrogs may pose problems for the use of PVC pipes in monitoring frog populations in two ways. If native treefrogs avoid PVC pipe refugia in use by Cuban Treefrogs, then bias is introduced into the sampling process.

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the sample, and populations cannot be estimated accurately. Alternatively, if native treefrogs do not avoid Cuban Treefrogs within PVC pipe refugia, they may be subjected to increased predation risk.

Laboratory and some field evidence indicate that the latter situation may apply (Hoffman 2007; Meshaka 2001; Waddle et al. 2010), suggesting that native treefrogs may be naïve to the threat of Cuban Treefrogs as possible predators. We examined data collected from a project in Everglades National Park in which Cuban Treefrogs as well as native Green Treefrogs and Squirrel Treefrogs were captured. The purpose of this study was to test the hypothesis that native treefrogs will use PVC pipe refugia regardless of whether a Cuban Treefrog is present. We used data from a site where a large number of pipe checks were made to determine if native frogs co-occurred with Cuban Treefrogs more or less often than randomly expected. We also examined body size of individuals to determine if size is a determining factor for whether native treefrogs and Cuban Treefrogs co-occur in pipes.

Methods.—This study was conducted at a site near Main Park Road approximately 2.5 km northeast of the developed area at Flamingo in Everglades National Park, Florida, USA. The site was a stand of mature black mangroves (Avicennia germinans) with a thick litter layer on the ground and almost no understory vegetation. Ninety-nine PVC pipe refugia were used at the site; 38 pipes were hung in pairs on trees and 61 were placed singly on trees. Pipes were 1-m long and 5-cm in diameter, with an end cap on the bottom allowing for the retention of water. A hole drilled approximately 10 cm from the bottom of the pipe controlled the water level. Each pipe was hung on a nail in the tree so that the top of the pipe was approximately 2 m from the ground.

The site was sampled about every two weeks from July 2001 through August 2003, unless prevented by weather or equipment failure. During each sample, frogs found within each pipe were identified to species and their snout–vent length (SVL) was measured to the nearest mm. Newly captured frogs were uniquely marked by removing one to four toes (no more than one toe per foot and never the proximal toe on either forelimb) and released back into the pipe where they were found. Recaptured frogs were identified and re-marked if necessary. Beginning in August 2002, Cuban Treefrogs found in the pipes were removed from the site as part of a study to determine the effects of Cuban treefrog removal on native treefrog populations (Rice et al. 2011). These frogs were euthanized, and their stomach contents analyzed to determine the prevalence of native frogs in the Cuban Treefrog diet (Glorioso et al. 2012). The co-occurrence of Cuban Treefrogs with natives within a pipe was noted, and native treefrogs were placed back into the pipes as before.

We examined the co-occurrence of the three species of treefrogs in the PVC pipes by subjecting a contingency table of presence-absence of the three species to a series of log-linear models (Crawley 2007). To account for the potential effect of site on the interaction of the species we used site as a factor in the analysis. Thus the count of pipe checks with each of the possible interactions was aggregated by each of the 99 pipe sites for analysis. We began with a fully saturated model including all possible interactions of the species and the sites (Count - Squirrel Treefrog * Green Treefrog * Cuban Treefrog * Site) and the used the step function in Program R (R Development Core Team 2011) to choose the best model based on Akaike’s Information Criterion (AIC). The inclusion of interaction terms in the final model was verified through a series of ANOVA tests (Crawley 2007).

Because we began permanently removing Cuban Treefrogs from the PVC pipes at the site about halfway through the study, we conducted the log-linear contingency analysis on the complete dataset, the data collected prior to removal, and the data collected post removal separately. All checks of the PVC pipes were included in the analysis, including those in which no frogs were found. In addition to the three-way contingency analysis, we also conducted a Pearson product moment correlation analysis of our data to test for direct comparison to Campbell et al. (2010).

To determine if body size of the native frogs affected their likelihood of co-occurring with Cuban treefrogs, body size measurements of Squirrel and Green Treefrogs caught with and without Cuban treefrogs were tested for equal variances and a two-sample t-test was used to compare the means of each group (Crawley 2007). The mean SVL of Cuban Treefrogs caught with and without a native frog species was also compared to test if body size of the Cuban Treefrogs might be a predictor of co-occurrence with native treefrogs. All statistical tests were performed in the R statistical software environment (R Development Core Team 2011).

Results.—There were 4158 total pipe checks at Flamingo including 1478 instances where at least one frog was found inside a pipe (Table 1). More than one species of frog was observed to be in a pipe in 149 (10.1%) of the pipe checks. Cuban Treefrogs were by far the most common species found within pipes at this site with 1371 captures; more than one conspecific was found in a pipe on 223 (20.9%) of the 1069 pipe checks with Cuban Treefrogs. There were 589 Green Treefrogs captured, and more than one Green Treefrog was found in 79 (15.9%) of the 497 pipe checks with Green Treefrogs. Squirrel Treefrogs were the least frequently encountered species with 76 captures, and more than one conspecific was found in 8 (11.9%) of the 67 pipe checks where Squirrel Treefrogs were captured. Only a small proportion

<table>
<thead>
<tr>
<th>Squirrel Treefrog</th>
<th>Green Treefrog</th>
<th>Cuban Treefrog</th>
</tr>
</thead>
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<tr>
<td>Absent</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Present</td>
<td>Present</td>
<td>Absent</td>
</tr>
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</table>

Table 1. Count of PVC pipe checks (with percentage of total) where Squirrel, Green, and Cuban Treefrogs were present or absent out of N = 4158 checks.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Interaction</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Visits</td>
<td>Squirrel and Green Treefrogs</td>
<td>1.713</td>
<td>0.2523</td>
<td>6.783</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pre CTF Removal</td>
<td>Squirrel and Cuban Treefrogs</td>
<td>-15.503</td>
<td>834.29</td>
<td>-0.019</td>
<td>0.9852</td>
</tr>
<tr>
<td></td>
<td>Green and Cuban Treefrogs</td>
<td>0.762</td>
<td>0.3690</td>
<td>2.065</td>
<td>0.0389</td>
</tr>
<tr>
<td>Post CTF Removal</td>
<td>Squirrel and Green Treefrogs</td>
<td>1.340</td>
<td>0.2623</td>
<td>5.107</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Table 2. Results of the log-linear model selection from the contingency analysis of the entire set of visits and those prior to and after the initiation of Cuban Treefrog (CTF) removal. The interactions listed are the species interactions that were saved in the best model. The coefficient with standard error (S.E.) specifies the direction and strength of the interaction, and the test statistic z and associated p value determine if the interaction is statistically significant.
of the encounters of the native treefrog species occurred prior to
the onset of the experimental Cuban Treefrog removal (30 pipe
checks with Green Treefrogs; 6 pipe checks with Squirrel Tree-
frogs), while the number of pipe checks with Cuban Treefrogs
was similar in the before and after Cuban Treefrog removal data-
sets (541 and 511, respectively).

The log-linear contingency analysis revealed no evidence of
a three-way interaction among either the three treefrog species
or any two species and a site (Table 2). In both the complete da-
set and the data collected after the start of the Cuban Treefrog
removal period only an interaction between Squirrel and Green
Treefrogs was present in the best model (Table 2). This interac-
tion was significant and indicated a positive association between
the two native treefrog species (i.e., the two were found together
more often than would be expected due to chance). The odds
ratio calculated from model coefficients indicated that Squirrel
Treefrogs were 5.6 (CI, 3.4 to 9.1) and 3.8 (CI, 2.3 to 6.4) times
more likely to occur in a pipe with a Green Treefrog in the full
data set and post Cuban treefrog removal dataset, respectively.
In the best model using the data from prior to the initiation of
Cuban Treefrog removal there was an interaction between Cu-
ban Treefrogs and Squirrel Treefrogs and an interaction between
Cuban Treefrogs and Green Treefrogs (Table 2). The interaction
of Cuban Treefrogs with Squirrel Treefrogs was negative, but was
not statistically significant. While significant, the interaction be-
tween Cuban Treefrogs and Green Treefrogs was weakly positive;
Green Treefrogs were 2.1 (CI, 1.01 to 4.42) more likely to occur in
pipes with Cuban Treefrogs. The Pearson product moment cor-
relation analysis also found no significant correlation between
the occurrence of Cuban Treefrogs and either Squirrel Treefrogs
(correlation = -0.0004, p= 0.979) or Green Treefrogs (correlation
= -0.0007, p = 0.963).

The body size of Squirrel Treefrogs caught with Cuban Tree-
frogs (x̄ = 27.3 mm, s = 2.27) was not significantly different from
the body size of Squirrel Treefrogs caught without Cuban Tree-
frogs (x̄ = 27.0 mm, s = 2.44; t = -0.3113, df = 63, p = 0.7566). Like-
wise, the body size of Green Treefrogs caught with Cuban Tree-
frogs (x̄ = 42.5 mm, s = 5.05) was not significantly different from
the body size of Green Treefrogs caught without Cuban Treefrogs
(x̄ = 44.2 mm, s = 4.76; t = -0.1276, df = 475, p = 0.8965). There
was, however, a significant difference in the size of Cuban Tree-
frogs caught with the native treefrog species (x̄ = 41.2 mm, s =
7.97) compared to Cuban Treefrogs caught in pipes without na-	ive treefrogs (x̄ = 49.5 mm, s = 11.31; t = 10.3511, df = 197.4, p <
0.0001). We also compared the size of Cuban Treefrogs captured
with any other frog (i.e. native or Cuban Treefrog) and found that
their size (x̄ = 45.8 mm, s = 8.91) was significantly smaller than
that of Cuban Treefrogs captured singly (x̄ = 49.8, s = 12.01; t =
-6.0828, df = 839.6, p < 0.0001).

Discussion.—Our contingency analysis found no conclusive
evidence that the occurrence of Cuban Treefrogs in PVC pipes
had an influence on the occurrence of either Squirrel or Green
Treefrogs in the pipes. The negative interaction between Squirrel
and Cuban Treefrogs in the period prior to the removal of Cu-
ban Treefrogs at the site was not statistically significant, and a
small positive association between Green Treefrogs and Cuban
Treefrogs during the pre-removal period was statistically signifi-
cant. These results are based on the low number of native tree-
frog encounters prior to the Cuban Treefrog removal period. We
did, however, find evidence that the two native species co-occur
more often than expected if they were randomly selecting pipes.
This may mean that the two species are somehow attracted by
the presence of their congener. There were no three-way interac-
tions between two species and a site kept in the most parsimoni-
ous models, indicating that location of the pipe did not play a
role in the interactions of the species.

The analysis of body sizes did not reveal evidence of size-
specific predator avoidance of Cuban Treefrogs by smaller in-
dividuals of either Squirrel or Green Treefrogs, as there was no
difference in the lengths of the native frog species caught with or
without Cuban Treefrogs. We would have expected to find a dif-
ference if, for instance, smaller native frogs avoided pipes with
Cuban Treefrogs but larger frogs did not. We did find that Cuban
Treefrogs found in pipes with the native species were significant-
ly smaller than those captured without native treefrogs. Cuban
Treefrogs caught with any other frog, including conspecifics,
were also significantly smaller than Cuban Treefrogs caught sin-
gly. This may suggest that all the frogs avoided large Cuban
Treefrogs, or larger Cuban Treefrogs were choosing to avoid other
frogs or prefer different locations within the site. Stomach con-
tent analysis found that about 3.5% of removed Cuban Treefrogs
had recently consumed a frog, including positively identified
Green Treefrogs and other treefrogs only identified as belonging
to family Hylidae (Glorioso et al. 2012). Batrachophagous Cuban
Treefrogs were distributed evenly among adult size classes, with
no evidence that larger individuals were more likely to take frog
prey (Glorioso et al. 2012).

There are other lines of evidence that support the conclusion
that native treefrogs are native to the threat of introduced Cuban
Treefrogs. Meshaka (2001) reported that the native treefrogs in
Everglades National Park exhibited behavioral interactions that
suggested neither species recognized the Cuban Treefrog as a
predator. He observed the native treefrogs foraging on lighted
buildings alongside Cuban Treefrogs large enough to be a threat.
In a laboratory experiment, Hoffman (2007) found that native
treefrogs are as equally likely to occupy pipes with Cuban Tree-
frogs as with conspecifics and that native treefrogs did not avoid
pipes that had been previously occupied by Cuban Treefrogs. At
a landscape scale, Waddle et al. (2010) found that although the
presence of Cuban Treefrogs at a site made it much less likely
that native treefrogs would also occur at the site, there was no
effect of Cuban Treefrog presence on the detection probability of
Green or Squirrel Treefrogs. Thus it seems that even though na-
tive treefrogs are vulnerable to predation, they fail to alter their
behavior to mitigate the threat.

There are at least two studies which reached the contradictory
conclusion that Squirrel Treefrogs are less likely to co-occur with
Cuban Treefrogs in PVC pipe refugia (Bartareau 2004; Campbell
et al. 2010). The study by Bartareau (2004) used three different di-
ameters of pipes, and demonstrated that Squirrel Treefrogs were
more commonly found in the smaller two diameter sizes whereas
Cuban Treefrogs were more commonly found in the largest di-
ameter pipes. Therefore it is impossible to determine if Squirrel
Treefrogs were avoiding Cuban Treefrogs or simply showing pref-
sence for smaller diameter pipes. All of the pipes used in our
study were the same diameter, thus eliminating this confounding
factor. A study by Campbell et al. (2010) found a negative corre-
lation between Cuban and Squirrel Treefrog observations by us-
ing a Pearson product-moment correlation. However, they also
found that Cuban Treefrogs were not evenly distributed among
the four habitats in their study, which may have confounded their
results. Our comparable analysis in this study found no signifi-
cant correlation between the occurrence of Cuban Treefrogs and
either Squirrel or Green Treefrogs. Neither Bartareau (2004) nor
Campbell et al. (2010) found evidence of a negative correlation between Cuban and Green Treefrog occurrence.

The findings of our study have direct monitoring implications. We found that there is no evidence that avoidance of Cuban Treefrogs at retreat sites will bias monitoring efforts of Green and Squirrel Treefrogs. Therefore, when other potential biases are controlled (Boughton et al. 2000) using PVC pipe refugia as a sampling technique may be a good method for estimating treefrog populations.

Wyatt and Forys (2004) suggest that because Cuban Treefrogs are known predators of Green Treefrogs, using PVC pipes to sample treefrogs where the two species co-occur could create an ideal setting for the sit-and-wait predation of Green Treefrogs by Cuban Treefrogs. Evidence from our study and others (Hoffman 2007; Meshaka 2001; Waddle et al. 2010) suggests that Green and Squirrel Treefrogs do not alter their behavior to avoid Cuban Treefrogs. This raises the concern that sampling with PVC pipes may increase the vulnerability of the native species to predation, warranting further research on this subject. Additionally, determining if native treefrogs eventually learn to avoid Cuban Treefrogs and if other species of native anurans avoid Cuban Treefrogs should be further investigated.

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Shanna Bittencourt
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Toad-headed pitvipers of the genus *Bothrocophias* are distributed throughout Andean South America, in Ecuador, Colombia, Peru, Bolivia, and Brazil (Fenwick et al. 2009). Morphological (Gutberlet and Harvey 2002) and molecular (Castoe and Parkinson 2006; Fenwick et al. 2009) data have supported the monophyly of *Bothrocophias*, and its position as sister to a *Bothrops* + *Bothriopsis* clade (Fenwick et al. 2009).

Six species are currently recognized, all occurring mainly in lowland rainforest, wet-montane forest, and cloud forest areas (Campbell and Lamar 2004; Cisneros-Heredia et al. 2006; Fenwick et al. 2009; Gutberlet and Campbell 2001). *Bothrocophias colombianus* (Rendahl and Vestergren, 1940), *B. myersi* Gutberlet and Campbell (2001) and *B. rhomboeatus* (Garcia, 1896) are known only from Colombia. *Bothrocophias campbelli* (Freire-Lascano, 1991) is known from northwest South America in Colombia and Ecuador; *B. microphthalmus* (Cope, 1835) occurs from eastern Colombia to northwestern Bolivia, and *B. hyoprora* (Amaral, 1935) is distributed at low elevations in equatorial forest in the Amazon Basin, in northern-western Brazil, Colombia, eastern Ecuador, Peru, and Bolivia (Campbell and Lamar 2004; Cisneros-Heredia et al. 2006).

Because it is a rarely registered species, the natural history and ecology of *B. hyoprora* are poorly known. Apparently it is a nocturnal pit viper that inhabits very humid tropical rainforest, and is most frequently found on the leaf litter, close to water bodies (Campbell and Lamar 2004). However, our knowledge about the species is based on few specimens, and probably due the lack of sampling, few papers have been published about this species. In fact, the largest collection of *B. hyoprora* available in Brazilian institutions houses only seven specimens, from which we obtained some of the data presented in this study.

Hemipenial morphology has been used to define taxonomic groups in Crotalinae (Campbell and Lamar 2004; Vellard 1946), and although Southern Hemisphere species share general characteristics, such as short and calyculate lobes rounded distally, subtle differences are expected, as in the number and size of spines. Indeed, hemipenial characters are closely associated with species differentiation, and thus are useful in evolutionary studies (Jadin et al. 2010).

The study of chromosomes is potentially useful for species definition and systematics, especially when external morphological characters are not sufficient for the clarification of taxonomic problems (Roze 1996). However, chromosomal data are rarely used for the characterization and differentiation of snake species. The karyotype has been described for few Brazilian snake species, and the paucity of data is especially acute for species from the Amazon Basin. There are no chromosomal data for *B. hyoprora* available in the literature. The chromosomal characterization of *B. hyoprora* will allow comparison with individuals of this species from other localities, with other species of this genus, and with individuals of sister-groups, assisting in the tracing...
of patterns of chromosomal evolution in snakes.

Considering the lack of basic data for *B. hyoprora*, we present information about geographic range, hemipenial characteristics, and morphology. Morphological data were obtained from expeditions throughout the Brazilian Amazon plus herpetological collection databases and data available in the literature. In addition, we present for the first time the karyotype of *B. hyoprora*.

**Materials and Methods**

Our data are based on independent sampling expeditions in northern Brazil, in the states of Amazonas, Mato Grosso, and Rondônia (Fig. 1). We found *B. hyoprora* specimens using diurnal and nocturnal visual searches, and in line with the recommendations of Franco and Salomão (2002), we deposited the specimens in the herpetological collection of the Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil. We used additional data from Herpetological Collections of Instituto Nacional de Pesquisas da Amazônia (INPA-H), Manaus and Museu de Zoologia of the Universidade de São Paulo (MZUSP), plus Coleção Zoológica de Vertebrados da Universidade Federal de Mato Grosso (UFMT-R), Cuiabá (Fig. 1).

**Morphometric and meristic data.**—We measured snout–vent length (SVL) and tail length (TL) with an accuracy of .01 millimeter. We determined the sex of the specimens by presence or absence of hemipenes, using a small subcaudal incision. We determined scutellation patterns by counting dorsal scale rows (D), ventrals (V), subcaudals (SC), cloacal (C), supralabials (SL), and infralabials (IL).

**Hemipenial Morphology.**—We prepared the right hemipenis from a preserved specimen, following the methods of Pesantes (1994). A 2% KOH solution was injected through the proximal end, hemipenis was immersed in KOH 2% solution to regain flexibility, and was filled with agar powder dissolved in distilled water. For hemipenial morphological terminology we followed Dowling and Savage (1960), Guo et al. (1999), and Jadin et al. (2010).

**Chromosomal Techniques.**—Karyotype analysis was conducted on a male *B. hyoprora* from the Parque Nacional Nascen
tes do Lago Jari (INPA-H 28044, see Fig. 1). Prior to preparation of the cell suspension, the individual was kept at 37°C for 24 h to induce mitosis. Mitotic chromosomes were obtained from intestine, liver, testicle, and spleen using the Ford and Harmerton (1956) “air-drying” method with modifications.

We used 0.2% colchicine at a proportion of 0.2 mL/10 g of body weight. After four hours we euthanized the snake using a veterinary anesthetic. We hypotonized cell material using 0.075 M potassium chloride solution, fixed in Carnoy fixer and stained with Giemsa. To locate the nucleolar organizer region (NOR), we used AgNO₃ following Howell and Black (1980). We organized chromosomes in decreasing size order and separated into groups by morphological type.

Chromosome morphology was determined based on the position of the centromere as described by Levan et al. (1964). We considered only macrochromosomes in the determination of the number of arms [fundamental number (FN)].

**Results**

We examined nine *B. hyoprora* specimens—five males: 171, 209, 270, 352 and 375 mm SVL; and four females: 295, 437, 465 and 515 mm SVL (Table 1; Appendix I). One specimen (UFMT-R 9391) was found in 1990 in the municipality of Alta Floresta d’Oeste, Rondônia (11.97833°S, 61.96166°W; datum WGS 84, as for all subsequent geocoordinates listed; Fig. 1). The second specimen (INPA-H 17135) was found on 17 May 2006, in the Reserva Extrativista do Baixo Juruá, municipality of Juruá, Amazonas (03.47277°S, 66.02638°W). Two specimens (INPA-H 26570, 26571) were found on 29 January 2009, in forested areas at the edges of the Highway BR-319, municipality of Manicoré, Amazonas, with 100 km of distance between them (04.98666°S, 61.56638°W, and 05.58777°S, 62.18472°W). A fifth specimen (INPA-H 28044) was found on 28 March 2011, in Parque Nacional Nascentes do Lago Jari, municipality of Tapauá, Amazonas (05.81527°S, 63.15361°W). The last specimen (INPA-H 28516) we also found along the edges of the Highway BR-319, in the municipality of Borba, Amazonas (04.41472°S, 60.92444°W), on 03 September 2011. One INPA-H specimen (INPA-H 26527) was found on 10 September 2009, in the municipality of Trairão, western Amazonas; 9) Floresta Nacional Trairão, Itaituba, Pará; 10) Samuel Hydroelectric Power Station, Porto Velho, Rondônia; 11) Reserva Biológica do Jaru, Vale do Paraíso, Rondônia; 12) Alto Floresta d’Oeste, Rondônia; 13) Aripuanã, Mato Grosso; 14) Fazenda São Nicolau, Cotriguaçu, Mato Grosso; 15) Juruena, Mato Grosso.

**Fig. 1.** Geographical distribution of *Bothrocophias hyoprora* in the Amazon Basin. Star = type locality, La Pedrera, Colombia. Squares = literature data. Circles = collected specimens in this study. Diamonds = uncollected additional specimens. 1) Serra do Divisor National Park, Acre; 2) Tabatinga, Amazonas; 3) Extractive Reserve of Baixo Juruá, Juruá, Amazonas; 4) Forested area near the highway BR-319, km 400, Manicoré, Amazonas; 5) Forested area near the highway BR-319, km 300, Manicoré, Amazonas; 6) Nascentes do Lago Jari National Park, Tapauá, Amazonas; 7) Forested area near the highway BR-319, km 220, Borba, Amazonas; 8) Vicinity of Borba, Amazonas; 9) Floresta Nacional Trairão, Itaituba, Pará; 10) Samuel Hydroelectric Power Station, Porto Velho, Rondônia; 11) Reserva Biológica do Jaru, Vale do Paraíso, Rondônia; 12) Alto Floresta d’Oeste, Rondônia; 13) Aripuanã, Mato Grosso; 14) Fazenda São Nicolau, Cotriguaçu, Mato Grosso; 15) Juruena, Mato Grosso.
Biconic lateral lobe shape "C" shape
Shape of lobes bifurcation "U" shape
Spines on each lobe in the sulcate face 18–19
Spines on each lobe in the asulcate face 14–20
Length of spines in the sulcate face (mm) 1.3–3.1
Length of spines in the asulcate face (mm) 1.16–2.71
Maximum width at the middle of lobes (mm) 5.17


<table>
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<td>Shape of lobes bifurcation</td>
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</tbody>
</table>

The geographical range of B. hyoprora determined by this study extends the distribution 1787 km SE (straight line) from the type locality at La Pedrera, Colombia (Amaral 1935), 939 km NE and 437 km S (straight line) from the Reserva Biológica Jaru, Rondônia (Bernarde et al. 2008), the nearest locality previously documented.

The scale counts were similar to those presented by Gutherlet and Campbell (2001), with little variation in the number of ventrals (123–128 in males, 123–131 in females), subcaudals (46–50 in males and females), and supralabials (7/7 or 7/8) scales (Table 1). The specimen from Alta Floresta d’Oeste, Rondônia (UFMT-R 9391) had a higher number of dorsal scale rows (25-25-20).

The general hemipenial morphology of B. hyoprora is consistent with all Crotalinae, strongly bilobed with clearly visible lateral spines, but scant information about the hemipenis of Bothrocophias has been published. All information contained herein was obtained from Campbell and Lamar (2004). Bothrocophias myersi, a closely related species, has a shorter hemipenis, reaching the second or third subcaudal when fully everted (10th in B. hyoprora), with bifurcation at the level of subcaudals 2–3 (4–5). Lateral spines in the B. myersi hemipenis are shorter and thicker than in B. hyoprora, and are distributed in longer rows, with 18–30 (14–20).

Several studies have been published on Neotropical pitvipers (e.g., Martins and Oliveira 2001; Turci et al. 2010), and many
species are relatively well known. However, among Neotropical pitvipers, *B. hyoprora* is possibly the least known species with regard to natural history, ecological patterns, and geographical range. This is due to the fact that the species is rarely recorded in field studies and poorly represented in herpetological collections. Our study was based on only seven collected specimens and two additional non-collected specimens, and this restricts the discussion of our results.

Some Neotropical pitvipers have been reported as the most frequently encountered species in field work, such as *Bothrops atrox* in the central Brazilian Amazon (Fraga et al. 2011; Martins and Oliveira 1998), and they can be good models for ecology or natural history studies. Even though this is a poorly known and rarely recorded species, we cannot assume that *B. hyoprora* is rare, or even that their population density is low, because there are still large sampling voids within the range of this species, where collecting attempts have not been made, especially in the Brazilian Amazon. The species is not currently on the IUCN Red List (IUCN 2011), but more long term systematic collections of snake populations in the Amazon Basin are needed to determine the population levels and abundances of all species.

Diet of *B. hyoprora* is not well known, but apparently they eat centipedes, amphibians, lizards, and small mammals (Bernarde et al. 2008). In this study we found remains (scales) of a snake in the digestive tract of a juvenile specimen (INPA-H 26571). Due to the advanced state of digestion, we were unable to identify the prey to more specific taxonomic levels.

This is the first time that the karyotype of *B. hyoprora* has been described. The chromosome number in snakes is a conservative character, with $2n$ varying between 24 and 56 (Oguiura et al. 2010). The karyotype reported here, $2n = 36$ (16 macro and 20 microchromosomes), is the most frequently recorded type in those genera with close phylogenetic affiliations with *Bothrocophias*, such as the genus *Bothrops*, and also in basal families (Beçak et al. 2003; Gorman 1981; Oguiura et al. 2010; Pyron 2011). However, the morphology of chromosomes is not always similar among them, which means that chromosomal rearrangements are present. The NOR position is generally restricted to the microchromosomes, although some species show variation in the number of tagged chromosomes and, in some cases show this on macrochromosomes (Trajtengertz et al. 1995). Although *B. hyoprora* had only three chromosomes that stained with silver nitrate, this species probably has a NOR on four chromosomes, but only three were active.

Chromosome number and structure, including the number of macro- and micro-chromosomes, the position and morphology of pairs, their secondary constrictions, and the karyotypic formula are all useful characters for differentiating among species in the genus *Micrurus* (Serafin et al. 2007). Considering $2n = 36$ (16 macro, 20 micro) to be the ancestral karyotype for the genus, two general evolutionary patterns were suggested: Central American species had a tendency for a decrease in the number of chromosomes, while those in South America had a tendency to increase this number. Although *B. hyoprora* possesses the putative ancestral pattern (Fenwick et al. 2009), it is not possible to reach a conclusion regarding chromosomal evolution, given that chromosomal information is not yet available for other members of this genus. Further karyotypic work on the genus *Bothrocophias* and also on the Viperidae in general will doubtless reveal evolutionary patterns.
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Literature Cited


Appendix 1
Specimens Examined

Bothrocophias hyoprora BRAZIL: Amazonas: Reserva Extrativista do Baixo Juruá, Comunidade Socó, Juruá (INPA-H 17135); Highway BR-319, km 300 and km 400, Manicoré (INPA-H 26570, INPA-H 26571); Highway BR-319, km 220, Borba (INPA-H 28516); Parque Nacional Nascentes do Lago Jari, Tapauá (INPA-H 28044); Pará: Floresta Nacional do Trairão, Trairão (INPA-H 26527); Rondônia: Alta Floresta d’Oeste (UFMT-R 9391); Mato Grosso: Ariquindá (MZUSP 11152); Jurua (MZUSP 11327).

Herpetological Review 44(3), 2013
A Galápagos Ectothermic Terrestrial Snake Gambles a Potential Chilly Bath for a Protein-Rich Dish of Fish

The Galápagos Islands are well known for their adaptive radiation of plants and animals (Grant 1986; Itow 1994). It seems logical that organisms should take advantage of new opportunities when they colonize new habitats. On the wild black shores of Fernandina Island, located on the extreme west of the Galápagos Archipelago, the coast is still taking shape under the action of recent eruptions (1995, 2005, and 2009; Smithsonian Institution Global Volcanism Program) from this extremely active shield volcano. This is particularly true of the west coast, which is bathed by cold productive upwellings from the Equatorial Cromwell Under Current. Two locations, Capes Douglas and Hammond, have not been flooded by fresh lava in the recent past and are havens for life, including fur seals, flightless cormorants, and marine iguanas.

Of the four species of xenodontine colubrid snakes reported from the central and southern Galápagos Islands, Fernandina has two species: Antillophis slevini, (Fernandina, Isabela, and Pinzon) and Pseudalsophis biseriatus occidentalis (Fernandina, Isabela, and Tortuga) (Thomas 1997). The latter species is common on the western shorelines, but not exclusive to them. Here we report on a previously unpublished account of Pseudalsophis biseriatus occidentalis feeding on an unsuspected prey, marine fish.

Setting.—Fernandina is a very young active shield volcano built over the Galápagos hotspot. Its coasts are composed of raw black basaltic lava with the west coast dominated by vertical cliffs often beaten by incoming swells. However, on the northwestern cape (Douglas), a low fractured level ledge of pahoehoe lava extends seaward (Figs. 1a, b). Just to the north of the southwestern cape (Hammond), a sand beach backing a semi-circular tidal pool protected by a boulder ramp is nestled between massive rock exposed at low tides much of the sandy rocky floor of the lagoon is uncovered but remains wet (Fig. 1c). On the low tides much of the sandy rocky floor of the lagoon is uncovered but remains wet (Fig. 3, inset). There are many basaltic boulders and plates of apparently old slabs of volcanic rock permeated by small crevices and holes. In December 2008, 15 snakes were seen patrolling this habitat, investigating holes and the undersides of boulders apparently seeking prey. A snake was observed with 1/3 of its body length in a hole (Fig. 3). When extracted, the snake was able to view the snake striking at the fish. The captured fish was taken back into the crack and carried tail first onto the surface of the lava where it was consumed (Fig. 2). This practice has been observed twice: in August 1995 and November 2009.

2) On a post-1998 El Niño survey in the same area, a snake was captured for identification. During this process, the snake regurgitated its prey. Because the prey item was partially digested it was difficult to identify to species, but it was definitely a fish. Merlen sent this specimen to John McCosker, Curator of Fish at the California Academy of Sciences, for identification. It was provisionally placed in the myctophid genus Bolinichthys, possibly B. longipes (Fig. 2, inset). John Paxton, specialist in lantern fish at the Australian Museum in Sydney also examined an image of this specimen and considered Bolinichthys the most likely genus. This is remarkable as this genus forms part of the oceanic deep scattering layer fauna and no terrestrial snake has ever been recorded swimming there. The extreme steepness of the underwater topography off the west coast permits oceanic ecosystems to exist within “a stone’s throw” of the shoreline, with myctophid fish and hatchetfish (Sternoptychini) being killed in abundance by lava entering the coastal waters (McCcosker et al. 1997; Merlen, unpubl. data 2009). Possibly the fish was moribund (ill or stunned by a predator such as a fur seal and drifted close in to the shore). Less likely is that the snakes swim at night for this prey, which is uniquely on the surface during darkness.

3) At Cape Hammond the small tidal lagoon and beach is surrounded by recent flows of lava (Fig. 1c). On the low tides much of the sandy rocky floor of the lagoon is uncovered but remains wet (Fig. 3, inset). There are many basaltic boulders and plates of apparently old slabs of volcanic rock permeated by small crevices and holes. In December 2008, 15 snakes were seen patrolling this habitat, investigating holes and the undersides of boulders apparently seeking prey. A snake was observed with 1/3 of its body length in a hole (Fig. 3). When extracted, the snake wasingesting a fish approximately 13 cm in length, apparently Labrisomus dendriticus, although the head and the distinctive spot on the gill plates were not visible (Fig. 4).

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Observations are unknown between these two west coast locations (18.7 km approximately), a little-walked and risky landing stretch of coastal cliff, nor are there recordings from the east coast of Fernandina, which is much more frequently visited. On the present limited data it appears that a piscivorous diet, for at least some snakes, is limited to, and to small areas of, the west coast.

Discussion.—Because there are so few observations available, conclusions beyond the presence of piscivory in *Pseudalsophis biserialis occidentalis* are not possible. Nevertheless it may be interesting and useful to state a few observations concerning snakes and their habits on Fernandina. There are striking differences in habitat possibilities on the east and west coasts of the island. Although all coastal areas are composed of rough open lava rock, the east coast offers a considerable mangrove habitat with numerous small beaches and sea lion colonies. This diverse habitat may offer greater variety and abundance of prey items, especially endemic rats, of which there are two species on this island (*Nesoryzomys narboroughi* and *N. fernandinae*), lava lizards *Microlophus albermarlensis* (which are subdued by constriction) (Merlen, unpubl. data), and the ubiquitous Marine Iguana, *Amblyrhynchus cristatus*. The west coast is a harsh, virtually treeless environment, yet is brushed by some of the most productive waters of the archipelago. Perhaps in the two areas where low-lying land suitable for snakes reaches the sea, Cape Douglas and Cape Hammond, *P. b. occidentalis* have been able to take advantage of this novel environment for a diet of fish.

The observation of 15 snakes at one time around and in the damp basin of the tidal pool at Cape Hammond suggests that fish hunting is not a unique habit of one individual, but one that has spread through, at least, the local population.

A final remark concerns predation. Snakes investigate holes in the bottom on the pool at Cape Hammond (Fig. 3). In order to do so an estimated 1/3 of the body was inserted. This exposes the rest of the body to attack from above because these probing searches are often under open skies. Tjitte de Vries, a specialist on the Galápagos Hawk, has observed on one occasion a snake in the talons of a hawk on Santa Fe Island (de Vries, pers. comm.). Hawks have territories at both Cape Douglas and Cape Hammond. We assume that this predation is not common on Fernandina and is not a deterrent to snakes feeding in exposed holes.

Conclusion.—Predation on marine fish by snakes appears to be a unique habit of *Pseudalsophis biserialis occidentalis* on the west coast of Fernandina, especially at Capes Douglas and
Hammond. We do not know when its ancestor, *Pseudalsophis elegans* (fide Thomas 1997) arrived in the archipelago, but today three subspecies of *P. biseriatus* span the central and southern islands. The spread to Fernandina has been recent, less than 70,000 years, (Geist et al., unpubl. ms.) and yet it appears that a new niche for coastal fish predation has been occupied by an adaptable colubrid snake.

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**Conserved Ontogeny of Color Pattern Leads to the Misdiagnosis of Scincid Lizards of the *Plestiodon skiltonianus* Species Complex**

Skinks of the *Plestiodon skiltonianus* species complex, which includes the Western Skink (*P. skiltonianus*), the San Lucan Skink (*P. lagunensis*), and Gilbert’s Skink (*P. gilberti*), can be very difficult to distinguish unless geographic information accompanies the specimen. This is due to similarity in the ontogeny of color pattern among the different recognized taxa, regional polymorphism in scale and color pattern characters, and a lack of fixed character differences that reliably distinguish each species across the range of the complex (Rodgers and Fitch 1947; Taylor 1935). Some authors have suggested that *P. skiltonianus* and *P. gilberti* be treated as conspecific (e.g., Camp 1916; Cope 1900; Grinnell and Camp 1917; Van Denburgh 1896), and certain statements in the literature (e.g., “…young *P. g. gilberti* specimens are marked just like the young and most adults of skiltonianus” [Smith 1946, p. 385]) have only added to the confusion. Phylogenetic analyses have also done little to resolve these taxonomic issues, as separate *P. gilberti* lineages have evolved multiple times within a paraphyletic *P. skiltonianus* (Brandley et al. 2012; Richmond and Reeder 2002), and species delimitation varies widely depending on the concept of species (Richmond and Jockusch 2007; Richmond et al. 2011). For the remainder of the paper, we place the name “gilberti” in quotation marks to reflect the non-monophyly of these lineages except where *P. gilberti* is specifically referred to in earlier studies.

The main characters used to distinguish members of the *P. skiltonianus* complex in the field include body size, dorsal color pattern, tail color (pink vs. blue), and to a lesser degree limb length, supralabial count, nuchal scale count, and a few others related to scalation (Grismer 1996; Rodgers 1944; Rodgers and Fitch 1947). Size (SVL) can be effective for differentiating adult individuals in most areas, but is of little use for young specimens. Color pattern is useful to a degree, but dorsal stripes are retained longer into adulthood in certain “gilberti” populations than in others, especially in females, and in some areas the stripes are often never completely lost. Abruptly large *P. skiltonianus* also have very degraded, or in some cases, no stripes at all (JQR, pers. obs.). Juvenile tail color is useful in regions where pink-tailed “gilberti” approach or are syntopic with *P. skiltonianus*; however, “gilberti” populations in the northern and central Sierra Nevada, as well as in scattered populations in the east Mojave Desert and the Panamint Mountains, are blue-tailed. Allopatry and different juvenile tail colors distinguish juvenile *P. lagunensis* in southern Baja California from *P. skiltonianus* in northern Baja California, but the adult phenotypes of the two species are similar enough that some authors have regarded them as conspecific (Lindsdale 1932; Schmidt 1922; Stejneger and Barbour 1933; Tanner 1908).

One of the most widely used characters for distinguishing juveniles of *P. skiltonianus* and “gilberti,” aside from tail color when the differences are obvious, is the distance that the dark lateral stripes extend onto the tail (Fig. 1). In various field guides and species descriptions, it is commonly stated that this stripe extends much further in *P. skiltonianus* (ca. 1/3 to 1/2 way down the tail) than it does in “gilberti”; in the latter, this stripe purportedly ends at the base of the tail just posterior to the hind limbs (Behler and King 1979; Jones and Lovich 2009; Lemm 2006;
Macey and Papenfuss 1991; Rodgers and Fitch 1947; Smith 1946; Smith and Brodie 1982; Stebbins 2003; Stebbins and McGinnis 2012; Storer et al. 2004; Tanner 1957, 1988). However, like the other characters used to differentiate *P. skiltonianus* and “gilberti,” we have detected notable variation in the extension of the lateral tail stripe in populations of both species, and below we present data that describe how the character fails to differentiate the two in certain parts of the range.

During recent survey work on *Plestiodon* populations in the western foothills of the northern Sierra Nevada in Yuba County, California, we discovered what appeared to be juvenile *P. skiltonianus* just south of the Yuba River in an area that is reported to be exclusive to “gilberti,” based on the bright blue tail color and the continuation of the dark lateral stripe well past the hindlimbs (Rodgers and Fitch 1947). A longstanding notion exists that *P. skiltonianus* is essentially restricted to the north side of the river, which runs perpendicular to the Sierra Nevada, and that the range of “gilberti” extends north to the Yuba River from the south but does not cross it (Rodgers 1944; Rodgers and Fitch 1947; Stebbins 2003; Fig. 2). Only four isolated *P. skiltonianus* populations have been formally documented from the immediate south side of the Yuba River (Rodgers and Fitch 1947; specimens MVZ 190472,190479; this study), occurring mainly in the conifer zone at approximately 900–1450 m, whereas “gilberti” occurs at lower elevation in blue oak woodland and grassland only on the south side of the river. This purported distribution is perplexing, as there are no salient habitat differences on either side of Yuba River, and none of the other major river drainages south of Yuba County have presented barriers that limit the distribution of “gilberti” along the western slope of the Sierra Nevada (although they may have intermittently in the past). Thus, we were not surprised to find *P. skiltonianus* south of the Yuba River. Because both species were expected to have blue-tailed juveniles and scale counts were ambiguous, our identification of juvenile specimens relied mainly on the degree to which the dark, lateral stripe extended onto the tail.

To confirm our identifications, we extracted DNA from small tail clips (~ 10.0 mm) preserved in 95% ethanol from 28 individuals and sequenced 16 for their ND4 mitochondrial haplotypes (~1500 bp: Dryad repository: doi:10.5061/dryad.2873b). We then compared these sequences to a large ND4 dataset representing the entire range of the *P. skiltonianus* complex (Fig. 3). *Plestiodon skiltonianus* and “gilberti” in Yuba County (the latter regarded as *P. g. placerensis*; de Queiroz and Reeder 2012) have high mitochondrial sequence divergence and are easily distinguishable based on their haplotypes (Richmond and Jockusch 2007; Richmond and Reeder 2002). Surprisingly, we found that all skinks sampled on the south side of the Yuba River below 1430 m had
Sierran "gilberti" haplotypes, and all those sampled on the north side of the river regardless of elevation had pure P. skiltonianus haplotypes, consistent with the supposition of Rodgers (1944) and Rodgers and Fitch (1947). We also noted that while adult male "gilberti" in this area completely lose the striped color pattern, as is generally the case for "gilberti," adult females retain dark lateral stripes on the flanks and well onto the tail, immediately below the area where the light dorsolateral stripe runs along the body axis in juveniles (Fig. 4; also noted in Rodgers 1944). This same pattern has been noted in other parts of the species' distribution (e.g., creeks along the eastern slopes of California's inner Coast Ranges; JQR, pers. obs.), where lateral stripes extend well beyond the hindlimbs even in some of the largest adult females. Thus, a character that is typically lost early in ontogeny in some parts of the "gilberti" range, or is absent altogether, is retained in adult females in other areas, particularly the northern Sierra Nevada.

In his description of P. g. placerensis, Rodgers (1944) did not address the lateral tail stripe character, and later accounts identifying this and other P. gilberti subspecies provide little else (e.g., Jones and Lovich 2009; Stebbins 2003). Rodgers and Fitch (1947) provided qualitative descriptions of the ontogeny of P. skiltonianus and the different forms of "gilberti," illustrating varying degrees in the loss of the dorsolateral stripes and the bright tail color. However, variation in the extension of the dark, lateral tail stripe for "gilberti" was not discussed. Consistent with the descriptions of Rodgers and Fitch (1947), we have found that hatchling, juvenile, and younger adult female "gilberti" (Fig. 4c)
in Yuba County appear to be *P. skiltonianus* upon initial inspection; in both forms, the tail color is bright blue and the lateral tail stripe extends well beyond the hind limbs (although the stripe may continue further on the tail in *P. skiltonianus* north of the Yuba River than it does in "gilberti" south of the Yuba River (Fig. 5a, b)). The similarity in this character between species fades further south in the Sierra Nevada foothills (Fig. 5c), where the dark lateral stripe ends closer to the base of the tail in young "gilberti.

Because of the variability of this character across the range of the species complex, we consider it unreliable for distinguishing *P. skiltonianus* and "gilberti" over large portions of the range of the *P. skiltonianus* complex. Despite years of field collecting and DNA sequence data from hundreds of individuals (including sequences obtained from museum specimens that were incorrectly identified as *P. skiltonianus*), we have yet to recover a *P. skiltonianus* specimen from locations south of the Yuba River, with the exception of a single site at approximately 1430 m and 14 km SSE of the Yuba River, until Tulare County in the southern Sierra Nevada. We suspect that a number of museum specimens collected from this same region at lower elevation are incorrectly identified as *P. skiltonianus* and instead belong to the Sierran "gilberti" lineage as identified in Richmond and Reeder (2002). In fact, bright blue juvenile tail color and the continuation of the dark, lateral stripe past the hindlimbs are the two characters that appear largely responsible for these misidentifications.

Perhaps the most interesting finding of our survey work is that *P. skiltonianus* and "gilberti" are most similar in the ontogeny of color pattern where their distributions meet but do not overlap at the Yuba River. Yet in southern California where the two species are sympatric, for example, they are easily distinguished by juvenile and adult color pattern (*P. skiltonianus* juveniles have blue tails and light dorsal stripes throughout adulthood whereas juvenile "gilberti" have pink tails and no stripes as adults), and adult body size. In fact, adult body size is more divergent in southern California than anywhere else in the range of the species complex, and is a predominant factor contributing to their reproductive isolation (Richmond and Jockusch 2007; Richmond et al. 2011). This suggests that sympathy in southern California may have influenced phenotypic divergence of the two forms, whereas allopatry in the northern Sierra Nevada may have contributed to retention of the ancestral juvenile color pattern.

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A Non-Invasive Method of Measuring Heart Rates in Small Reptiles and Amphibians

Measuring the heart rate of animals is crucial to the work of many biologists, including applications in veterinary, physiological, through to ecological studies. Determining heart rate is valuable because it is an indirect indicator of metabolic rate (Bennett 1972; Bradford 1983; Butler et al. 2004; Greenvald 1971). As such, heart rate measurements can be a substitute for metabolic chamber and doubly-labelled water studies. Aside from the traditional methods of measuring heart rates such as electrocardiography and seismocardiography, recent technical advances have democratized the use of a variety of external or internally implanted data loggers (Altimiras et al. 2000; Woakes et al. 1995). The choice of method depends on the application (long-term field study versus lab work), and the size (technical difficulties arise in animals < 40 g) and type of animals used (i.e., importance of stress as a confounding factor). We suggest a simple and inexpensive method of measuring heart rate in small vertebrates (< 40 g) applicable to both field and laboratory studies.

Methods.—The Buddy® digital egg monitor (MK2, Avitronics) was developed for measuring heart rates of avian and nonavian reptile embryos for the poultry industry and research applications (Du et al. 2009; Lierz et al. 2006). The Buddy® system works by shining an infrared beam onto the surface of the egg, detecting minute distortions caused by embryonic heart beats (Du et al. 2009). Muscle impulses other than cardiac ones, as well as external vibrations, generate stronger signals than the study animal’s heart beats, which preclude the monitor from measuring concurrent heart beats (Lierz et al. 2006).

Du and colleagues (2010) expanded the use of the monitor when they recorded heart rates in hatchlings of two emydid turtle species, Chrysemys picta, and Graptemys pseudogeographica kohnii. To do so, young turtles were placed into egg-shaped plastic balls and then onto the Buddy® monitor sensor pad. While this method worked effectively with turtle hatchlings that are roughly round in shape and fit into an egg-shaped plastic ball, we wished to extend this method to other small vertebrates, including elongated animals such as snakes, lizards, and newts.

The major problem faced when trying to record heart rates in small animals (rather than eggs) is immobilizing the animal on the Buddy® system sensor pad to avoid interference with the machine readings. To solve this problem, we made small cotton material bags of various sizes and shapes in order to accommodate...
Fig. 2. Heart rates were recorded in eight Viperine Water Snakes (Natrix maura) at three body temperatures (14, 18, and 25°C) and 10 Wall Lizards (Podarcis muralis) at two body temperatures (18 and 25°C). In both snakes and lizards, heart rates significantly increased with body temperature (see text for details). Means ± standard errors are plotted.

Fig. 3. Heart rate values recorded in three Edible Frogs (Rana esculenta), one Agile Frog (Rana dalmatina), and four Pyrenean Brook Salamanders (Calotriton asper) are shown. Data are plotted against body temperature.

the different individual snakes, lizards, newts and frogs we wished to test (Fig. 1). We first validated heart rate measurement obtained with the Buddy® egg monitor in young snakes against a proven method (echocardiography). We then recorded heart rates as a function of body temperature in snakes, lizards, newts, and frogs of varying sizes. Body temperatures were recorded with the temperature probe Trotec® BP20.

Because repeated measurements were made on the same individuals, we analysed heart rate measurements using Wilcoxon Matched Pairs Test when comparing two dependent samples, and Friedman ANOVA when comparing multiple dependent samples.

Validation of the method.—We measured heart rates in 12 captive Natrix maura (Viperine Water Snakes; born to six different clutches in September 2011; ranging from 4.6 g to 15.1 g in body mass and from 19.9 cm to 27.2 cm in snout–vent length [SVL]) using the Buddy® egg monitor and by echocardiography as a control proven method. Measurements were performed in a controlled temperature room (CTR) maintained at a constant 22°C within a Veterinary Hospital (Dr. Breuil and Feix; Toulouse, France). Light was dimmed inside the CTR to limit potential stress to the snakes. We used a balanced testing order: 6 snakes were first measured using the Buddy® egg monitor, then using an ultrasound device (Esaote® MyLab™30Gold Cardiovascular) and probe (SC3123 Microconvex 10 MHz), and vice versa for the remaining six snakes. Snakes were maintained in plastic boxes Exo-Terra® (30.0 × 19.5 × 20.5 cm) and acclimated to ambient temperature for a minimum of 30 minutes prior to testing. Three heart rate readings were taken with each snake and each technique, from which we calculated average heart rates. Each series of measurements was completed in under 5 minutes, and snakes were allowed to rest 5 minutes between the two measurement series (total experimental time for each snake: 15 minutes).

There was no significant difference in individual average heart rates between the two techniques: heart rates averaged 104.78 ± 7.16 BPM according to the ultrasound method and 103.17 ± 10.91 BPM using the Buddy® egg monitor (Wilcoxon Matched Pairs Test; N = 12; T = 34.00; Z = 0.39; P = 0.70).

Heart rates as a function of body temperature.—We measured heart rate in eight captive born Natrix maura originating from 5 different clutches (three juveniles captive born in August 2011 and five neonates captive born in August 2012). Snakes ranged from 2.1 g to 21.2 g in body mass, and from 12.6 cm to 35 cm in SVL. Each individual was tested at three different body temperatures (14, 18, and 25°C) on three consecutive days applying a balanced order design. Snakes were placed inside their individual testing bags, and into temperature controlled chambers for 30 minutes in order to reach testing temperature and ensure minimum stress levels at the time of testing. As expected, heart rates significantly increased with body temperature (Friedman ANOVA; \( \chi^2_g = 16.00; P = 0.0004; \) Fig. 2).

We measured heart rate in 10 field-caught Wall Lizards (Podarcis muralis) using the same protocol (see Fig. 1). Lizards ranged from 3.2 g to 7.5 g and from 52.1 mm to 65.6 mm in SVL. Heart rates measured at 25°C were significantly greater than heart rates measured at 18°C (Wilcoxon Matched Pair Test; N = 10; T = 0.01; Z = 2.80; P = 0.0005; Fig. 2). In addition to lizards and snakes, we also used the Buddy® system to measure heart rates in frogs and salamanders. We measured heart rates in three Edible Frogs (Rana esculenta) that ranged from 22.7 g to 64.7 g body mass and 61.0 mm to 81.9 mm body length, one Agile Frog (Rana dalmatina) (body mass = 35.0 g; SVL = 75.0 mm), and four specimens of the Pyrenean Brook Salamander (Calotriton asper) that ranged from 7.5 g to 11.0 g in body mass and from 64.0 mm to 82.0 mm in SVL (Fig. 3).

Applications.—The possible applications of the Buddy® system to record heart rates in small animals are broad, although some fine tuning may be necessary depending on the model system and the conditions of use. For instance, heart rate detection was straightforward in snakes and frogs (heart rates usually stabilized in under 30 sec), but required more repositioning of the bag when measuring a lizard or a newt (perhaps due to their more rigid elongated shape and impossibility to coil into a ball shape). However, differently shaped sensor pads might be developed and work better on differently shaped animals. Notably, it might be possible to fine tune this method to recording heart rates in small mammals (mice, bats etc.) as well as small birds.
In conclusion, the main advantages of using the Buddy® system are that the unit is affordable, accurate, transportable, and can be battery operated; and therefore may be used in remote field locations. Using the system in the laboratory provides researchers with a quick and easy tool to record heart rates (and incidentally metabolic rates) in small animals without relying on high maintenance or expensive (and sometimes fragile) machinery or data loggers.

Acknowledgments.—Funding was provided by the Centre National de la Recherche Scientifique (CNRS), the University Paul Sabatier Toulouse (project entitled EXUVIE), and the Agence Nationale pour la Recherche (ANR project INDHET). Capture permit was issued by the Direction Régionale de l’Environnement, de l’Aménagement et du Logement (DREAL, permit # 2012-10). We complied with all applicable institutional animal care guidelines. We wish to thank Olivier Guillaume for his help with accessing the colony of Calotriton asper, and Dr. Lugardon for ultrasound measurements. This work is part of the “Laboratoire d’Excellence” (LABEX) entitled TULIP (ANR-10-LABX-41).

Literature Cited


Evaluation of Traps to Capture Eastern Hellbenders (Cryptobranchus alleganiensis alleganiensis) in Deep Water Habitat

Cryptobranchus alleganiensis (Hellbenders) are large, aquatic salamanders that prefer streams and rivers with moderate to swift-flowing water with large rocks. Cryptobranchus alleganiensis individuals are mostly nocturnal, remaining under large rocks and in bedrock crevices during the day and emerging at night to forage primarily on crayfish with fish, insects, worms, snails, frogs, etc., accounting for secondary dietary items (Petranka 1998). Two subspecies are currently recognized, both restricted to the eastern United States: C. a. alleganiensis (Eastern Hellbender) and C. a. bishopi (Ozark Hellbender; Crother et al. 2012), and both subspecies have experienced population declines throughout much of their range, especially in Missouri (Briggler et al. 2007; USFWS 2011; Wheeler et al. 2003). Cryptobranchus alleganiensis population declines in Missouri are mainly linked to habitat degradation and alteration, water quality, commercial exploitation, predation, and disease (Briggler et al. 2010; Briggler et al. 2007; USFWS 2011). A wide array of capture methods have been used to sample C. a. alleganiensis (Foster et al. 2008; Nickerson and Krysko 2003; Williams et al. 1981). A thorough review and critique of the various methods can be found in Nickerson and Krysko (2003) and Browne et al. (2011). Snorkel diving coupled with turning rocks has been and continues to be the most effective method for capturing C. alleganiensis (Browne et al. 2011; Foster et al. 2008; Nickerson and Krysko 2003). This technique works well for shallow to moderately deep (<2 m), clear water streams; but sampling turbid (Secchi depth < 1 m), deeper water habitat is difficult, if not impossible, with this method.

Anglers have reported catching C. alleganiensis on hook and line (Beck 1965; Dundee and Dundee 1965; Ferguson 1961; Gates et al. 1985; Wortham 1970) or hoopnets (Trauth et al. 1992) in several states, including Missouri. Several photographic reports from anglers capturing C. a. alleganiensis on trotlines during the winter in Missouri, especially the Gasconade River, have been received over the years (J. Briggler, pers. comm.). Based on these reports of C. alleganiensis being attracted to baited hooks, it seems plausible that baited traps could be an effective method of capturing C. alleganiensis in select Missouri rivers.
There have been several investigations that attempted to capture *C. a. alleganiensis* using baited traps with varying success (Foster et al. 2008; Kern 1984; Soule and Lindberg 1994). Soule and Lindberg (1994) baited wire-mesh traps with chicken livers with no success in New York. Kern (1984) used hoop-nets baited with cut sucker fish and captured 29 *C. a. alleganiensis* in Indiana. Foster et al. (2008) captured 22 individuals in New York drainages over 627 trap nights using plastic-coated hardware cloth traps baited with *Catostomus commersonii* (White Sucker). We are unaware of any previous attempts to sample deep, turbid habitat. Based on angler reports, some reported trapping success, and limited knowledge of sampling deeper water habitat, we decided to experiment with trapping design and trapping implementation to sample deep, turbid water habitat that was not conducive for other sampling techniques. The distribution and relative abundance of *C. a. alleganiensis* in these deep-water habitats is relatively unknown and likely to be important to the long-term recovery of the species. The objectives of this study were to 1) determine the distribution and relative abundance of *C. a. alleganiensis* on the lower sections of the Gasconade River, 2) examine the efficacy of baited traps to sample *C. a. alleganiensis* in deep, turbid water conditions, and 3) determine if trapping site characteristics influenced *C. a. alleganiensis* presence.

**Materials and methods.**—This study was conducted on the lower Gasconade River (7th order) in Gasconade, Maries, Osage, Phelps, and Pulaski counties, in Missouri. Water depths on the lower Gasconade River range from shallow riffles (< 0.5 m) to deep pools (> 8 m). Turbidity in the Gasconade River can be extremely high (Secchi depth < 0.5 m), especially during the summer as a result of algae blooms and sediment in the water. Water clarity does improve during the winter months but snorkeling and diving in cold, deep, flowing water is not recommended. With the aid of topographic maps and prior knowledge of *C. a. alleganiensis* habitat, sampling sites (N = 63) were identified along bluff banks over approximately 192 river km of the lower section of the Gasconade River. The substrates along these bluff banks are typically covered with large rocks suitable for *C. a. alleganiensis* occupancy.

Considerable trapping effort was conducted from February 2006 through August 2007 to evaluate bait types (*Dorosoma cepedianum*, *Hypophthalmichthys* sp., *Orconectes punctimanus*, crayfish magic bait, and chicken liver), distance between trap sets at a particular location, trap type (e.g., wire-mesh trap vs. mesh-net traps), trap design (two throats vs. one throat, collapsible vs. non-collapsible), trap set duration (24 vs. 48 h), and season of trapping (cooler vs. warmer weather months). Based on our experiences in 2006 and 2007, we decided to use custom-made collapsible wire-mesh traps and a few collapsible net-mesh traps. Collapsible traps allowed us to make efficient use of limited space in the boat and set a larger number of traps in a single day. We further decided on a 48-h trap set during the cooler months (November through early May) and to bait the traps with *D. cepedianum* (Gizzard Shad).

**Trap design.**—We used a wire-mesh and net-mesh trap design for this study. The wire-mesh trap was originally designed by
the anchor rope was then tossed upstream. As the boat floated an anchor. The boat was then backed away from shore, and was passed through the loop in the bank rope and secured to the rope had a small loop (approximately 7.5–10 cm diameter) in water conditions and often cold temperatures of the Gasconade River. Traps were secured by two means. First, a rope was set. Traps were set from a boat due to the deep water velocity. The number of traps set per site varied on site cover rocks (e.g., boulder, cobble, and slab rocks) with sufficient ability for during the course of this study.

Results.—Sixty-three river bluffs were trapped from November 2007 through May 2009 with C. a. alleganiensis captured at 31 (49.2%) of these sites. All C. a. alleganiensis captured were adults (N = 51) with an average (range) TL of 45.8 (40.0–51.0) cm, SVL of 30.4 (26.0–36.5) cm, and mass of 573 (360–981) g. Monthly trapping during the first sampling period from November 2007 through May 2008 showed the highest captures for C. a. alleganiensis in April and November, while the highest captures in the second sampling period was March 2009 (Table 1). We captured a C. a. alleganiensis in each month, except for February, when we were unable to sample due to high river levels. During the pilot testing, however, we did capture a C. a. alleganiensis in February 2006.

Capture efficiency for C. a. alleganiensis was highly variable among sites, ranging from 0.02–0.14 captures/trap and 0.01–0.07 captures/trap night with March and April accounting for the highest capture rates (Table 1). Average capture efficiency for C. a. alleganiensis combining wire-mesh trap and net-mesh trap for both sampling periods was 0.073 captures/trap (1 individual/13.7 traps) and 0.036 captures/trap night (Table 1). Wire-mesh traps (0.079 captures/trap night) were almost twice as efficient at capturing C. a. alleganiensis as net-mesh traps (0.042 captures/trap night). On average, wire-mesh traps captured 1 C. a. alleganiensis per 12.6 traps compared to 1 C. a. alleganiensis per 23.6 traps for net-mesh traps. On four separate occasions, 2 C. a. alleganiensis were captured in one trap (Fig. 2) and in one trap a C. a. alleganiensis and N. maculosus were captured together.

TECHNIQUES

Traps were only set along bluff bank sites that appeared suitable for C. a. alleganiensis occupancy; the sites contained large cover rocks (e.g., boulder, cobble, and slab rocks) with sufficient water velocity. The number of traps set per site varied on site length (i.e., longer sites had more traps) and ranged from five to 23 traps, and we randomly selected whether a wire-mesh or net-mesh trap was set. Traps were set from a boat due to the deep water conditions and often cold temperatures of the Gasconade River. Traps were secured by two means. First, a rope was secured to a tree or rock on the river bank (bank rope). The bank rope had a small loop (approximately 7.5–10 cm diameter) in the unsecured end. Next, the rope tied to the trap (anchor rope) was passed through the loop in the bank rope and secured to an anchor. The boat was then backed away from shore, and the anchor rope was then tossed upstream. As the boat floated downstream and slack in the anchor rope tightened, the trap was gently dropped in the water. Traps were scattered along the site length. A conscious effort was made to place each trap on a flat area of the river bottom adjacent to a large rock when water and weather conditions allowed. Traps were baited with a medium-size (approximately 14 cm), whole or cut shad (D. cepedianum) that was secured in a cloth mesh bag in the center of the trap. Secchi depth (m), water temperature (°C), and water velocity (m/sec) were measured at a representative spot at each unique sampling site, and photographs were taken of each location sampled. In addition, Global Positioning System (GPS) coordinates and water depth were recorded at each individual trap set location. Distance between traps (m) at a unique site was calculated from UTM coordinates. Length of site was distance between the most upstream and downstream trap. Trap setting was completed within eight hours each day, and traps were checked approximately 48 h later.

Each C. a. alleganiensis captured was measured for total length (TL), snout-to-vent length (SVL), and mass (g). Each C. a. alleganiensis captured was tagged in the dorsolateral musculature of the tail with a passive integrated transponder (PIT) tag. Photographs were taken of each C. a. alleganiensis captured. Each animal was released at the specific trap of capture after processing.

Capture efficiency was calculated as the number of C. a. alleganiensis captures per unit of effort (captures/trap and captures/trap night). Student’s t-tests were used 1 to assess if trap parameters (depth of trap set, distance between traps) differed between individual traps with or without C. a. alleganiensis, and 2 to assess if site parameters (length of sampling site, water temperature, water flow, and Secchi depth) differed between sites with or without hellbenders. All sites and trap sets were independent because each unique site was only sampled once for the duration of this study. All statistical analyses were performed using JMP statistical software (SAS Institute, 2000).

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Mean, SD, and range of the site and trap-set parameters can be found in Table 2. Student’s *t*-tests results found no significant patterns for distance between traps, length of sampling site, water temperature, water flow, and Secchi depth for the presence or absence of *C. a. alleganiensis* (Table 2). Although average water temperature at sites with and without *C. a. alleganiensis* was similar, 53% of captures occurred within a range of 10–13°C (Fig. 3). Traps with *C. a. alleganiensis* present were on average significantly deeper (*t* = -2.33, *P* = 0.02; Table 2).

**Discussion.**—Considerable information was gained regarding the distribution and relative abundance of *C. a. alleganiensis* in the Gasconade River, Missouri, through trapping in deep-water habitat along river bluffs that were not conducive to traditional snorkel diving methods. *Cryptobranchus a. alleganiensis*, a declining Missouri state endangered species (Briggler et al. 2007; NatureServe 2011), were detected at 31 undocumented sites with 51 individuals captured (Table 1). Wheeler et al. (2003) only captured 33 *C. a. alleganiensis* on the upper sections of the Gasconade River via snorkel diving. The deep water, river bluff sites we sampled may contribute significantly to the long-term persistence of this species in the Gasconade River. However, Wheeler et al. (2003) and our data show a lack of young age classes. We only captured adult *C. a. alleganiensis* estimated to be between 15 and 30 years of age (Taber et al. 1975). This lack of young age classes is likely due to the absence of these individuals in the population compared to historical sampling (Wheeler et al. 2003). Our trap mesh size was definitely narrow enough to capture small *C. a. alleganiensis*, and our traps did capture the smaller *N. maculosus* (TL range 22.5–31.0 cm). Additionally, trapping by Foster et al. (2008) captured mainly adult *C. a. alleganiensis* (> 40 cm TL), but 20% of captures were smaller animals even with the same mesh size as our study.

There have only been a few published accounts of researchers surveying *C. a. alleganiensis* via use of baited traps with varying success (Foster et al. 2008; Kern 1984; Soule and Lindberg 1994). Foster et al. (2008) was the first to report capture efficiency for *C. a. alleganiensis* by using wire traps. Our capture efficiency (ranging from 0.01–0.07 captures/trap night) was similar to Foster et al. (2008; ranging from 0.01–0.10 captures/trap night) and was highly variable among sites and among months (Table 1). The wire-mesh traps used in this study were of the same design and

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>Hellbender presence ± SE</th>
<th>Hellbender absence ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of Trap Set (m)</td>
<td>698</td>
<td>1.8 ± 0.7</td>
<td>0.4–4.5</td>
<td>2.1 ± 0.09*</td>
<td>1.8 ± 0.03</td>
</tr>
<tr>
<td>Distance between Traps (m)</td>
<td>635</td>
<td>32.1 ± 18.2</td>
<td>1.4–114.0</td>
<td>30.3 ± 2.8</td>
<td>32.1 ± 0.8</td>
</tr>
<tr>
<td>Length of Sampling Sites (m)</td>
<td>63</td>
<td>485 ± 351</td>
<td>60–1,966</td>
<td>524.7 ± 65.4</td>
<td>451.7 ± 60.4</td>
</tr>
<tr>
<td>Water Temperature (°C)</td>
<td>63</td>
<td>10.4 ± 5.2</td>
<td>1.5–21.3</td>
<td>10.1 ± 1.0</td>
<td>10.7 ± 0.9</td>
</tr>
<tr>
<td>Water Flow (m/sec)</td>
<td>63</td>
<td>0.32 ± 0.22</td>
<td>0.01–0.93</td>
<td>0.27 ± 0.04</td>
<td>0.36 ± 0.04</td>
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<td>Secchi Depth (m)</td>
<td>63</td>
<td>1.8 ± 0.8</td>
<td>0.5–3.4</td>
<td>2.1 ± 0.2</td>
<td>1.7 ± 0.1</td>
</tr>
</tbody>
</table>

*Indicates significant difference.

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Table 2. Capture efficiency, measured as number of captures/trap and number of captures/trap night, for *Cryptobranchus a. alleganiensis* (Eastern Hellbender) from November 2007 through May 2009 in the Gasconade River, Missouri. First sampling period was designed for monthly trapping. Second sampling period focused only on the months listed.

<table>
<thead>
<tr>
<th>Date</th>
<th>No. traps set</th>
<th>No. trap nights</th>
<th>No. sites trapped</th>
<th>No. sites with Hellbenders</th>
<th>No. individuals</th>
<th>Captures/trap</th>
<th>Captures/trap night</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Sampling Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nov 2007</td>
<td>50</td>
<td>100</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>Dec 2007</td>
<td>50</td>
<td>100</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Jan 2008</td>
<td>50</td>
<td>100</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Feb 2008*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>Mar 2008</td>
<td>50</td>
<td>100</td>
<td>7</td>
<td>1</td>
<td>2</td>
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<td>0.02</td>
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<td>4</td>
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<td>5</td>
<td>0.10</td>
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<tr>
<td>May 2008</td>
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<td>1</td>
<td>0.02</td>
<td>0.01</td>
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<td>Second Sampling Period</td>
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<td></td>
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<td>Nov 2008</td>
<td>48</td>
<td>96</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>0.08</td>
<td>0.04</td>
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<tr>
<td>Dec 2008</td>
<td>100</td>
<td>200</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>0.05</td>
<td>0.03</td>
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<tr>
<td>Mar 2009</td>
<td>125</td>
<td>250</td>
<td>14</td>
<td>8</td>
<td>17</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>Apr 2009</td>
<td>100</td>
<td>200</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>May 2009</td>
<td>25</td>
<td>50</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>Total</td>
<td>698</td>
<td>1396</td>
<td>63</td>
<td>31</td>
<td>51</td>
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</table>

* Unable to trap in February 2008 due to high river levels.
size as Foster et al. (2008), but we modified the trap by making it collapsible and adding an entrance funnel at each end of the trap. The collapsible wire-mesh traps (1 capture/12.6 traps) were almost twice as efficient at capturing *C. a. alleganiensis* compared to collapsible net-mesh traps (1 capture/23.6 traps). It is unknown why *C. a. alleganiensis* would more likely be captured in the wire-mesh traps. It might be that the individuals can more easily escape the net-mesh trap, that the animals like the increased firm footing of the wire-mesh trap when entering the trap, or that the wire-mesh traps are more stable on the river bottom due to its heavier weight (wire-mesh traps = 2.08 kg compared to 0.91 kg for net-mesh traps). Even though the net-mesh trap can be purchased and modified accordingly with reduced labor cost, the significant increase in capture efficiency for the wire-mesh trap is definitely worth the effort to construct. Plus, the wire-mesh traps are more durable compared to the net-mesh traps; several of the net-mesh traps were damaged or destroyed by river debris.

Based upon reports of local anglers capturing *C. a. alleganiensis* in the winter on hook-and-line in the Gasconade River (JTB, pers. obs.) and our pilot data, we concluded that trapping during the cooler months was likely optimal for success. Trapping success was highest post-breeding of the species in November/December and again in March/April (Table 1). We were unsuccessful in capturing *C. a. alleganiensis* in the warmer months during our pilot testing on the Gasconade River unlike Foster et al.’s (2008) success in New York streams. In addition, we experimented with later spring and early summer trapping at sites known to support higher densities of *C. alleganiensis* on the Big Piney River and North Fork of the White River with no success. In Indiana, Kern (1984) showed seasonal variation in feeding activity with most *C. a. alleganiensis* containing food items in their stomach from January through April and very low percentage during summer and breeding season. This pattern is similar to what Peterson et al. (1989) observed in Missouri, and our ability to capture animals during the colder weather months. Also, high water conditions from January to May made sampling somewhat difficult and also might have influenced capture rates. November to mid-December might be the optimal time to sample due to more stable water levels and increase foraging due to post-breeding. An additional consideration, however, is that November is also a time when male *C. alleganiensis* are guarding nests. There is no doubt that *C. a. alleganiensis* are attracted to baited traps based upon our success and the success of Foster et al. (2008), as well as the keen olfactory senses that *C. a. alleganiensis* are believed to possess (Gall and Mathis 2010; Nickerson and Mays 1973), but the majority of the diet reported for *C. a. alleganiensis* is primarily crayfish with occasional fish (Kern 1984; Nickerson and Mays 1973; Peterson et al. 1989). During our pilot data collection, we experimented with crayfish baits with no success. The lower Gasconade River appears to have lower numbers of crayfish compared to most other rivers inhabited by *C. a. alleganiensis* in Missouri (JTB, pers. obs.), and therefore, consumption of fish would be strongly related to availability compared to other prey items. *Cryptobranchus a. alleganiensis* captured during this study regurgitated native fish species on several occasions. Although *C. a. alleganiensis* have low metabolism and do not require frequent feeding (Nickerson and Krysko 2003; Nickerson and Mays 1973), limited preferred food resources in these deeper water habitats may contribute to trapping success because these animals are more likely forced to seek prey rather than to wait for prey to approach them.

Monthly captures may be influenced by food availability and/or reproductive season as discussed above, but water temperature likely plays an important role. The majority of the *C. a. alleganiensis* captures occurred at water temperatures < 14°C (Fig. 3). No *C. a. alleganiensis* were captured below 3°C or above 20°C. We believe that temperature likely affects trapping rates due to concerns such as decreased animal movements during extreme cold water temperatures and increase bait decay during warm water temperatures. Further investigations are needed to determine the role of water temperature, but we would recommend that trapping should not occur at water temperatures below 3°C or above 18°C and ideally between 8–16°C.

*Cryptobranchus a. alleganiensis* were significantly more likely to be captured in deeper trap sets in this study. Foster et al. (2008) showed that trapping appeared to be most successful at depths between 0.75 and 1.0 m; however, their study site was not as deep as the Gasconade River. Our data show *C. a. alleganiensis* were unlikely to be captured along shallow banks and in the deepest trap sets (> 4 m). These results are more likely an artifact of the preferred habitat of cover rock with the optimal river conditions (i.e., flow, water temperature, etc.) along these bluff banks than the actual depth of the water.

Compared to other sampling methods, trapping causes minimal habitat disturbance especially compared to turning rocks during snorkeling surveys (Browne et al. 2011; Foster et al. 2008). In addition, trapping is likely the most successful technique to use in deep water conditions, especially those affected by turbidity. Advantages to sampling in the colder months are that traps are less likely to be disturbed by river users (i.e., fewer individuals on river) and the by-catch mortality (e.g., turtles and fish) are almost nonexistent in colder water (Barko et al. 2004; Fratto et al. 2008). Trapping may not work for all river conditions throughout the range of the species since trapping success is likely influenced by stream characteristics (e.g., water depth, water temperature, etc.) food availability, *C. a. alleganiensis* density, and time of year (e.g., breeding). However, based upon our successes, trapping should be considered in larger, deeper, turbid rivers to locate additional populations of this declining species rangewide.

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Evaluating a Method for Non-destructively Obtaining Small Volumes of Blood from Gilled Amphibians

In many herpetological research projects, researchers incorporate measures of immunity, stress or other aspects of physiology that necessitate obtaining blood samples from their amphibian subjects. There are a number of proven techniques for sampling blood from amphibians (Baranowski-Smith and Smith 1983; Gentz 2007; Tapley et al. 2011; Thrall 2004), although some may only be useful with large species. For the smaller species (which have limited blood volume), the animals sometimes must be sacrificed. There are certain physiological measures though, that only require minor amounts of blood (less than 10 µl), such as investigations involving blood smear analysis, or molecular assays. For such projects, it would be beneficial to have a method for non-destructively obtaining blood so that the animals could be returned to their natal environment following the study, or so that more than one sample could be obtained from individual amphibians.

If larval or paedogenic salamanders are the subjects under study, it might be possible to obtain blood samples from their external gills, where blood flows continuously as part of normal respiration. In fact, such methods are already established for small fish (Watson et al. 1989); by making a minor incision in the gill filaments on one side of the animal, small amounts of blood can be siphoned with a microcapillary tube. The goal of the current project was to modify this same procedure for use with gilled amphibians, and evaluate its effectiveness for herpetological research. Here we report the results of an experiment where a collection of gilled salamanders (a paedogenic species) were sampled in the above manner, with and without anesthesia, to determine if the procedure affects survival in the days following the sampling.

Salamander collection and housing.—On 3 March 2011, we captured 34 aquatic, paedogenic Mole Salamanders (Ambystoma talpoideum) from an impounded pond near the University of Georgia campus (Athens, Georgia, USA). This species is routinely used for studies in our lab (Davis and Maerz 2008a, 2010) and they are common to a range of habitats including streams and ponds. The salamanders were captured using dipnets from the Ozark plateaus of Missouri and Arkansas. Copeia 1965:369–370.


The herpetofauna of Tishomingo County, Mississippi, with comments on its zoogeographic affinities. Copeia 1961:391–396.


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in northeast Georgia, especially in permanent water bodies. All salamanders were transported to the laboratory in a cooler of pond water, where they were placed individually into 1.9-L plastic containers filled with dechlorinated tap water and with one to two leaves (also collected from the source pond) for refugia. All containers were placed in an environment chamber that was set to a 12 h day length and at a constant temperature of 15°C. Salamanders were left in the chamber for 24 h before undergoing the blood sampling procedure (below).

Blood sampling.—Salamanders were randomly divided into three groups. Salamanders in Group 1 (N = 13) were first anesthetized via immersion in a solution of Orajel (20% benzocaine) following Cecala et al. (2007). Once immobile, each was blotted dry and weighed with an electronic balance, then lightly wrapped in a paper towel (to aid in handling), leaving the head and gills exposed. Then, using a sterilized pair of scissors, the distal end of one gill frond (Fig. 1) was cut off, and a heparinized microcapillary tube used to siphon the blood that welled from the severed gill. Salamanders in Group 2 (N = 13) underwent the same procedures (weighing, blood sampling), only without anesthesia. For salamanders in groups 1 and 2 we also noted the volume of blood obtained in the microcapillary tubes. The remaining salamanders (N = 8) were weighed and were subjected to the same degree of handling, but were not sampled. These salamanders served as a sham, or control group. All salamanders were returned to their respective containers (and placed in the environment chamber) following the processing and were monitored daily thereafter for four days. After four days, the salamanders were re-weighed, then released into their original pond.

Data analysis.—We first examined whether the volume of blood obtained with this procedure differed between anesthetized and non-anesthetized salamanders, using a Student’s t-test. Next, we examined the degree of weight change for salamanders in each group using paired t-tests. Finally, we had intended to test for differences in survival rates across the three treatment groups, although there was no mortality in any group (below). Tests were performed using Statistica 6.1 software package (Statistica 2003).

Effects of the procedure.—No salamanders died in the experimental or the control groups during the four-day monitoring period. We also did not observe any atypical behavior in the salamanders that had been bled, during the post-procedure monitoring. The severed gills of experimental salamanders appeared to have healed by day 4, but we saw no evidence of regeneration. When we examined the change in weight from the day of bleeding to the last day, we found no significant weight change in either the Group 1 (t = 1.22, df = 12, p = 0.243) or Group 2 salamanders (t = 0.311, df = 12, p = 0.760). Collectively, these results all indicate that this blood-sampling procedure has minimal outward effects on salamanders.

Effectiveness of the procedure.—The average volume of blood obtained in both bleeding groups was 3.2 µl (standard deviation = 3.1 µl). Interestingly, we obtained significantly more blood from anesthetized salamanders than from non-anesthetized individuals (t = -2.14, df = 24, p = 0.043); the average for anesthetized salamanders was 4.4 µl while for non-anesthetized salamanders it was 1.9 µl. Part of this difference may stem from our inability to draw blood from one non-anesthetized salamander that thrashed during the procedure and made it difficult to place and hold the capillary tube on the gills. In fact, all non-anesthetized salamanders wiggled somewhat during the procedure, making it challenging (but not impossible) to siphon the blood. On the other hand, we cannot rule out the alternative possibility that more blood flowed from the anesthetized individuals because of some “relaxation” effect of the anesthesia on the animals’ blood vessels.

It is important to point out that the overall volume of blood yielded by this procedure (~5 µl or 0.005 g) would constitute less than 1% of the body weight of A. talpoideum (the average weight of A. talpoideum in this study was 3.0 g ± 0.6 g SD) and of other similarly-sized salamanders, which is a criterion recommended by Wright and Whitaker (2001). Similar-sized species (with gills) would include paedogenic newts (family Salamandridae), paedogenic Tiger Salamanders (A. tigrinum), and Axolotls (A. mexicanum). Late-stage, gilled larvae of other species could also be used if they weighed more than 0.5 g.

The small amount of blood obtained may also limit the suitability of this technique for research purposes (because much larger volumes are needed for many clinical tests). Nevertheless, this volume would indeed be sufficient to conduct certain hematological investigations where only blood smears are needed (e.g., Davis and Maerz 2009; Davis and Maerz 2011; Davis and Milanovich 2010). With practice, it is possible to make (small) blood smears with this amount of blood (AKD, pers. obs.), which can be used to examine blood cells or search for intra- or extra-cellular parasites (e.g., Davis and Cecala 2010; Dessier 2001; McAllister et al. 1993). Therefore, although the volume of blood obtained is small, this procedure appears to be useful for non-destructively collecting blood from gilled amphibians, and should serve a variety of purposes to researchers and herpetologists.

Acknowledgments.—We thank Sonia Altizer for allowing use of lab space for this project. All procedures in this project were approved by the University of Georgia’s Animal Care and Use Committee (AUP # A2011 02-034-A1).

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The Use of Photo-identification as a Means of Identifying Western Painted Turtles (Chrysemys picta bellii) in Long-Term Demographic Studies

Critical to any successful long-term demographic study is the ability to accurately identify subjects during recapture events. Previous mark-recapture studies involving freshwater turtles have employed a number of various mutilation techniques such as toe clipping, notching of the shells, or the use of PIT tags. However, the use of mutilation techniques may present a potential risk to the turtles as notching or filing of the shell can cause fracture or lead to potential infections, particularly in hatching and juvenile turtles (Cagle 1939). Additionally, there are ethical concerns when marking rare or endangered species. While the use of PIT tags can reduce the risk of injury, PIT tags cannot be employed in any long-term demographic studies on Painted Turtles (Chrysemys picta). This makes it an ideal candidate for the evaluation of photo-identification as an identification technique.

Recent studies have demonstrated that photo-identification could successfully identify hatchling and juvenile turtles during demographic studies. Janzen et al. (2000a; 2000b) used plastron marking to successfully identify hatchling and juvenile turtles. However, photo-identification has been successfully used to identify individuals in populations of Spotted Salamanders (Ambystoma maculatum, Loafrman 1991), Daruma Pond Frogs (Rana porosa brevipoda, Kurashina et al. 2003), Leatherback Turtles (Dermochelys coriacea, McDonald et al. 1996), and Loggerhead Sea Turtles (Caretta caretta, Schofield et al. 2008). The plastron markings of some species of turtles are unique to individuals and as such may provide an accurate means of identifying individuals during demographic studies. Janzen et al. (2000a; 2000b) used plastron marking to successfully identify hatching and juvenile Red-eared Sliders (Trachemys scripta elegans). More recently, Tichy and Kintrova (2010) demonstrated that plastron morphology could be used to accurately identify individuals in populations of European Tortoises (Testudo graeca ibera). To date, the use of photo-identification to identify individuals has not been employed in any long-term demographic studies on Painted Turtles (Chrysemys picta). The Western Painted Turtle (C. p. bellii) possesses expansive and distinct plastron markings that make it an ideal candidate for the evaluation of photo-identification as an individual recognition technique. The goal of the present study was to determine if the use of plastron markings on C. p. bellii could provide a non-invasive method for accurately identifying

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individuals during long-term demographic studies. To address this, we used both experienced field observers and untrained volunteers to identify individuals using initial and recapture photographs maintained in a photographic data base.

We captured and photographed 371 Western Painted Turtles from Chapman Lake in Durango, Colorado, USA, between April 1995 and August 2012. Each individual was assigned a unique ID number that was placed on the plastron with an adhesive label or a non-toxic, non-permanent marker that was later removed after photographing the plastron. Plastrons were photographed using a Canon 35mm SLR with a 52mm macro lens. Each plastron was photographed under natural lighting at a distance of 0.2–0.4 m depending on the size of the plastron in order to fill the entire field of view. Photographs were later scanned into digital format where they were cropped and edited for contrast using Adobe Lightroom (v 2.0). Plastron photographs were taken during every capture event and a catalog of 100 × 150 mm color prints was maintained for each individual.

To ensure accurate identification during recapture events and to verify that the plastron marks remained unchanged over time, it was necessary to use additional means to positively identify individuals during recaptures, such as notches filed in the marginal scutes, damaged or deformed shells, and carapace scute anomalies such as supernumerary scutes. Of the 371 turtles that were photographed from our study area, 15 turtles (seven males and eight females) had distinct physical features that allowed verification of identity in addition to the plastron markings.

We assessed the validity of photo-identification using three experienced field observers and 15 untrained volunteers. Experienced observers were trained on how to use photo-identification and had a minimum of 10 hours in the field using this technique. The untrained observers had no prior experience with painted turtles or the use of photo-identification. For each observer, we randomly selected a subset of 10 turtles from the set of all photographs (15 initial photographs and 65 recapture photographs). Age of turtles within each subset varied from 1–19 years (as estimated from growth annuli and original capture dates) and the time between the initial photograph and the subsequent recapture photograph varied from 3–16 years. Midline plastron length (PL) for turtles ranged from 52–214 mm. Photos that showed shell deformities or notches were not included in any of the subsets. Each observer was asked to identify the 10 turtles in the subset by matching a recapture photograph with the initial photograph from a set of 20 photographs, 10 of which contained turtles not included in the recapture subset. A new subset of photographs was used for each volunteer. Observers were not timed, but most were able to complete the task in less than 10 minutes.

The overall success rate for the three experienced field observers in correctly identifying individuals was 100%. The overall success rate for untrained observers was 95.3%. Nine of the untrained observers correctly identified all 10 turtles from recapture photographs. Of the remaining observers, five correctly identified nine out of 10 and one correctly identified eight of 10. Juveniles proved to be more difficult to identify as the pigmentation patterns are not as fully developed as in older individuals. However, our experience with this technique has indicated that distinct plastron markings of juvenile western painted turtles older than one year of age (one growth season) do not change over time and in fact, become more defined with age (Fig. 1). The overall success rate achieved in these trials suggests that photo-identification can be used reliably for this subspecies of painted turtle.
In one case, we were able to compare plastron markings on an individual that was marked in 1996 and had died sometime between 2001 and 2002 by matching the remains of the plastron with an earlier photograph. While the characteristic orange and yellow pigmentation had faded from the plastron, the distinct background markings remained, making identification possible (Fig. 2). We noted one potential problem when using this technique in late summer when the turtles were shedding their scutes: during this time the markings of the plastron became noticeably hazy and minute details of the plastron markings were sometimes obscured. Ideally, sampling events should be avoided during the shed cycle as the quality of photographs may be adversely affected.

Acknowledgments.—We are indebted to the Whitley family for allowing us to collect on their property. We also wish to thank T. Whitley and K. Cooley for their invaluable help in the field. All turtles were caught and released in accordance with the Colorado Department of Wildlife scientific collecting permits and all research protocols were conducted under the Colorado State University and Regis University IACUC guidelines.

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The advent of passive acoustic monitoring has vastly improved our ability to collect data on wildlife species that vocalize. Studies that examine a wide variety of taxa have taken advantage of these data collection devices to answer questions of species presence, community diversity, and the effects of sound on wildlife (Goyette et al. 2011; Milne et al. 2004; Shearin et al. 2012). These systems have been used in a wide variety of conditions from arctic wetlands to arid deserts, to forested systems and even in urban settings. Each of these settings comes with its own problems and pitfalls. In this study, we describe some of the problems and solutions for protecting passive recording devices in rangeland systems lacking vertical structure.

We used passive recording devices in northeastern New Mexico, USA, to monitor amphibian communities in the southern High Plains, a semi-arid grassland dominated by agriculture and rangeland. In this region, ephemeral surface water is located in playa wetlands and stream drainages crossing the grasslands. Earthen cattle tanks and artificial impoundments associated with the river serve as permanent water sources.

Heavy monsoon rains are typical during the spring and summer in the plains, and amphibians residing here have developed an explosive-breeding style to take full advantage of novel breeding habitat. Because of the remoteness of the system and haphazardness of rain events, audio data loggers are useful in allowing us to sample amphibian breeding choruses when we are not available to conduct manual call surveys. These devices are typically attached to trees or other vertical surfaces; however, due to the lack of vertical structure in these grasslands we needed to attach the data loggers to posts. Deploying devices on the ground was not an option due to the risk of water damage from submergence during monsoon rains.

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Ungulates can interfere with field equipment through several mechanisms. Researchers in various systems worldwide have had problems with these animals ingesting different types of plastic (Provenza 1996; Ramaswamy and Sharma 2010; KLG, unpubl. data, A. Berentsen pers. comm.). Ungulates also tend to rub against objects, and in landscapes such as the southern High Plains that lack vertical structure, they can significantly damage equipment secured to these structures.

During our initial use of the audio data loggers in 2011, we deployed 10 devices. We attached each device with screws to the top of two, 1.5-m wooden posts and placed them at different playa wetlands. After 7 days, 7 of the 10 devices had either had the microphones consumed or had the stand knocked down. This led us to design the following study, evaluating the degree of protection needed to guard the Wildlife Acoustics Song Meter SM2+ Recorder from ungulate depredation. This work will provide other researchers with suggestions for the level of protection needed in a grassland system.

Methods. —This study was conducted on privately owned rangeland in the southern High Plains in northeastern New Mexico during 2011. We evaluated the following treatments: control (no protection), box treatment (protection for the logger only), and fence treatment (protection for the logger and the post). Because the initial goal of the project was to evaluate amphibian breeding choruses, each device was deployed at the edge of a playa wetland. We had seven replicates (each with a different playa wetland and different landowner) with all three treatments represented within each replicate.

Because audio data loggers can be expensive, we created model devices by attaching foam balls with plastic stems (to simulate microphones) to either side of an ammunition box. In all treatments we attached the passive recording device with fencing wire to the top of a 1.8 m t-post. The control treatment (Fig. 1A) had no protection. To create the box treatment (Fig. 1B) we devised a rectangular enclosure (48.3 cm × 27.9 cm × 12.7 cm) out of mesh (5 cm × 2.5 cm) hardware cloth, placed it over the device, and secured the box using fencing wire. We created the fence treatment (Fig. 1C) by constructing a triangular fence, constructed from cattle panels (1.8 m long by 2.1 m tall) and 3 T-posts, around the data-logger. Cattle panels are rectangular sections of rigid welded fencing that do not need to be stretched between fence posts (Fig. 1, 2). These three treatments represent a continuum of physical and financial costs, from fewest to most resources needed.

We spaced the three treatments approximately 1 m apart next to the playa and positioned a motion sensitive game camera (HyperFire Semi Covert IR; Reconyx, Inc.; Holmen, Wisconsin) across from them (Fig. 1D), with all three treatments within its field of view. We left the treatments up for 7 days and upon returning, evaluated the damage by recording levels of destruction of the mock equipment. The protection was considered unsuccessful if either the microphones were destroyed/removed (Figs. 2a, 3a) or the audio data logger was dislodged from the post (Figs. 2b, 3b). We analyzed the data using a contingency table and Kendall’s tau-b (Agresti 1990; SPSS 2011).
The Use of Gastric Transmitters to Locate Nests and Study Movement Patterns of Breeding Male Ozark Hellbenders (Cryptobranchus alleganiensis bishopi)

Hellbenders (Cryptobranchus alleganiensis) are large fully aquatic salamanders inhabiting rivers and streams of the eastern United States. Two subspecies occur in the Ozark Highlands of Missouri: the Ozark (C. a. bishopi) and Eastern Hellbender (C. a. alleganiensis). Throughout most of the year, Hellbenders are solitary animals moving among large rocks or bedrock crevices for foraging and shelter (Peterson and Wilkinson 1996; Smith 1907). However, during the breeding season (September–October), male Hellbenders establish nesting sites under specific rocks and aggressively defend nests from other males (Alexander 1927). Males occupying a nesting site guide females into the cavity in an attempt to secure a mating (Petranka 1998). Females deposit a clutch of 200 to > 400 eggs, and males fertilize the eggs externally (Nickerson and Mays 1973; Phillips and Humphries 2005; Smith 1907). After egg deposition, males chase the females out of the nesting cavity and actively guard the eggs and larvae (Petranka 1998).

Both subspecies of Hellbenders have experienced marked population declines in Missouri (Briggler et al. 2007; Wheeler et al. 2003) and are considered critically-imperiled and state-endangered (MONHP 2012). In November 2011, C. a. bishopi was added to the federal endangered species list (USFWS 2011).

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Results.—We found that the three exclosure types were significantly different from each other (τ = 12.6, p < 0.0005) in their ability to protect equipment from ungulate damage. Specifically, we found that the fence enclosure protected the data-loggers in all replicates while 57% in the box treatments and 0% in the control treatments were protected.

Discussion.—Our study documented clear evidence that cattle fence exclosures are the most effective at protecting passive recording devices from ungulates when compared to box exclosures and no exclosures. Fence exclosures kept ungulates from rubbing against the post and protected the microphones from consumption. Others have used exclosures to protect young trees from browsing (e.g., Kota and Bartos 2010), but we have found no published literature on the protection of passive recording devices.

Fences provided the most protection for the passive recording devices for two reasons. First, a large amount of force can be applied to a triangular fence design without it being destroyed. Furthermore, the width and gauge of fencing we used provided strength, but flexibility. Second, the devices were placed within the fence, and were out of reach from ungulates. An added benefit of our fence treatment is its mobility and reusability. Each fence treatment was assembled by one person in 30 minutes, and disassembled in 10 minutes. We recommend this protection technique for studies requiring equipment placement in a conspicuous location where ungulates are present. We recommend the use of fences approximately 0.3 m taller than the shoulder height of tallest damage-prone ungulate in the region. Choosing the appropriate protection method for field equipment is generally constrained by time and funding; however, when using costly equipment such as passive recording devices, it is worth the extra expense to protect them in grassland systems.

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Acknowledgments.—We thank New Mexico Game and Fish Share with Wildlife Program and the Department of Natural Resources Management at Texas Tech University for supporting this research. We also thank the volunteers on this project including R. Ramesh, L. Arvidson, J. Quigley, and M. McConnell, as well as the private landowners who graciously gave us permission to use their land and cattle. This is manuscript number T-9-1238, College of Agricultural Sciences and Natural Resources, Texas Tech University, Lubbock, Texas.
Due to the severe population declines, there is a vital need to collect eggs from the wild for captive propagation efforts and use of young for research projects to address the decline. Although few nests have been found in the wild in Missouri (Dunde and Dunlee 1965; Nickerson and Tohulka 1986; Unger and Mathis 2013), the nest-guarding behavior of male Hellbenders provides an ideal opportunity to track their movements as a technique to locate egg clutches.

Radio-telemetry is a technique widely used to monitor animal movements across a variety of taxonomic groups and habitat types. The study of movements and dispersal in small organisms such as salamanders has become more feasible given the technological advances in the size, weight, and battery life of transmitters. External and surgically-implanted internal transmitters have been used to track various species of salamanders including ambystomatids (Faccio 2003; Madison 1997; Madison and Farrand 1998; Rittenhouse and Semlitsch 2006; Steen et al. 2006; Trenham 2001), cryptobranchids (Ball 2001; Blais 1996; Bodinof et al. 2012; Burgmeier et al. 2011; Coatney 1982; Gates et al. 1985; Okada et al. 2006; Stouffer et al. 1983; Wheeler 2007; Zheng 2006), and salamandrids (Jehle and Arntzen 2000). Although data on the utility of gastric implant transmitters are more limited, they appear to be a useful tool for tracking salamander movements on a short-term basis (Blais 1996; Coatney 1982; Schabetberger et al. 2004).

The purpose of this study was to use gastric implant transmitters to radio-track adult male Ozark Hellbenders (C. a. bishopi) during the breeding season to understand their movement patterns, but more importantly, to locate egg clutches in the wild. Gastric implants were selected over external or surgical implants due to the increased risk of impairment these latter attachment methods pose to the animals (i.e., anesthesia overdose, prolonged recovery, skin abrasions or tears, infection, or entanglement) and for ease of implantation at the study site.

Materials and methods.—Movements of adult male Ozark Hellbenders were tracked on the lower North Fork of the White River in southern Missouri from 28 September–8 November 2006 and 21 September–1 November 2007. The study site was a small 0.17-ha area of habitat characterized by shallow, moderately-flowing water, and a substrate comprised of numerous chunk rocks, boulders, and gravel. Animals were collected by turning suitable cover rocks, via snorkeling, and then replaced to their original position. Individual Hellbender locations were temporarily marked with numbered floats, and GPS coordinates, water depth, rock measurements (length, width, height), and substrate composition were recorded. A portable digital scale (Ohaus) and tape measure mounted in 10 cm diameter PVC pipe cut longitudinally in half were used to obtain mass (± 0.1 g), snout-vent length (SVL ± 0.5 cm), and total length (TL ± 0.5 cm) of each male, and PIT tags (Avid) were subcutaneously injected into the dorso-medial surface of the tail. Individual males are hereafter identified using the last three digits of their PIT tag number.

Gastric radio transmitters were purchased from Advanced Telemetry Systems (ATS Model F1010; Isanti, Minnesota) with a marketed battery life of 26 days. Transmitters measured 17 mm × 7 mm (length × diameter) and weighed 1.4 g. Transmitters emitted a pulsed signal with a frequency range of 164–165 MHz (pulse rate: 30 ppm; pulse width: 20 ms) (Table 1). To ensure that transmitters would safely pass through the digestive tract, we selected transmitter size based on the average size of undigested crayfish pinchers that are commonly excreted (pers. obs.). In all cases, transmitters comprised less than 0.6% of body mass (Table 2).

Transmitters were coated with KY Jelly and inserted into a gel-coated disposable oral pill dispenser (11 mm diameter × 115 mm length; Four Paws, No. 01915). The mouth of an animal was gently prodded open using a thin, flat-tipped duckbill clip (Sally Beauty Supply). The pill dispenser was inserted approximately 4 cm into the esophagus and the plunger was depressed to release the transmitter into the esophageal cavity. The entire implantation process from opening the mouth to insertion of the transmitter took less than 10 seconds to complete. Males were then placed into plastic holding containers filled halfway with fresh stream water for a period of one hour to monitor for potential regurgitation of the transmitter, upon which they were returned to their exact capture location.

Seven male Hellbenders were captured on 28 September and 5 October 2006. Five males were selected for gastric implants, and the other two were deemed unsuitable due to small size and

![Image](https://example.com/image.png)

**FIG. 1.** Weekly locations of individual Ozark Hellbenders (*Cryptobranchus alleganiensis bishopi*) in the North Fork of the White River, 2006 and 2007.

### Table 1. Transmitter specifications used in tracking male Ozark Hellbenders (*Cryptobranchus alleganiensis bishopi*) in 2006 and 2007 on the North Fork of the White River. Transmitters had a marketed battery life of 26 days, mass of 1.4 g, and frequency between 164.058 to 164.408 MHz. * Indicates individuals that received a second transmitter.

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Initial signal strength</th>
<th>Actual battery life (days)</th>
<th>Final signal strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NFR 056</td>
<td>Strong</td>
<td>41+</td>
<td>V. Weak</td>
</tr>
<tr>
<td>NFR 293*</td>
<td>Strong</td>
<td>35–40</td>
<td>None</td>
</tr>
<tr>
<td>NFR 293*</td>
<td>Strong</td>
<td>30+</td>
<td>Strong</td>
</tr>
<tr>
<td>NFR 586</td>
<td>Moderate</td>
<td>1–6</td>
<td>None</td>
</tr>
<tr>
<td>NFR 778</td>
<td>Strong</td>
<td>34+</td>
<td>Moderate</td>
</tr>
<tr>
<td>NFR 805</td>
<td>Strong</td>
<td>34+</td>
<td>Moderate</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NFR 349*</td>
<td>Moderate</td>
<td>19–26</td>
<td>None</td>
</tr>
<tr>
<td>NFR 349*</td>
<td>Moderate</td>
<td>17+</td>
<td>Weak</td>
</tr>
<tr>
<td>NFR 573</td>
<td>Moderate</td>
<td>19–26</td>
<td>None</td>
</tr>
<tr>
<td>NFR 778</td>
<td>Moderate</td>
<td>19–26</td>
<td>None</td>
</tr>
</tbody>
</table>

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poor body condition (i.e., partial limbs with open lesions). The following year, four males were captured on 21 September 2007 of which three received transmitter implants. Because Ozark Hellbenders are critically imperiled, we opted not to increase our sample size until the safety of this technique was verified. Water depth at the study site was typically less than 1 m, but levels fluctuated by 0.5 m during 2006 due to several heavy rain events.

Hellbenders were radio-tracked during the day using either a Lotek (model STR1000) or ATS (model R2000) receiver in conjunction with a two-element folding Yagi antenna or an H-antenna (Telonics). Individuals were relocated one day post-implant to verify that the transmitters were not regurgitated, and then relocated approximately once per week thereafter. Once a transmitter position was located through triangulation, we visually relocated approximately once per week thereafter. Once a transmitter was still retained. The status of the transmitter was confirmed the presence of the animal with an underwater camera or by carefully lifting the targeted rock. Starting the second week post-implant, each animal was captured to ensure that the transmitter was still retained. The status of the transmitter was recorded, i.e., retained within the animal, discarded (emitting a signal from outside the animal), or unknown (no longer emitting a signal) (Table 2). A GPS reading was also recorded for each location as were measurements of rock size, water depth, and type of substrate.

Locations for each individual were plotted using a Garmin GPS 76 in conjunction with aerial photographs to minimize error; UTM coordinates were adjusted according to known layout of habitat to reduce error to less than 1 m. To quantify movements, we calculated the linear distance between successive relocation points using the measure tool in ArcMap (version 9.1, ESRI Inc., Redlands, California).

**Results.—**A total of 10 gastric transmitters were implanted in seven individual male Ozark Hellbenders. In the first year, five males were implanted on 28 September and 5 October 2006; one of these males NFR 293 received a second transmitter on 9 October 2006 (Table 1). In the second year, three males were implanted with transmitters on 21 September 2007; one male (NFR 349) received a second transmitter on 10 October 2007 (Table 1). NFR 778 was the only individual implanted with a transmitter during both years of the study.

Mean TL of implanted animals was 39.1 ± 1.6 cm with a mean mass of 378.2 ± 44.8 g (mean ± SE, N = 8) (Table 2). On average, transmitter mass comprised only 0.4% of male body mass. No animals regurgitated the transmitter within the one hour post-implant observation period or discarded the transmitter for at least 13 days post-implant. The possible exception is NFR 586 which lost its transmitter signal within the first week of the study. Five of seven animals maintained the transmitter for a minimum of 19 days with NFR 293 retaining its transmitter over 30 days (Table 2).

During the study period, most of the Hellbenders utilized a small area of the available habitat (Fig. 1). In 2006, there was considerable overlap in habitat use compared to no overlap in 2007 (Fig. 1). Weekly relocations showed that males moved a median distance of 3.8 ± 1.0 m per week (mean ± SE, N = 8), and individual male movements ranged from 0.0–17.5 m per week (Table 3). Although movements were generally small, some males (e.g., NFR 056, 293, 349) moved among locations from week to week whereas other males remained mostly sedentary (e.g., NFR 805, NFR 778 in 2007). NFR 778 tended to move from location

### Table 2. Morphological measurements of male Ozark Hellbenders (*Cryptobranchus alleganiensis bishopi*) on the North Fork of the White River.

*Indicates individuals that received a second transmitter; 1.4 g was subtracted from their mass during the second implant to account for the mass of the first transmitter.

<table>
<thead>
<tr>
<th>Male ID</th>
<th>SVL (cm)</th>
<th>TL (cm)</th>
<th>Initial mass (g)</th>
<th>% Mass (Trans/HB)</th>
<th>No. of days retained</th>
<th>Transmitter status</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFR 056</td>
<td>24.0</td>
<td>34.5</td>
<td>293.2</td>
<td>0.48</td>
<td>20–27</td>
<td>Discarded</td>
</tr>
<tr>
<td>NFR 293*</td>
<td>26.5</td>
<td>40.5</td>
<td>375.6</td>
<td>0.37</td>
<td>15–27</td>
<td>Discarded</td>
</tr>
<tr>
<td>NFR 293*</td>
<td>26.5</td>
<td>40.5</td>
<td>348.7</td>
<td>0.40</td>
<td>30+</td>
<td>Retained</td>
</tr>
<tr>
<td>NFR 586</td>
<td>28.0</td>
<td>41.0</td>
<td>376.0</td>
<td>0.37</td>
<td>1+</td>
<td>Unknown</td>
</tr>
<tr>
<td>NFR 778</td>
<td>26.0</td>
<td>37.5</td>
<td>323.7</td>
<td>0.43</td>
<td>13–20</td>
<td>Discarded</td>
</tr>
<tr>
<td>NFR 805</td>
<td>34.0</td>
<td>47.5</td>
<td>668.0</td>
<td>0.20</td>
<td>22–27</td>
<td>Discarded</td>
</tr>
<tr>
<td>NFR 293*</td>
<td>26.0</td>
<td>39.5</td>
<td>324.0</td>
<td>0.43</td>
<td>19+</td>
<td>Unknown</td>
</tr>
<tr>
<td>NFR 349*</td>
<td>26.0</td>
<td>39.5</td>
<td>322.0</td>
<td>0.44</td>
<td>22+</td>
<td>Retained</td>
</tr>
<tr>
<td>NFR 573</td>
<td>21.5</td>
<td>32.0</td>
<td>258.0</td>
<td>0.54</td>
<td>19+</td>
<td>Unknown</td>
</tr>
<tr>
<td>NFR 778</td>
<td>26.5</td>
<td>40.0</td>
<td>407.0</td>
<td>0.34</td>
<td>19+</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

* Discarded = transmitter was no longer in animal but still emitting signal, retained = transmitter still emitting a signal within animal, and unknown = transmitter no longer emitting signal either within animal or on river bottom.

### Table 3. Movements of male Ozark Hellbenders (*Cryptobranchus alleganiensis bishopi*) between successive weekly relocations on the North Fork of the White River. * Indicates individuals that received a second transmitter.

<table>
<thead>
<tr>
<th>Male ID</th>
<th>No. of fixes</th>
<th>No. of unique locations</th>
<th>Mean Distance moved (m)</th>
<th>Median Distance moved (m)</th>
<th>Range Distance moved (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFR 056</td>
<td>7</td>
<td>7</td>
<td>6.8</td>
<td>7.0</td>
<td>1.2–10.0</td>
</tr>
<tr>
<td>NFR 293*</td>
<td>9</td>
<td>8</td>
<td>4.1</td>
<td>3.8</td>
<td>0.0–11.7</td>
</tr>
<tr>
<td>NFR 586</td>
<td>2</td>
<td>2</td>
<td>5.8</td>
<td>5.8</td>
<td>N/A</td>
</tr>
<tr>
<td>NFR 778</td>
<td>5</td>
<td>4</td>
<td>6.8</td>
<td>6.8</td>
<td>0.0–10.0</td>
</tr>
<tr>
<td>NFR 805</td>
<td>6</td>
<td>2</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0–7.5</td>
</tr>
<tr>
<td>NFR 349*</td>
<td>8</td>
<td>7</td>
<td>5.7</td>
<td>5.4</td>
<td>0.0–13.6</td>
</tr>
<tr>
<td>NFR 573</td>
<td>5</td>
<td>3</td>
<td>2.7</td>
<td>1.4</td>
<td>0.0–4.1</td>
</tr>
<tr>
<td>NFR 778</td>
<td>5</td>
<td>2</td>
<td>4.4</td>
<td>0.0</td>
<td>0.0–17.5</td>
</tr>
</tbody>
</table>
to location in 2006, whereas in 2007 this male only moved once from its initial capture location (Fig. 1; Table 3). The week after implantation, NFR 778 moved to the largest rock (surface area = 15,800 cm²) used by any Hellbender in the study and stayed under this rock for the next four weeks. This male was found guarding a clutch of eggs on 17 October 2007.

There was considerable variation in rock size (length, width, and depth) used by male Hellbenders, with a mean rock length and width of 69.7 and 47.3 cm respectively (Table 4). However, we found no significant relationship between the size of males and the size of cover rocks (i.e., rock surface area) (N = 8, R² = 0.09, p = 0.47). Twenty-nine specific cover rocks and two bedrock crevices were used during the study. Although individual males were observed under the same rocks from week to week (Table 3), there was no overlap observed among males in rock selection during the study period.

Upon the conclusion of this study, three follow-up surveys were conducted between 2008 and 2010 to search for Hellbenders and egg clutches. While no concerted efforts were made to recapture the study animals, these surveys resulted in the recapture of five of the seven animals used in this study. Each animal had gained an average of 140 g. NFR 778 (used in both years of this study) gained 96 g between the 2006 and 2007 breeding season, and was recaptured in 2008 and 2009 where it had gained an additional 142 g.

Discussion.—Radio-telemetry has been used as a valuable tool to obtain information on movement, home range, and behavior in Hellbenders using a variety of different types of transmitter implants including coelomic, subcutaneous, gastric, and external (Ball 2001; Blais 1996; Bodinof et al. et al. 2012; Burgmeier et al. 2011; Coatney 1982; Gates et al. 1985; Wheeler 2007). Gastric implants have been shown to be a suitable method for assessing Hellbender movements on a short-term basis (Blais 1996; Coatney 1982), but the utility of this technique for locating egg clutches has not been previously investigated. Over the course of this study, we tracked seven individual males using gastric implants and determined that these transmitters are a practical, non-invasive method to locate nests and to learn information about male movement patterns during the breeding season.

The size, mass, and battery life of transmitters used in this study were suitable for our short-term tracking needs. Prior studies on Hellbenders indicated retention rates of gastric transmitters between 18-30 days (Coatney 1982) and 16-25 days (Blais 1996). In our study, males retained gastric implants for a minimum of 13 days to over 30 days with the exception of NFR 586 (Table 2). This male had a weak transmitter signal when relocated 24 h after implantation, and no signal could be detected during subsequent relocation attempts. Transmitter failure is a likely explanation for the loss of signal from this male; however, it is also possible the male migrated up- or downstream, was depredated, or was illegally collected from the study area. As of 2012, this animal has not been observed again despite extensive relocation efforts. We determined that a 26-day battery life

<table>
<thead>
<tr>
<th>Male ID</th>
<th>No. of unique rocks measured</th>
<th>Rock length (cm)</th>
<th>Rock width (cm)</th>
<th>Rock depth (cm)</th>
<th>Water depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>NFR 056</td>
<td>6 (40–129)</td>
<td>80.0 ± 29.0</td>
<td>53.5 ± 15.3</td>
<td>18.5 ± 10.9</td>
</tr>
<tr>
<td></td>
<td>NFR 293</td>
<td>7 (36–78)</td>
<td>56.9 ± 13.1</td>
<td>37.0 ± 8.1</td>
<td>18.7 ± 10.3</td>
</tr>
<tr>
<td></td>
<td>NFR 586</td>
<td>2 (45–64)</td>
<td>54.5 ± 13.4</td>
<td>37.0 ± 1.4</td>
<td>10.0 ± 2.8</td>
</tr>
<tr>
<td></td>
<td>NFR 778</td>
<td>2 (73–79)</td>
<td>76.0 ± 4.3</td>
<td>56.0 ± 26–41</td>
<td>33.5 ± 10.6</td>
</tr>
<tr>
<td></td>
<td>NFR 805</td>
<td>2 (51–111)</td>
<td>81.1 ± 42.4</td>
<td>58.0 ± 31.1</td>
<td>24.0 ± 15.6</td>
</tr>
<tr>
<td>2007</td>
<td>NFR 349</td>
<td>7 (39–101)</td>
<td>67.4 ± 22.8</td>
<td>44.7 ± 12.8</td>
<td>30.3 ± 22.5</td>
</tr>
<tr>
<td></td>
<td>NFR 573</td>
<td>1*</td>
<td>51.0</td>
<td>29.0</td>
<td>28.0</td>
</tr>
<tr>
<td></td>
<td>NFR 778</td>
<td>2 (45–152)</td>
<td>98.5 ± 75.7</td>
<td>74.0 ± 42.4</td>
<td>40.0 ± 38.2</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>3.6 (36–152)</td>
<td>69.7 ± 27.2</td>
<td>47.3 ± 17.6</td>
<td>24.0 ± 16.7</td>
</tr>
</tbody>
</table>
expectancy was sufficient for tracking Hellbenders during the active breeding period. While ATS transmitters were used in both years of this study, batteries lasted longer than the marketed 26-day life expectancy in year one, whereas performance was lower and more consistent with life expectancy in year two (Table 1). We also learned that a second gastric implant could be administered to extend tracking time; two animals (NFR 293 and 349) received a second implant with no observable harmful effect.

Transmitter size was selected based upon the size of crayfish pinchers and/or other chitinous parts that would pass through the digestive system of an adult Hellbender. Conversely, Schaebesberger et al. (2004) selected transmitters large enough that they would not pass through the digestive system and were forced to remain in the stomach. It is possible that Hellbenders could regurgitate our transmitters, but we attempted to select a size that was small enough to safely pass through the system without harming the animal (CCAC 2004; HACC 2004) and not so large that the animal would immediately attempt to regurgitate it. Further consideration needs to be taken into account when using gastric transmitters on Eastern Hellbenders which are larger than Ozark Hellbenders (Nickerson and Mays 1973). Blais (1996) implanted 5 g gastric transmitters (20 mm x 10 mm) in two Eastern Hellbenders and had similar retention rates as in our study, with transmitters being excreted after passing through the digestive system. While Blais (1996) did not provide any length data for these two individuals, the mass of his study animals ranged from 545–1318 g. General guidelines recommend that transmitters should be less than 5% of an animal’s body mass for studies on amphibians and reptiles (ATS 2012). The Canadian Council on Animal Care and Use has adopted specific guidelines that suggest gastric transmitters not exceed 1% of an animal’s body mass because they can alter behavior by mimicking food in the stomach (CCAC 2004). Therefore, mass and size of transmitters should be carefully considered when using gastric implants. Our transmitters were well within the recommended parameters (< 0.6% of body mass).

Only a few telemetry studies provide information on movements in wild Hellbenders (Ball 2001; Blais 1996; Burgmeier et al. 2011; Coatney 1982). Three of these studies either focused on short-term movements outside of the breeding season or on long-term seasonal movement patterns. However, Burgmeier et al. (2011) reported specifically on male movements during the active breeding season. Although our primary objective was not to address diel movements of male Hellbenders, our study does provide insight into movement patterns and habitat utilization during the breeding season. Our data for 2006 demonstrated considerable overlap in habitat used by five males, which is similar to results of other studies (Blais 1996; Coatney 1982; Peterson and Wilkinson 1996). Even though the areal extent of suitable habitat encompassed an area approximately 70 m in length by 25 m in width, four of the five males were clustered in a small 13 m x 14 m area during the entire 2006 study season (Fig. 1). Conversely, in 2007 the three tracked males utilized independent areas of habitat and showed little overlap (Fig. 1); however, we are unsure why this spatial pattern differed from 2006. Considerable variation in movement frequencies was observed among the animals in our study. Some individuals moved between rocks with greater frequency whereas others rarely moved and remained relatively stationary between weekly relocations (Table 3).

Hellbenders are known to use rock and bedrock crevice habitat for shelter and nest sites (Nickerson and Mays 1973; Nickerson and Tohulka 1986; Smith 1907). We found that Ozark Hellbenders utilized large rocks most frequently, and on two occasions, bedrock crevices as shelter sites. Individual males were often found under the same rock from week to week with an average of 3.6 rocks used per male (range: 2–9) during the breeding season. Previous studies reported similar variability in movement patterns and rock use in wild Hellbender populations (Ball 2001; Peterson and Wilkinson 1996). Peterson and Wilkinson (1996) found individual males on average utilized 6.3 cover rocks with a range of 1 to 13 rocks over a five month period from August to January. We would expect overall rock use (i.e., movement) in our study to be reduced since we targeted the breeding season when males are more sedentary. In Hellbenders it is rare to observe more than one individual under the same rock simultaneously (Hillis and Bellis 1971; Nickerson and Mays 1973; Peterson 1988); however, it is not uncommon for the same rock to serve as shelter for multiple animals over time (Peterson and Wilkinson 1996). In our study, male Hellbenders utilized 31 unique locations (i.e., 29 cover rocks and two bedrock crevices), but we never observed the same shelter site being utilized by more than one individual over the entire course of the study.

We conclude that the use of gastric implants is a practical technique for short-term studies of wild Hellbenders as previously demonstrated by Blais (1996) and Coatney (1982). But, more importantly, our study demonstrated the effectiveness of this technique in locating active nests. The importance of locating nests cannot be overestimated since this endangered species has experienced marked population declines with larger, mature individuals predominating while small size classes are underrepresented (Briggler et al. 2007; Wheeler et al. 2003). The single egg clutch that we collected as a result of this study was incorporated into the long-term captive propagation efforts of the Ozark Hellbender. Gastric transmitters are quickly and easily implanted on site which reduces the stress and risk associated with surgical implant transmitters (i.e., off-site transportation, anesthesia, surgical procedure, extended recovery time, etc.). To achieve the goal of locating egg clutches, temporary removal (< 1.5 hours) of males from the river to implant gastric transmitters has less impact on their breeding behavior than other external or internal transmitter attachment methods. There has also been recent success using artificial nest boxes to augment nesting habitat, collect wild egg clutches, and propagate Hellbenders in captivity (Briggler and Ackerson 2012). However, the best technique to use in future studies will depend on factors such as stream morphology, water clarity, amount of suitable nesting habitat, and specific research objectives.

The long-term utility of this technique can be measured by the survivability and subsequent condition of the study animals. Coatney (1982) and Blais (1996) did not report adverse effects of gastric transmitters on Hellbenders on a short-term basis; however, they did not monitor animals for a long-term. In this study, five of the seven Hellbenders were recaptured in subsequent years and gained weight (mean =140 g gained). With at least 71% (5 of 7) survivorship and documented weight gains in subsequent years, gastric implant telemetry appears to be a useful, non-lethal tool for short-term studies in Ozark Hellbenders. This method may also have applications in short-term studies learning more about movement patterns and behavior of other imperiled species.

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Marking tadpoles is challenging. Traditional methods include fin-clipping and staining with neutral dye (Donnelly et al. 1994). More recently, researchers have trialed visible implant elastomers (VIE) and coded wire tags (CWT) as techniques to mark tadpoles (Anholt et al. 1998; Grant 2008; Martin 2011). The drawback to fin-clipping and staining is that their use is largely restricted to batch marking (e.g., dates or cohorts), rather than unique identification (Donnelly et al. 1994). Additionally, staining may affect the behavior of marked tadpoles (Carlson and Langkilde 2013), and the effect of fin-clipping on behavior or survival is unknown. VIE may be problematic because marks often migrate away from the marking site, are lost, or are read incorrectly (Bailey 2004; Grant 2008). CWT also has a high rate of tag loss (Martin 2011). Visible implant alphanumeric tags (VIAAlpha tags, Northwest Marine Technology Inc., Shaw Island, WA) have the potential to solve these problems. VIAAlpha tags are soft, biocompatible, fluorescent tags with a unique alphanumeric code printed on one side. Thus, they represent a promising approach to uniquely identify individuals. They have been used for marking a number of taxa including fish (Oncorhynchus mykiss, Isely et al. 2004; Gadus morhua, Olsen et al. 2004), crayfish (Procambarus clarkia, Isely and Stockett 2001; Cherax destructor, Jerry et al. 2001), lobsters (Jasus edwardsii, Woods and James 2003), and seahorses (Hippocampus abdominalis, Woods 2005). VIAAlpha tags have also been used to successfully mark adult anurans (Ackleh et al. 2010; Buchan et al. 2005; Chelgren et al. 2006; Heard et al. 2008), caecilians (Measey et al. 2001; 2003), and salamanders (Osbourn et al. 2011). To date their use in marking tadpoles has not been tested, and this study is the first to report on tag retention in a larval anuran, the Green Frog (Lithobates clamitans). Our objective was to assess VIAAlpha tag retention in this species.

Materials and methods.—As part of a larger study examining the reproductive success of amphibians inhabiting created wetlands (in which unique identification and mass of individuals were required), in March 2010 we collected 110 green frog tadpoles from a pool connected to a wetland in Grant County, West Virginia (39.2125°N, 79.42361°W). All individuals had hatched the previous summer and overwintered in the pool and were of similar developmental stage (Gosner stage 30–33; Gosner 1960). We transported tadpoles to the laboratory where they were housed in 33 aquaria (~3 L plastic containers), with five tadpoles per aquarium. We maintained aquaria on a 14 h light: 10 h dark photoperiod at about 22°C. We fed a consistent amount of food (3:1 mixture of rabbit chow and flake fish food, Skelly 1994) to tadpoles once every other day. In an attempt to achieve a balance between disturbance to tadpoles and maintaining conditions as natural as possible, we did not aerate tanks and limited water changes to 1/3 of the water volume once a week with water collected from wetlands. As water was siphoned during water changes, we vacuumed uneaten food, feces, and debris from the bottom of tanks. We randomly assigned aquaria to spaces along a 9 m-long bench and randomly allocated individual tadpoles to aquaria.

Tadpoles were anesthetized in buffered 440 mg/L tricaine methylsulphonate (MS-222), placed on a water-saturated piece of soft foam and tagged using an injector specifically designed to accommodate the 1.2 mm × 2.7 mm VIAAlpha tags (Fig. 1). We injected the tags by piercing the first layer of skin at the midpoint of the tail with the pointed injector tip and sliding the injector parallel to the skin towards the base of the tail above the muscle (Anholt et al. 1998). The tip of the injector was rinsed with clean water after each use (although rinsing with ethanol may be more appropriate to prevent disease transmission). We placed all tags on the left side of the tail fin, and care was taken to ensure that tag placement was consistent. Tadpoles recovered (until they resumed normal behavior, 2–5 minutes) in a container of clean distilled water before being placed into aquaria. We monitored tadpoles for tag retention daily until they either died or metamorphosed (mean 14 weeks, range: 1–80 weeks). To minimize disease risk associated with reintroducing amphibians into the wild, all metamorphs were euthanized in a 2% solution of MS-222.

Results.—VIAAlpha tag retention was poor, with 25% of the tags lost in the first week (21% were lost in <24 h) and 82% lost within the first two weeks of the experiment. Four tags were not lost: three tadpoles died and one metamorphosed with tags still implanted. The remaining tags were lost by week 11 (day 75) for a total percentage loss of 96% (Fig. 2). No signs of infection, redness or swelling were present at the location of the incision, and marked tadpoles appeared to behave normally.

Discussion.—Contrary to many other taxa that have been marked with this method, VIAAlpha tag retention in Green Frog tadpoles was poor. We believe that tag loss is most likely due to the nature of tadpole anatomy. Tags were initially secure in the tail because they were kept against the skin by the support of the tail myotomes. However, tail movement gradually pushed the tags posteriorly toward the skin incision where they exited the tail because they were kept against the skin by the support of the tail myotomes. However, tail movement gradually pushed the tags posteriorly toward the skin incision where they exited the body and were lost (this took < 24 h in 23 individuals). Before the initiation of the experiment, additional tadpoles were used to identify alternative tagging locations; attempted locations included the belly, dorsum, and the cheek just beneath the eye. These locations could not be used because substantial subcutaneous musculature is minimal or absent; the tags immediately slid out of place or disappeared under layers of skin. In some instances, particularly on the dorsum, the tags would appear secure but were occluded by dark pigmentation and were not visible even when viewed with the deep violet wavelength light. This occlusion occurred on several experimental tadpoles as well, due to extensive pigmentation on the tail of some individuals.

Tag retention was much poorer in our study compared to two recent studies that used similar techniques. Grant (2008) used...
visual implant elastomer (VIE) to mark larval Wood Frogs (*Lithobates sylvaticus*) and Martin (2011) used coded wire tags (CWT) to mark larval Mexican Spadefoot Toads (*Spea multiplicata*). Implantation of VIE is done with a small hypodermic needle (4 µm), and the liquid elastomer fills the cavity and then cures into a solid, most likely reducing the probability of loss through the small incision created by the needle. In contrast, the injector for the VIAlpha tags is relatively large (19 µm) and shaped identically to the tag, which probably makes loss of the 12-µm tag through the large incision more likely. Grant (2008) injected tadpoles in the same body location as in the present study and, although still too high for most mark-recapture studies, observed a tag loss of only 50% of one of two marks after 20 days, with no tadpole losing both marks. Martin (2011) injected CWT into the ventral tail fin of tadpoles and had a retention rate of 80% after eight days. We did not attempt tagging in the ventral fin, but CWT uses an injector that is small, similar to the VIE needle, and it may be that smaller incisions are less prone to tag loss than the larger incision created with VIAlpha tags, regardless of tagging location. It would be interesting to determine if CWT tag retention remains high over a longer time period.

We have identified two potential solutions that may improve retention in the future and thus render VIAlpha tags effective for individually marking tadpoles. First, closing the incision site with instant glue such as cyanoacrylate has been used in other studies involving aquatic amphibians (Heard et al. 2008; Reh and Constantine-Paton 1984), and it may prevent tag loss in tadpoles; however, this method is not completely effective (Heard et al. 2008) and its efficacy in submerged conditions is unknown. Second, Chelgren et al. (2006) described their procedure for marking adult Northern Red-legged Frogs (*Rana aurora*) with VIAlpha tags in which upon injection into the dorsum of the thigh they pushed the tag to a position on the ventral side of the thigh, away from the site of incision. Pushing the tag from the dorsum of the tail on tadpoles laterally to the side of the tail may significantly increase retention. This solution needs testing to determine its efficacy because the tail is frequently in motion and may expel tags regardless of position. Refining the application of VIAlpha tags with these potential solutions might yield an effective method whenever identification of individual tadpoles is required. We recommend more work to assess tag retention with protocol modifications and to determine the effect of VIAlpha tags on tadpole survival and behavior.

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Traps used to sample animal populations or communities may be biased with respect to the probability of capturing particular subsets of species or individuals (Willson et al. 2008). For example, capture probabilities may differ between the sexes for specific trap types or during different portions of the active season (Noyce et al. 2001; Thomas et al. 1999). Likewise, the efficacy of some traps may vary across different habitats (Lambert et al. 2005; Ryberg and Cathey 2004). Biased sampling methods may produce inaccurate estimates of community or population-level parameters, hampering the development of management and conservation policies. Therefore, it is important to investigate the potential biases associated with methods used to sample animal populations and communities (Willson et al. 2008).

Some turtle traps are more likely to capture certain species, sexes, or sizes (Bluett et al. 2011; Browne and Hecnar 2005; Cagle and Chaney 1950; Fidencci 2005; Ream and Ream 1966; Sterrett et al. 2010). Basking traps take advantage of the basking habit of some turtle species (Boyer 1965) and usually consist of a basking platform (sometimes with treadles) mounted over a net or holding pen (Plummer 1979). Turtles are captured after diving or falling off of the basking platform. Basking traps are used to successfully capture species that commonly exhibit aerial-basking behaviors (e.g., Trachemys scripta; Gamble 2006; Thomas et al. 1999), but are unlikely to catch species that do not commonly engage in such behaviors (e.g., Macrochelys temminckii; Lagler 1943). In addition, some basking traps are more likely to catch large females than other individuals within a population (Ream and Ream 1966). However, the sexual biases of basking trap captures may vary seasonally (Thomas et al. 1999). The design of some basking traps may allow some turtles to escape from the holding pen (R. B. Thomas, pers. observ.). Gamble (2006) mentioned the possibility that escape rates from basking traps may vary for turtles of different sizes. However, no published studies have compared escape rates of turtles from basking traps.

Baited funnel traps are commonly used to sample freshwater turtle populations and communities (Gibbons and Greene 1990; Plummer 1979; Ream and Ream 1966). Bait (usually food) is used to motivate turtles to enter these traps through an inverted-funnel entrance. The ability of some turtles to escape from funnel traps has been documented (Brown et al. 2011; Frazer et al. 1990; Gamble 2006; Mali et al. 2013). Frazer et al. (1990) found that female Chrysemys picta often escaped from funnel traps, with 16 of 20 escaping during a 24-h period. In contrast, Brown et al. (2011) investigated the escape rates of T. scripta from funnel traps and found a negligible rate of escape (only 5 out of 139 T. scripta escaped within 34 h). Similarly, Mali et al. (2013) reported that only 8 of 107 Apalone spinifera emoryi escaped from funnel traps. Possible explanations for the disparity of results among these studies have not been explored. Differential escape rates between sexes or sizes could bias a sample and negatively impact estimates of population-level parameters. We examined the escape frequency of C. picta and T. scripta from basking traps and funnel traps. Specifically, we compared escape rates among males, females, and juveniles and examined the influence of body size on escape rates for both species.

**Methods and Materials.** We trapped turtles using funnel traps and basking traps from nine ponds in Lyon County, Kansas, USA, from 8 June to 26 September 2010. Traps were constructed with three rectangular 65 × 90 cm frames covered in 3.8-cm treated nylon mesh (Nichols Net and Twine, Inc., Granite City, Illinois); each trap had a single opening with a mouth height (the maximum vertical height of the inner opening of the funnel entrance; see Brown et al. 2011) that ranged between 10 and 15 cm (mean ± SD = 11.5 ± 1.5). We baited each funnel trap with canned mackerel held in a perforated PVC tube to prevent bait consumption (Nall and Thomas 2009); bait was changed every two days. Basking traps consisted of a 60 × 60 cm wood and Styrofoam frame with a 90-cm deep net basket underneath (Memphis Net and
Turtles were considered adult males if they had elongated foreclaws, cloacae positioned posterior to the rear carapace margins, and PL >160 mm for *C. picta* or >120 mm for *T. scripta*; turtles with relatively short foreclaws, cloacae positioned near or anterior to the rear carapace margins, and PL >160 mm for *T. scripta* or >120 mm for *C. picta* were considered adult females (Gibbons and Greene 1990; House et al. 2010). Individuals smaller than these specified sizes that lacked these secondary sex characters were categorized as juveniles.

Captured individuals (both *C. picta* and *T. scripta*) were returned (at random) to either funnel traps or basking traps in their pond of capture. Traps were checked the next day and any of these animals found in the trap ~24 h later were recorded as “non-escapees,” while those missing were assumed to have “escaped.” Individuals were used as a test animal only during these trials.

We tested escape frequency from basking traps with 77 turtles: 49 *C. picta* (22 males, 14 females, and 13 juveniles) and 28 *T. scripta* (11 males, 12 females, and 5 juveniles). We tested escape frequency from funnel traps with 88 turtles: 49 *C. picta* (23 males, 16 females, and 10 juveniles) and 39 *T. scripta* (11 males, 18 females, and 10 juveniles).

Male, female, and juvenile escape rates were compared using a Fisher exact test (Zar 2009). The likelihood-of-escape correlation with plastron length was analyzed using a Wilcoxon signed-rank test (Zar 2009). Level of significance was set at 0.05 for all statistical tests.

**Results.—** Overall, 74% of all turtles escaped from basking traps or funnel traps within 24 h. *Chrysemys picta* escaped from basking traps in 56% of trials (55% of males, 86% of females, and 31% of juveniles; Table 1). We observed significant differences among the escape rates of males, females, and juveniles ($\chi^2 = 9.07; P = 0.011$). Juvenile *C. picta* escaped from the basking traps significantly less frequently than adult males or females. Mean PL of escapees and non-escapees were 133.9 mm and 106.0 mm, respectively. We found a significant difference in mean PL between escapees (133.9 mm) and non-escapees (106.0 mm; $Z_1 = −3.21; P = 0.0013$).

*Trachemys scripta* escaped from basking traps in 86% of trials (82% of males, 100% of females, and 60% of juveniles; Table 1). We did not observe a statistically significant difference among the escape rates of males, females, and juveniles, although our results approached significance ($\chi^2 = 5.80; P = 0.055$); the low numbers in certain cells may have diminished the precision of the test statistic (Zar 2009). However, juvenile *T. scripta* were 40% less likely to escape than adult females. Mean PL of escapees (185.1 mm) and non-escapees (107.0 mm) was significantly different ($Z_2 = −2.79; df = 1; P = 0.0052$).

*Chrysemys picta* escaped funnel traps in 74% of trials (70% of males, 65% of females, and 90% of juveniles; Table 2). Differences in escape rates among these groups were not significant ($\chi^2 = 2.05; P = 0.36$). The Wilcoxon signed-rank test comparing escapee and non-escapee PL showed no significant difference in escape rates by body size for *C. picta* ($Z_1 = 1.44; P = 0.15$; means 116.7 mm for escapees and 133.3 mm for non-escapees).

*Trachemys scripta* escaped funnel traps in 82% of trials (91% of males, 72% of females, and 80% of juveniles; Table 2). Differences in escape rates among these groups were not significant ($\chi^2 = 0.92; P = 0.63$). The difference in mean PL of *T. scripta* categorized as escapees (171.2 mm) and non-escapees (159.7 mm) was not significant ($Z_2 = −0.48; P = 0.62$).

We investigated whether the incidence of escape in turtles was affected by their previous trap experience; for this purpose, we compared escape rates in a subset of first-time captures and experienced turtles (i.e., recaptured turtles). We compared the trap-experience of 69 escapee turtles and 20 non-escapees using Fisher’s exact test. Trap experience and escape were independent ($\chi^2 = 0.66; P = 0.58$).

**Discussion.—** Overall escape rates of turtles were greater than expected. Smaller *C. picta* and *T. scripta* were significantly less likely to escape from basking traps while large females of both species frequently escaped from the basking traps. Therefore, the use of basking traps to sample populations of these two species may result in an underrepresentation of large adults (particularly females).

Escape from funnel traps was relatively frequent; however, relative to basking traps, these traps were less biased with respect to differential rates of escape among males, females, and juveniles. Our results for *C. picta* escape from funnel traps (74%) were very similar to those reported by Frazer et al. (1990; 75%). In contrast, Brown et al. (2011) reported a negligible escape rate (3.6%) of *T. scripta* from funnel traps, versus 82% in our study. It is possible that differences in trapping methods or trap types could be responsible for the disparity among these studies. Our traps were constructed with rectangular 60 × 90 cm frames, while
Brown et al. (2011) used circular 76.2-cm diameter frames. The specific design and dimensions of the traps used by Frazer et al. (1990) were not reported. Perhaps different shapes and sizes of these traps were relevant to the different rates of escape. Specifically, our traps had a mouth height considerably larger (mean = 11.5 cm) than the mouth height of those used by Brown et al. (1.27–2.03 cm); the opening in our traps may have been easier to find and subsequently use for escape. Frazer et al. (1990) also used C. picta from a long-term study population of turtles and some of their study animals may have had extensive prior experience in funnel traps. Conversely, Brown et al. (2011) used T. scripta that were unmarked and presumably had not been trapped before. Our study used a combination of both “new” turtles and turtles that had been caught and marked previously and we found no difference in escape based on prior trap knowledge. Frazer et al. (1990) reported results similar to ours: 75% escape rate for female C. picta in 24 h. These studies also involved two species from three widely spaced study sites (Michigan, Kansas, and Texas) and the potential for geographic variation cannot be dismissed.

Future research should examine possible differences in turtle escape frequency among variations of funnel trap design (one-throated vs. two-throated, round vs. rectangular, etc.). In addition, the possible influence of the frequency of checking traps has not been investigated; Brown et al. (2011) found that all of the turtles who escaped did so in <27 h. Some researchers believe that checking traps more often than once per 48 h disturbs the site and reduces trap yield; others prefer to check their traps every 6–12 h (Cagle and Chaney 1950; Fidenci 2005; Lagler 1943). However, there have been no formal studies conducted to support or negate the efficacy of these practices.

We can conclude that T. scripta and C. picta have a great potential for escape from some forms of basking and funnel traps and that escape from these basking traps, in some cases, is biased by size. The trap types used for this research were only two of a variety of many different trap designs (Cagle and Chaney 1950; Fratto et al. 2008; Kennett 1992; Lagler 1943; Ream and Ream 1966) that may yield different results with similar testing. Researchers would benefit from an examination of their own trap types and potential escape bias. Of the two traps compared in this study, funnel traps yielded less biased samples of C. picta and T. scripta in these ponds.

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Color Recognition as a Management Tool with a Female Nile Crocodile (*Crocodylus niloticus*) at the Wildlife Conservation Society’s Bronx Zoo

Animal sensory systems are the product of environmental and evolutionary pressures. As such, these systems play important and varying roles for animals that influence behavior. Sensory systems aid in predator detection and avoidance (Dial and Schwenk 1998), prey location and capture (Garamszegi et al. 2002), mate location (Shine et al. 2005), and even habitat orientation (Costanzo 1989; Reinert and Zappalorti 1988). Animals are evolutionarily shaped by all aspects of their environment and species often utilize certain sensory systems more heavily than others. In extreme cases, some species have lost entire sensory systems (e.g., the loss of eyes in blind cave fish, *Astyanax mexicanus* [Jeffery and Martasian 1998]). In zoos and similar institutions, animal caretakers develop species-specific husbandry, breeding, enrichment, and training programs that are largely based around sensory and behavioral ecology.

Training is commonly employed by zoos for various purposes (Ramirez 1999). A well-designed and scientifically validated training and enrichment program can benefit animal husbandry, improve animal and trainer safety, and enrich the lives and increase the well-being of animals maintained in a captive environment. Training also increases activity levels and provides mental stimulation for animals in managed care (Ramirez 1999).

When developing any training program, it is important to consider the sensory and behavioral adaptations of the focal animal. Crocodilians utilize visual signals such as a wide range of postures and head slaps atop the water’s surface, which play an important role in crocodilian communication (McMahan 2001). When training crocodilians in captivity, this visual communication channel has been used successfully by implementing visual cues such as targets and stations (Augustine 2009). One of the most fundamental and applicable behaviors used for training is targeting, an animal touching a part of its body to a defined object or “target” (Ramirez 1999). Once targeting is learned the animal can be conditioned to “station,” or remain at a specific object or place for a predetermined length of time. These two behaviors allow trainers to safely and easily direct and work with an animal. Operant conditioning to a target and/or station can be utilized as a safe and effective way to obtain desired behaviors in crocodilians. In addition to natural history, the animal’s cognitive abilities should also be taken into consideration when developing a training program. The ability of reptiles to learn has been demonstrated in several species (Augustine 2009, 2011; Burghardt et al. 2002; Bustard 1968; Leal and Powell 2011; Manrod et al. 2008).

At the Wildlife Conservation Society’s Bronx Zoo, crocodilians are trained to increase safety and improve husbandry. When a training regimen for crocodilians is instituted, a specific color target or station is chosen for each individual animal. For animals that are or will be housed together, we choose two colors on opposite ends of the grey scale. We are not aware of literature that discusses the ability to distinguish between colors or shades in the Nile Crocodile (*Crocodylus niloticus*), a species with which we have had success with training in both group and individual settings.

The Nile Crocodile is a large predator native to Africa that can grow up to 6 m (Trutnau and Sommerlad 2006). It is likely due to this impressive size that *C. niloticus* is relatively common in zoos (39.16.3 [= males, females, unsexed] individuals being kept in 14 institutions in North America; International Species Information System search 25 April 2012). The staff at the Bronx Zoo has had success with conditioning Nile Crocodiles to target and station both as individuals and in pairs. The lack of evidence suggesting crocodilians can behaviorally distinguish between colors led us to question our methodology of assigning different colored plastic discs to individual animals within the collection. Herein, we examine the response of 0.1 *C. niloticus* previously conditioned to a yellow station when presented with a choice between yellow and black stations.

**Materials and Methods.**—The Bronx Zoo obtained a six-year-old female Nile Crocodile on 25 April 2008 from Crocodile Creek, Kwazulu-Natal, Republic of South Africa. A consistent operant conditioning program began in May 2008, focusing on targeting...
and stationing behaviors. The crocodile is housed in a two-part enclosure with a shift door between the two sections. The front portion of the enclosure (exhibit) is approximately 18 m² with a pool 2.3 m × 4.7 m and 0.5 m deep. The enclosure has a cement base with two plants, two logs, and a basking spot. The back, off-exhibit section of the enclosure (holding) measures 15.8 m² with a pool approximately 2.6 m × 3.5 m and 0.7 m deep. Two sand beaches, each with a tree, encompass one-half of the area and a basking spot is provided on the larger of the two beaches. The land portion of the exhibit connects through a shift door to the larger beach in the holding. This crocodile began shift training between exhibit and holding in 2010. When training for this experiment commenced on 8 February 2011, the female crocodile was conditioned to a yellow target and station (first using a painted pole and then to a yellow plastic disc) and to shift between exhibit and holding on cue.

Ten eyebolts (3 ¾” × 1 ¼” with ¾” opening) were secured along the back wall of the holding and labeled 1 through 10 from left to right. They were positioned one foot apart and at equal heights ca. 3 m above the pool. Two plastic discs, one black and one yellow, were attached to broom handles with a hook-and-eye and metal latch to allow for suspension from the eyebolts positioned along the back wall. This back wall is directly across from the shift door, separating exhibit and holding to ensure that the animal would see both plastic discs immediately. The crocodile had not been previously exposed to the black disc. Each colored disc was randomly assigned to a specific eyebolt for each trial. Every trial began by targeting the crocodile in her exhibit to a yellow target pole. She was always rewarded with small mice for the completion of this behavior. The shift door was then opened and when the crocodile passed through the shift door she was requested to “station” with a verbal cue. Once all four of her feet were in the water of the holding pool, a timer was started. Final choice was determined when she approached within 1 inch of the station or plastic discs at which point the timer was stopped. Both discs were removed immediately after the trial and the crocodile was shifted back to the exhibit. This process was repeated at random intervals throughout the day for the duration of this study (17 days). If she failed to choose a disc within a two-minute time frame, she was marked with a zero. We recorded the position of each disc, the color chosen and the time it took for her to complete the behavior. It was also recoded if she chose not to participate by not shifting.

**Results.**—A total of 48 trials were conducted over 17 days. The animal did not participate during two trials by not shifting into the rear pool; these trials were excluded from analyses. There were 4 trials where she did not choose a color/shade within the two-minute time restriction. The crocodile chose yellow 71.7% of the time and black 19.6% of the time. She was significantly more likely to choose yellow, regardless of position (33 out of 46 times; Chi Square test, p < 0.001). However, if she chose black, she only chose it when it was placed on the right side (9 out of 9 times; Chi Square test, p = 0.003). There was no relationship between how long it took her to choose and the date in which we performed the trial (Spearman Correlation, p = 0.268, α = 0.05; Fig. 1).

**Discussion.**—Crocodilians have fairly good eyesight and their elliptical pupil has great light-gathering ability (McMahan 2001). The crocodilian eye contains single rods (detect presence or lack of light; Kolb 2003) and single and double cones (distinguish between different frequencies of light; Kolb 2003), possibly suggesting an ability to see color (Gans and Parsons 1970; Laurens and Dewiler 1921). Jacobs (1981), however, does not equate the presence of cones to an ability to see color. Certain reptile genera possess rods and four spectral classes of cones, each representing one of the five visual pigment families, which suggests, at least, the potential for tetrachromatic color vision (Bowmaker 1998). Although there is no documentation of crocodiles having color vision or the ability to distinguish different shades along our visible color spectrum, American Alligator (*Alligator mississippiensis*) and caiman (*Paleosuchus sp.*) both have blue- and green-sensitive single cones, and *A. mississippiensis* has a type of cone that absorbs red light (Sillman et al. 1991). The potential for these dangerous predators to utilize color vision could prove to be a useful tool in captive management.

The crocodile examined in this study was previously conditioned to approach the yellow disc but had never been exposed to the black disc. We speculate that if the animal had been preconditioned to the black disc, and never rewarded for approaching it, the percentage of times she went to the black disc during the study (19.6%) would have been significantly lower. We hypothesize that she approached the black station to test or determine the outcome of such an action.

The use of color/shade training can be an important management tool when working with multiple animals in an enclosure, particularly when they pose a threat to one another in times of high excitation such as feeding or breeding introductions. Animals are often separated to decrease or avoid these types of dangerous interactions. Color or shade training has been used with several types of animals in managed collections, including horses (Smith and Goldman 1999), parrots (Pepperberg 1987), primates (Cole 1953), seals (Wartzok and McCormick 1978), and crocodilians (Jepsen, pers. comm.). Although evidence for color vision in crocodiles is scant, we examined whether Nile Crocodiles can distinguish different color stations, at minimum on a gray scale. The results of this experiment demonstrate that the crocodile was able to distinguish between the black and yellow stations, choosing yellow, the previously conditioned station, significantly more often than black (33 out of 46 times), regardless of the position of the station. This would be expected since her entire reinforcement history has been with yellow objects.

This Nile Crocodile was able to discriminate between the two discs when presented with a choice. The crocodile could have
noticed the difference on the grey scale, yellow being much lighter than black, or a difference in brightness or luminance (Jacobs 1981). Further studies are needed to provide a more complete understanding of Nile crocodile vision. While the crocodile in this study was able to distinguish between black and yellow, future studies should address different colors that are similar on the grey scale and in brightness. At minimum, this study has indicated that implementing color/shade training and recognition into operant conditioning can be an important method in managing crocodilians, as our subject preferentially chose to station at her previously conditioned color when given a choice.

Advantages of using learned responses to test color or shade recognition include a greater degree of control for the experimenter, the ability to more closely approximate the behavior, and a smaller possibility that the animal will habituate or lose the behavior during testing (Jacobs 1981). Further studies are needed to provide a more complete understanding of Nile crocodile vision, including close examination of the anatomy of the eye. From an animal management perspective, these types of studies can improve captive husbandry; e.g., while feeding multiple animals in an enclosure simultaneously, or separating animals in times of high excitation. Not only will color or shade recognition be a valuable tool for training crocodilians, but it can also create a more visually stimulating environment.

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Folklore Husbandry and a Philosophical Model for the Design of Captive Management Regimes

Keeping reptiles and amphibians is an activity enjoyed by many hobbyists worldwide and is also undertaken by zoos, museums, research organizations, and other professional animal care facilities. The United Kingdom pet trade alone consists of over 500 species of reptiles and amphibians (Tapely et al. 2011), including the importing of 100,000 individual reptiles (Raymont-Dyble 2004). Imports into the European Union include many CITES-listed species and therefore many species of conservation concern (Auliya 2003). Furthermore this trade has seen a continuous increase in both numbers and species diversity of animals as the private keeping of such animals has notably gained popularity over the last 10–20 years (Auliya 2003; Barten 2006; Mader and Mader-Weidner 2006; Tapely et al. 2011; Varga 2004; Wilson 2005). From the perspectives of animal welfare and conservation it is important to develop appropriate husbandry regimes so that these species thrive in captivity, and ideally these would be based on some form of empirical data (Arbuckle 2009; Hosey et al. 2009; Kaumanns et al. 2000; Swaisgood 2007; Wiese and Hutchins, 1994).

There has been a steady stream of both published and unpublished studies that have provided data relevant to the husbandry of captive animals, though these vary greatly in quality and detail (Fidgett 2005; Hosey et al. 2009). The herpetocultural literature is no exception to this general trend, but the level of research interest tends to be somewhat lower than in certain other groups, particularly mammals (Anderson et al. 2008; Arbuckle 2009; Hosey et al. 2009). Some recent changes including the creation of the Herpetoculture section in *Herpetological Review* are a step in the right direction and should help to fuel studies allowing keepers to develop an evidence-based approach to husbandry.

It should be noted however that such an evidence base is only of benefit if it is consulted and integrated into captive management plans. Unfortunately, it is often the case, both in professional and private contexts, that evidence-based husbandry is not used for a variety of reasons including lack of information, a belief (either explicit or implicit) that experience is a better guide than research, and lack of encouragement or ability (real or perceived) to pursue such an approach (Arbuckle 2010; Clauss et al. 2003).

The aim of this paper is to draw attention to the problem of folklore husbandry for exotic animals, specifically reptiles and amphibians, and to encourage professional and amateur keepers alike to strive towards applying evidence-based methods to their husbandry routines.

*What is folklore husbandry and why does it matter?—The term “folklore husbandry” was coined by Arbuckle (2010) to refer to “methods or supposed ‘best practices’ [which] become established without proper evaluation, often justified simply because ‘it has always been done that way’ or for otherwise unknown or poorly substantiated reasons.” In essence, it refers to the widespread practice in many professional institutions and among many private keepers of doing things by tradition and/or uncritically accepting anecdotal husbandry information.*

An important point is whether this actually matters. After all, many species have been kept successfully for many years and often bred using methods that fit the definition of folklore husbandry. Indeed, this may be the primary reason why such methods have been so widely adopted. It is likely that some folklore husbandry methods will prove to be suitable once they have been properly evaluated. Nevertheless there is an inherent issue in that they have not been adequately tested and so should not be blindly accepted as the best nor the only possible solution. Unfortunately that is how folklore husbandry methods are often portrayed, particularly among private keepers (de Vosjoli 2007).

What can result are dogmatic assertions of the “correct” way of doing things that hamper the further development of methods via condemnation of different practices (de Vosjoli 2007). This is an attitude that is to be discouraged on at least two grounds. Firstly, it is problematic to take any current situation and proclaim it to be the best one possible. This is particularly true for the care of reptiles and amphibians, which is still in a stage of frequent development, as it can directly lead to a decrease in motivation to continue to improve husbandry. In fact the basic natural history and ecology of many commonly kept species are poorly known, reducing further our certainty that a given approach is the best one. Secondly, the successful maintenance of a given species is a matter of degree. One method may give good results but another may confer even better results or improved welfare standards. The idea of encouraging a diversity of husbandry practices is not new, and is in fact a key aspect of de Vosjoli’s (2007) “multifactorial model of herpetoculture,” although he does not explicitly highlight the benefits of such a philosophy to continual methodological improvement.

In addition to the ideological disadvantages noted above, folklore husbandry can also incur time and financial costs that are of more practical concern. As an example of the former is the removal of beaks from avian prey or the chopping of foods for herbivorous species. These are time-consuming methods that are used with some regularity but their benefits have always simply been assumed by those who perpetuate their use. As an aside, recent research by Plowman et al. (2008) has shown that chopping foods provides none of the perceived benefits and is actually contraindicated in some situations. This is a good example of a folklore husbandry claim perceived as beneficial for numerous reasons, but that on investigation turned out to be false. Application of the results of Plowman et al. (2008) should alleviate the time cost of food preparation for keepers, and in a professional setting where “time is money” should also present a financial saving.

Furthermore it is clear that some folklore husbandry claims, if refuted, would also provide a direct financial cost saving. Arbuckle (2009) found that providing a gut-loading diet with the aim of adequately supplementing calcium was not a successful...
approach. However, although supported by a review of previous studies his experimental results did not permit statistical evaluation of this, and therefore require further work to provide concrete evidence. If it does prove to be accurate however, dusting with a relatively cheap supplement may give better results than the use of a specific gut-loading diet, many of which are relatively expensive.

Hopefully, I have now shown that it is important to be aware of folklore husbandry, and to adopt a more evidence-based approach to the care of exotic animals such as reptiles and amphibians. I will now provide some more examples of folklore husbandry that require investigation and also highlight a few studies that have evaluated such claims. I will then offer some guidelines in the form of a framework for establishing a husbandry regime. Finally, I will attempt to encourage dissemination of the basic ideas contained here with the aim of improving husbandry practices in both professional and private collections.

Some examples of folk husbandry.—Examples of folklore husbandry are ubiquitous and in many cases are so deeply ingrained that they may not be instantly recognized as such. Nevertheless it might be useful to highlight a few of these so that a better idea of what the subject encompasses can be gained. These are somewhat dominated by nutritional examples, and this reflects both my own background and also that captive feeding appears to be a particularly prominent area of research into animal husbandry. Many examples have not been directly examined and the current availability of data to test them is variable. They represent potential for future directed studies and include a wide range of claims.

Do nutritional products such as supplements and “complete” diets that are marketed in a species-specific fashion give better results than equivalent products marketed in a more general way? Given that the nutritional requirements for reptiles and amphibians are for the most part extrapolated from domestic animals (Allen and Oftedal 1994; Baer 1994), the existence of species-specific marketing raises suspicion as to whether any genuine benefit to these products exists. Studies directed at evaluating whether the performance of a given species is better with products marketed for them than others would provide key information to guide which option to use.

Do particular livefood species represent a better staple diet than others? It is a long held belief that locusts are a better staple prey than crickets, and feeder cockroaches have recently become somewhat of a vogue food item that is touted for a high nutritional value. However, despite much published data on nutrient compositions of various invertebrate prey (Finke 2002; Nijboer et al. 2009; Oonincx and Dierenfeld 2011) the relative benefits in practice have rarely been tested. It is an important step to know the composition of a given prey item, particularly compared to another prey item, but in itself this provides no measure of how an animal will perform on that diet. It has previously been highlighted that direct comparison of prey composition to recommended nutrient intake is notable by its absence from most studies (Arbuckle 2009). Furthermore, there are little or no data on nutrient digestibilities for most reptile and amphibian species currently kept, despite the importance of this information for relative assessment of prey species. It is clear that much information is lacking to answer this question with confidence, but many folklore husbandry claims are made apparently without reference to those data that do exist.

Does the substrate influence general activity level or natural behaviors such as burrowing? Despite the almost ubiquitous use of substrates in enclosures, there has been surprisingly little research investigating whether a particular choice is better than any other. There is a plethora of anecdotal evidence available on the issue. For instance I have used a mix of sand, soil, and a few bark chips in an attempt to create a substrate mimicking the reported natural soils of the Plains Hog-nosed Snake (Heterodon nasicus). Following the change from newspaper to this substrate I noticed an apparent increase in activity and some burrowing behavior. However, like most such reports this represents a purely untested anecdote. Similarly, based on ecological observations and successful results of the entire husbandry regime used, Bennett and Thakoordyal (2003) strongly recommend the use of deep substrates for burrowing in Savannah Monitor (Varanus exanthematicus) enclosures. They particularly advocate soil but mention that others can be used, though the former “is easily the best.” While I would personally agree with this last comment, it would be useful to have data from a comparison of various options, providing a direct evidence base to complement the natural history observations.

Is environmental enrichment necessary for reptiles and amphibians, and if so which form should it take? Enrichment is strongly advocated as a strategy to improve the welfare of captive animals (Swaisgood 2007), but specific considerations for reptiles and amphibians are lacking from most treatments of the subject. The general aim of many enrichment strategies is to increase activity or to encourage natural behaviors (Hosey et al. 2009). The latter aim is probably responsible for the idea that creating naturalistic enclosures promotes good welfare through environmental enrichment (Fábregas et al. 2011). However, often such benefits are assumed rather than empirically tested. Some notable exceptions exist including Hurme et al.’s (2003) demonstration that an enrichment feeding device for dendrobatid frogs resulted in increased activity, but unfortunately such studies are not the rule. On the basis of natural history observations, Rosier and Langkilde (2011) examined whether the provision of a climbing structure is beneficial to a lizard that regularly climbs off the ground (Sceloporus undulatus). In contrast to what might be expected, these authors found no effect on a variety of welfare and behavioral measures. Their study highlighted the non-intuitive nature of providing enrichment, particularly to animals that
are phylogenetically distant from humans. It is a good example of why folklore husbandry claims should be properly tested, not simply accepted because they “make sense.”

Can we take information on natural food groups and convert these straight to a captive diet? In other words, if we know that an herbivorous reptile naturally eats 50% leaves, 30% fruit, and 20% other vegetable matter, can we replicate these proportions in captivity? In this example, it is particularly important to note that, although providing some fruit would probably be acceptable, it would be unwise to uncritically make up 30% of the diet with it. One concern is that fruits more than many other plant parts are highly seasonal (Jordano 2000), and so either the absolute amount or the specific fruits eaten or both are likely to vary considerably over the year. This is very different from a constantly high proportion of fruit in the diet. Furthermore, the nutritional content of the food is more important that the “package” in which the nutrients are given to the animal. Schwitzer et al. (2008) highlighted the fact that domesticated fruits, those cultivated for human consumption and taste buds, have a very different nutrient composition to those found in the wild. It seems that wild fruits are actually more similar to cultivated vegetables. Since it is unlikely that most keepers will be able to source the wild fruits that form the natural diet of their animals, it appears as though substituting at least some of the fruit with vegetables in captivity would be preferred. It is likely that further scrutiny of simple “cut and paste” methods will reveal other cases where amendment is needed. This is a case of a partially evidence-based approach but with some aspects remaining under the umbrella of folklore husbandry.

How should we develop husbandry regimes?—With such a spectrum hanging over our heads, how should we design our husbandry regimes so as to ensure the best approach we can? Because we must look after our animals now, we don’t have the luxury of waiting for a full evaluation of every technique we use and thus we must act with imperfect knowledge. It is certainly true that the reason so many folklore husbandry claims exist is because we simply do not currently have the information to test them—in many cases we have to reserve ourselves to using such methods if we are reasonably confident they will be effective.

The goal should be to implement each part of a given animal’s care with the best information available. This can be conveniently divided into three levels of increasing reliability: folklore, integrated, and direct evidence-based husbandry. The former has already been described and so needs no more definition here. Before discussing the other two approaches I should emphasize that although they are discrete categories, any given regime will undoubtedly incorporate all three. Despite the negative light under which I have cast folklore husbandry, as previously mentioned it is prevalent due to the fact that it works (at least to some degree) in many cases. It thus has a place in husbandry regimes when no better information exists as it can represent a conservative approach providing its limitations are borne in mind.

Integrated husbandry is the most common form of evidence-based husbandry and was the view detailed in Kaumanns et al. (2000). It involves integrating the existing ecological and, more generally, biological information on a given species, and assimilating this into a husbandry plan that attempts to mimic nature. This has important benefits in that such information is available for many species, albeit the quantity and quality will vary widely. However, it suffers from two main constraints.

Firstly, as highlighted above care must be taken to ensure that it is the important parts of the information that are replicated. There is no sense in providing a diet with the same set of food groupings as the natural diet if the nutrient composition is vastly different. Similarly, providing light for many species is not as important as providing the appropriate quality of light to enable biosynthesis of vitamin D in the skin.

Secondly, there may be differences between captive animals and their wild counterparts that impact the husbandry methods used or the evaluation of such methods. The captive environment differs from the natural habitat, and different species will not necessarily respond to this in the same way (Mason 2010). Although such differential responses to captive stressors are perhaps unsurprising, other effects of short- and long-term periods in captivity have been noted that are less intuitive. Captive animals have been shown to diverge from their wild counterparts in behavior (Guyon 2009; McPhee 2003), physiology (Studier and Wilson 1979), and even morphology (Moore and Battenley 2006; Moss 1972; O’Regan 2001), all of which might have implications for the application of field-collected data to captive management.

Integrated husbandry is an excellent way of introducing an evidence-based approach to captive management, especially since data are far more abundant than for direct evidence-based husbandry. It can also act as an information platform from which hypotheses for direct empirical studies can be based. However, it does have some limitations which should be recognized and we should not accept it as the be-all-and-end-of all husbandry methods.

Direct evidence-based husbandry on the other hand represents the gold standard. It involves empirical examination of methods used and ideally their alternatives. An ongoing example of this is work on the use of ultraviolet B (UVB) lamps to create an appropriate lighting regime in captivity. It is beyond the scope of this paper to offer a thorough discussion of the issue, but comparisons of the light output of different bulbs currently in use (Schmidt et al. 2010) combined with a field study on exposure that is used to provide guidelines in captivity (Ferguson et al. 2010) is a commendable endeavor.

Although forming a discrete category of information, direct evidence-based husbandry often follows folklore and integrated husbandry by using them to generate hypotheses. For instance, a direct study might aim to evaluate a folklore husbandry claim or might be designed to test whether a particular integrated strategy does indeed offer the benefits it proposes in captivity. Once empirically examined, such methods can then be discouraged or elevated to the direct evidence-based category.

The main limitation of this approach is the time and financial resources necessary to investigate each technique, and as a result data from direct studies are lacking for most methods currently in use. With time and effort however, we can increase the proportion of any given husbandry regime that results from a direct evidence-based approach.

The FID model.—I have divided husbandry methods into three discrete categories, but emphasized that these categories will often combine in various proportions to result in the complete husbandry regime. This perspective can be represented by a simple visual model, consisting of a ternary diagram with folklore (F), integrated (I), and direct evidence-based (D) husbandry at separate corners (Fig. 1). In this case each corner represents 100% use of that principle.

The strategy illustrated by the FID model is an attempt to push our husbandry regimes as far as possible in the direction of the arrows (Fig. 1a). In no case should we try to move towards F but the ultimate goal is to use a regime that is as close to D.
as possible. If we are close to F then we should look at moving towards either I or D (the side ID represents an evidence-based approach). If we are close to I then the preferred direction would be towards D.

In many cases it is useful to talk about a range of possibilities for the reasons highlighted earlier. Most current designs lie near the side FI (Fig. 1b). This is largely due to the fact that often there are few direct data to rely on, but where this applies we can still attempt to move towards I. Similarly we can denote a range of good approaches which lie along or close to side ID, those which are heavily evidence-based (Fig. 1c).

The ideal scenario would be to have perfect knowledge of the best option (or range of options) to use, and this would lie on corner D (Fig. 1d). Unfortunately this ideal situation is unlikely to be fully realized, certainly for most species and in the near future. However, just because this hypothetical scenario represents 100% direct evidence-based husbandry does not imply that an integrated approach should not apply. As discussed above many direct evidence-based methods are and will be a result of formal tests of integrated methods in captivity. It is not the case that the former will overturn all integrative (or even folklore) husbandry methods, but might often confirm them such that they receive more support and are thus elevated to the status of direct evidence-based.

Finally, it is also worth discussing where anecdotal evidence enters this framework since it has not been explicitly covered here. The reason for this is that anecdotal evidence cannot be allocated to any discrete category and often arises in part from two or even all three categories described here. Nevertheless it is possible to make some comments on its distribution since anecdotes are not expected to occur evenly through the parameter space in the FID model. Anecdotal evidence is expected to be most prevalent near E showing a decreasing presence through I and declining to zero at the ideal point on D (Fig. 1e).

Note that anecdotes are still expected to be moderately common even in regimes that use a high degree of integrated husbandry; this is a result of the limitations of such an approach highlighted above. Note also that I do not regard them as equivalent to folklore husbandry, despite a strong relationship between them. This is because although they share many similarities, a single piece of anecdotal evidence can be influenced by both folklore and evidence-based methods. In contrast, by definition a folklore husbandry technique is not a result of any evidence-based approach, either direct or integrated.

Finally, and in common with folklore husbandry, although we should aim to move away from anecdotal evidence it is not necessarily a bad thing in all cases. For instance, where better approaches are lacking an anecdotal observation can steer the keeper away from poor practices. Furthermore, anecdotal observations can also provide new hypotheses for further examination and in that sense can contribute to development and improvement of husbandry regimes.

A call to action.—I hope that the ideas presented above can be used to improve professional and private captive management regimes. However, this is only likely to happen if they can stimulate new research and implementation of that research. In this vein, I rely on two (non-mutually exclusive) groups of people for this: researchers and keepers.

Researchers with an interest in animal husbandry and welfare should focus on evaluating folklore husbandry claims and providing a direct evidence base for use by keepers. Aside from such direct studies, reviews of the biology and particularly the ecology of a given species would also be useful, if written from a practical perspective aimed at informing husbandry. Such reviews can provide a good background for integrated husbandry regimes and can give recommendations for further studies. Given the practical nature of such research, I believe that the workers involved have a responsibility to make their studies available to those who can apply their findings, wherever possible. The best study on animal husbandry is useless if keepers cannot read it.

Keepers have a responsibility to share their knowledge and ideas. This should not be a problem since it is the sharing of information that leads to folklore husbandry in the first place. However the important point is that keepers should foster an attitude of awareness of different perspectives on husbandry, particularly folklore husbandry. With an understanding of the different categories of methods and their limitations keepers can evaluate the reliability of any information received.

When disseminating information keepers should make an effort to explain why a particular method is done, not simply pass it on in a manner that promotes parroting of poorly substantiated claims. Finally, it is also the responsibility of keepers to retain an open (but critical) mind to new methods. Trying new methods is the only way we can ultimately improve our husbandry practices, particularly if these represent at least a partially evidence-based approach. This is what we as keepers should continually strive to do, for the benefit of all concerned.

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both conditions, during *ad libitum* observations, we recorded the drinking behavior at 1300 h on 20 April 2009 and 1000 h on 25 October 2012 using an SLR camera. In both treatments (with and without the availability of fruit), it was possible to verify the drinking behavior. The behavior consisted of approaching the water source, followed by the animal lowering its head and using its tongue to collect water. Once the water was obtained, the animal raised its head, keeping it perpendicular to the soil surface for up to five seconds. Further, the animals simultaneously kept their front limbs flexed, such that the anterior ventral surface of the body was not in contact with the ground.

Although there are no published data concerning ingestion of water in natural habitat for *A. abaetensis*, these observations suggest that this behavior can be common when water is available in a xeric ecosystem, despite water availability within the diet (e.g., *B. microphyla*). The opportunistic behavior of drinking water has been described in other species of heliophilous lizards (Ribeiro and Freire 2009. Herpetol. Rev. 40:228–229) and it can be considered a convergent behavioral adaptation for lizards occurring in habitat with low water availability.

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**PHRYNOSOMA ASIO** (*Giant Horned Lizard*). **DRINKING BEHAVIOR**. Stereotypical behaviors surrounding water intake in the genus *Phrynosoma* have been well reported (Mayhew and Wright 1971; Peterson 1998; Sherbrooke 1990). Desert lizards like *Phrynosoma* rarely have access to bodies of water and are adapted to take little or no water for long periods of time (Meyer 1966). Herein we report an unknown and unusual water ingestion method in *P. asio*, a horned lizard widely distributed in southwest Mexico (Reeve 1952). On 30 April 2012 we observed a captive female *P. asio* (95 mm SVL) dipping her head, neck, and forelimbs into the water trough of her terrarium while making light and leisurely sucking motions with her throat (Fig. 1). We also recorded the behavioral display time, having a duration of 7 minutes and a repeat of the same behavior the next day with a duration of 5 minutes. The knowledge of this horned lizard’s ecological and ethological aspects are relatively little documented (Pianka and Parker 1975). We thank Oscar Avila Morales, Jonathan Vazquez Sanchez, and Jose Antonio Rosas by supporting us in the field and Tania Raya Garcia for support in caring for the specimen in captivity.

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**SQUAMATA — SNAKES**

**CROTalus OREGANUS OREGANUS** (*Northern Pacific Rattlesnake*). **LONGEVITY**. At a local non-profit education center in Mather, California, USA, we believe we have one of the oldest captive rattlesnakes on record. During the spring of 1982, a small juvenile male *Crotalus oreganus oreganus* was collected in Auburn, California, USA, by a student attending Placer High School. It was presented to Placer High biology teacher, Douglas Stryker, who kept the specimen as an educational classroom pet. The snake was kept in the classroom for 31 years. Recently Mr. Stryker retired, and in November 2012 the snake was given to a local non-profit, Sacramento Splash, and now resides in the Splash Education Center.

*Crotalus oreganus* are typically born in the fall, but do not emerge until the following spring (Diller and Wallace 1984). As this specimen of *C. o. oreganus* was collected as a small juvenile in the spring, it is believed to have been born in the fall of 1981. This makes this *C. o. oreganus* over 31 years old at the time of submission (April 2013). We believe this is the oldest *C. oreganus* on record and among the oldest *Crotalus* that have been recorded.

The average lifespan for *C. oreganus* in the wild is approximately 20 years (Fitch 1949). A captive *C. o. oreganus* that was recorded at 22 years, 7 months is reported by Slavens (http://www.pondturtle.com/lstnaked.html#Crotalus). Still, no records document an individual *C. o. oreganus* older, or even close to the age of the snake reported herein.

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**MASTICOPHIS MENTOVARIUS** (*Neotropical Whipsnake*). **REPRODUCTION**. *Masticophis mentovarius* is a neotropical colubrid that ranges from northern Mexico to northern South America (Lemos-Espinal and Smith 2007. Amphibians and Reptiles of the State of Chihuahua, Mexico. CONABIO-UNAM. 178 pp.). The reproductive mode is oviparous and, at least in a population in Veracruz, Mexico, wild females are gravid from April to May (Pérez-Higareda et al. 2007. Serpientes de la Región de los Tuxtla, Veracruz, México. UNAM. 189 pp.). Eggs have been reported to be laid inside abandoned burrows or cracks in the ground (Vázquez and Quintero 2005. Anfibios y Reptiles de Aguascalientes. CIEMA-CONABIO. 197 pp.). In populations studied, the eggs are white and are laid in clutches of 17–20, have a granular surface, are not adhesive to one other, and measure 46–64 mm

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**Fig. 1** Adult Female *Phrynosoma asio* exhibiting their water intake behavior.
The herpetology laboratory at Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, supports a diverse live collection of reptiles and amphibians. The majority of them are Mexican species. The collection includes *Masticophis* spp., including two individuals of *M. mentovarius*. Here we report reproductive information about this species, based on our observations in recent years, including timing of copulation events, clutch production, hatchings, and egg sizes.

Between 1991 and 2000, four copulation events were recorded, two during February and two during March. Four clutches have been laid, two in April and two in July (9, 7 and 2, 5 eggs respectively). Two clutches have hatched during June (4 and 5 hatchlings respectively); on this last clutch, the eggs (N = 5) had a mean mass of 5.14 g, mean length of 42.8 mm, and mean width of 16.4 mm.

During 2008 and 2009 we recorded two additional reproductive events. In April 2008, in an exhibition enclosure (165 × 165 × 65 cm), copulation was observed; temperature was 28–30°C and relative humidity (RH) was 50–70%. The male (1330 mm SVL) came from the state of Morelos and the female (1180 mm SVL) was from the state of Guerrero, Mexico. On 7 July 2008, the female laid a clutch of 11 eggs, of which six were judged to be in good condition. Those eggs were incubated at 28–30°C and a RH of 50–70%. The mean weight of the eggs was 11.30 g. Two hatchlings were found on 13 and 14 August (mean mass 7.73 g, mean SVL 221.1 mm). On 19 August the rest of the eggs were discovered in poor condition and four snakes were found dead inside the eggs (mean mass 5.74 g, mean SVL 194.5 mm).

The second observation was on 13 February 2009. The same pair of *M. mentovarius* produced a clutch of nine eggs (mean mass 13.83 g, mean length 49.9 mm, and mean width 21.4 mm). The eggs were infertile.

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During the fall of 2011, MZ collected a large adult female *T. radix* along a busy highway in Edmunds Co., South Dakota, USA. The female was kept in an enclosure with an adult male *T. radix* and both were hibernated during the winter. The pair was kept in the enclosure until early August 2012 at which time the male was moved into a separate enclosure in anticipation of the female giving birth. Starting on the evening of 9 August 2012, the female gave birth to one unfertilized ovum, six stillborn, one malformed, and 90 seemingly healthy offspring (Fig. 1). Three of the stillborn and the single live malformed offspring displayed bicephaly. The production of 97 offspring represents the largest brood for *T. radix* documented to date.

We thank Erica P. Hoaglund and John J. Moriarty for reviewing this note.

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Ranaviruses are an emerging pathogen responsible for numerous amphibian die-offs throughout Europe and North America (Miller et al. 2011). In the southeastern United States, local anuran die-offs due to ranavirus have been observed (Green et al. 2002; Hoverman et al. 2012; Todd-Thompson 2010), and suggested to contribute to local species declines (Gray et al. 2009a). The southern Appalachian Mountains have one of the greatest global diversities of plethodontid salamanders (Dodd 2004), and disease emergence could have devastating impacts on community structure and ecosystem function (Whiles et al. 2006). Ranavirus infections have been reported in 14 species of plethodontid salamanders occurring in the southern Appalachian Mountains (Miller et al. 2011). Initial surveys for ranavirus infections have focused on the Great Smoky Mountains National Park (81% prevalence; Gray et al. 2009b), which is known for high species richness of plethodontid salamanders (Dodd 2004). However, much of the remainder of the southern Appalachian Mountains has not been investigated except for a single study in the Ridge and Valley physiographic province of Wise County, Virginia (33% prevalence; Davidson and Chambers 2011). Many other Appalachian peaks have high plethodontid salamander richness and include many species with limited distributions, but the occurrence of ranavirus in these communities is unknown.

We sampled salamanders in the Mount Rogers National Recreation Area (MRNA), Virginia from Whitetop and Beech Mountains (Grayson, Smyth, and Washington counties). Many species reach the extreme northern limit of their range on these mountains with 15 species of plethodontid salamanders found on Whitetop Mountain alone (Organ 1991). Our sampling focused on five species with aquatic larval stages (i.e., complex life cycle), which have shown higher prevalence of ranavirus infection (Gray et al. 2009b), and four terrestrial-breeding species with direct development. Nine species that we targeted for sampling included: Northern Dusky (Desmognathus fuscus), Seal (D. monticola), Blue Ridge Dusky (D. orrestes), Northern Pygmy (D. organi), Black-bellied (D. quadraramaculatus), Blue Ridge Two-lined (Eurycea wilderae), Northern Gray-cheeked (Plethodon montanus), Ravine (P. richmondii), and Weller’s (P. welleri) salamanders. In Virginia, Weller’s, Northern Pygmy, Blue Ridge Dusky, and Blue Ridge Two-lined salamanders are listed as species of greatest conservation need (Virginia Department of Game and Inland Fisheries 2005).

Salamanders were captured along transects from June to August 2008 and May to August 2009 from Byars Creek (1158–1311 m elev.; 36.62755°N, 81.58903°W), Whitetop Creek (1158–1615 m elev.; 36.64016°N, 81.60040°W), Dells Branch (945–1585 m elev.; 36.64774°N, 81.60254°W), Beech Mountain (956–1097 m elev.; 36.63362°N, 81.63030°W), and Daves Ridge (1128–1433 m elev.; 36.6475°N, 81.59185°W). Each transect was positioned perpendicular to the elevational gradient centered on either a stream or ridge line. We searched for salamanders on each side of the transect for one person-hour (~150 m) at every 30.5 m of elevation by turning all cover objects. We placed each captured salamander in individual 1.2-liter plastic bags. We used sterile forceps to remove a small tail section along the natural break point and placed each sample in a sterile microcentrifuge tube with 99% reagent grade isopropyl alcohol. We used a different set of sterilized forceps for each individual tail sample. Between sampling events, forceps were autoclaved to destroy remnant DNA.

We extracted genomic DNA from tail samples using a DNeasy Blood and Tissue Kit (Qiagen Inc., Valencia, California), and used a Qubit™ fluorometer to quantify the concentration of genomic nuclear DNA from tail samples. Samples from 2008 (N = 99) were extracted and quantified at the Diagnostic and Investigational Laboratory in the College of Veterinary Medicine at the University of Georgia (UGA). In 2009, we extracted and quantified the 2009 samples (N = 320) in the Center for Wildlife Health at the University Tennessee (UT). Real-time qPCR was performed using the identical primers and protocol of Gray et al. (2012). The qPCR was conducted using a SmartCycler system (Cepheid, Sunnyvale, California) for 2008 samples and an ABI 7900HT PCR system (Live Technologies Corp., Carlsbad, California) was used for 2009 samples. Controls included two positive controls (cultured virus and known positive tadpoles) and two negative controls (water and known negative animal). The qPCR was run in
Table 1. Ranavirus prevalence in salamander communities inhabiting Whitetop Mountain (Grayson, Smyth, Washington counties), Virginia, USA.

<table>
<thead>
<tr>
<th>Species</th>
<th>No. infected / total no. sampled</th>
<th>Prevalence of infection (95% confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desmognathus fuscus</td>
<td>1 / 11</td>
<td>0.09 (0.02–0.37)</td>
</tr>
<tr>
<td>Desmognathus monticola</td>
<td>2 / 22</td>
<td>0.09 (0.03–0.28)</td>
</tr>
<tr>
<td>Desmognathus orestes</td>
<td>3 / 145</td>
<td>0.02 (0.01–0.05)</td>
</tr>
<tr>
<td>Desmognathus organi</td>
<td>3 / 70</td>
<td>0.04 (0.01–0.12)</td>
</tr>
<tr>
<td>Desmognathus quadramaculatus</td>
<td>1 / 32</td>
<td>0.03 (0.01–0.16)</td>
</tr>
<tr>
<td>Eurycea wilderae</td>
<td>0 / 5</td>
<td>0 (0–0.44)</td>
</tr>
<tr>
<td>Plethodon montanus</td>
<td>3 / 101</td>
<td>0.03 (0.01–0.08)</td>
</tr>
<tr>
<td>Plethodon richmondi</td>
<td>0 / 3</td>
<td>0 (0–0.56)</td>
</tr>
<tr>
<td>Plethodon welleri</td>
<td>1 / 30</td>
<td>0.03 (0.01–0.17)</td>
</tr>
<tr>
<td>Total</td>
<td>14 / 419</td>
<td>0.03 (0.02–0.06)</td>
</tr>
</tbody>
</table>

duplicate and a $C_v$ value ≤ 30 was deemed positive, according to equipment optimization at UGA and UT.

Our results document the first known presence of ranavirus infection in amphibians of the MRNA. Salamanders sampled and all other salamanders observed did not display external signs of ranavirus infection such as swelling or ulcerations (Miller et al. 2011). We detected ranavirus in seven salamander species (Table 1)—four of the species were first-time detections: Weller's, Northern Pygmy, Blue Ridge Dusky, and Northern Gray-cheeked (Miller et al. 2011). Ranavirus prevalence ranged from 3–9% within species, and was 3% among all species that tested positive (Table 1). Infected salamanders were found between elevations of 945–1554 m, and along all transects except Daves Ridge. Species with a more aquatic life history (D. fuscus and D. monticola) had the highest prevalence of infection (9%), as reported by Gray et al. (2009b). However, there was no association between larval life history (aquatic larvae or terrestrial direct development) and infection status ($\chi^2 = 0.01, p = 0.920$), which may be a consequence of low overall prevalence. Additionally, there was no association between sampling years ($\chi^2 = 0.196, p = 0.658$).

Our low detection of ranavirus infection could be partly influenced by the type of tissue collected. Gray et al. (2012) demonstrated that tail clips produced false-negative results for 20% of tail samples in American Bullfrog (Lithobates catesbeianus) tadpoles when compared to liver tissue samples and suggested that false negatives could relate to the sensitivity of the amphibian host. Even with the possibility of a 20% false detection rate, salamanders from the MRNA appear to have lower ranavirus prevalence than salamanders from the Great Smoky Mountains National Park (81%; Gray et al. 2009b) and Wise County, Virginia (33%; Davidson and Chambers 2011). Future research could include histological analyses to reduce the potential of false negatives (Gray et al. 2012) as well as genetic sequencing to identify the strain(s) of ranavirus present in the MRNA.

We documented ranavirus infections occurring in secluded areas (often ≥ 300 m from trails, roads, or other areas of public activities) of the MRNA, indicating that this pathogen is not always associated with human-impacted sites (Gray et al. 2007). We documented infections in four additional species of plethodontid salamanders, including rare species. Weller’s Salamanders are an IUCN (2008) Red List species, and our positive results from this species are a concern suggesting that further monitoring may be warranted. These results provide additional evidence that ranavirus could be distributed throughout the Southern Appalachian Mountains. In the MRNA, ranavirus was found to infect both rare and more abundant salamanders as well as those with aquatic or terrestrial embryonic development, suggesting that ranavirus is not selective and any southern Appalachian salamander could be at risk. Additionally, six other species of plethodontid salamanders, Eastern Newts (Notophthalmus viridescens), and five anuran species are found in the MRNA, but were not part of this study (Hamed, unpubl. data). Given the tendency for anurans to be more susceptible to ranavirus than salamanders (Hoverman et al. 2011), frogs may be important reservoirs and amplifying hosts for ranavirus (Paull et al. 2012). It would be prudent to include all amphibian species in future monitoring designs to provide a more comprehensive understanding of ranavirus prevalence in the MRNA, and to increase the likelihood of identifying amplifying species and disease hotspots (Paull et al. 2012).

Acknowledgments.—This research was completed with funds provided by the Virginia Department of Game and Inland Fisheries through a State Wildlife Grant from the U.S. Fish and Wildlife Service and additional funding from the University of Tennessee Institute of Agriculture. We extend special thanks to James and Della Organ for providing sampling locations and guidance. We thank Gary Poe and Brian Parks for assistance in collecting and Becky Hardman, Kate Carpenter, and Lisa Whittington for assistance with molecular testing and extraction. Additionally, we are grateful to the MRNA staff for project assistance and to many private land owners for access to our study sites. This manuscript was improved with comments from Trang Nguyen, Dede Olson, and two anonymous reviewers. All sampling was approved by the Virginia Department of Game and Inland Fisheries (Scientific Collection Permit #41396) and followed UT Institutional Animal Care and Use Committee protocol #2084-0412.

Literature Cited


Although the amphibian chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), has been well-studied across the United States, there are still several regions where little is known regarding its presence or prevalence (Oullet et al. 2005; www.Bd-maps.net). Currently, there is no information regarding *Bd* occurrence in South Dakota, yet of the 15 amphibian species known to reside in South Dakota, many have been documented as hosts to *Bd* in other states (Oullet et al. 2005; Woodhams et al. 2008). Additionally, neighboring states have documented the presence of *Bd* in these and other species (Hossack et al. 2010; Rodriguez et al. 2009). To help fill the knowledge gap for South Dakota, we sampled for the occurrence of *Bd* at several locations across the state.

We opportunistically sampled amphibians for *Bd* in seven regions of South Dakota (Fig. 1) from April 2010–August 2011. Using nylon swabs, amphibians were rubbed along the ventral side of their hands, feet, legs and abdomen five times each for a total of 25 swipes per amphibian. To prevent cross contamination, animals were handled and swabbed separately, and swabs were stored individually in tubes. Samples were kept on ice until brought to a molecular biology facility at the University of South Dakota where they were kept at 0°C until processed.

DNA was extracted from swabs using the included protocol for DNeasy® spin column kits (Qiagen, Inc., Germantown, Maryland). Each sample was run using an Applied Biosystems StepOne Plus quantitative PCR machine (Applied Biosystems, Inc., California) according to the fast qPCR protocol as described by Kerby et al. (2013). Each sample was run in triplicate and was considered positive if at least two of the three replicates were positive. A negative control was placed on each plate and the *Bd* standards utilized were from CSIRO laboratories in Australia. The pathogen load estimates are provided in zoospore genome equivalents per swab.

**Batrachochytrium dendrobatidis** in South Dakota, USA Amphibians

**Fig. 1.** Locations sampled for *Batrachochytrium dendrobatidis* (*Bd*) within South Dakota, USA. Blue dots represent sites with *Bd* detections.
A total of 1525 amphibians of 10 species were swabbed for Bd during the study (Fig. 1). Bd was detected on 90 animals (6%) in five different species, and in 5/7 regions sampled (Table 1). One site had particularly high Bd occurrence, with 64 of 68 Pseudacris maculata being Bd-positive near Vermillion, South Dakota. There was no mortality observed at this site, nor were any symptomatic individuals detected.

As expected, Bd was present in most of our sampled sites in South Dakota. We found Bd in half the species examined, and in all regions with > 30 samples taken (Table 1). There was no mortality observed at this site, nor were any symptomatic individuals detected.

Table 1. Infection status and pathogen load (# zoospores/positive swab) of species by each region sampled. Fractions represent the number of infected/tested. Average pathogen load estimates for positive values are provided in parentheses. MRV- Missouri River Valley in southeastern part of the state; N- Northern region; NE- Northeastern region; Pierre- Pierre National Grasslands; Black Hills- Black Hills National Forest; Pine Ridge- Pine Ridge Reservation; Custer- Custer State Park.

<table>
<thead>
<tr>
<th>Species</th>
<th>MRV</th>
<th>N</th>
<th>NE</th>
<th>Pierre</th>
<th>Black Hills</th>
<th>Pine Ridge</th>
<th>Custer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithobates blairi</td>
<td>1/428</td>
<td>0/3</td>
<td>1/28</td>
<td>0/34</td>
<td>2/62 (2.29)</td>
<td>0/9 (1.15)</td>
<td>7/37 (8.15)</td>
<td>11/599 (5.4)</td>
</tr>
<tr>
<td>Lithobates pipiens</td>
<td>0/55</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0/55 (0%)</td>
</tr>
<tr>
<td>Anaxyrus woodhousii</td>
<td>3/343 (2.28)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0/1 (0.15)</td>
<td>3/344 (2.28)</td>
</tr>
<tr>
<td>Acris crepitans</td>
<td>2/102 (110)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2/102 (110)</td>
</tr>
<tr>
<td>Pseudacris maculata</td>
<td>68/249 (638)</td>
<td>-</td>
<td>1/12</td>
<td>1/30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>70/291 (24%)</td>
</tr>
<tr>
<td>Hyla chrysoscelis/versicolor</td>
<td>0/53</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0/53 (0%)</td>
</tr>
<tr>
<td>Spea bombifrons</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0/15 (0.48)</td>
<td>-</td>
<td>0/16 (0.11)</td>
<td>0/16 (0%)</td>
</tr>
<tr>
<td>Ambystoma tigrinum</td>
<td>0/6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0/6 (0.35)</td>
<td>-</td>
<td>0/12 (0.15)</td>
<td>0/12 (0%)</td>
</tr>
<tr>
<td>Anaxyrus cognatus</td>
<td>4/100 (0.35)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4/100 (0.35)</td>
</tr>
<tr>
<td>Anaxyrus hemiophrys</td>
<td>-</td>
<td>0/2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0/2 (0.11)</td>
<td>0/2 (0%)</td>
</tr>
<tr>
<td>Total by region</td>
<td>7/1287 (535)</td>
<td>0/6</td>
<td>1/28</td>
<td>1/46</td>
<td>3/90 (1.58)</td>
<td>0/30 (8.15)</td>
<td>7/39 (8.15)</td>
<td>90/1525 (5.9%)</td>
</tr>
</tbody>
</table>

Acknowledgments.—We thank our field crew, in addition to the field assistance from several biologists across the state. Samples were received from D. Swanson, S. Martin, R. Mars, A. Kiesow, S. Miller, B. Smith, M. Miller, P. Lynch, and A. Higa; and field sampling was aided by R. Verheul, E. Weisser, T. Snyders, K. Wert, C. Duhon, and D. Quist. This research was supported by funding from a Wildlife Action Plan grant from South Dakota Fish, Game and Parks, and qPCR was performed on instrumentation obtained from NSF funding MRI-0923419.

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Amphibian Chytrid Fungus in Woodhouse’s Toads, Plains Leopard Frogs, and American Bullfrogs along the Platte River, Nebraska, USA

We recently documented the first published record of the fungal pathogen *Batrachochytrium dendrobatidis* (chytrid) in Nebraska, USA, where we detected a high prevalence of chytrid in American Bullfrogs (*Lithobates catesbeianus*) in off-channel aquatic habitats on an island of the Platte River (Harner et al. 2011). This pathogen causes the disease chytridiomycosis (Longcore et al. 1999), and widespread amphibian mortality from infection is contributing to declines and regional extirpation of amphibians worldwide (Berger et al. 1998; Collins 2010; Daszak et al. 1999; Lips et al. 2006). We were concerned by the high prevalence of chytrid in American Bullfrogs on this island because American Bullfrogs have been introduced to the region (Fogell 2010), and they may negatively affect native amphibians through both direct (e.g., predation) and indirect (e.g., competition, disease transmission) interactions. Loss of native amphibians is of conservation concern for a number of reasons, notably the loss of biodiversity (e.g., Collins 2010) and alterations to ecosystem structure and function (Whiles et al. 2006). Along the Platte River, amphibian declines also have potentially negative consequences for an endangered migratory bird, the Whooping Crane (*Grus americana*), which relies on the river and surrounding wetlands for critical habitat during spring and autumnal migrations (USFWS 1978) and preys upon frogs during migratory stops (Geluso et al., in press).

Objectives of our study were to spatially extend sampling for chytrid to other sites and species along the central Platte River. In our prior survey we also sampled native Plains Leopard Frogs (*Lithobates blairi*) and Woodhouse’s Toads (*Anaxyrus woodhousii*) and did not detect chytrid, but our sample sizes were low (N = 20 and 21, respectively) and from a small geographical area, so we may have failed to detect infection (Skerratt et al. 2008). Therefore, in this survey we focused on obtaining sample sizes of greater than 40 individuals for each species and sampled several locations to determine whether chytrid was present in native species and at multiple locations along the central Platte River in Nebraska.

We sampled amphibians along a 100-km reach of the Platte River in central Nebraska (Fig. 1) on Jeffrey Island (40.6901°N, 99.5956°W) and Cottonwood Ranch (40.6868°N, 99.4784°W) in Dawson County; Blue Hole East (40.6836°N, 99.3758°W) in Kearney County; Dippel (40.7036°N, 98.7950°W) in Buffalo County; and Shoemaker Island (40.7920°N, 98.4620°W) in Hall County. Property ownership was as follows: Jeffrey Island (Central Nebraska Public Power and Irrigation District), Cottonwood Ranch, and Shoemaker Island (The Crane Trust). Sampling effort was more extensive on Jeffrey Island to compare this more western portion of the river reach to the previously sampled Shoemaker Island (Harner et al. 2011).

Amphibians were sampled from a variety of habitats including river channels, sloughs (natural and created), ponds, borrow pits, stock tanks, and uplands. Sampling occurred in autumn 2011 (Shoemaker Island) and spring-summer 2012 (all sites).

Individuals were captured by hand, and researchers wore disposable gloves to minimize contamination and changed gloves between each capture. After capture we rubbed a sterile swab (Fisherfinest® Dry Transport Swab; Fisher HealthCare, USA) across the abdomen, throat, inner thighs, webbing of toes, and mouthparts. Swabs were air-dried, stored frozen, and shipped frozen to the University of South Dakota for testing.

Samples were analyzed for chytrid with real-time Taqman PCR assay. DNA was extracted from swabs using Qiagen DNEasy Blood and Tissue spin column kits according to manufacturer’s protocol. Pathogen load per swab was determined with quantitative PCR on a StepOnePlus machine (Applied Biosystems). Reactions were run based on a standard protocol described in Kerby et al. (2013). Each plate contained a standardized dilution

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series of quantified zoospore numbers to use as a standard curve. A negative control also was included on every plate. Samples were run in triplicate, and positive values were averaged to determine a final estimated pathogen load for each swab.

The study area experienced prolonged drought in 2012 with an onset of abnormally dry conditions by late May that transitioned to extreme drought by the end of August (droughtmonitor.unl.edu; accessed 30 November 2012). As a result, virtually no temporary ponds were present, hindering our ability capture any Plains Spadefoots (*Spea bombifrons*) and restricting our captures of Boreal Chorus Frogs (*Pseudacris maculata*) to only three. Both species rely on temporary ponds and both are known from the region (Ballinger et al. 2010, Fogell 2010).

We sampled a total of 163 individuals of four species for chytrid (Table 1). Five Plains Leopard Frogs were sampled from Shoemaker Island on 25 October 2011 prior to winter, whereas all other individuals were sampled from 9 May to 21 August 2012. Four Plains Leopard Frogs were metamorphs, and all other individuals were adults.

Across sites, prevalence of chytrid was 35% for Woodhouse’s Toads, 18% for American Bullfrogs, and 39% for Plains Leopard Frogs (Table 1). None of the Boreal Chorus Frogs tested positive. One Plains Leopard Frog metamorph tested positive. For positive samples, the pathogen load (number of zoospore equivalents per swab) ranged from 0.87-6560 (median = 51) in Woodhouse’s Toads; 0.02-84 (median = 2) in American Bullfrogs; and 0.04-8139 (median = 27) in Plains Leopard Frogs.

Our findings add to the geographical extent and list of species infected by chytrid in central Nebraska along the Platte River. Results confirm presence of chytrid in invasive American Bullfrogs as well as in two native species, Woodhouse’s Toads and Plains Leopard Frogs, across this 100-km reach of river. Prevalence of chytrid was moderate (30%) across species sampled, but pathogen load did not exceed levels reported as a threshold for mass mortality in other species (~10,000 zoospore equivalents per swab; Vredenburgh et al. 2010). Prevalence of chytrid was lower in American Bullfrogs from Shoemaker Island in this study (25%) compared to our 2010 survey (41%; Harner et al. 2011). This difference may be linked to climatic differences between years, as 2010 had above-average precipitation (4th wettest over 74-year record), whereas 2012 had below-average precipitation (4th driest over 74-year record) measured at Grand Island, NE (www.ncdc.noaa.gov; accessed 30 November 2012). The influence of drought on chytrid mycosis is currently debated, but some argue that dry conditions may decrease prevalence and severity of chytrid (Kriger and Hero 2009). Regardless, presence of chytrid in invasive American Bullfrogs is a concern because they are nonclinical carriers of chytrid (Daszak et al. 2004; Garner et al. 2006; Schloegel et al. 2009).

Seasonality of chytrid infection was not a focus of this study, but trends emerged that warrant further investigation. Prevalence of chytrid in Plains Leopard Frogs from Shoemaker Island went from 1 in 5 to 4 in 5 individuals between autumn and spring, and prevalence of chytrid was higher in May than subsequent months in 2012 across sites. These trends potentially suggest that Plains Leopard Frogs may be at an elevated risk in spring. Other studies have observed peaks in chytrid prevalence and pathogen load in early spring (Gaertner et al. 2012; Kriger and Hero 2007a; Retallick et al. 2004), as well as a negative relationship between temperature and chytrid prevalence (e.g., Kriger and Hero 2007a). From a conservation standpoint, availability and abundance of Plains Leopard Frogs in March and April may be important for foraging Whooping Crane during migratory stopovers in the region (Geluso et al., in press).

There is need for ongoing monitoring of chytrid along the central Platte River to capture variation across habitats as well as through time. Along with the seasonal patterns noted above, we saw a trend of varying incidences of infection among different habitats (data not presented due to small sample size), though more systematic sampling is required to draw inferences about prevalence among different habitats. Other studies have detected an effect of local environmental conditions on chytrid, such as greater prevalence in permanent compared to ephemeral water bodies (Kriger and Hero 2007b). A better understanding of the seasonality and influence of habitat on the pathogen may help resource managers target conservation measures to reduce the threat of chytrid to native amphibians along the central Platte River, and thus help maintain the natural structure of the interconnected aquatic and terrestrial food webs along these flood plains.

Acknowledgments.—We thank Central Nebraska Public Power and Irrigation District (CNPPID) and the Crane Trust for funding; Mark Peyton (CNPPID) and Jim Jenniges (Nebraska Public Power District) for providing information about and access to the western study sites; the laboratory of Jacob Kerby at the University of South Dakota for conducting analyses; Keith Geluso for comments on an earlier version of the manuscript; and Alexandra Frohberg, Jamie Jones, Liz McCue, Evan Suhr, and Angelina Wright for assistance with sampling. Amphibians were studied under authorization of the Nebraska Game and Parks Commission (Scientific and Educational Permit issued to Keith Geluso).

**Table 1. Batrachochytrium dendrobatidis (Bd) prevalence (no. Bd-positive individuals/total no. individuals sampled) at sites along the central Platte River, Nebraska, USA.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Site</th>
<th>Woodhouse’s Toad</th>
<th>American Bullfrog</th>
<th>Plains Leopard Frog</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2011</td>
<td>Shoemaker Island</td>
<td>—</td>
<td>—</td>
<td>1/5</td>
</tr>
<tr>
<td>May 2012</td>
<td>Jeffrey Island</td>
<td>0/2</td>
<td>6/18</td>
<td>7/11</td>
</tr>
<tr>
<td></td>
<td>Dippel</td>
<td>—</td>
<td>1/3</td>
<td>10/13</td>
</tr>
<tr>
<td></td>
<td>Shoemaker Island</td>
<td>—</td>
<td>2/8</td>
<td>4/5</td>
</tr>
<tr>
<td>Jun 2012</td>
<td>Jeffrey Island</td>
<td>0/5</td>
<td>0/11</td>
<td>1/8</td>
</tr>
<tr>
<td>Jul 2012</td>
<td>Jeffrey Island</td>
<td>10/17</td>
<td>—</td>
<td>0/8</td>
</tr>
<tr>
<td></td>
<td>Cottonwood Ranch</td>
<td>4/14</td>
<td>0/3</td>
<td>3/14</td>
</tr>
<tr>
<td>Aug 2012</td>
<td>Jeffrey Island</td>
<td>—</td>
<td>1/12</td>
<td>0/2</td>
</tr>
<tr>
<td></td>
<td>Blue Hole</td>
<td>0/2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>14/40 (35%)</td>
<td>10/55 (18%)</td>
<td>26/66 (39%)</td>
</tr>
</tbody>
</table>

**Literature Cited**


Herpetological Review 44(3), 2013
The chytrid fungus (Batrachochytrium dendrobatidis) is a potential carrier of chytridiomycosis, an emerging fungal disease of amphibians. Herpetol. J. 14:201–207.

In the United States, Bd distribution reports are being added frequently (http://www.bd-maps.net/). In the United States, Bd occurrence among populations of Acris crepitans blanchardi in Texas, USA. Herpetol. Rev. 43:274–278.


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Chytrid fungus in American bullfrogs (Lithobates catesbeianus) along the Platte River, Nebraska, USA. Herpetol. Rev. 42:549–551.


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AMPHIBIAN DISEASES

Herpetological Review 44(3), 2013


**Herpetological Review, 2013, 44(3), 461–464.**

Amphibian Populations in Brazos River Basin, Texas, Show No Evidence of Bd Infection

Discovered and described only a decade ago (Longcore et al. 1999), amphibian chytrid fungus Batrachochytrium dendrobatidis (Bd) has rapidly expanded its range, and new geographic distribution reports are being added frequently (http://www.bd-maps.net/). In the United States, Bd infection has been documented in amphibian populations in nearly all of the states (Olson et al. 2013). However, except for two studies, the state of Texas remains under-surveyed for this pathogen. Gaertner et al. (2009) reported Bd occurrence in individuals of five salamander species along parts of the Colorado and Guadalupe River basins in Central Texas. Saenz et al. (2010) reported incidences of Bd infection in five anuran and one plethodontid species spread across forested areas in Eastern Texas. To address the lack of surveys in the Brazos River basin of Texas, we sampled amphibians for Bd from two disjunct areas along the watershed (Fig. 1).

In August–September 2011 and April–May 2012 we sampled from urban modified playa wetlands within the city of Lubbock, located in northwest Texas near the upper reaches of the Brazos River basin. Lake Waco wetlands, situated in the central portion of the Brazos River basin in central Texas, were sampled in May–July 2012. Areas of study were under severe drought in the year 2011. However, sampling in 2012 for Lubbock and Lake Waco wetlands (sampled only in 2012) was carried out earlier in the year when temperatures were cooler and rain events facilitated breeding aggregations.

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Post-metamorphic amphibians were swabbed 20-25 times along the ventral side of their abdomen, legs, and between their toes following established field protocol (Brem et al. 2007). Additionally, we also took scrapes from tadpole mouthparts using wooden toothpicks (procedure described by Retallick et al. 2006) while sampling in 2011 as very few post-metamorphic amphibians were being observed in Lubbock during this year. Amphibians were swabbed during call/visual surveys conducted following rain events and tadpole mouthparts were scraped during dipnet surveys conducted during the day in the following two weeks.

Overall, we sampled 76 individuals from Lubbock and 51 individuals from Lake Waco wetlands comprising a total of ten anuran and one caudate species (Table 1). Collected swabs and scrapes were stored in 70% ethanol (Brem et al. 2007) and placed in temperatures at or below –20°C until further analysis. Because swabs were stored in cold temperatures there was no danger of degradation (Hyatt et al. 2007; K. Kriger, pers. comm.). In March 2013, swabs and scrapes from Lubbock, pooled by species, location, and year, were sent to Pisces Molecular LLC in Boulder, Colorado. Total DNA was extracted from all samples using a spin-column DNA purification procedure; these were then assayed for the presence of Bd by a modified version of the procedure described by Annis et al. (2004) which increases sensitivity and specificity for Bd detection at the laboratory (J. Wood, pers. comm.). Each PCR run included the following controls: positive DNA-DNA prepared from a laboratory culture of Bd Strain JEL 270, negative DNA-DNA prepared from an uninfected amphibian, no DNA (control)-water in place of template DNA (information from this paragraph has been directly adapted from test results for the PCR assay from Pisces laboratory).

Samples from Waco were tested for the presence of Bd at Texas Tech University in Lubbock using the DNA extraction method and subsequent polymerase chain reaction protocol described by Annis et al. (2004). Samples were pooled in groups of ten, and DNA was extracted using the PrepMan Ultra reagent according to supplier protocol (Life Technologies, Grand Island, New York). We then used the Bd-specific primers Bd1a and Bd2a to amplify any Bd DNA present from the samples. In addition, we also ran a positive control containing Bd genomic DNA and a negative control containing sterile water only. Following PCR analysis, we ran the products on a 1.2% agarose gel and included a 1 kb DNA ladder in order to determine the size of any amplified products. GelStar nucleic acid gel stain (Cambrex Bio Science Rockland, Inc. Rockland, Maine) was used to visualize bands.

Overall, we collected 76 swabs (including tadpole mouthpart scrapes) from Lubbock and 51 swabs from Lake Waco wetlands. All 127 swabs tested negative for the presence of Bd. Because our sample size safely exceeds that recommended by Skerratt et al. (2008) for achieving 95% certainty, we can reasonably infer that Bd infection has either not spread into, or remains exceedingly rare, in urban wetlands in Lubbock and the Lake Waco wetlands of the Brazos River basin despite reported incidences of Bd infection in adjacent river basins to the south and east (Gaertner et al. 2009; Saenz et al. 2010) (Fig. 1).

We acknowledge that the occurrence of false-negatives is a possibility. The year 2011 was a period of intense drought in the region, with Lubbock and Waco setting new records for minimum precipitation and high temperatures. June–August 2011 were the warmest three months ever recorded in the region: the 100-day streak of 32.2+ degree days at Lubbock finally ended on 3 September 2011, while Waco saw a similar streak of 44 days ending on 12 August 2011 (NOAA 2011, 2012). The unprecedented drought and high temperatures, clearly detrimental to amphibian activity and reproduction (Ramesh et al. 2012), may have ironically contributed to keeping Bd at bay (Kriger 2009). Bd grows best, has a better chance of spread, and is more likely to survive as zoospores in cool, wet conditions and in permanent water bodies (Gaertner et al. 2012; Johnson et al. 2003; Kriger and Hero 2007a). Moreover, Bd zoospores are highly prone to desiccation (Johnson et al. 2003), and occur at higher levels in permanent versus ephemeral water bodies (Gaertner et al. 2012; Kriger and Hero 2007b). Lack of standing water for long periods combined with prolonged temperatures well above 30°C during this period could have resulted in the lack of Bd occurrence in 2011 and into 2012.

Sampling for this study was conducted over two years in Lubbock and one year in Waco. It would have been ideal to sample under “normal” conditions considering the seasonality associated with chytrid fungus prevalence and persistence. However, such a “normal” year is unlikely in the near future of Texas where climate projections depict increased extreme temperatures, heat waves, and prolonged droughts along with decreased precipitation. Under such circumstances amphibian populations may already be vulnerable, and one cannot discount the additional influence of Bd (if present). We suggest that continuous monitoring for Bd presence be conducted in the long-term to catch the spread of this deadly pathogen in the state irrespective of climatic conditions.

Acknowledgments.—We are extremely grateful to The Center for Forest Sustainability at Auburn University for their financial support. This project was largely possible because of the invaluable field assistance afforded by V. Viswanathan, J. Lippert, U. Kawai, J. Kissner,
TABLE 1. Amphibian species, dates, and locations of *Batrachochytrium dendrobatidis* sampling in Lubbock and Waco, Texas, USA. Post-metamorphic animals were sampled unless noted. Location numbers for Lubbock, Texas are mapped in Fig. 1.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Species</th>
<th>Common name</th>
<th>No. swabs collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 August 2011</td>
<td>7, Lubbock</td>
<td>Bufonid tadpole</td>
<td>Unknown</td>
<td>8</td>
</tr>
<tr>
<td>1 September 2011</td>
<td>7, Lubbock</td>
<td>Bufonid tadpole</td>
<td>Unknown</td>
<td>3</td>
</tr>
<tr>
<td>2 September 2011</td>
<td>4, Lubbock</td>
<td>Bufonid tadpole</td>
<td>Unknown</td>
<td>2</td>
</tr>
<tr>
<td>13 August 2011</td>
<td>8, Lubbock</td>
<td><em>Pseudacris clarkii</em></td>
<td>Spotted Chorus Frog</td>
<td>1</td>
</tr>
<tr>
<td>13 August 2011</td>
<td>5, Lubbock</td>
<td><em>Gastrophryne olivacea</em></td>
<td>Great Plains Narrowmouth Toad</td>
<td>1</td>
</tr>
<tr>
<td>15 August 2011</td>
<td>3, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>8</td>
</tr>
<tr>
<td>15 August 2011</td>
<td>4, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>2</td>
</tr>
<tr>
<td>16 September 2011</td>
<td>4, Lubbock</td>
<td><em>Lithobates catesbeianus</em></td>
<td>American Bullfrog</td>
<td>1</td>
</tr>
<tr>
<td>12 April 2012</td>
<td>7, Lubbock</td>
<td><em>Pseudacris clarkii</em></td>
<td>Spotted Chorus Frog</td>
<td>1</td>
</tr>
<tr>
<td>12 April 2012</td>
<td>7, Lubbock</td>
<td><em>Spea multiplicata</em></td>
<td>New Mexico Spadefoot</td>
<td>1</td>
</tr>
<tr>
<td>12 April 2012</td>
<td>7, Lubbock</td>
<td><em>Ambystoma tigrinum mavortium</em></td>
<td>Barred Tiger Salamander</td>
<td>1</td>
</tr>
<tr>
<td>12 April 2012</td>
<td>2, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>3</td>
</tr>
<tr>
<td>30 April 2012</td>
<td>5, Lubbock</td>
<td><em>Gastrophryne olivacea</em></td>
<td>Great Plains Narrowmouth Toad</td>
<td>1</td>
</tr>
<tr>
<td>1 May 2012</td>
<td>1, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>9</td>
</tr>
<tr>
<td>1 May 2012</td>
<td>1, Lubbock</td>
<td><em>Anaxyrus cognatus</em></td>
<td>Great Plains Toad</td>
<td>1</td>
</tr>
<tr>
<td>1 May 2012</td>
<td>7, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>4</td>
</tr>
<tr>
<td>1 May 2012</td>
<td>8, Lubbock</td>
<td><em>Spea multiplicata</em></td>
<td>New Mexico Spadefoot</td>
<td>13</td>
</tr>
<tr>
<td>1 May 2012</td>
<td>8, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>1</td>
</tr>
<tr>
<td>1 May 2012</td>
<td>6, Lubbock</td>
<td><em>Anaxyrus speciosus</em></td>
<td>Texas Toad</td>
<td>8</td>
</tr>
<tr>
<td>2 May 2012</td>
<td>4, Lubbock</td>
<td><em>Lithobates catesbeianus</em></td>
<td>American Bullfrog</td>
<td>1</td>
</tr>
<tr>
<td>11 May 2012</td>
<td>8, Lubbock</td>
<td><em>Anaxyrus speciosus</em> (dead)</td>
<td>Texas Toad</td>
<td>6</td>
</tr>
<tr>
<td>15 May to 20 July 2012</td>
<td>Lake Waco wetlands, Waco</td>
<td><em>Hyla cinerea</em></td>
<td>American Green Tree Frog</td>
<td>40</td>
</tr>
<tr>
<td>15 May to 20 July 2012</td>
<td>Lake Waco wetlands, Waco</td>
<td><em>Acris crepitans</em></td>
<td>Northern Cricket Frog</td>
<td>9</td>
</tr>
<tr>
<td>15 May to 20 July 2012</td>
<td>Lake Waco wetlands, Waco</td>
<td><em>Incilius valliceps</em></td>
<td>Gulf Coast Toad</td>
<td>1</td>
</tr>
<tr>
<td>15 May to 20 July 2012</td>
<td>Lake Waco wetlands, Waco</td>
<td><em>Lithobates sphenoecephalus</em></td>
<td>Southern Leopard Frog</td>
<td>1</td>
</tr>
</tbody>
</table>

Sample size: 127

S. Ramireddy, J. Bradstreet, A. Hicks, E. Marler, B. Garcia, J. Mathews, J. Flores, J. Quigley, D. Marquez, C. St.Clair, S. Krishnamurthy, C. Crow, N. Stewart, G. Tomer, T. McFarlane, L. Kuhl, J. Proctor, S. Rooney, and G. Richarte. We are grateful to A. Godbee and J. Lippert for their assistance with obtaining landowner permission. We thank N. Schell and T. Conry of the Lake Waco Wetlands and City of Waco. We also thank M. San Francisco for providing us with lab space for molecular work, swabbing supplies, and his invaluable input. This research was carried out in compliance with the Texas Tech University Institutional Animal Care and Use Committee (IACUC permits 12012-04 and 10036-10). This is manuscript number T-9-1244, College of Agricultural Sciences and Natural Resources, Texas Tech University, Lubbock.

**LITERATURE CITED**


High Prevalence of Ranavirus Infection in Permanent Constructed Wetlands in Eastern Kentucky, USA

Amphibians are declining globally, and both land-use change and infectious diseases are major drivers (Miller et al. 2011; Stuart et al. 2004). Because most wetlands have been destroyed or altered throughout the United States (e.g., Kentucky has lost >81% of its historic wetlands; Dahl 2000), wetlands have been created for mitigation or wildlife management (Brown and Richter 2012; Dahl 2000). Hundreds of closely spaced permanent wetlands have been constructed on ridge tops in eastern Kentucky for wildlife management within the same landscape as natural, ephemeral wetlands (Brown and Richter 2012). Although constructed wetlands provide breeding habitat for amphibians, they might not replace the function of natural wetlands, supporting different amphibian communities than natural ponds (Denton and Richter 2013; Drayer 2011). Moreover, constructed ponds have been associated with ranavirus outbreaks (Harp and Petranka 2006). None of the individuals that were chosen because they have been associated with ranavirus disease die-offs in eastern North America (Green et al. 2002; Greer et al. 2005; Harp and Petranka 2006). None of the individuals that were collected had signs of ranaviral disease (Miller et al. 2011). Each Eastern Newt surveyed was swabbed using a BBL™ CultureSwab™ (Beckton, Dickinson, and Company, Franklin Lakes, New Jersey, USA) and had a 10-mm portion of its tail clipped. Swabs and tail clips were stored in 70% ethanol. Each *Lithobates sylvaticus* larva was euthanized in 10% ethanol and stored in 95% ethanol (EKU Institutional Animal Care and Use Committee; protocol #04-2012).

Ranavirus and *Bd* testing was performed at the University of Tennessee Center for Wildlife Health following published standardized procedures (Hoverman et al. 2011a; Souza et al. 2012). Genomic DNA (gDNA) was extracted from a homogenate of liver and kidney tissue (Wood Frogs), tail clips (Eastern Newts), and swabs (Eastern Newts) using a commercially available kit (DNeasy Blood and Tissue Kit, Qiagen Inc., Valencia, California, USA) with molecular-grade water as the extraction control. We measured the concentration of gDNA in each sample and standardized the amount of gDNA (0.25 µg) used for PCR among samples. Quantitative real-time PCR (i.e., TaqMan® PCR) was performed following Boyle et al. (2004) for *Bd* assays and following Picco et al. (2007) for ranavirus assays. Positive controls were similar for each assay, and included DNA extracted from culture and a positive animal for each pathogen. Negative controls included molecular-grade water and DNA extracted from an animal that was known to be negative for each pathogen. Each assay was run for 40 cycles on an ABI 7900 Fast Real-Time PCR System (Life Technologies Corporation, Carlsbad, California, USA). Each sample was run in duplicate and considered positive only if the PCR cycle threshold (CT) was < 30 for both samples. The CT value was determined by developing a standard curve for our PCR equipment using serial dilutions of known pathogen quantities. When samples were positive, we used the standard curve to predict virus concentration (i.e., plaque forming units, PFU) using the average CT for the sample.

We did not detect *Bd* in any samples; however, nine samples from two constructed wetlands were positive for ranavirus habitat associations in a drought year. Reptiles & Amphibians 19(4):243–253.

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infection (prevalence = 70% and 33%; Table 1). Eight of nine positive samples had titers < 100 PFU and the other had a titer of 4114 PFU. The lower titers are consistent with these newts being subletally infected (Miller and Gray, unpubl. data). From our controlled research (e.g., Hoverman et al. 2011a), individuals with titers > 4000 PFU frequently develop ranaviral disease (Miller and Gray, unpubl. data). Given that adult newts are known to move among wetlands in close proximity (Porej et al. 2004) and use ephemeral and permanent wetlands (Hunsinger and Lan- noe 2005), it is possible that this species could transport ranavi- rus overland among sites similar to Tiger Salamanders (Ambysto- ma tigrinum, Brunner et al. 2004) into amphibian communities composed of highly susceptible species (e.g., Wood Frogs; Hov- erman et al. 2011a). The role of Eastern Newts in the epidemiol- ogy of ranavirus needs greater attention.

While our sample sizes do not allow for meaningful compar- isons of ranavirus prevalence between natural and constructed wetlands, there are several reasons we think that constructed ponds might have important consequences for ranavirus epi- demiology. First, the constructed wetlands where ranavirus was detected are permanent compared to the ephemeral and larger sample size per wetland type. Additionally, post- metamorphic stages should be tested to determine if terrestrial stages of amphibians are important reservoirs as hypothesized by Brunner et al. (2004).

Acknowledgments.—We thank the Department of Biological Sci- ences at Eastern Kentucky University (EKU) for use of field vehicles and equipment, Daniel Douglas for field assistance, Jennifer Tucker for laboratory assistance, and Tom Biebighauser, Richard Hunter, and Ben Miller of the U.S. Forest Service for logistical guidance and field assistance. Funding was provided by a EKU University Funded Scholarship Grant. Research was approved by EKU’s Institutional Animal Care and Use Committee (protocol #04-2012).

Table 1. Prevalence with 95% confidence intervals of Batrachochytrium dendrobatidis (Bd) and ranavirus infection in Eastern Newts (Notophthalmus viridescens; Ne) in five constructed wetlands and Wood Frogs (Lithobates sylvaticus; Ls) from one natural wetland in the Daniel Boone National Forest, Kentucky. For each Ne, tail clips were tested for ranavirus, and swabs were tested for Bd. For each Ls, a homogenate of liver and kidney tissue was tested for ranavirus. Confidence intervals were calculated for small sample size using Wilson Score method with continuity correction (Newcombe 1998).

<table>
<thead>
<tr>
<th>Study Site</th>
<th>Coordinates</th>
<th>Sample Size</th>
<th>Bd Prevalence (95% CI)</th>
<th>Ranavirus Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Line Natural</td>
<td>38.284583°N 83.366972°W</td>
<td>Ne: N = 10</td>
<td>not tested</td>
<td>0 (0–0.345)</td>
</tr>
<tr>
<td>Gas line Artificial 2</td>
<td>38.285556°N 83.371778°W</td>
<td>Ne: N = 10</td>
<td>0</td>
<td>0 (0–0.345)</td>
</tr>
<tr>
<td>P5</td>
<td>38.087889°N 83.425278°W</td>
<td>Ne: N = 10</td>
<td>0</td>
<td>0 (0–0.345)</td>
</tr>
<tr>
<td>P5 Algae</td>
<td>38.087911°N 83.423889°W</td>
<td>Ne: N = 6</td>
<td>0</td>
<td>0.333 (0.060–0.759)</td>
</tr>
<tr>
<td>Jones Ridge Artificial</td>
<td>38.092306°N 83.354722°W</td>
<td>Ne: N = 10</td>
<td>0</td>
<td>0 (0–0.345)</td>
</tr>
<tr>
<td>Elk Lick Artificial Large</td>
<td>38.329806°N 83.364472°W</td>
<td>Ne: N = 10</td>
<td>0</td>
<td>0.700 (0.354–0.919)</td>
</tr>
</tbody>
</table>

Ranavirus has been previously documented in two wetlands in Kentucky (J. MacGregor, Kentucky Department of Fish and Wildlife Resources, pers. comm.). We recommend more intensive studies in the future that examine a larger geographic area and larger sample size per wetland type. Additionally, post- metamorphic stages should be tested to determine if terrestrial stages of amphibians are important reservoirs as hypothesized by Brunner et al. (2004).

Literature Cited


Herpetological Review 44(3), 2013
Low Prevalence or Apparent Absence of *Batrachochytrium dendrobatidis* Infection in Amphibians from Sites in Vietnam and Cambodia

*Batrachochytrium dendrobatidis* (Bd), the causative agent for the amphibian disease chytridiomycosis, is widespread, but patchily distributed throughout Asia. Within Asia, Bd has so far been detected from amphibians in Cambodia, China, India, Indonesia, Japan, Kyrgyzstan, Laos, Malaysia, the Philippines, South Korea, Sri Lanka, and Vietnam (Bai et al. 2010; Goka et al. 2009; Kaiser and Grafe 2012; Kusrini et al. 2011; Mendoza II. et al. 2009; Nair et al. 2011; Savage et al. 2011; Swei et al. 2011; Vörös et al. 2012; Wei et al. 2010; Yang et al. 2009). The pattern of Bd prevalence in Asia appears drastically different to that in Australia, Africa, the Americas, and Europe, with isolated cases and low infection prevalence (or apparent absence) at most sites (Swei et al. 2011). To date, there have been no reports of Bd-associated morbidity or mortality and no evidence of enigmatic amphibian population declines in Southeast Asia (Rowley et al. 2010).

Bd was first reported to occur in Vietnam in 2011, with seven samples taken in 2008 from Bidoup-Nui Ba National Park, Lam Dong Province, testing positive for Bd (Swei et al. 2011). To date, these are the only positive records published for Vietnam. Here we carried out an additional survey for Bd at Bidoup-Nui Ba National Park, and performed surveys at localities in central and southern Vietnam, and in adjacent eastern Cambodia (Fig. 1; Table 1).

Amphibians were sampled for Bd as part of broader amphibian surveys in evergreen forest areas between May 2009 and July 2010. During nocturnal surveys, conducted along rocky streams and adjacent evergreen forest, adult amphibians were captured by hand and placed in individual plastic bags. Immediately after capture, or the following morning (<8 h after collection), the ventral surface of each frog was swabbed using...
a sterile cotton swab (Medical Wire & Equipment, Potley, UK). Due to taxonomic uncertainty and the presence of undiagnosed diversity within the amphibians of the area, only the generic identity of the individuals swabbed is given (Table 2).

Samples were stored in the field at ambient temperatures (below that known to reduce the amount of Bd detectable; Van Sluys et al. 2008) for 5–14 days, and then at approximately –20°C for 3 weeks to 4 months prior to analysis. Storage conditions are unlikely to have affected our results, as storing swabs for 18 months at 4°C, 23°C, and –20°C does not reduce the amount of Bd detected (Hyatt et al. 2007). Due to the cost of PCR and our previous negative results (Swei et al. 2011), our 2009 samples from three sites were analyzed in batches of up to 8 samples via PCR (full volume or half volume pooling; Table 3). Samples from 2010 were analyzed individually via qPCR (Table 3).

All samples were analyzed by Pisces Molecular (Boulder, Colorado, USA). Samples pooled by full volume were transferred into a 50-ml tube of ethanol and vortexed to dislodge any zoospores from the swabs before pooling. Samples pooled by half volume had 1.1 ml of 70% ethanol added to the sample tubes and 500µl was transferred into a 15 ml screw-capped centrifuge tube for each pool. Individually analyzed samples had 1.0 ml of 70% ethanol added before mixing by vortexing, and then the entire volume was transferred into a clean microfuge tube. Total DNA was extracted from all samples using Qiagen DNeasy tissue kits. Samples were evaluated for the presence of Bd using diagnostic PCR (Annis et al. 2004), modified for greater specificity and sensitivity at Pisces Molecular. Samples were assayed in triplicate and each PCR run included three controls: a positive control (Bd DNA), negative control (sample from an uninfected amphibian), and No DNA control (remains uncapped during addition of sample DNA to detect contaminating DNA in the PCR reagents or carryover of positive DNA during reaction set-up). PCR results were scored as very strong positive (equivalent to the positive control), strong positive, positive, weak positive and negative (no signal/below the limit of detection). Each qPCR run included positive controls of Bd DNA in serial ten-fold dilutions from 3 × 10^6 to 3 × 10^0 molecules per reaction (used to generate the standard curve). Each qPCR run also included a No DNA control (as above). The detection sensitivity of these assays is three target sequence molecules (~0.02 zoospore equivalents).

**Table 1.** Locations and taxonomic breadth of amphibians sampled for *Batrachochytrium dendrobatidis* (*Bd*) in Cambodia and Vietnam.

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
<th>Location</th>
<th>Elevation (m)</th>
<th>No. Families</th>
<th>No. Genera</th>
<th>Approx. No. Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>Seima</td>
<td>12.32°N, 107.10°E</td>
<td>485–585</td>
<td>7</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Bidoup-Nui Ba</td>
<td>12.18°N, 108.68°E</td>
<td>1470–1625</td>
<td>5</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Ngoc Linh</td>
<td>15.22°N, 107.73°E</td>
<td>1085–2300</td>
<td>5</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15.06°N, 107.86°E</td>
<td>935–2105</td>
<td>5</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Nui Ong</td>
<td>11.02°N, 107.72°E</td>
<td>140–1020</td>
<td>5</td>
<td>14</td>
<td>21</td>
</tr>
</tbody>
</table>

**Table 2.** Number of individual amphibians in each family and genus sampled for *Batrachochytrium dendrobatidis* (*Bd*) in Cambodia and Vietnam.

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>No. individuals sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bufonidae</td>
<td><em>Duttaphrynus/Ingerophrynus</em></td>
<td>7</td>
</tr>
<tr>
<td>Dicroglossida</td>
<td><em>Fejervarya</em></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Limnonectes</em></td>
<td>69</td>
</tr>
<tr>
<td></td>
<td><em>Occidozyga</em></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>Quasipaa</em></td>
<td>4</td>
</tr>
<tr>
<td>Ichthyophiidae</td>
<td><em>Ichthyophis</em></td>
<td>1</td>
</tr>
<tr>
<td>Megophryidae</td>
<td><em>Leptobrachium</em></td>
<td>71</td>
</tr>
<tr>
<td></td>
<td><em>Leptolalax</em></td>
<td>40</td>
</tr>
<tr>
<td></td>
<td><em>Ophryophryne</em></td>
<td>56</td>
</tr>
<tr>
<td></td>
<td><em>Xenophrys</em></td>
<td>12</td>
</tr>
<tr>
<td>Microhylidae</td>
<td><em>Kalophrynus</em></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><em>Microhyla</em></td>
<td>16</td>
</tr>
<tr>
<td>Ranidae</td>
<td><em>Amolops</em></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><em>Hylarana</em></td>
<td>39</td>
</tr>
<tr>
<td></td>
<td><em>Odorrana</em></td>
<td>48</td>
</tr>
<tr>
<td>Rhacophoridae</td>
<td><em>Gracixalus</em></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td><em>Karixalus/Raorchestes</em></td>
<td>73</td>
</tr>
<tr>
<td></td>
<td><em>Polypedates</em></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td><em>Rhacophorus</em></td>
<td>41</td>
</tr>
<tr>
<td></td>
<td><em>Theloderma</em></td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>500</td>
</tr>
</tbody>
</table>
For individually analyzed samples, we calculated the lower and upper 95% binomial confidence limits of infection prevalence. For pooled samples, we calculated infection prevalence and lower and upper confidence intervals using a bias-corrected maximum likelihood estimation for pooled samples of unequal sample size (Hepworth 2005), using PooledInfRate 4.0 (Biggerstaff 2009).

A total of 500 skin swab samples from at least 52 species of amphibian was analyzed for Bd. Only samples from the July 2009 survey of Ngoc Linh tested positive for Bd using diagnostic PCR (Table 3). Four of the 18 pooled samples collected from the site in 2009 tested strong positive, giving an overall estimate of 3.29% infection prevalence and maximum likelihood estimates of confidence intervals of 1.08–7.86%. Follow-up surveys at Ngoc Linh during 2010 failed to detect Bd at the site, with a maximum likelihood estimate of upper confidence interval of 19.51%. Because samples were not pooled by species, the identity of infected species could not be determined. However, positive pools included sampled from the families Megophryidae (Leptobrachium, Leptolalax, Ophryophryn e, Xenophry s), Microhylidae ( Microhyla, Ranidae ( Odor rana) and Rhacophoridae (G rexicalus, K urixalus, Rhacophorus). Samples from the three survey sites at which Bd was not detected had upper limits of infection prevalence ranging from 3.39–7.86%. We did not detect Bd on samples from Bidoup-Nui Ba, a site at which we previously detected Bd at low prevalence and at low intensity of infection in 2008 (6.36% “low” infection prevalence in May 2008 [7/110]), but failed to detect Bd again in March 2008 (0/155) (Swei et al. 2011).

Our results are consistent with a previous, large-scale survey of Asia, which found a surprisingly low Bd prevalence throughout Asia (2.35%; Swei et al. 2011). Surveys at many sites in the region have failed to detect Bd, despite often relatively large sample sizes including Ratanakiri Province, Cambodia (0/178); Lao Cai Province, Vietnam (0/82); Savannakhet, Laos (0/191), Hong Kong (0/274), and Thailand (0/123) (Rowley et al. 2007; McLeod et al. 2008; Swei et al. 2011). Recent surveys of captive native frogs in the trade markets in Cambodia, Laos, Singapore, and Vietnam also reported low infection prevalence, with <1% (14/2389) of amphibians testing weakly positive for Bd (Gilbert et al. 2013).

Although most surveys for Bd in Asia have reported low prevalence or apparent absence, Bd has been reported at high infection prevalence at some sites (Yang et al. 2009; Swei et al. 2011), including four sites in Cambodia, where Bd was reportedly detected on 41% (59/144) of swab samples from southwestern Cambodia (Mendoza et al. 2011), and on 36% (86/238) of swab samples at three lowland sites in Cambodia (Gaertner et al. 2011). These survey results are in contrast to our survey at Seima and our previous surveys in eastern Cambodia, which did not detect the pathogen (Swei et al. 2011). Differences in the habitat and the amphibian species sampled makes comparisons between surveys difficult. However, Mendoza et al. (2011) and Gaertner et al. (2011) surveyed a very different suite of amphibians (most of which were lowland, pond-breeding amphibians).

The global distribution (Olson et al. 2013) and emergence of Bd remains far from clarified, and recent evidence suggests that Bd may have evolved from or at least have a long history in Asia (Goka et al. 2009; Bai et al. 2012). Additional disease surveys in Asia, molecular analysis of Bd from throughout Asia, and infection trials to assess disease susceptibility in Asian amphibians are required in order to assess the threat of Bd to amphibians in Asia. We also recommend assessing the identity and distribution of Bd haplotypes present throughout Asia. Given that qPCR appears unable to detect all strains of Bd present in Asia (Goka et al. 2009), it may also be necessary to identify the Bd haplotypes present at a site in order to assess the accuracy of Bd infection prevalence estimates obtained using qPCR.

Acknowledgments.—The Vietnamese Ministry of Agriculture and Rural Development and staff at Bidoup-Nui Ba National Park, Ngoc Linh Nature Reserve, and Nui Ong Nature Reserve kindly facilitated surveys and issued permission to collect (Permit numbers 3023/ GTBNN-KL, 1430/GT-BNN-KL, 776/BNN-KL, 748/BNN-KL). The People's Committee of Kon Tum Province issued permit number 548/ UBND-DN for JLLR for work in the province. H.E Ty Sokun provided field survey permission for Seima Biodiversity Conservation area and WCS Cambodia greatly facilitated fieldwork. This work was supported by the ADM Capital Foundation, Ocean Park Conservation Foundation Hong Kong, the John D. and Catherine T. MacArthur Foundation and the Lawrence Foundation. Cao Tien Kien, Phung Thi Huong, Nguyen Hoang Vu, Huynh Tan Hop, Da Du Ha Tien, Vu Hanh Dung, Ta Van Thuc, Pham Xuan Nguyen, Le Van Kanh, Nguyen Quoc Hung, Le Thi Than Ngan, A Phuoc, A Tru, A Nap, A Doi, Chad Minshew, and Eleanor Appleby assisted in the field. For all this assistance we are most grateful.

**Table 3.** Batrachochytrium dendrobatidis (Bd) infecting amphibians in Cambodia and Vietnam. Prevalence and lower and upper 95% binomial confidence limits (CL; singlicate) or bias-corrected maximum likelihood estimates (MLE) for Bd infection from samples analyzed using diagnostic PCR.

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
<th>Date</th>
<th>Analysis</th>
<th>N</th>
<th>Prevalence</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>Seima</td>
<td>July/August 2009</td>
<td>PCR; Pooled (full volume)</td>
<td>100</td>
<td>0.00</td>
<td>0.00</td>
<td>3.62</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Bidoup Nui-Ba</td>
<td>July 2010</td>
<td>qPCR singlicate</td>
<td>124</td>
<td>0.00</td>
<td>0.00</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>Ngoc Linh</td>
<td>July 2009</td>
<td>PCR; Pooled (full volume)</td>
<td>133</td>
<td>3.29</td>
<td>1.08</td>
<td>7.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>March/April 2010</td>
<td>qPCR; singlicate</td>
<td>43</td>
<td>0.00</td>
<td>0.00</td>
<td>19.51</td>
</tr>
<tr>
<td></td>
<td>Nui Ong</td>
<td>May 2009</td>
<td>PCR; Pooled (half volume)</td>
<td>100</td>
<td>0.00</td>
<td>0.00</td>
<td>3.62</td>
</tr>
</tbody>
</table>

**Literature Cited**


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**GEOGRAPHIC DISTRIBUTION**


Individuals were identified to species by sequencing 800 bp mtDNA d-loop and cytochrome b loci (18 individuals; Bi and Boggart 2010. BMC Evol. Biol. 10:238). Larvae were caught with nets in a leafy temporary pond in hardwood forest, sampled for DNA, and immediately released.

Field work supported by Central Michigan University and ATCG laboratory. Scientific Collector’s Permit Issued 1 May 2012/ Michigan DNR, Central Michigan University IACUC Approval #12-18, 26 June 2012.


**KEVIN M. ENGE** (e-mail: kevin.enge@myfwc.com) and **PAUL E. MOLER**, Florida Fish and Wildlife Conservation Commission, 1105 S.W. Williston Road, Gainesville, Florida 32601, USA.

**BOLITOGLOSSA SALVINII** (Salvin’s Mushroom-tongued Salamander). **EL SALVADOR:** CUSCATLÁN: MUNICIPALITY OF CHIQUITEPEC: Cerro Las Pusas, Canton El Carrizal (13.709774°N, 88.938550°W; WGS 84), 820 m elev. 31 August 2012. Esmeralda Martínez Umaña. Verified by Eric N. Smith. KUDA 01227–73. New department record (Köhler et al. 2006. The Amphibians and Reptiles of El Salvador. Krieger Publ. Co., Malabar, Florida. ix + 238 pp.), extending the species’ range ca. 25 km ENE from the only other known Salvadoran locality at Instituto Tropical de Investigaciones Científicas, San Salvador. The salamander was caught and released after photographs were taken by a farmer in a banana plantation surrounded by coffee groves and remnants of tropical broadleaf submontane semideciduous forest. The area is now almost completely deforested and replaced by housing developments and agricultural fields. Because the species was last collected in El Salvador over 50 years ago and since west-central El Salvador lacks natural vegetation, Greenbaum and Komar (2010. *In Wilson et al. [eds.], Conservation of Mesoamerican Amphibians and Reptiles, pp. 436–459. Eagle Mountain Publ., LC, Eagle Mountain, Utah*) speculated that the species was already extirpated from the country, but our record indicates that its ability to survive in banana plantations may sustain the species until proper conservation actions can be initiated.

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**BOLITOGLOSSA SALVINII** (Salvin’s Mushroom-tongued Salamander). **MÉXICO:** PUEBLA: MUNICIPALITY OF CHICHIOQUIA: El Cantill, Río Tenejapa (19.206889°N, 97.052611°W; WGS84), 1467 m elev. 24 April 2010. Andrés Alberto Mendoza Hernández. Verified by Edmundo Pérez Ramos. MZFC 26528. First record for the state, extending its known range ca. 7 km (airline) NW of Las Cañadas. **KEVIN M. ENGE** (e-mail: kevin.enge@myfwc.com) and **PAUL E. MOLER, Florida Fish and Wildlife Conservation Commission, 1105 S.W. Williston Road, Gainesville, Florida 32601, USA.

**PSEUDOEOURYCEA CAFETALERA** (Coffee Grove Salamander). **MÉXICO:** PUEBLA: MUNICIPALITY OF CHICHIOQUIA: El Cantill, Río Tenejapa (19.206889°N, 97.052611°W; WGS84), 1467 m elev. 24 April 2010. Andrés Alberto Mendoza Hernández. Verified by Edmundo Pérez Ramos. MZFC 26528. First record for the state, extending its known range ca. 7 km (airline) NW of Las Cañadas.
Municipality of Huatusco, Veracruz (Parra-Olea et al. 2010. Zootaxa 2725:57–68). The salamander was found in an ecotone between cloud forest and tropical evergreen forest.

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Field work was in support of Naval Facilities Engineering Command Contract No. N62470-08-D-1008, Task Order No. WE41. VDGIF Threatened/Endangered Species Permit No. 047472.

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ANURA — FROGS

AMEEREKA HAHNELI. BOLIVIA: BENI DEPARTMENT: MOSOS PROVINCE: East of Municipality of San Ignacio de Mojos (14.724444°S, 65.0023056°W, WGS84; 153 m elev.). 2 May 2009. Steven Poe and Eric Schaad. Museum of Southwestern Biology at the University of New Mexico (MSB 94808) and Colección Boliviana de Fauna CBF-6661). This species was previously known from the Amazonian lowlands from Colombia, eastern Ecuador, Peru, Guiana, Brazil, and northwestern Bolivia. Within Bolivia this species is known from the Beni, La Paz, and Pando departments, and has been expected to occur in Mojos Province (De la Riva et al. 2000. Rev. Esp. Herpetol. 14:19–164; Kohler 2000. Amphibians in Bolivia. A Study with Special Reference to Montane Forest Regions. Bonn. Zool. Monogr. 48, 243 pp.). Here we report the first record of this species from the Mojos Province approximately 438 km from the western edge of A. hahneli’s previously known range from José Ballivian Province. The fieldwork for this project was funded by NSF DEB-0844624 to Steven Poe.

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for the species, first record for Atlántico Norte, and a ca. 260 km range extension N from El Recreo, S side of Río Mico, Department of Atlántico Sur (Köhler 2001. Anfibios y Reptiles de Nicaragua. Herpeton, Verlag Elke Köhler, Offenbach, Germany. 208 pp.). The frog was found on vegetation over a roadside pond surrounded by tropical moist forest.

Specimen was collected under permit No. 011-102010 issued by MARENA. Field work was supported by a NSF grant (DEB 0949359) to Nicholson and laboratory work was partially supported by a COLFUTURO grant to Solano.

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Two individuals observed basking on a floating log in vegetated water. Nearest confirmed record ca. 59 km SE in Haywood Co. Available at http://apsu.edu/reptatlas/ [accessed 6 May 2012]. Atlas of Reptiles in Tennessee. The Center of Excellence for Field Biology, Austin Peay State University, Clarksville, Tennessee 37040, USA (e-mail: jflaherty1@my.apsu.edu).


**TERRAPENE NELSONI** (Spotted Box Turtle). MEXICO: JALISCO: Municipalidad de Ameca: Sierra de Quila, near Tecolotlán, 100 km SW of Guadalajara (20.4016°N, 104.122°W; WGS84), 2020 m elev. 6 August 2000. John Pint. Verified by Jacobo Reyes-Velasco. UTADC 7639. First municipality record, extending range 32 km S from its closest reported locality near Guachinango, Jalisco, although the coordinates provided by Buskirk and Ponce-Campos (2011. Chelon. Res. Monogr. [5]:060.1–060.9) for that distance were inaccurate when compared to our measures. The turtle was active during the day in an oak forest disturbed to a certain extent by agricultural fields.

**TERRAPENE NELSONI** (Spotted Box Turtle). MEXICO: JALISCO: Municipalidad de Ameca: Sierra de Quila, near Tecolotlán, 100 km SW of Guadalajara (20.4016°N, 104.122°W; WGS84), 2020 m elev. 6 August 2000. John Pint. Verified by Jacobo Reyes-Velasco. UTADC 7639. First municipality record, extending range 32 km S from its closest reported locality near Guachinango, Jalisco, although the coordinates provided by Buskirk and Ponce-Campos (2011. Chelon. Res. Monogr. [5]:060.1–060.9) for that distance were inaccurate when compared to our measures. The turtle was active during the day in an oak forest disturbed to a certain extent by agricultural fields.

**SQUAMATA — LIZARDS**


**SQUAMATA — LIZARDS**


lizards are new introductions from Florida, via the tropical plant over 225 km S of Nacogdoches. Many of the tropical plants at the Brazos Co, over 200 km SW of this locality, and from Harris Co., is not known from any other locations in Nacogdoches. The nearest records for A. sagrei is not known from any other locations in Nacogdoches. The nearest records for A. sagrei are from Brazos Co, over 200 km SW of this locality, and from Harris Co., over 225 km S of Nacogdoches. Many of the tropical plants at the Lowe's store are shipped from Florida. Thus, it is likely that the lizards are new introductions from Florida, via the tropical plant trade, rather than a range expansion in Texas.

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HEMIDACTYLUS TURCICUS (Mediterranean Gecko). USA: CALIFORNIA: LOS ANGELES CO.: San Fernando Valley, Chatsworth (34.250946°N; 118.608146°W; WGS 84; elev. 286 m). Seven individuals representing adult (N = 4) and juvenile (N = 3) age classes and both sexes were collected in a residential community on stucco or stone walls or stone mailbox posts exposed to direct exterior illumination from 2100–2230 h, 14 and 16 August 2010. R. W. Bernstein, W. L. Bernstein, A. Lopez, and Z. M. Lopez. CSUN 3475 (additional specimens are alive in captivity at CSUN). Verified by R. E. Espinoza. New county records. Originally submitted as photo vouchers to the Natural History Museum of Los Angeles County (LACM) Lost Lizards of Los Angeles citizen science project (http://www.nhm.org/site/activities-programs/citizen-science/lost-lizards-project; LACM photographic vouchers PC 1633–1634). Extends the range ca. 195 km NW (airline) from the closest vouchered localities at Palm Springs, Riverside Co., California (LACM 147938, 152671, 179871–76). In Southern California, H. turcicus has also become established at one or more localities in the counties of Imperial, San Bernardino, and San Diego (Beaman et al. 2005 Herpetol. Rev. 36:79). Although we observed at least 10 additional specimens within a two-block radius of the residential area from which these geckos were collected, surveys outside of this region produced no further sightings suggesting a very limited distribution and relatively recent introduction. Several residents in the area independently suggested that they first noticed the geckos approximately 10 years ago. Repeated visits (2010–13) to the neighborhood by us and herpetologists and staff from California State University, Northridge and LACM indicate the population is thriving, but not expanding.

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LEPIDOPHYMA GAIGAEAE (Gaige's Tropical Night Lizard). MÉXICO: SAN LUIS POTOSÍ: MUNICIPALITY OF AUQUISÍMON: Cascada de Tamúl (21.80282°N, 99.179946°W; WGS84), 220 m elev. 2 January 2010. Iván T. Ahumada-Carrillo. Verified by Jacobo Reyes Velasco. UTAD.C 7504–7505. First municipality record and first voucherer state record. Lemos-Espinal and Dixon (2013. Amphibians and Reptiles of San Luis Potosí. Eagle Mountain Publ., Eagle Mountain, Utah. xii + 300 pp.) mapped and listed localities for the species from the municipalities of Huichuelán, San Vicente Tancuayalab, and Zaragoza, but gave no reference to voucher specimens. Municipality of Auquisímon is located directly adjacent to Huehuetlán, and Cascada de Tamúl represents the lowest reported elevation for the species, as all others were from above 700 m (Bezy and Camarillo R. 2002. Contr. Sci. Nat. Hist. Mus. Los Angeles Co. [493]:1–41). The lizard was found inside a rock crevice in subtropical dry forest, in pine-oak forest, the normal habitat for this species (Lemos-Espinal and Dixon, op. cit.).

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SCELOPORUS ALBIVENTRIS (Western White-bellied Spiny Lizard). MEXICO: SONORA: MUNICIPAL DE ACONCHI: Sierra Aconcchi, 9.5 km WSW Aconchí (29.793019°N, 110.315929°W; WGS84), 1316 m elev. 3 September 2012. Martín F. Villa A. Verified by G. Ferguson. UAZ 57457-PSV. Northernmost locality for this species, extending the range 136 km NW of closest known locality, Arroyo Santa Rosa, Rancho Santa Rosa, 32 km NE Sahuaripa, Sonora 29.28251°N, 109.04432°W (Rorabaugh et al. 2011. Son. Herpetol. 24:126). The specimen was basking in rocky foothills thornscrub near its interface with oak woodland.

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SCELOPORUS DIGESII (Duges' Spiny Lizard). MEXICO: GUANAJUATO: MUNICIPALITY OF CORTAZAR: Cerro La Gavia, 90 km S of La Gavia (20.387139°N, 100.882444°W; WGS84), 2193 m elev. 20 January 2009. Israel Solano Zavaleta, José Carlos Arenas Monroy, and Uri Omar García Vázquez. MZFC 27071. Cerro La Gavia, 1.6 km NE of Mandinga (20.441556°N, 100.922083°W; WGS84), 2030 m elev. 29 November 2009. José Carlos Arenas Monroy. MZFC 27072. Both lizards verified by Edmund Perez Ramos. First records for municipality, extending the known distribution ca. 41 km (airline) NE from 2 km E of Moroleón, Guanajuato (Martínez-Méndez and Méndez-de la Cruz 2007. ZooTaxa 1609:53–60). Both specimens are adult males and were found under rocks in tropical deciduous forest.

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SQUAMATA — SNAKES


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CROTALUS INTERMEDIUS (Mexican Small-headed Rattlesnake). MÉXICO: HIDALGO: MUNICIPALITY OF MINERAL DE LA Reforma: Azoyatla (20.09836°N, 98.69054°W; WGS84), 2505 m elev. 8
July 2006. Elizabeth Cervantes Cornish. Verified by Norma Manriquez Morán. Colección Herpetológica, Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo (CIB-UIH 2808). First municipality record and only third specific locality reported for the state. The closest known record is from the Municipality of Tepeji del Río de Ocampo at Presa Requena (Valencia-Hernández et al. 2007. Acta Zool. Mex. 23:29–233), located 80.41 km SW of our record. The snake was found in xerophytic scrub vegetation.

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DRYMARCHON MELANURUS (Central American Indigo Snake). MEXICO: JALISCO: MUNICIPALITY OF CAÑADAS DE OB. The snake was found basking in the afternoon sun, on a rock inside a canyon covered by tropical deciduous forest.

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GEOPHIS BICOLOR (Mexican Plateau Earth Snake). MEXICO: JALISCO: MUNICIPALITY OF TECOLOTLAN: Sierra de Quila, near Tecolotlán, 100 km SW of Guadalajara (20.312533°N, 104.013385°W; WGS84), 2450 m elev. 13 October 2011. Jesús Rodríguez-Canseco and Matías Domínguez-Laso. Verified by Jacobo Reyes-Velasco. UTADC 7613. First municipality record, and extending the range 89 km N from its nearest location in the Sierra de Manantlán (Orozco 2006. Herpetofauna de la Estación Científica Las Joyas en la Reserva de la Biosfera Sierra Manantlán, Jalisco, México: Guía Ilustrada y Claves para su Determinación, Univ. de Guadalajara, Cent. Univ. Cienc. Biol. Agr., Zapopan, Jalisco, 90 pp.). The snake was found in pine-oak forest under a rock in the morning after a rainy night.

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LAMPROPEL TIS ELAPSOIDES (Scarlet Kingsnake) USA: ALABAMA: COVINGTON CO.: US Route 29, Conecuh National Forest (31.14052°N 86.67253°W; WGS 84). 22 May 2013. S. Graham and M. Herr. Verified by David Laurencio. AUM 40225. New county record (Mount 1975. The Reptiles and Amphibians of Alabama, 347 pp.). Funding was provided by a Penn State Department of Undergraduate Education Summer Discovery Grant to Mark Herr and a National Science Foundation grant (IOS-1051367, DEB-0949483) to Tracy Langkilde.

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LEPTOPHIS MEXICANUS (Mexican Parrot Snake; Ranexa Mexicana). HONDURAS: LA PAZ: Potrerillos (14.292983°N, 87.7068°W; WGS84), 920 m elev. 9 April 2012. Alexander Gutsche and James R. McCranie. Verified by Steve W. Gotte. USNM 580445. First record for La Paz, with the closest known locality ca. 15 km N at Lo de Reina, Comayagua (McCranie 2011. The Snakes of Honduras. Systematics, Distribution, and Conservation. SSAR 2933, USA (e-mail: jmccrani@bellsouth.net); Alexander Gutsche, Museum für Naturkunde, Herpetologie, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstr. 43, D-10115 Berlin, Germany (e-mail: alexander.gutsche@mfm-berlin.de).


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LEPTOPHIS MEXICANUS (Mexican Parrot Snake; Ranexa Mexicana). HONDURAS: LA PAZ: Potrerillos (14.292983°N, 87.7068°W; WGS84), 920 m elev. 9 April 2012. Alexander Gutsche and James R. McCranie. Verified by Steve W. Gotte. USNM 580445. First record for La Paz, with the closest known locality ca. 15 km N at Lo de Reina, Comayagua (McCranie 2011. The Snakes of Honduras. Systematics, Distribution, and Conservation. SSAR 2933, USA (e-mail: jmccrani@bellsouth.net); Alexander Gutsche, Museum für Naturkunde, Herpetologie, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstr. 43, D-10115 Berlin, Germany (e-mail: alexander.gutsche@mfm-berlin.de).


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New Geographic Distribution Records for Reptiles from North Carolina, USA

The geographic distribution of reptiles in North Carolina (USA) was summarized by Palmer and Braswell (1995) and has since been supplemented by others, including Beane (1998), Beane and Palmer (2006), Eskew et al. (2008), and Beane and Corey (2010). Here I report additional new records based upon specimens and photographs verified by William M. Palmer or Bryan L. Stuart and housed at the North Carolina State Museum of Natural Sciences (NCSM). Geocoordinates are based on datum WGS 84.

**TESTUDINES — TURTLES**


TYRRELL Co.: ca. 3.1 km SSW Woodley, Scuppernong River State Park along Scuppernong River (35.867734°N, 76.350560°W). 29 April 2011. J. Edward Corey III. NCSM photo vouchers JEC 11-1. New county record and first record for Albemarle-Pamlico Peninsula.


HEMIDACTYLUS TURCICUS (Mediterranean Gecko). COLUMBUS Co.: 1.9 km S Whiteville (34.3260°N, 78.7028°W). 12 July 2010. Gail Reynolds. NCSM photo vouchers KL 10-1. New county record. This introduced species was first vouchered from North Carolina in 2003, from an apparently established population in New Hanover Co. (Beane et al. 2010; Beane and Corey 2010). It is unknown whether this Columbus Co. record represents an established colony or an isolated introduction.

ORANGE Co.: 5.2 km N center Chapel Hill (35.9605°N, 79.0525°W). 7 August 2011. Jacob Judd and Jessica Hampton Judd. NCSM 78421. New county record. Numerous individuals of different age classes were observed at this locality during 2011 and 2012 (pers. obs.; A. Iyoob, J. Judd, and J. H. Judd, pers. comm.), suggesting a well-established population.

WAKE Co.: 0.5 km WSW center Raleigh (35.7781°N, 78.6421°W). 17 November 2009. Michael E. Dunn. NCSM 77274. 1.6 km ESE center Cary (35.7800°N, 78.7661°W). 30 November 2010. Gail Powell et al. NCSM 77728. New county records and second and third specimen vouchers for North Carolina (Beane and Corey 2010). There have been additional reports of this species at the two Wake Co. localities, as well as unsubstantiated reports from other localities in Orange and Wake counties, suggesting established populations. The population at the second Wake Co. locality (1.6 km ESE center Cary) reportedly originated from several escaped captives in the early 1980s, and has apparently persisted for over 30 years (Daniel E. Lockwood, pers. comm.). Over 400 individuals were captured at this site in June and July 2012, during a mark-recapture study (Kevin Durso, pers. comm.).


SQUAMATA — SNAKES


SQUAMATA — LIZARDS


**Rhamphophis braminus** (Brahminy Blindsnake). **Wake Co.**: ca. 6.8 km NW center Raleigh (35.825°N, 78.690°W). Ca. 2 December 1994. Lawrence T. Englert. NCSM 78302. New county record and first record for North Carolina. Thus far, this appears to represent an isolated introduction; no established populations of this widely introduced, parthenogenetic species have been reported in North Carolina.


**Acknowledgments**—I sincerely thank all those whose fieldwork resulted in new distributional records. William M. Palmer reviewed the manuscript.

**Literature Cited**


New County Records and an Update for Kansas and Nebraska, USA

Kansas and Nebraska are states found within the midwestern region and the geographical center of the United States. Although both have enjoyed a long history of herpetological exploration, much still needs to be done to verify the existence and distribution of reptiles and amphibians within the region. Here, I report 24 new county records from this region, supported by photo vouchers. Most collections occurred during May 2012. All voucher photographs are deposited in the Herpetology Section of the Natural History Museum of Los Angeles County (LACM). All were verified by Neftali Camacho. These records were determined by examination of the three regional field guides for the area, Collins et al. (2010), Fogell (2010), and Ballinger et al. (2010). The Kansas Herpetofaunal Atlas (Taggart et al. 2013), an online map of county vouchers, was also consulted for updates to the previously cited publications. Most of these records are for turtles, which are underrepresented in museum collections within the region. Geocoordinates were obtained from GoogleEarth/Google Maps WGS84 datum. All observations were made by the author.

KANSAS

TESTUDINES — TURTLES

CHRYSEMYS PICTA BELLI (Western Painted Turtle). Dickerspoon Co.: Abilene, DOR on I-70 (38.942991°N 97.20183°W). 11 May 2012. LACM PC 1575. This is the first voucher record of this species in Dickinson Co. with complete locality data. Three voucher specimens exist from 1916 (KU 3191, 3192, 157811), with ambiguous locality information. These specimens were verified by Andrew Campbell on 4 June 2012 as from “Dickinson County” with no further information.


NEBRASKA

ANURA — FROGS


TESTUDINES — TURTLES


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New and Updated Records of Amphibians and Reptiles from Minnesota, USA

In preparation for the publication of the revised edition of “Amphibians and Reptiles in Minnesota” (Moriarty and Hall, pers. comm.), authors accessioned several new or updated records at the Bell Museum of Natural History (JFBM) based on Oldfield and Moriarty (1994) and Gamble and Moriarty (2006). Previously accessioned vouchers documented during or before 1960 were considered outdated. Voucher records include physical specimens, digital photographs (accession number preceded by “P”) and audio recordings (accession number preceded by “AUD”). Of the 36 records included here, 11 were collected by state employees from the Minnesota Department of Natural Resources - Nongame Wildlife Program, and their acquisition was funded in part by a grant from the State Wildlife Grants Program administered by the U.S. Fish and Wildlife Service. Don Shepard verified records. Geocoordinates are based on datum WGS 84. Fieldwork conducted on federal lands with special-use permit processed 3 June 2013.

CAUDATA — SALAMANDERS


ANURA — FROGS


**PSEUDACRIS MACULATA** (Boreal Chorus Frog). 03 May 2011. New county record. E. P. Hoaglund. JFBM P422.


**LE SIEUR CO.:** Township Rd. 140, 0.45 km N of 480th St. (44.25812°N, 94.00687°W). 26 August 2011. New county record. E. P. Hoaglund and C. E. Smith. JFBM P430.

**GRAPTEMYS PSEUDOGEOGRAPHICA** (False Map Turtle). NICOLET CO.: Minnesota River, 0.70 km down river from outlet to Seven Mile Creek (44.24033°N, 94.02103°W). 14 July 2008. Updated county record. Jeff LeClere and C. E. Smith. JFBM P357.

**SQUAMATA — LIZARDS**


**SQUAMATA — SNAKES**


**SIBLEY CO.:** Scenic Byway Rd 2.5 km S of County Hwy 5 (44.60502°N, 93.88869°W). 05 November 2011. Updated county record. E. P. Hoaglund and C. E. Smith. JFBM P439.

**Acknowledgments.**—We thank Don Shepard for verifying species identity. We also thank Dav Kaufman, Jeff LeClere, Duane McDermott, and Steve Pucktel for taking the time to document field observations as well as Liz Harper and John Moriarty for reviewing this note.

**Literature Cited**


Geographic Distribution of Herpetofauna of Middle Tennessee

Geographic distribution of Tennessee herpetofauna has been well documented by Scott and Redmond (2002), and is regularly updated via online atlas. However, some distribution gaps remain in the Middle Tennessee region. The following records fill some of these gaps. All specimens were collected from a eight-county area in Tennessee to include Hardin, Hickman, Lawrence, Macon, Marshall, Maury, Smith, and Williamson counties. Identification and distribution of species followed Conant and Collins (1998). All specimens represent new county records supported by Scott and Redmond (1996, 2008). GPS datum is WGS 84. Photo vouchers were deposited in the Austin Peay State University’s Museum of Zoology (APSUMZ). Nomenclature follows Crother (2012). All specimens were independently verified by A. Floyd Scott (APSU).

CAUDATA — SALAMANDERS

EURYCEA CIRRIGERA (Southern Two-Lined Salamander). MAURY CO.: Mount Pleasant, Creek 200 m downstream from the fall at Stillhouse Hollow Falls (35.470526°N, 87.26777°W). 10 October 2012. Nicole Foster and Cameron Hargrove. APSUMZ 19386.

ANURA — FROGS


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NOMENCLATURE Following

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The Persian Gulf is approximately 1000 km long with a depth of approximately 35 m but with depths of more than 100 m in the Strait of Hormoz. The Persian Gulf Islands in Hormoz strait are part of the Zagros formation; of these, Qeshm Island was formed by collision of the Iran and Arabian plates in the Cenozoic (Janakipour 2007; Majnonian et al. 2006; Motamed 1998). The Gulf has been frequently filled and emptied during glacial and interglacial periods in the Quaternary (Mahmoodi 1988). The sandy dunes along the gulf are important habitat for many amphibian and reptile species in this region. To date, there have been no general studies of the lizard fauna of the islands in the Persian Gulf. Here we report on the lizard fauna of one island, Qeshm, based on surveys in the northern and central parts of the island near Deyrestan village.

Materials and Methods.—Qeshm Island is the largest island in the Persian Gulf and is part of Hormozgan Province. The island is located between 27°01’ and 26°32’N and 055°16’ and 056°27’E (Fig. 1). The island is 135 km long and the widest part, at about 40 km, is located between Laft and Shibberaz, though in most areas it is approximately 11 km wide. The average annual temperature is 25°C, the warmest month of the year is August (with highs of ~46°C), and the coldest month is January (with lows of ~0°C).

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Our investigation was carried out in March 2011 on Qeshm Island for three days. Four people surveyed habitats (sand dune, coastal regions, villages) three times each day—morning, afternoon, and early evening. Sampling was by hand, and after obtaining tissue samples for genetic studies, each specimen was fixed according to standard methods in herpetology (Simmons 2002). Localities were recorded by a handheld GPS unit (eTrex Vista 245000 T-E) and digital photos were recorded for each specimen by Canon camera (G7). Voucher specimens are deposited at the Sabzevar University Herpetological Collection (SUHC) and were identified by the published sources for the Iranian herpetofauna (Anderson 1999; Rastegar Pouyani et al. 2007).

Results.—Our surveys identified six lizard species representing three families and five genera on Qeshm Island (Table 1). Based on comparisons to previously published sources on the Iranian herpetofauna, we have added four other lizard species, thus raising the total to 10 species (Table 2).

Discussion.—As mentioned above, the Persian Gulf has been emptied several times in the Quaternary, and during those times, there were land connections between the island and the mainland. The conditions of the island suggest that the herpetofauna is a southern extension of the Arabian fauna (Anderson 1999). Our investigation of the island’s herpetofauna indicates that as many as ten lizard species occur on the island (Table 1; Fig. 2; Anderson 1999; Dakhte et al. 2007). Among these, Pseudoceramodactylus khobarensis was not recorded from the nearby mainland and Qeshm Island appears to be the northernmost locality for this species (Dakhte et al. 2007). Another species recorded on Qeshm Island, Scincus mitranus, probably dispersed from the Arabian Peninsula to the island during the second glacial period before 11,000 years ago (Dakhte et al. 2007). This species has also been reported from Khuzestan, suggesting that it extends into Iranian territory from the Mesopotamian Plain (Fahimi et al. 2009); we expect that future studies may find this species along the northern coastal plains of the Persian Gulf.

Islands are important to understanding phylogeographical patterns and evolutionary divergences. Because the Persian Gulf was a dispersal corridor for the Iranian and Arabian herpetofaunas approximately 20,000–30,000 years ago (Mahmoodi 1988), we suggest that genetic methods on the localized populations in this region will aid our understanding of the history of the island and the biogeography of this region.

Acknowledgments.—We thank Mohammad Dakhte, Mojtaba Ranaei, and Yaser Gholami for help during field surveys and investigations in this region. Our special thanks go to David Blackburn for editing a previous version of this manuscript.
FIG. 2. Species collected from Qeshm Island. A) Acanthodactylus blanfordi (SUHC 848); B) Pristurus rupestris (SUHC 845); C) Hemidactylus flaviviridis (SUHC 855); D) Hemidactylus turcicus (SUHC 853); E) Trachelus agilis (SUHC 844); F) Mesalina watsonana (SUHC 856).

LITERATURE CITED


CAUDATA — SALAMANDERS

AMBYSTOMA MACULATUM (Spotted Salamander). UNUSUAL EGG ENTRAPMENT. On 9 March 2012 while surveying ridge-top wetlands in Daniel Boone National Forest (DBNF), Rowan Co., Kentucky, USA, we observed a planorbid snail that had become entrapped in an Ambystoma maculatum egg mass (Fig. 1). Planorbid snails are known to feed upon bacteria growing on structures present in water and detritus (Brown and Lydeard 2010. In Thorp and Covich [eds.], Ecology and Classification of North American Freshwater Invertebrates, pp. 277–307. Academic Press, London). The individual observed likely became entrapped by either being very close to the jellies as they swelled or attempting to consume bacteria that was present on the egg mass and burrowed in deeply enough to become encased with no mode of escape. To our knowledge, this is the first report of a non-amphibian species becoming entrapped in an egg mass in this portion of DBNF.

Fig. 1. Planorbid snail entrapped within an Ambystoma maculatum egg mass.

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BOLITOGLOSSA LIGNICOLOR (Camron Mushroom-tongue Salamander). PREHENSILITY. On 15 June 2012, six Bolitoglossa lignicolor were observed on a trail system adjacent to the ANAM station (Autoridad Nacional del Ambiente) between 2000–2300 h at the Montuoso Forest Reserve (Herrera Province) in the Azuero Peninsula of Panama (7.73251°N, 80.80033°W; 582 m elev.). When approached, one individual located ca. 1 m off the ground on the leaf of a shrub flipped its body to escape and propelled itself off its perch, catching itself by its tail on a branch about 30 cm below its initial position on the same plant. With the tail encircling the branch, the B. lignicolor proceeded to right itself on the branch and returned to its initial perch. To our knowledge there have been no published records where any Bolitoglossa has used its tail in any such utility to catch itself or grasp an object following a flipping escape, but this behavior has been observed previously in B. colonnea (T. Leenders, pers. comm.; D. B. Wake, pers. comm.). As this behavior has yet to be described, we hereby term the behavior of using the tail in a hook-like fashion to prevent falling and aid in climbing as caudate prehensility.

Similar flipping behavior has been reported in other members of Bolitoglossa including B. colonnea (Leenders and Watkins-Colwell 2003. Phyllomedusa 2:101–104; pers. obs.), B. schizodactyla (pers. obs.), B. engelhardti, B. franklini, B. repledens, and B. subpalmata (Brodie Jr. 1982. Nat. Geogr. Soc. Res. Rep. 14:77–88). These species give a broad representation of the Bolitoglossa clade (Pyron and Wiens 2011. Mol. Phylog. Evol. 61:543–583), indicating this behavior may be present within the majority of Bolitoglossa species as an ancestral behavior. The mechanics of a similar flipping mechanism has been described in Chiropterotriton and Oedipina, which are similar bolitoglossine genera (Dodd Jr. and Brodie Jr. 1976. Herpetologica 32:269–290), but such motion has not yet been analyzed in Bolitoglossa. All observations of flipping in Bolitoglossa occurred while the salamanders were on vegetation or in a laboratory setting, not on solid ground in the rain forest. This behavior has not been observed in laboratory tests of Bolitoglossa with snake predators (Ducey et al. 1993. Biotropica 25:344–349), so it is possible that flipping is typically employed as a defense mechanism against large predators that can readily attack Bolitoglossa above the ground such as large mammals and birds. Predominantly terrestrial Bolitoglossa may not gain the same defensive advantages from flipping that may benefit arboreal salamanders. Although a number of snake predators are known for the genus Bolitoglossa (six species listed in Brodie Jr. et al. 1991. Biotropica 23:58–62), other predators are largely unknown or unreported as to corroborate this hypothesis. Further field observations are necessary to determine whether these observations were isolated incidents, or if prehensility occurs frequently within Bolitoglossa and perhaps other related species.

We thank D. Laurencio and S. Burton for aid in fieldwork, and D. Wake and T. Leenders for correspondence on this note. Special thanks also to R. Bonett for many insightful comments on this manuscript. The fieldwork during which these observations took place was made possible by NSF grant DEB 0949-359. We complied with all applicable Animal Care guidelines (CMU-IACUC # 10-02) and all federal and international permits are on file and available from K.E.N.

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CRYPTOBRANCHUS ALLEGANIENSIS (Hellbender). LARVAL DIET. Little is known about the natural history of Cryptobranchus alleganiensis larvae. Only two larval Hellbender diet samples have been published (Smith 1907. Biol. Bull. 13:5–39; Pitt and Nickerson 2006. Herpetol. Rev. 37:69). On 21 Sept 2010, a gilled larva (40 mm SVL, 50 mm TL, 3 g) was collected from beneath a rock during skin diving surveys in Great Smoky Mountains National Park, Tennessee, USA. We flushed the individual’s stomach using an Easy Feeder Nipple Tip Syringe (Four Paws Products, Ltd., Hauppauge, New York) filled with river water. The larval C. alleganiensis regurgitated an intact Eurycea salamander measuring ca. 40 mm TL, which we subsequently preserved in a buffered 10% dilution of concentrated formalin. The Hellbender weighed 2 g following regurgitation.

This is the first report of a first-year C. alleganiensis larva consuming vertebrate prey, and also the first indication that C. alleganiensis larvae consume other salamander species. Although it has been suspected that larval C. alleganiensis feed primarily on aquatic insects (Pitt and Nickerson 2006, op. cit.), Smith (1907, op. cit.) stated that a second year individual measuring ca. 120 mm TL regurgitated a 60 mm TL conspecific. Hill (2012. Herpetol. Rev. 42:580) indicated that sub-adult C. alleganiensis may prey upon salamanders of approximately the same size. The consumption of a large vertebrate prey item relative to body size suggests that young C. alleganiensis larvae are able to utilize a wide variety of prey items and may be opportunistic feeders.

This research was conducted under National Park Service Permit (GRSM-2008-SCI-0052) and University of Florida ARC Protocol (#017-08WEC). We thank the National Park Service, The Great Smoky Mountains Institute at Tremont, Philip Colclough, Marcy Souza, and all volunteers for their assistance. Funding was provided by the Cryptobranchid Interest Group Jennifer Elwood Hellbender Conservation Grant, the Reptile and Amphibian Conservation Corps, and the Carlos C. Campbell Memorial Fellowship.

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EURYCEA CIRRIGERA (Southern Two-Lined Salamander). PARTIAL ALBINO LARVA. Larvae of Eurycea cirrigera are described as having two rows of small, paired, lightly colored dorsolateral spots, and as sometimes having two darkly pigmented irises. Typically, when albinos are described, the iris lacks melanin and eye-stripes that would have contained melanin in normal individuals appear red (albino Iris melanolophus variegatus). The irises of the albino larvae of E. bislineata collected by Bartley (1959. Herpetologica 15[4]:192) retained the eye-stripes typical of that species, and the albino larvae of Ambystoma opacum found by Deegan et al. (1998. Herpetol. Rev. 29[4]:229) had regularly pigmented irises. Typically, when albinos are described, the iris lacks melanin and eye-stripes that would contain melanin in normal individuals appear red (albino Gyrinophilus porphyriticus). Hill et al. 2012. Herpetol. Rev. 43(1):116–117.

We thank G. Thibaudeau, T. Vandeveer, and R. Altrig for their insights regarding this larva. Funding was provided by the National Science Foundation Graduate Research Fellowship Program (#0940712), and by U.S. Geological Survey Cooperative Agreement (#G10AC00689). This research was approved by the USM Institute for Animal Care and Use Committee (No. 11061301). After metamorphosis, this specimen will be deposited in the Mississippi Museum of Natural Science in Jackson, Mississippi.

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HEMIDACTYLMUS SCUTATUM (Four-toed Salamander). REPRODUCTION. In New Brunswick, Canada, the occurrence of Hemidactylemus scutatum is based on a small number of specimens observed, but none retained in collections, from sphagnum-shrub (Kalmia angustifolia, Chamaedsaphne calyculata) -rimmed Marven Lake in Fundy National Park (45.571633°N, 65.093460°W). The Fundy National Park (FNP) consists of 206,650 hectares that has been recorded for other species of salamanders. The irises of the albino larvae of E. bislineata collected by Bartley (1959. Herpetologica 15[4]:192) retained the eye-stripe typical of that species, and the albino larvae of Ambystoma opacum found by Deegan et al. (1998. Herpetol. Rev. 29[4]:229) had regularly pigmented irises. Typically, when albinos are described, the iris lacks melanin and eye-stripes that would contain melanin in normal individuals appear red (albino Gyrinophilus porphyriticus). Hill et al. 2012. Herpetol. Rev. 43(1):116–117.

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HEMIDACTYLMUS SCUTATUM (Four-toed Salamander). REPRODUCTION. In New Brunswick, Canada, the occurrence of Hemidactylemus scutatum is based on a small number of specimens observed, but none retained in collections, from sphagnum-shrub (Kalmia angustifolia, Chamaedsaphne calyculata) -rimmed Marven Lake in Fundy National Park (45.571633°N, 65.093460°W). The Fundy National Park (FNP) consists of 206,650 km² of heavily wooded mixed Acadian forest in the Caledonia Highlands along the Bay of Fundy coast (Freedman et al. 2010. In Mc Alpine and Smith [eds.], Assessment of Species Diversity in the Atlantic Maritime Ecozone, pp. 63–70. NRC Press, Ottawa).
The first recorded New Brunswick occurrence of *H. scutatum* is a single presumptive female photographed on 3 May 1983 (Woodley and Rosen 1988. Can. Field-Nat. 102:712; McAlpine 2010. In McAlpine and Smith [eds.], op. cit., pp. 613–631). At the time one of us (DFM) confirmed the identification. Marven Lake continues to be the sole location in the province from which the species is known, in spite of extensive searching inside and outside FNP (DFM, unpubl.; M. MacDonald, pers. comm. to DFM). Since 1983, FNP personnel have surveyed Marven Lake on two occasions (1999, 2000) to confirm the persistence of the species. However, beyond presence, no other information regarding the species in New Brunswick has been recorded. In 2012 we obtained a federal Parks Canada permit to collect one whole specimen from FNP and to retain up to three tail-tips for genetic archiving in the New Brunswick Museum (NBM) frozen tissue collection (whole animal: NBM AR 9764; tissue: NBM FTC AR2012.001-002). Here we report on the specimens handled and provide the first reproductive data for the *H. scutatum* in New Brunswick. The province is at the species’ northeastern range limit (Petranka 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington. 587 pp.) and at latitude from which there is limited natural history information for *H. scutatum* (Gilhen 1984. Amphibians and Reptiles of Nova Scotia. Nova Scotia Museum, Halifax. 162 pp.).

We visited Marven Lake on 29 June 2012 and during 105 minutes of searching along ca. 15 m of bog shoreline on the northeastern shore of a lake inlet (45.57284°N, 65.09332°W to 45.57310°N, 65.09397°W) located 3 km northeast of a lake inlet (45.57284°N, 65.09397°W) of the *Sphagnum magellanicum* zone. Two of these were accompanied by females (420 person minutes [pms] of search time; 1 clutch/140 pms). One clutch of 13 eggs was accompanied by a female (71.2 mm TL), and a female (79.9 mm TL) guarded a clutch of 18 eggs. No female was observed with a clutch of 10–30 eggs predominate (among clutches ranging from 4–114) and most nests (87.4%) are located in pure Sphagnum. Likewise, New Brunswick clutches were situated in circumstances similar to those described for Maine by Chalmers (2004. MSc thesis, Univ. Maine, Orono. 109 pp.). There appears to be no previous information concerning hatch dates for *H. scutatum* in Maritime Canada (Gilhen 1984, op. cit.), although Chalmers (2004, op. cit.) reported hatch dates for central coastal Maine from 16 June to 9 July.

This work was conducted under Parks Canada scientific permit FNP-2012-12934. We thank Dan Mazerolle, FNP, for facilitating the issuing of this permit. Michael MacDonald, Stantec Inc., shared information from a 1999 search for *H. scutatum* in FNP. Bruce Bagnell, New Brunswick Museum, kindly identified the *Sphagnum* sp. for us.

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**NECTURUS BEYERI** (Gulf Coast Waterdog). **DETECTION BY LEAF LITTER BAG.** Leaf litter bags made of plastic mesh and stuffed with leaf litter, are passive traps used to sample salamanders (Pauley et al. 1998. Banisteria 12:32–36; Waldron et al. 2003. Appl. Herpetol. 1:23–36). This method has detected at least 28 species of Plethodontidae. Prior to this note, we only know of one species of salamander outside of this family that has been caught in litter bags (*Necturus alabamensis*) (Graeter et al. 2013. In-ventory and Monitoring: Recommended Techniques for Reptiles and Amphibians, with application to the US and Canada. PARC Tech. Rept. Aiken, South Carolina). Herein, we report the detection of *Necturus beyeri* using leaf litter bags.

In November and December 2011, JYL deployed leaf litter bags at 10 creeks within the Pascagoula River Drainage in the DeSoto National Forest, in southern Mississippi, USA. *Necturus beyeri* were caught in litter bags at two of these creeks and identified based on range maps (Gayer 2005. In Lannoo [ed.], Amphibian Declines: The Conservation Status of United States Species, pp. 867–868. Univ. California Press, California). Two individuals were caught at Deep Creek (30.93009°N, 88.92031°W), the first on 13 Nov 2011 (20 mm SVL, 37 mm TL), and the second on 16 Dec 2011 (35 mm SVL, 58 mm TL). One individual was caught at Beaver Creek (30.97380°N, 88.93868°W) on 30 Nov 2011 (36 mm SVL, 57 mm TL). No *N. beyeri* were caught from May through July 2012 when the same reaches of Deep and Beaver Creeks were resampled with litter bags. A total of 169 salamanders were caught in bags in Fall 2011, and 1235 salamanders were caught using this method in Summer 2012.

Deep and Beaver creeks are medium-sized creeks. At the tributaries we sampled, these creeks had total drainage areas of 11.8 km² and 11.0 km² (ArcMap 10.1), and average widths of ca. 2.5 m and 3 m. For both creeks, sampled reaches averaged shallower than 0.5 m. Sand was the dominant substrate. Leaf litter packs, coarse wood, and submerged roots were the most abundant types of available cover. Over the course of litter bag sampling during Fall 2011 and Summer 2012, three species of plethodontids were detected at Deep Creek (*Eurycea cirrigera, E. quadridigitata, Desmognathus conanti*) and two plethodontids were detected at Beaver Creek (*E. cirrigera, E. guttolineata*).

Detecting any organism depends on using an appropriate method in the right place and at the right time. C. Gayer (pers. comm..) found that dip-netting for *N. alabamensis* was a more time-efficient method than was using litter bags. Leaf litter bags may not capture large numbers of *Necturus*, but they have been successful at detecting other cryptic or rare species of salamanders (Waldron et al. 2003, op. cit.).

Funding was provided by the National Science Foundation Graduate Research Fellowship Program (#0940712), and by U.S. Geological Survey Cooperative Agreement (#G10AC00689). This research was approved by the USM Institutional Animal Care and Use Committee (No. 11061301).

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**SIREN SP. PREDATION.** On 5 February 2012 at 2027 h, a remote game camera captured a digital image of a Barred Owl (*Strix varia*) perched on stump with a sirenid in its talons (Fig. 1). The game camera was situated along Goodland Creek, a first order stream in the Upper Coastal Plain of Orangeburg Co., South Carolina, USA. Although *Siren intermedia intermedia* (Eastern Lesser Siren) has been captured on the property and is the only
documented sirend to occur in the creek, S. lacertina (Greater Siren) is also found in sluggish intermittent backwaters in the region (“Pen Branch Delta” Luhring and Jennison 2008 J. Fresh. Ecol. 23:445–450) and there are intermittently connected pools on the property. Because the sirend in the picture appears to be within the size range of a large S. i. intermedia or medium S. lacertina we are withholding its species-level designation. There are several documented avian predators of “aquatic salamanders” (amphiumids and sirens) although few cases are specified to the species or even familial level (Luhring 2008. M.S. Thesis, Univ. Georgia, Athens, Georgia). This is the first confirmed observation of a Barred Owl depredating a sirend.

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On 2 Feb 2013 at Viera Wetlands, ca. 8.5 km WSW Pineda, Brevard Co., Florida, USA (28.216°N, 80.762°W; WGS84), we observed an adult American Bittern (Botaurus lentiginosus) stalk, catch, subdue, and swallow a subadult (ca. 25–30 cm TL) S. lacertina (Fig. 1). The bittern was foraging in thickly vegetated, shallow water at the edge of a wetland, and appeared to be feeling for prey with its feet. After watching the water intently for several minutes, it seized the S. lacertina in its bill at 12:31 h, but immediately dropped it. After focusing intently on the spot for another 4 min, it grabbed presumably the same siren again and manipulated it with its bill for slightly less than 1 min before swallowing it. The American Bittern is a generalist predator of small aquatic, semiaquatic, and terrestrial vertebrates and invertebrates, including various amphibians (Terres 1982. The Audubon Encyclopedia of North American Birds. Alfred A. Knopf, New York. 1109 pp.), and would be expected to include sirens in its diet. To our knowledge, this represents the first published record of B. lentiginosus as a predator of S. lacertina.

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ANURA — FROGS

ANAXYRUS FOWLERI (Fowler’s Toad). INTERSPECIFIC NEST USE. Pittosporus melanoleucus (Pinesnake) females in the New Jersey Pine Barrens excavate nests in open canopy, sandy upland areas. Nests, consisting of a tunnel up to 2 m and a hollowed egg chamber, are excavated and not revisited after oviposition (Burger and Zappalorti 1991. J. Herpetol. 25:152–160). The mouth of the tunnel typically collapses within a month of excavation, though the inner tunnel system may stay intact (pers. obs.). Little is known about the biophysical constraints and site selection pressures on P. melanoleucus nesting. We study P. melanoleucus in the northern extent of its range where it overlaps with several amphibians known to burrow into the sandy soil typical of this region. Specifically, much of the P. melanoleucus habitat is shared with the Fowler’s Toad (Anaxyrus fowleri).

When investigating P. melanoleucus nests in the Franklin Parker Preserve, Chatsworth, New Jersey, USA, in July 2011, using a fiber-optic camera, we video captured A. fowleri use of an active nest. The toad was located 1 m into the tunnel, not in the egg chamber. At this point, the mouth of the nest was open and there was no sign of additional excavation by the toad. This nest produced four hatching P. melanoleucus that year. Another A. fowleri was found in an artificially dug hole near the nest site the same day. The artificial hole was similar in dimensions to

Fig. 1. A Barred Owl (Strix varia) landing on a stump with a siren in its talons on 5 Feb 2012 at 22:27 h. The species is probably the Lesser Siren (Siren intermedia) as several have been captured in the marginal swampy areas of the stream. Wildlife camera set up by Whit Gibbons.
the test holes often dug by female *Pituhphis* spp. near true nests, 30 cm deep (Wright 2008. Can. Field Nat. 122:138–141; Burger and Zappendorl 1986. Copeia 1986[1]:116–121). It is unknown if neonate *P. melanoleucus* prey on *A. fowleri*, though the toads are prey to other snakes in the surrounding habitats including Black Racer (*Coluber constrictor*) and Eastern Hognose Snake (*Heterodon platirhinos*). Fowler’s Toads have a small annual home range, limited to ca. 75 m diameter (Clark 1974. Am. Midl. Nat. 92:257–274). During *P. melanoleucus* incubation months (July and August), nest tunnels may serve as temperature and humidity refugia for Fowler’s Toads. Toad predator avoidance and breeding success are contingent on optimal body temperature and humidity (Preest and Pough 2003. Physiol. Biochem. Zool. 76:229–239). Although the potential effects of toad presence on *P. melanoleucus* egg development are unknown, cooler, humid, and more stable conditions of the subterranean nests may make them important resources for Fowler’s Toads (Burger 1989. Behav. Ecol. Sociobiol. 24:201–207).

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**COLOSTETHUS INGUINALIS** (Common Rocket Frog). DIET. *Colostethus inguinalis* is an endemic Colombian species found in the lowlands of northern Choco and the Valley of Magdalena (Grant 2004. Amer. Mus. Novit. 3444:1–24). This diurnal species occurs in rocky areas along the bank of streams in rainforests and mountainous forests. The species is abundant, but populations are decreasing due to deforestation by agricultural and livestock activities, illegal plantations, human establishments, and contamination by fumigation of illegal plantations (Grant and Lynch 2004. IUCN Red List of Threatened Species. Ver. 2012.1 www.iucnredlist.org, 19 March 2013). The food habits and many aspects of its ecology are unknown. Herein we describe the diet of *C. inguinalis* from Reserva Campoalegre, Córdoba, Colombia. Volume in mm$^3$.

<table>
<thead>
<tr>
<th>Prey</th>
<th>Number (%)</th>
<th>Volume (%)</th>
<th>Frequency of occurrence</th>
</tr>
</thead>
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<tr>
<td>Diplopoda</td>
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<tr>
<td>Crustacea</td>
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<tr>
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<tr>
<td>Tettigonidae</td>
<td>1 (0.47)</td>
<td>342 (54.49)</td>
<td>1</td>
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</table>

**TABLE 1. Composition of prey in the diet of Colostethus inguinalis** from Reserva Campoalegre, Córdoba, Colombia. Volume in mm$^3$.

The food habits and many aspects of its ecology are unknown. Herein we describe the diet of *C. inguinalis* in the dry tropical forest of Colombia in the Natural Reserve of Civil Society Campoalegre (8.48502°N, 76.19520°W; 120 m elev.), municipality Los Cordobas, Department of Cordoba.

We examined 30 stomachs of *C. inguinalis* collected during 0800–1200 h and 1600–1800 h, Feb–Nov 2007 along the banks of streams inside the forest. These samples were collected during the dry season (January–March), first rains (April–June), and heavy rains (September–December). We identified prey to family and genus when possible, measured the length and width of each complete prey item by using a digital caliper (to 0.1 mm). We estimated the volume using the volume for a prolate spheroid.

All frogs collected (N = 30; 15.5–29.5 mm SVL; mean 21.6 ± 2.7) had prey in their stomachs. The diet consisted mainly of arthropods and mollusks (Table 1). Insects (9 orders, 19 families, and 37 morphotypes) and arachnids (especially spiders) were the most important prey. Orthoptera, Coleoptera, and Araneae was the most important volumetrically however Orthoptera was represented by a single large prey consumed by a single individual. Numerically, the most important prey were ants, *Pheidole* and larval Carabidae and Diptera (*Ceratopogonidae*). Ants (*Pheidole* and *Solenopsis*) and Staphilinidae had the greatest frequency of occurrence.
We found *C. inguinalis* consumes a large of ants; however, its diet consists of a large number of different prey, which is consistent with other investigations. Volumetrically, the most important prey are somewhat different than those represented in the diet of other closely related species.

We are grateful to Fernando Fernández, Vivian Sandoval, Larys Fontalvo, Yamileth Domínguez, Eduardo Flórez, Orlando Combita, Rodulfo Ospina, Jorge de las Salas, Adriana Tinoco, Ángel Solís, Cesil Solís, and Rudolf H. Scheffrahn for their help in identifying the prey contents. Luis Velazquez provided logistical aid in Reserve Campoalegre. Co ciencias and Universidad del Atlántico provided funding for this investigation.

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**DENDROBATIDAE and BUFO CONIFERUS. DEFENSE.** Little is known of the taxonomic identity of predators on chemically defended species such as poison frogs of the family Dendrobatidae. Studies of predation on poison frogs have found marks thought to be attributable to ants (Saporito et al. 2007. *Copeia* 2007:1006–1011; Hegna et al. 2011. *Ann. Zool. Fennici* 48:29–38), and frogs are occasionally found missing digits, which could also be due to encounters with ants (pers. obs.). Here I describe an interaction of an army ant swarm (*Eciton hamatum*) on three species of poison frogs (*Dendrobates pumilio, D. auratus*, and *Phyllobates lugubris*) and on a toad (*Bufo coniferus*) on mainland Panama adjacent to the Bocas del Toro archipelago. Though *E. hamatum* predominantly feed on ants, bees, and wasps (Bartholomew et al. 1988. *Physiol. Zool.* 61:57–68), differences in their interaction with anuran species provides further evidence for the likelihood of an olfactory signal in the chemical defense of poison frogs.

At 1040 h on 27 Dec 2012 while sampling a polymorphic population of *D. pumilio* from the Agua cate Peninsula an army ant swarm entered the study area. Channels of ants quickly over took the site and many invertebrates (crickets, katydids, and scorpions) emerged from the leaf litter and escaped. A blue subadult *D. pumilio* became completely surrounded by ants, and remained untouched perched on a leaf. Shortly thereafter three more blue adults and one brown adult were surrounded but also left untouched. Throughout the swarm a small margin (2–3 cm) was maintained between the ants and the frogs. Twenty-four minutes into the ant invasion an adult *D. auratus* perched on a large buttress was similarly approached and avoided as the ants climbed up the tree. Two additional blue and one brown *D. pumilio* were then observed to be surrounded by ants during which one male continued to produce an advertisement call. One hour into the swarm an adult *P. lugubris* and a second *D. auratus* were also surrounded and avoided by ants in a tree buttress, as was a second male *P. lugubris*, which vocalized nearby.

At no point in the column swarm did the ants come into direct contact with any of the three species of poison frogs present in the site; rather the ants maintained about a 2-cm margin from all frogs. In contrast, ants covered a toad (*Bufo coniferous*), which closed its eyes as its body was pressed flat again against a tree. Its eyes remained closed until there were gaps in the ant column when its eyes would open, then close again as more ants arrived.

Though this observation unfortunately does not add to our knowledge of specific poison frog predators, it does provide some insight into the possible disparity between results from clay model studies and actual predation. Saporito et al. (2007, op. cit.) note that some attack marks on their clay models appeared to be due to the incisors of what they hypothesize could be attributable to *Atta* spp., another group of ants encountered in high densities throughout the tropics. Additionally, the “buffer” distance observed from the frogs could be due to an olfactory component of the alkaloids possessed by these poison frogs which clay models would lack. Poison frog activity during the ant swarm did not appear to be inhibited by the presence of ants. Male vocal advertisements continued for two species during the swarm. At no point did individuals appear threatened by the presence of ants and initiate an escape. These observations further support previous studies mentioning alkaloid olfactory cues in the context of other arthropods, including spiders (*Cupiennius coccineus*; Szelistowski 1985. *Biotropica* 17[4]:345–346) and other predatory (“bullets”) ants (*Paraponera clavata*; Fritz et al. 1981 *Biotropica* 13:158–159).

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**HYLA ARENICOLOR (Canyon Treefrog). HABITAT USE.** Several species of treefrogs have been documented using tree cavities and avian nest boxes as refuge or hibernacula, including *Hyla chrysoscelis* (Ritke and Babb 1991. *Herpetol. Rev.* 22:5–8), *H. cinerea* (Redmer and Brandon 2005. *In M. Lannoo [ed.], Amphibian Declines: The Conservation Status of United States Species*, pp. 452–454. Univ. California Press, Berkeley, California), and *H. squirrela* (McComb and Noble 1981. *Wildl. Soc. Bull.* 9:261–267). Treefrogs may use these structures to exploit favorable microclimates or diverse invertebrate food sources. Herein, we report two observations of related behavior in *H. arenicolor*, a treefrog that inhabits isolated mountain canyons in the southwestern USA. Unlike most other treefrogs, *H. arenicolor* is typically found on rock surfaces along stream courses and rarely climbs trees. On 18 June 2012 at 1121 h, we observed three adult *H. arenicolor* inside a Black Phoebe (*Sayornis nigricans*) nest in the Rincon Mountains east of Tucson, Arizona (32.26278°N, 110.62744°W, WGS84; elev. 1068 m; Fig. 1). The cup nest was constructed of mud and plant material and cemented to a vertical rock surface.
ca. 1 m above a bedrock-lined pool, typical of Black Phoebe nests in the desert southwest (Wolf 1997. *In Poole and Gill [eds.], Birds of North America, No. 268, Acad. Nat. Sci., Philadelphia, Pennsylvania*). Similarly, on 21 June 2013 at 1100 h, ERZ observed one *H. arenicolor* in a Black Phoebe nest in another canyon in the Rincon Mountains (32.15668°N, 110.60713°W, WGS84, elev. 1077 m). This nest was attached to the angled underside of a large boulder >0.8 m above the surface of a pool. In both cases, the nests appeared to be intact and undamaged, but there was no evidence that birds had used the nests recently.

Although *H. arenicolor* have lower rates of evaporative water loss than many other anurans (Preest et al. 1992. *Herpetologica* 48:210–219), they are still at considerable risk of desiccation at midday in June. The bird nests provided shade for the treefrogs, which were >30 mm below the nest opening, likely reducing their risk of dehydration. During summer months, canyon treefrogs are often observed on vertical surfaces of boulders above pools of water, a strategy that presumably reduces rates of predation by vertebrate and invertebrate aquatic predators, including *Thamnophis cyrtopsis* and insects in the family Belostomatidae (Jones 1990. *Southwest. Nat.* 35:115–122; Swann 2005. *Sonoran Herpetol.* 18:39–42; Wylie 1981. PhD Dissertation, Arizona State Univ., Tempe, Arizona). Nests may have further reduced risk of predation by concealing treefrogs from potential predators when using these vertical rock surfaces.

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**HYLA CHRYSOSCELIS** (Cope’s Gray Treefrog). **BREEDING ACTIVITY.** Little is known about the biotic and abiotic factors that influence the timing and intensity of reproduction in most anurans. One potentially important but rarely examined factor is lunar phase (Grant et al. 2009. *Anim. Behav.* 78:349–357). Here, we report observations on the relationship between lunar phase and the intensity of breeding in populations of *Hyla chrysoscelis* in east-central Minnesota, USA.

We observed reproductive activity over six consecutive breeding seasons (28 April to 8 July, 2006–2011) in populations located within 80 km of St. Paul, Minnesota. Teams of 3–4 people used headlamps or handheld lanterns to search for and collect pairs found in amplexus (Fig. 1). Searching occurred between 2200 and 0200 h and was concentrated in areas of ponds with the highest numbers of calling males. Our sampling regime was neither randomized nor systematic in any way; rather, it was guided by the objective of collecting as many pairs as possible each night for use in ongoing behavioral studies of female mate choice; pairs were returned to their collection site within 48 h.

We observed a total of 3293 pairs on a total of 317 “breeding nights” on which at least one pair was observed (range: 1–97 pairs/night; median: 12 pairs/night). The day of the lunar cycle assigned to each breeding night was expressed as an angle and calculated as the days since full moon divided by 29.5 days (0° = 360° = full moon; 180° = new moon). Breeding was statistically more likely to occur closer to the new moon than the full moon when we considered all pairs together (Raó’s spacing test: 356.3, p = < 0.01, N = 3293 pairs; Fig. 1A). This trend also held for nights when relatively large breeding events occurred, which we defined as those nights ranking above the 90th percentile within a season in terms of the numbers of pairs collected (median = 70.5 pairs/night, range = 30–97 pairs/night, N = 17 nights). Nights on which these large breeding events occurred were relatively rare around the time of the full moon (Fig. 1B; Raó’s spacing test: 168.7, p = < 0.05, N = 17 nights).

These observations suggest lunar phase could be one, albeit weak, factor influencing decisions by some females of *Hyla chrysoscelis* about when to breed. One hypothesis that might explain these data is that breeding, and especially nights when large numbers of females breed, was restricted to darker times during the lunar cycle because of potentially increased risk of predation by visually-oriented predators on nights surrounding a full moon. Other correlates of the lunar cycle (e.g., changes in geomagnetism or gravity), however, might also play some role. Interestingly, our observations contrast with data on several European frogs, for which Grant et al. (2009, *op. cit*.) showed that large breeding events were more likely to occur closer to the full moon. This evidence suggests the lunar cycle might be important in anuran breeding phenology and that there might be patterns of species differences worth investigation.

Research and collecting were conducted with permission from the Minnesota Department of Natural Resources, the Three Rivers Park District, and the University of Minnesota Institutional Animal Care and Use Committee.

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**HYPSIBOAS CINERASCENS. PREDATION.** *Hypsiboas cineras-cens* is a small (31–37 mm SVL), common Amazonian treefrog, predominantly arboreal, nocturnal, and frequents the vegetation in riparian and wetland areas (Lima et al. 2006. *Guide to the Frogs of Reserva Adolpho Ducke – Central Amazonia. Attéma Design Editorial, Manaus. 168 pp.*). Antbirds, Thamnophiliidae, are a family of Neotropical passeresines that feed predominantly on arthropods, however a substantial proportion of the diet of some species may also consist of small vertebrates, principally frogs and lizards (Poulin et al. 2001. *J Trop. Ecol.* 17:21–40). On 12 Feb 2013, ACL and I. Thompson found a pair of nest-building Spot-winged Antshrikes (*Pygypitila stellaris*) at the ecotone of degraded primary forest and *varzea* on the left bank of the lower Rio Guama at the Comunidade Menino Jesus, Marituba, Pará.

![Fig. 1. Lunar cycle and breeding activity in *Hyla chrysoscelis*. Circular histograms showing the distribution, mean vector (μ), and vector strength (r) for A) the number of breeding pairs observed per night over all breeding nights relative to the lunar phase (μ = 141°, r = 0.06); and B) the number of nights on which large breeding events occurred relative to the lunar phase (μ = 213.9°, r = 0.21). Time during the 29.5-day lunar cycle is here expressed as an angle such that 0° and 360° correspond to the full moon and 180° corresponds to the new moon. Inset: Breeding pair of *H. chrysoscelis* in amplexus.](image-url)
state, Brazil (1.48666°S, 48.31666°W). The birds were loosely associating with a mixed species flock. While under observation the female of the pair was observed carrying a live *H. cinerascens*. The frog was captured within the same tree that was presumed to hold the nest (the female was observed carrying nesting material a few minutes before), which was about 4 m tall and situated in varzea forest with a water depth of ca. 50 cm. The *Pygipitila* appeared to experience some difficulty in securing the large prey item and the frog repeatedly grabbed the vegetation surrounding the bird’s perch. To subdue the frog the *Pygipitila* was observed to violently bash the frog against its perch on four occasions over the course of two minutes after which point the frog ceased to move. The bird then moved out of sight and we could not confirm that the prey item was consumed. ACL documented the event with a series of digital photographs, reproduced here (WA882353, http://www.wikiaves.com.br/882353&p=1&t=b). *Pygipitila* exhibits a strong preference for foraging for food items extracted from curled dead leaves (Rosenberg 1997. Ornithol. Monogr. 48:673–700), and it is likely that the treefrog was captured in its diurnal hideout under leaves. Although predation of frogs by Thamnophilidae is probably not uncommon we believe this to be the first well-documented incident of such a predation event.

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During the evening of 6 August 2012 we observed *L. savagei* actively hunting Túngara Frogs (*Engystomops Physalaemus pustulosus*) at a water channel in Gamboa, Panama (9.11666°N, 78.69833°W). A male *L. savagei* was first observed when it attacked and missed catching a calling male Túngara Frog. After that, the same individual was followed and video recorded while it attacked and consumed three additional Túngara Frogs within 4 m from the first attack. This predator moved by sporadic jumps but once it was closer to a Túngara Frog, within about 100–200 cm, it lowered its body so at least half of it would be submerged under water and began to slowly drag itself towards its prey by staying close to the bottom of the puddle in a movement reminiscent of an army crawl (Fig. 1). When it was within about 30 cm, the *L. savagei* attacked the smaller frog by jumping onto it to catch it by its mouth. The Túngara Frog was pushed deep into the mouth using the front legs and was rapidly swallowed. After a few seconds of having swallowed the frog, the *L. savagei* scoped for its next victim using the same strategy. We observed this frog-eating predator successfully performing the “jump-army crawl-capture” strategy three consecutive times. In all cases the attacked frogs were calling male Túngara Frogs. Although *L. savagei* is known to be a voracious predator of Túngara Frogs (Ryan et al. 1981. Behav. Ecol. Sociobiol. 8:273–278), hunting strategies have not been described. As in the observations reported here, previous studies have documented *L. savagei* attacking Túngara Frog males aggregated at breeding areas, where the individuals attacked were apparently calling. Eavesdropper predators and parasites that exploit the communication system of Túngara Frogs are known (Tuttle and Ryan 1981. Science 214:677–678; Bernal et al. 2006. Behav. Ecol. 17:709–715), but whether *L. savagei* individuals are also using the mating calls to cue in on this prey needs further investigation.

The army crawl described here is similar to the walking behavior characteristic of some species of frogs (e.g., *Physalaemus*). As with walking, crawling involves alternated movement of front and back legs from both sides with little lateral movement of the trunk. It differs, however, in that the body is lowered to the bottom of the puddle and the frog’s back legs slide along the ground while the front legs are bent very low. In contrast to jumping, the characteristic locomotor behavior of *L. savagei* was performed by submerging at least half of the body. The army crawl allows this predator to move closer to its intended prey creating less water displacement by its large body mass and without producing splash sounds associated with jumping. By reaching an appropriate position to seize its prey with minimal disturbance, foraging success is likely improved. Crawling behavior on land has been observed in *Rana esculenta* during feeding (Nauwelaerts and Aerts 2002. J. Zool. 258:183–188), but it is unclear if this sneak attack strategy is deployed by other anurans.

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**LIMNONECTES PALAVANENSIS** (Smooth Guardian Frog). **OCULAR ANOMALY.** *Limnonectes palavanensis* is a small anuran (to 40 mm SVL) which dwells in the leaf litter of primary

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**Fig. 1.** A) Male *Leptodactylus savagei* with body lowered to the ground prepared to move forward. B) Male lunged forward by force from hind legs. C) The individual *Leptodactylus savagei* stretched with right foreleg in front as the individual crawled forward. D) Male halted crawl and the crouched position is reassumed.

On 6 Oct 2012 at 2055 h during the Localized Nature Guide Course organized by Borneo Tourism Institute (BTI), an adult male L. palavanensis (29 mm SVL) was collected on the forest floor among dead leaves at Crocker Trail (5.4047°N, 116.1104°E; 1049 m elev.), Ulu Kimanis Substation, Crocker Range National Park, Papar District, West Coast Division, Sabah, Bornean Malaysia. The anuran was void of a right eye, while the left eye was present and normal (Fig. 1). Compared to typical L. palavanensis, the anuran displayed lighter body hue, but was agile during an indoor ex-situ photography session. The anomaly appeared not to affect the overall field of view and did not restrain its visual response and movement. In Dec 2010, Kueh et al. (2011. Herpetol. Rev. 42(3):410) reported ocular anomaly in the microhylid Chaperina fusca from highland West Coast, Sabah. Further studies are warranted to determine if such anomaly occurs in other Bornean anuran families and species either with similar or dissimilar effects, the frequency of occurrence of the anomaly in different families and species, and geographical range of the anomaly, to help understand the nature and pattern of ocular anomaly in anurans.

Ocular anomaly in anurans can be caused by physical injuries and selective predation, infections and diseases (fungal infection by Batrachochytrium dendrobatidis [Bd]), exposure to chemicals and UV radiation, mutation, and developmental errors (Adams et al. 2008. Herpetol. Rev. 39:460–461; Silva and Toledo 2010. Herpetol. Rev. 41:333–334; Streicher et al. 2010. Herpetol. Rev. 41:208–209; Pirani and Moura 2012. Herpetol. Rev. 43:471). However, examination of the anuran showed no body injuries. The anuran was found on a dry trail without any water bodies in the vicinity to corroborate the causal factors of chemical pollution and Bd infection.

The anuran was released after photographs and measurements were taken, in accordance to the requirement of the management of Crocker Range National Park under the Sabah Parks. Photographic vouchers are available from the first author. To our knowledge, this is the first observation of ocular anomaly in L. palavanensis.

We are grateful to Borneo Tourism Institute (BTI), Sabah Parks, and the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah for support.

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LITHOBATES SYLVATICUS (Wood Frog). EGG PREDATOR ENTRAPMENT. On 9 March 2012 while surveying ridge-top wetlands in Daniel Boone National Forest (DBNF), Rowan Co., Kentucky, USA, we observed a L. sylvaticus larva that had become entrapped within an L. sylvaticus egg mass. This represents the second observation of an amphibian species entrapped in an egg mass that has occurred in this portion of DBNF (Richter 2012. Herpetol. Rev. 43:459). The L. clamitans larva presumably became entrapped while attempting to eat embryos inside the egg mass, as they are known to depredate L. sylvaticus eggs (Vasconcelos and Calhoun 2006. Wetlands 26:992–1003). Upon further examination, it was evident that the egg mass had been preyed upon based on the amount of damage observed, however it was undetermined if the entrapped larva or other L. sylvaticus larva present in the pond were responsible for the damage.

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LITHOBATES SYLVATICUS (Wood Frog). UNUSUAL MORTALITY. Lithobates sylvaticus is a common species throughout the northern United States and Canada. They are explosive breeders that lay communal egg masses in ephemeral ponds during the early spring. Lithobates sylvaticus are often the first amphibian breeders to arrive at these ponds (followed by Ambystoma jef-fersonianum and A. maculatum; J. MacGregor, pers. comm.). On warm, rainy nights, frogs can be seen and heard commuting to
breeding ponds. However, atypical weather patterns can act as false cues for the frogs to begin breeding.

On 31 Jan 2013, several *Lithobates sylvaticus* egg masses were observed in trees overhanging an ephemeral pool (37.519472°N, 084.234128°W) on the border of Rockcastle and Metcalfe counties in eastern Kentucky (Figs. 1, 2). I believe the cause of this phenomenon was an atypically warm and wet night followed by several days (and nights) with temperatures below freezing. The *L. sylvaticus* likely received temperature and humidity stimuli that initiated their breeding behavior. Eggs were then laid in an unfrozen, relatively warm pond. During subsequent weeks, Kentucky (and much of the eastern USA) was hit with an ice storm. Ice deposition on trees must have weighed them down to the point where they entered the water among the frog egg masses. Upon thawing, the trees would have then returned to their position above the ponds pulling the egg masses with them. The scenario presented above appears to be the most likely explanation, but other possibilities surely exist.

This observation emphasizes the important role weather and climate cues play in amphibian life histories. Indeed, as anthropogenic climate change continues to alter weather patterns, occurrences such as this may become more common.

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**Pseudacris crucifer** (Spring Peeper). **Myiasis.** Calliphorid flies are known to parasitize North American anurans (Kraus 2007. J. Nat. Hist. 41[29–32]:1863–1874). However, to the best of our knowledge, there have been no published accounts of *Pseudacris crucifer* parasitism by the blowfly *Lucilia sylvarum* (previously *Bofolucilia sylvarum*).

On 24 July 2012, at ca. 0930 h, we observed *P. crucifer* with 32 blowfly eggs of *L. sylvarum* attached to its back. Seventeen eggs were attached just anterior to the sacral hump and lateral of the midline. Another 15 eggs were attached just posterior of the sacral hump, ca. 30 degrees dextral to the antero-posterior axis (Fig. 1).

The specimen was discovered on the ground in southeastern Minnesota, USA, as we collected anurans for a chytridomycosis survey (44.7245°N, 93.3425°W, 275 m elev.). The frog appeared healthy other than the aforementioned infestation. No lesions, injuries, or signs of disease were noted. Seventeen *P. crucifer*, 4 American Toads (*Anaxyrus americanus*), 22 Gray Treefrogs (*Hyla* sp.), 27 Green Frogs (*Lithobates clamitans*), 2 Northern Leopard Frogs (*Lithobates pipiens*), and 6 Western Chorus Frogs (*Pseudacris triseriata*) were collected.
The parasitized _P. crucifer_ was held for observation. No efforts to dislodge the eggs were observed and the individual behaved normally until the eggs hatched. After hatching, the maggots quickly penetrated the skin of the host and produced a single lesion just lateral of the dorsal midline and anterior to the sacral hump (Fig. 2). Myiasis and larval development followed the course observed in Wood Frogs (Bolek and Janovy 2004. _J. Parasitol._ 90[5]:1169–1171) and the specimen was quickly reduced to slurry and bones.

It appears from the number of _L. sylvarum_ eggs deposited on the specimen (i.e., 32) that host size and parasitic intensity are uncorrelated variables. Bolek and Janovy (2004, _op. cit._) observed approximately the same number of _L. sylvarum_ eggs on juvenile Wood Frogs in southeastern Wisconsin, USA (i.e., 28–31, _N_ = 2). Although they did not report the mass of the parasitized frogs collected, their photographs and the natural histories of the two species suggest a 2× or greater difference in body mass, with Wood Frogs being substantially larger than _P. crucifer_. American Toads (_N_ = 9) parasitized by _L. sylvarum_ in southeastern Wisconsin averaged 8.7 g (Bolek and Coggins 2002. _J. Wildl._ Dis. 38[3]:598–603), which is ca. twice the mass of a typical _P. crucifer_.

We supplemented the _P. crucifer_ carcass with a _L. clamitans_ carcass weighing ca. 35 g. The larva reduced both carcasses to bones. Because the eggs of _L. sylvarum_ hatch within hours of deposition and the host can be reduced to skeletal remains within 96 h, anuran parasitism by the blowfly _L. sylvarum_ is likely to escape notice and may be considerably more common than our observations and published records indicate.

Elevated temperatures resulting from climate change are likely to advance the emergence of anurans and blowflies in the spring, extend their activities in the fall, and increase the cumulative incidence of myiasis in temperate anurans, as anticipated and observed in other species (Goulson et al. 2005. _J. Appl. Ecol._ 42:795–804). Unfortunately, it may be difficult to document the impacts of climate change on myiasis-induced death rates due to the difficulty of observing myiasis in wild populations and a scarcity of published observations suitable for constructing baseline rates in North American anurans.

We thank University of Minnesota entomologists J. Luhman and P. Tinerella for confirming the identity of the _L. silvarum_.

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**RANA DRAYTONII** (California Red-legged Frog). **UNUSUAL DEATH.** _Rana draytonii_ has been declining in southern California since the late 1960s and is currently listed as Vulnerable by the IUCN and Threatened by the U.S. Fish and Wildlife Service. It has been extirpated in California from San Diego, Orange, Riverside, and San Bernardino counties and only two populations are known for Los Angeles Co.. While conducting surveys on 26 Feb 2013 at the southernmost extant population in the USA in Ventura Co., an adult male _R. draytonii_ was discovered dead, entangled in several native blackberry (_Rubus ursinus_) vines just below the surface of the water. The frog's hind right leg was wrapped with six small vines that were cut to free the body. The frog's leg was broken, indicating it struggled to free itself before its demise. The frog was collected (U.S. Fish and Wildlife Recovery Permit TE-045994) and deposited in the Los Angeles County Natural History Museum (LACM 183590). This is contribution 455 of the USGS Amphibian Research and Monitoring Initiative.

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**SCINAX CF. ARDOUS** (Bromeliad Frog). **PREDATION.** Composed of 13 species, the _Scinax perpusillus_ group is distributed along the Atlantic rainforest between the states of Santa Catarina and Espírito Santo, southeastern Brazil (Frost 2013. _Amphibian Species of the World: an Online Reference. Ver. 5.6._ Electronic database accessible at http://research.amnh.org/herpetology/amphibia/index.html, American Museum of Natural History, New York). This group is thought to be strictly bromeligenous in having the larval stage associated with water stored in Bromeliaceae (Peixoto 2005. _Rev. Universidade Rural_ 17:75–83). The freshwater crab _Trichodactylus fluviatilis_ is widely distributed in the states of Bahia and Rio Grande do Sul (IUCN 2012. www.iucnredlist.org) and is present in freshwater environments, lentic and lotic, where it is known to feed on plant material, eggs, crustaceans,
mollusks, and tadpoles. On 6 Oct 2012, at Área de Proteção Ambiental do Mestre Álvaro (20.16722°S, 40.18040°W; 246 m elev.), we observed a male *T. fluviatilis* (2.8 × 3.2 cm carapace) feeding on a *Scinax* cf. *arduosus* (2.2 cm SVL) (Fig. 1). The anuran was held by the larger chela (3.6 × 1.6 cm) of the crab. The observation took place on the edge of a stream environment in a secondary patch of Atlantic rainforest. When first observed, the crab was feeding on the anuran, which already had the hind limbs missing. Only photographs were taken, no specimens were collected.

The occurrence of this anuran in the stream environment may be linked to the presence of bromeliads in rock outcrops present in the immediate area of our observation. We cannot confirm the act of predation as the anuran was already being consumed at the beginning of our observation. Because they are associated with different environments, we believe that such interaction between the taxa cited is not frequent, which possibly would not affect the structure of the anuran population in the study area.

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**SCINAX RUBER. PREDATION.** Between 2145 and 2210 h on 30 Dec 2009, we observed a *Trachycephalus typhonius* (94 mm SVL) preying on two *Scinax ruber* in the city of Carolina, Maranhão, northeastern Brazil (7.29277°S, 47.49305°W; 168 m elev.). The *T. typhonius* was observed ca. 4 m above ground on a tree. It captured an adult *S. ruber* and in less than 30 min there was a second attack on another adult. Both attacks occurred in savanna (Cerrado) vegetation. When captured, the *T. typhonius* regurgitated the second *S. ruber*, the first was extracted from the stomach. All specimens are deposited in the Herpetological collection of the Pontifícia Universidade Católica de Goiás, Goiânia (*T. typhonius* CEPB9241). These observations confirm that *T. typhonius* is a predator of *S. ruber*, although it is unknown if *S. ruber* is an important dietary item or if they are only sporadically ingested.

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**TESTUDINES — TURTLES**

**APALONE FEROX** (Florida Softshell). DIET. *Apalone ferox* is thought to be omnivorous, with a strong preference for carnivory. Although the majority of reported prey consists of invertebrates, a wide variety of vertebrate prey has been documented, including fish, turtles, snakes, and birds. Ranid frogs are, to date, the only reported anuran prey (Ernst and Lovich 2009. Turtles of the United States and Canada, 2nd ed. Johns Hopkins University Press, Baltimore, Maryland. 827 pp.).

**CHELYDRA SERPENTINA** (Snapping Turtle). DIET. *Chelydra serpentina* is known to have a varied diet of both plants and animals, as well as carrion (Ernst and Lovich, 2009. Turtles of the United States and Canada, 2nd ed., Johns Hopkins University Press, Baltimore, Maryland. 827 pp.).

On 12 September 2012 at approximately 0900 h, an adult *A. ferox* was observed in a drainage canal in Homestead, Florida, USA (25.471190°N, 80.468122°W). At the time of observation, the *A. ferox* was in the process of partially consuming a still living *Rhinella marina* (Fig. 1). The turtle proceeded to consume much of the toad’s lower right leg. It is unknown whether the *A. ferox* consumed the remainder of the *R. marina*, as the observer left the area before the end of the feeding event.

This documents the first known instance of *A. ferox* preying upon *R. marina*. *R. marina* was introduced to southern Florida in 1955 as a result of an accidental release at Miami International Airport (Krakauer 1968. Herpetologica, 24:214–221). It has since expanded its range to include much of south and central Florida (Krysko et al. 2011. Atlas of Amphibians and Reptiles in Florida. Final Report, Project Agreement 08013, Florida Fish and Wildlife Conservation Commission, Tallahassee. 524 pp.). The relationship between *R. marina* and native south Florida predators has received little attention. *R. marina* possess large parotoid glands that produce bufotoxins, which can result in cardiac failure if ingested (Toledo and Jarett 1995. Comp. Biochem. Phys. 111A:1–29). Mortality associated with ingestion of *R. marina* has been attributed to the decline of certain predatory species, especially within their introduced range (Letnic et al. 2008. Biol. Conserv. 141:1773–1782). However, consumption of *R. marina* resulting in little to no detrimental effect has been documented in several species of vertebrates (Phillips et al. 2003. Conserv. Biol. 17:1738–1747; Calderón-Patrón et al. 2012. Herpetol. Rev. 43:125; Beaty and Beaty 2012. Herpetol. Rev. 43:471). In the case of this observed predation by *A. ferox*, it is possible that by feeding primarily on the lower leg of the *R. marina*, the turtle avoided the high concentration of bufotoxin produced on and near the parotoid glands.

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Chrysemys picta (Painted Turtle) and Chelydra serpentina (Snapping Turtle). Commensalism. Over a period of several years (late-1980s to 1992) from late spring to early fall, I observed apparent commensalism between Chrysemys picta and Chelydra serpentina in a pond (area = 0.15 ha) in Williamson Township, Wayne Co., New York, USA (43.2131°N, 77.1771°W; WGS 84). This site was visited weekly, and on approximately two-thirds of all visits, I observed a small Chrysemys picta (10 cm carapace length [CL]) always in close proximity (approximately 2 m) to a very large Chelydra serpentina (ca. 45–50 CL). During the entire duration of all observations (2–3 per visit, and up to 10 minutes each), the Chrysemys would promptly move as necessary to maintain its position behind the Chelydra, presumably to avoid a predation attempt. When the Chelydra was observed feeding upon frogs and fishes, the Chrysemys would occasionally snap at and consume small food scraps that floated behind the Chelydra. Whenever I came within view of the Chelydra, it would immediately dive into the aquatic vegetation at the bottom of the pond and the Chrysemys, which was evidently more focused on the Chelydra than its other surroundings, would follow the same flight path after about a two-second latency.

On one occasion, while attempting to capture the Chelydra by net, the Chrysemys was opportunistically captured instead. The Chrysemys was sexed (as a male) and measured, and was clearly in healthy condition, as the soft body parts at the base of its anterior and posterior legs were bulging, and the plastron was slightly convex. The Chrysemys was released onsite within 5 minutes of capture. A week later, I returned to the site and the two turtles were again in association as observed during previous visits. This symbiotic relationship continued to the time of my last visit in August 1992. I can find no reference to a commensalistic relationship between these species in the literature. Chrysemys is a known prey item of Chelydra (Ernst and Lovich 2009. Turtles of the United States and Canada. Smithsonian Institution Press, Washington D.C. 827 pp.), and thus such behavior incurs a potential risk to the Chrysemys of which it was evidently aware because it focused upon and always remained posterior to the Chelydra. However, in doing so, the Chrysemys was less wary of and thus more vulnerable to other potential threats, as evidenced by its capture by me. Nonetheless, this was apparently a long-term and beneficial relationship for the Chrysemys, as evidenced by its healthy condition. Due to abundant food sources available to the Chelydra, it is highly improbable that the scavenging activities by the Chrysemys resulted in food deprivation or any other adverse impacts to the Chelydra. Therefore, I believe this is a genuine example of commensalism between these turtles.

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Macrochelys temminckii (Alligator Snapping Turtle). Unusual habitat and trap survivability. Macrochelys temminckii is the largest freshwater turtle in North America and typically inhabits deep creeks and rivers in southeastern and midwestern states (Ernst and Lovich 2009. Turtles of the United States and Canada. Smithsonian Institution Press, Washington D.C. 827 pp.). Juveniles occasionally occupy and prefer shallow water environments (Allen and Neill 1950. Spec. Publ. Ross Al. Press, Baltimore, Maryland. 827 pp.). During a survey of the Louisiana Nature Center (heavily damaged by Hurricane Katrina in late August 2005) by the Gulf Coast Herpetological Society on 15 April 2012, a large male Chelydra serpentina (CL = ± 33 cm) was observed on the bank of the Farrar Canal feeding on ripe Southern Dewberries (Rubus trivialis). When encountered (by IW and SW) the turtle was holding a berry in the front of its mouth, apparently positioning it for swallowing. The turtle's mouth on each side of the berry was stained red, suggesting that the turtle had eaten other berries (Fig. 1). Amy LeGaux, of the Audubon Nature Institute, encountered a Snapping Turtle of similar size eating dewberries along the same canal on 1 April 2013. We believe this is the first report of dewberries in the diet of this species. Dewberries is the first report of dewberries in the diet of this species. Dewberries along the same canal on 1 April 2013. We believe this is a genuine example of commensalism between these turtles.
Traps (size: 25 cm x 25 cm). Traps were set in small creek channels, gaps in beaver dams, and paths made by furbearers both upstream and downstream of a moderate-sized farm pond dam in Hale Co., Alabama, USA (32.76083"N, 87.629722"W). The pond (6.2 ha) is fed by two intermittent streams, with a small, first order stream (~1–2 m wide) that exits from the dam. Below the dam, the stream flows into several, successive shallow pools that are surrounded by freshwater marsh vegetation (primarily Polygonum species [Smartweed] and Salix nigra [Black Willow]). The pools along the stream were formed likely due to the constriction of water flow by a culvert that passes underneath a county road (0.1 km downstream of dam, Hale County Road 28). This creek eventually flows into the Black Warrior River (following ~22.5 river km), a large tributary of the Mobile River system, which is inhabited by M. temminckii (Mount 1975. The Reptiles and Amphibians of Alabama. The University of Alabama Press, Tuscaloosa. 270 pp.).

On 26 March 2013 (1500 h), AC found a moderate-sized M. temminckii (~11.3 kg) captured in a Conibear trap that was set on the edge of one of the shallow pools. The turtle was still alive even though the trap captured the individual around the neck. Because of the size of the turtle and likely struggle after the turtle was captured, the trap was pulled up from its original location, but was still anchored at another point. Therefore, we were unable to determine which direction the turtle was traveling before it entered the trap. The turtle was carefully removed from the trap and placed downstream of the trap site. To confirm the species that AC observed, WS returned to the site with AC (1630 h) and indeed found the M. temminckii in the stream approximately 15 m downstream of the trap site. Thereafter, the individual was removed from the creek and found to be full of vigor, while showing no visible signs of trauma to the head and neck region. The individual was photographed (Florida Museum of Natural History Herpetology Department photographic archive, UF 170047) and then placed downstream of the last trap. On 27 March 2013, WS and AC returned to the site and did not find the M. temminckii.

The habitat at the capture site is unique for this species for multiple reasons. First, the area downstream of the dam and around the capture site is not typical habitat for M. temminckii; it was a marshy, ephemeral shallow pond setting and more typical habitat for other pond turtle species such as C. serpentina and kinosternid turtles. Second, the stream below the dam, between the shallow pools, and downstream of the county road is relatively narrow (1–2 m wide) and while moving through this creek, the M. temminckii individual likely occupied most of the channel width. Third, the creek was relatively shallow (10–61 cm deep) and in some sections, the water likely did not completely cover the adult turtle. It is unknown why this individual was in this type of habitat, but it may have been seeking more shallow environments during the spring for thermoregulatory reasons as suggested by Riedle et al. (2006. Southwest. Nat. 51:35–40). Further, it is unknown if the turtle came from upstream (farm pond side) or downstream (small, first order stream) prior to being captured in the trap. For both of these scenarios, the habitat is not typical for the species and the closest “apparently suitable” creek habitat is >15 river km downstream. However, M. temminckii will disperse over long distances (Wickham 1922. Proc. Oklahoma Acad. Sci. 2:20–22), which might explain the presence of this individual in this apparently unsuitable habitat.

The Conibear trap is designed to be “triggered” by a target animal and to snap shut and kill the target animal quickly via fracturing of the spinal column or asphyxiation. Thus, Conibear 330 traps effectively kill large beavers, otters, and nutria. However, many non-target species are captured with these body-gripping traps, including larger turtles. AC captured approximately 20 turtles via Conibear trap at this site over six months of trapping (Snapping Turtle, Chelydra serpentina; Red-eared Slider, Trachemys scripta), but this was the first and only M. temminckii captured. Almost all other turtles captured survived because their shells were strong enough to withstand the force of the trap; however, the lone mortality was a C. serpentina that was similarly caught by the neck. Further, smaller turtles are not large enough to trigger the trap mechanism, and thus are likely not killed by larger Conibear traps. It is unknown how long the M. temminckii individual had been in the trap, but it was <22 h as the trap was checked at ~1730 h the previous day. The survivability of this individual to a Conibear trap neck capture is probably due to the robustness of the skin and musculature of the neck in this species, which is likely associated with both the thrust-bite feeding and defensive behavior and protection during conspecific aggressive encounters.

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TERRAPENE CAROLINA (Eastern Box Turtle). MIDWINTER COMBAT and REPRODUCTIVE BEHAVIOR. At ca. 1400 h on 13 January 2007, 7.9 km NE of Wewahitchka, Gulf Co., Florida, USA (30.16414°N, 85.14253°W; WGS 84), I observed combat between two adult male Terrapene carolina. Conditions were sunny, with a light breeze, and an air temperature of ca. 24°C. When first discovered, the two individuals were ca. 30 cm apart. The smaller (15 cm carapace length [CL]) was inverted on its carapace, and presumably had been overturned by the larger individual (20 cm CL). I placed it right-side-up and stepped back 2 m, whereupon the larger turtle almost immediately charged and overturned the smaller one by placing his head under its carapacial margin and then thrusting his head upwards. I picked up the larger individual and placed it back onto the ground, whereupon it walked into a backwater area of the Apalachicola River and immersed itself in ca. 1 m water. I then picked up and moved the smaller individual ca. 60 cm from its original location and placed it on the ground right-side-up, whereupon it walked to the same area and immersed itself in ca. 1 m water as well.

At ca. 0900 h on 12 January 2013, 5.3 km NE Vernon, Washington Co., Florida, USA (30.65860°N, 85.675661°W; WGS 84), I observed copulation by a pair of Terrapene carolina. Conditions were partly sunny, with a moderate breeze, and an air temperature of ca. 18°C. The turtles were located in partial sunlight and adjacent to a large hardwood log. After 5 min of observation from 3 m away (during which time the turtles remained in the same position), I left the area without disturbing the turtles further.

Because a female individual was not seen in the vicinity of the two males during the first observation, it is impossible to determine if the combat behavior was territorial or in defense of a mate or other limited resources. However, with the exception of the Florida Peninsula (Dickson 1953. Everglades Nat. Hist. 1:58–62), reproductive behavior has only been reported in Terrapene carolina from spring to fall (Ernst and Lovich 2009. Turtles of the United States and Canada, Smithsonian Institute Press, Washington D.C. 827 pp.). Similarly, of the few reports of potential territorial behavior in Terrapene carolina (e.g., Stickel.
1989. J. Herpetol. 23:40–44), none have occurred during the winter. Moreover, in the Florida Peninsula, *Terrapene carolina* is less active during the winter (Pilgrim et al. 1997. Chelon. Conserv. Biol. 2:483–488). Thus, territorial or reproductive behavior by this species during the comparatively cooler winters in the Florida Panhandle (where my observations occurred) would appear to be noteworthy. Additional observations are desirable before conclusions can be made on the causes of these behaviors and their overall frequency of occurrence.

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CROCODYLIA — CROCODILIANS


Wild crocodilians have been examined for abnormalities and injuries; a thorough study of 1345 wild caught Saltwater Crocodiles (*Crocodylus porosus*) showed only three (0.2%) had “growths.” The crocodiles were released after examination, and histology was not available (Webb et al. 1977. Aust. Wildl. Res. 4:311–319). A similar survey of 797 wild caught Freshwater Crocodiles (*C. johnstoni*) noted only six "growths," two appeared to be associated with older injuries and three appeared to be sites of infection; the other was described as a "lump" in the ventral pelvic region (Webb et al. 1983. Aust. Wildl. Res. 10:407–420); without histology this may not have been a neoplasm. A smaller disease surveillance study of 144 wild caught Nile Crocodiles (*C. niloticus*) did not reveal any growths or tumors; the only external lesions were an old bite injury and a recent puncture injury (Leslie et al. 2011. J. S. Afr. Vet. Assoc. 82:155–159). Other studies have focused on endohelminth prevalence and infections in *Alligator mississippiensis* (Scott 1995. Proceedings of the Wildlife, Production, Management and Utilization Conference, Texas A&M Univ., College Station, Texas. 12 pp.) and more recently on West Nile Virus prevalence in free-ranging American Alligators (hereafter, alligators) in Florida (Jacobson et al. 2005. J. Wildl. Dis. 41:107–114) and Louisiana (McNew et al. 2007. Southeast. Nat. 6:737–742).

The state of Louisiana has an alligator management program which includes a regulated harvest of wild alligators (Elsey and Kinler 2004. In Crocodiles. Proc. 17th Working Meeting Crocodile Specialist Group, pp. 92–101. IUCN–The World Conservation Union, Gland, Switzerland and Cambridge UK.). Recently we recovered a harvested wild *A. mississippiensis* with an unusually large growth on the left rear foot (Fig. 1).

The male specimen was harvested on 14 September 2011, total carcass length 9 ft., 4 in. (112 in. or 284.5 cm). It was taken on private property in Terrebonne Parish in southeastern coastal Louisiana. The mass measured approximately 30 cm wide × 30 cm long and 18 cm high. The circumference around the equator was 106 cm, and around the upper and lower poles was 83.5 cm. The mass was 10.4 kg; however that includes a bit of the remaining bone after the limb was crudely excised. Upon palpation the mass was quite solid (not cystic or fluctuant); histological evaluation revealed it was a fibrosarcoma and radiological examination showed evidence of erosion of bony structures (Fig. 2). The alligator appeared relatively healthy; although not particularly robust it was also not emaciated; we are unclear if the alligator

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**FIG. 1.** Wild harvested *Alligator mississippiensis* with large fibrosarcoma on left foot.

**FIG. 2.** Radiograph of excised fibrosarcoma from *Alligator mississippiensis*. 
could ambulate and it seems likely the volume/bulk of the mass may have interfered with normal streamlined swimming. We surmise the alligator was healthy and feeding, as it was caught on a baited hook as is standard practice in Louisiana. The trapper confirmed he caught alligators that year by baited hook, and recalls this alligator exhibited normal evasive behavior during the harvest procedure (C. Lovell, Jr., pers. comm.).

To our knowledge this is one of the largest tumors ever reported in a wild crocodilian. It would be of interest to know how long it may have taken for a tumor of this size to develop in a wild alligator. Studies have shown alligators do have a strong capacity to resist infection and their blood has antibacterial (Merchant et al. 2003. Comp. Biochem. Physiol. 136:505–513), amoebicidal (Merchant et al. 2004. J. Parasitol. 90:1480–1483), and antiviral properties (Merchant et al. 2005. Antiviral Res. 66:35–38) but little is known about resistance to neoplasms. A recent study on ocular disease in American Crocodiles (Crocodylus acutus) found no association between contaminant accumulation and eye disease, but could not rule out infection or chemical toxicity as causes of eye lesions (Rainwater et al. 2011. J. Wildl. Dis. 47:415–426). It may be that wild alligators do succumb to malignancies, but after death in the wild carcasses may rapidly deteriorate in ambient heat and humidity, and then are not known to or recovered by researchers. It is possible that environmental stressors such as recent hurricanes in Louisiana followed by drought years may suppress the immune system and predispose some alligators to development of abnormal lesions. Additional research investigating disease mechanisms in valuable crocodilian resources may be warranted.

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SQUAMATA – LIZARDS

AMEIVA POLOPS (St. Croix Ground Lizard). BEHAVIOR. We report on burrowing and aggressive behavior in the endangered teiid lizard Ameliva polops herein. This species is a relatively small (32–88 mm SVL), active lizard remaining in remnant populations on four small islands <104 m above sea level off the northern and southern coasts of St. Croix, United States Virgin Islands, USA (17.7°N, 64.7°W). Adult males can often be distinguished from females by bluish coloring on the flanks and tail, as well as a deeper red throat patch and the size of the head (Heatwole and Torres 1971. Herpetologica. 27:450–454). Individuals retreat overnight in burrows, and previous studies observed that lizard abundance was highest in habitat with loose soil, land crab burrows (Gecarcinus ruricolor), and ground cover (Heatwole and Torres 1976, op. cit.; Meier et al. 1993. Carib. J. Sci. 29:147–152). No reports of burrow construction or defense have been published to our knowledge.


A female Ameliva abaetensis (SVL = 61.89 mm) was observed eating a soft-shelled elliptical egg (volume = 312.61 mm³; measuring accuracy of 0.01 mm) at 1300 h on 14 March 2012 at Parque Nacional Serra de Itabaiana, Areia Branca municipally, Sergipe, Brazil (10.747500°S, 37.339444°W; datum WGS84; 201 m elev.). The species that produced the egg was not identified. After feeding on the egg, the specimen was captured by hand (collection permit: 31047–1 IBAMA/RAN), euthanized and deposited in the collection of the Laboratório de Biologia e Ecologia de Vertebrados/Universidade Federal de Sergipe. This is the first documented case of egg predation by A. abaetensis. The diet of A. abaetensis is known to consist of small arthropods with the presence of various plant matter and fruits (Dias and Rocha 2007, op. cit.; Rosa et al. 2012. Bol. Mus. Biol. Mello Leitão [N. Ser.]
Further, *A. abaetensis* is known to prey on juveniles of the lizard *Tropidurus hygomi* (Dias and Rocha 2004. *Herpetol. Rev.* 35:398–399). Our observation reported here indicates that *A. abaetensis* is a source of mortality in the offspring of small squamates that lack nest attendance behavior by parents.

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The only report on the reproductive biology of *A. abaetensis* was provided by Rosário et al. (2011. *Herpetol. Rev.* 42:428), in which the authors observed the occurrence of oviposition in April. Thus, the aim of this research is present the first report of *in situ* mating behavior of *A. abaetensis*.

On 24 November 2012 at 1137 h, mating behavior of *A. abaetensis* was observed at Restinga de Ahaeté, Salvador municipality, State of Bahia (12.914378°S, 38.322402°W; datum WGS84; 31 m elev.). The behavior began with the movement of two individuals within a shrub. After approximately 20 seconds, the subjects moved to the edge of the shrub, the male being guided by the female, where they then mated. At this point, male and female were interconnected by cloacal apposition. The female remained motionless on the sandy soil, while the male was biting her near the pelvic region during the entire copulatory event. Copulation lasted about 30 seconds. At the end of interaction, the two individuals separated and moved to a new shrub, ca. 2 m away. Field observations of behaviors related to reproduction are rarely recorded, even for common species (Mesquita et al. 2012. *Herpetol. Bras.* 1:41–42). From our observations and those published by Rosário et al. (2011. *Herpetol. Rev.* 42:428), we believe that *A. abaetensis* begins the reproductive process in intermediate months of the dry season (September to March), with oviposition between the end of this period and the beginning of the rainy season (March to August).

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On 1 November 2012, at ca. 1100 h, a juvenile *A. gularis* (approximate SVL = 30 mm) was found dead, trapped in spider web occupied by a *L. mactans*, in a cistern near a house (Fig. 1), at Municipality of Chihuahua, Chihuahua, Mexico (28.666856°N, 105.942033°W, datum WGS84; elev. = 1376 m).

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of unreduced diploid eggs. Sexual reproduction in the species occurs only when its eggs are fertilized by sperm from a male of a gonochoristic species such as *A. sexlineata* (Manning et al. 2005. Am. Mus. Novitat. 3492:1–56; Walker et al. 1990. Am. Midl. Nat. 123:404–408) resulting in sterile triploid hybrid males and mostly sterile triploid females. However, it is conceivable that a rare fertile female could become the founder of a new allotriploid parthenogenetic species as has occurred repeatedly through hybridization in the genus *Aspidoscelis* (see Reeder et al. 2002. Am. Mus. Novitat. 3365:1–61).

We used phenotypic attributes to confirm the identity of a hybrid of *A. neomexicana × A. sexlineata viridis* in order to establish that hybridization between these species has occurred over a period of >30 years in the vicinity of Conchas Lake and the Canadian River, San Miguel Co., New Mexico, USA. This female (originally catalogued as University of Arkansas Department of Zoology 8578 and recently re-catalogued as Arkansas State University Museum of Zoology 32422) was collected by one of us (JEC) at 1145 h on 9 August 2009 at Conchas Lake in the South Recreation Area (35.37722°N, 104.1094444°W, datum

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**Fig. 1.** Color pattern and morphological characteristics of a hybrid female specimen of *Aspidoscelis neomexicana × A. sexlineata viridis* from Conchas Lake, San Miguel Co., New Mexico. A) Dorsal coloration and pattern of ASUMZ 32423; line = 10 mm for A and B. B) Ventral coloration of ASUMZ 32422. C) Moderately enlarged mesoptychial scales of ASUMZ 32432; line = 1 mm. D) Slightly enlarged postantebrachial scales of ASUMZ 32422; line = 1 mm. E) Incomplete circumorbital scale series (see arrow) in ASUMZ 32423; line = 1 mm.
In this area, one of three near Conchas Lake where hybrids between these species have been collected (Manning, op. cit.), the guild of whiptail lizards includes *A. e. sanguis* (triploid parthenogen, rare), *A. neomexicana* (diploid parthenogen, abundant), *A. sexlineata viridis* (gonochoristic, moderately abundant), and *A. tesselata* pattern classes C and D (diploid parthenogens, moderately abundant). Prior to preservation, ASUMZ 32422 had a SVL of 71 mm, tail length of 244 mm, and body mass of 9.2 g. It could not be identified to *A. sexlineata viridis* because of the presence of spots (i.e., rounded pale areas) in the dark fields between the stripes, parts of primary stripes with uneven margins, and distinct vertebral stripe with interruptions. *Aspidoscelis sexlineata viridis* is characterized by straight-margined stripes and lack of spots throughout ontogeny (Conant and Collins 1998. A Field Guide to Reptiles and Amphibians of Eastern and Central North America, 3rd ed. Houghton Mifflin Co., New York, New York. 616 pp.; Perez-Ramos et al. 2010. Southwest. Nat. 55:420–426; Trauth 1992. Texas J. Sci. 44:437–443). Although the specimen resembles *A. neomexicana* more closely than *A. sexlineata viridis*, characters indicating its hybrid origin are these intermediate aspects of color pattern (Fig. 1A–B): paired lateral and dorsolateral stripes relatively straight-margined only posterior to level of the forelimbs, paired paravertebral stripes relatively straight-margined anterior to forelimbs and unevenly margined posteriorly, vertebral stripe single and relatively straight-margined anteriorly and with numerous interruptions posterior to forelimbs, strongly contrasting pale stripes and dark fields to produce an ornate effect, large round spots in the fields superior to the lateral stripes, and off-white rather than gray-blue venter. Observations for three characters of scutellation are also consistent with the hypothesis for a hybrid origin for ASUMZ 32422 (comparison with *A. neomexicana* in parent): moderately enlarged mesoptychial scales bordering the gular fold (Fig. 1C, rather than small); very slightly enlarged postantebrachial scales on posterior aspect of forelimbs (Fig. 1D, rather than granular), and incomplete circumorbital scale series between supracocular and median head scales (Fig. 1E, rather than extending anteriorly past the second supraocular sutures or with complete series). The specimen described herein establishes that production of viable, if infertile, hybrids of *A. neomexicana × A. sexlineata viridis* has been ongoing in the vicinity of Conchas Lake for more than 30 years. The first of these was collected by B. E. Leuck and companions on the north side of the Canadian River/Conchas Lake in 1978 (Manning et al., op. cit.) followed by collection of other hybrids on the south side of the lake/river between 1988 and 2009 (Manning et al., op. cit.; Walker et al., op. cit.; this study). The general area from which ASUMZ 32422 was collected on the south side of Conchas Lake has been the source of more than a dozen hybrids to date. An internal examination of the present hybrid by one of us (SET) revealed the following: right oviduct elongated and thin, undeveloped; right gonad translucent, around 3 mm in length, and only slightly larger in width than its associated ligament, no evidence of ova; left oviduct elongated and slightly developed; left gonad translucent and minute (around 2 mm in length), and only slightly larger in width than its associated ligament; no evidence of ova. Both abdominal fat bodies were yellow and greatly enlarged. We infer that the individual was sterile.

Specimens from San Miguel Co. referenced in this study were collected under authority of permit number 1850 issued to JEC by the New Mexico Department of Game and Fish, and in cooperation with the U.S. Army Corps of Engineers.

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**ASPIDOSCELIS TIGRIS** (Tiger Whiptail). **DIET.** On 22 April 2007 at 1410 h in Lower Colorado River Valley subdivision Sonoran Desert (Brown 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. Univ. of Utah Press, Salt Lake City, Utah. 342 pp.), just north of the Mexican border south of Yuma, Yuma Co., Arizona, USA (32.420405°N, 111.562379°W; 57 m elev., T₂, 26°C), we observed an adult *Aspidoscelis tigris* (98 mm SVL, 209 g) carrying a dead juvenile *Dipsosaurus dorsalis* (Desert iguana, 56 mm SVL, 4.1 g) in its jaws (photo voucher UAZ 57461-PSV). The head of the desert iguana was badly crushed. The whiptail carried the desert iguana by the head to a Creosote Bush (*Larrea tridentata*) ca. 10 m distant. Once in cover it stopped, repeatedly dropped and picked up the prey, biting down on its head. Within a few minutes the *Aspidoscelis* abandoned its prey, likely disturbed by our presence.

We believe this is the first report of predation of *D. dorsalis* by *A. tigris*. Invertebrates compose the bulk of *A. tigris* prey (Aspland 1964. Herpetologica 20:91–94; Best and Gennaro 1985. Great Basin Nat. 45:527–534; Scudder and Dixon 1973. Southwest. Nat. 18:279–289; Vitt and Ohmart 1977. Herpetologica 33:223–234) and prey varies seasonally (Vitt and Ohmart, op. cit.) and prey varies seasonally (Vitt and Ohmart, op. cit.). Vitt and Ohmart (op. cit.) noted lizard parts in the stomach of one of 82 *A. tigris* examined, and Best and Gennaro (op. cit.) found two occurrences of lizard prey in 174 stomachs; species of prey lizards were not reported. It is likely that lizards and perhaps other small vertebrates comprise a small portion of *A. tigris* diet seasonally, perhaps more so in the spring and late summer when young of many lizards are most abundant.

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**COLEONYX VARIEGATUS** (Western Banded Gecko) and **RENA HUMILIS** (Western Threadsnake). **ATTEMPTED PREDATION.** On 8 July 2008, 2045 h we encountered a small, ca. 127 mm TL *Rena humilis* surface active on the edge of a wash near Queen Valley, Pinal Co., Arizona, USA (33.301018°N, 111.314240°W; 611 m elev.). While we were watching the snake, a ca. 63 mm SVL *Coleonyx variegatus* attempted to prey on it. When the gecko first encountered the snake, it cocked its head to one side then rushed forward a few centimeters and grabbed the snake, which thrashed wildly. The gecko shook it a couple of times, then released it. We do not know if the gecko decided the snake was too large, or if it was simply disrupted by our presence, but we suspect the latter as the gecko fled after dropping the snake.

This is the first report of *C. variegatus* as a potential predator of *R. humilis*. *Coleonyx variegatus* is primarily a predator of small invertebrates (Parker and Pianka 1974. *Copeia* 1974:528–531), and vertebrate prey is virtually unknown. Though Parker and Pianka (op. cit.) documented the remains of four lizards or lizard skin in the stomachs of 185 *C. variegatus* examined, they
did not elaborate as to whether those were ingested shed skin or actual prey items. Though this predation attempt was unsuccessful, it is not unlikely that small vertebrates such as hatchling lizards (e.g., *Uta, Xantusia*) and small snakes (e.g., *Rana, Tantilla, Sonora*) may occasionally fall prey to *C. variegatus*.

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On 26 February 2011 at 1200 h, while conducting herpetofaunal surveys in Veragua Rainforest Adventure Park, Limón Province, Costa Rica (9.926361°N, 83.19095°W, datum WGS 84; 200 m elev.), we observed a Sunbittern (*Eurypyga helias*) standing over a stone at the edge of a river exhibiting feeding behavior. Upon arriving at the site for inspection, a carcass of a *D. monotropis* was found on the same stone where the Sunbittern had been perched. The carcass retained only the back and ribs of the reptile; all the organs were consumed. However, the carcass was relatively fresh (Fig. 1). It is known that this aquatic-foraging bird is capable of feeding on lizards such as *Anolis oxylopus* and *Ameiva festiva* (Lyon and Fogden 1989. *Auk* 106:503–507). The behavior of the Sunbittern suggests it was original predator of the lizard, or was at least feeding on the carrion, and to our knowledge this would be the first record of predation on a *D. monotropis* (or for the genus *Diploglossus*) by an avian predator. Further, this is the largest lizard species reported for the diet of the Sunbittern to date.

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On 21 March 2013 at 0730 h an adult capuchin monkey was observed searching for, catching, and eating an adult *H. frenatus* on the patio of the second floor of a residence (09.404678°N, 84.157719°W, datum WGS 84; 140 m elev.) in the town of Manuel Antonio, Costa Rica. Manuel Antonio is located next to Parque Nacional Manuel Antonio, where capuchin monkeys and other animals are frequently seen active on the dense vegetation of the surrounding residences. That morning a group of about 10 capuchin monkeys arrived at the patio of our residence in search of potential food items, an event we had witnessed on four occasions during the previous three days. Two individuals climbed to the ceiling and methodically began to examine every crevice in the ceiling that might potentially harbor prey; in this case, *H.*
frenatus. One monkey succeeded in locating and capturing one gecko from its shelter, and descended to the floor holding its prey with one hand (Fig. 1). First, the monkey ate the tail and a significant portion of the skin covering the trunk and head of the body, and then bit the venter of the gecko and ate some of the internal organs while the lizard was still alive. After nibbling on the gecko for ca. three minutes, another capuchin approached and took the remains of the gecko and disappeared into the surrounding vegetation. At that point, all four limbs and the head and body, and most of the muscle tissue was intact. The second capuchin found another gecko remained attached to the body, and most of the internal organs, while the lizard was still alive. After nibbling on the prey with one hand (Fig. 1), first, the monkey ate the tail and a piece of the body, and then bit the venter of the gecko and ate some of the lizard’s death, this process lasting approximately 30 minutes. The family Lycosidae, typically referred to as wolf spiders, is one of the most diverse groups of spiders, with 2393 currently described species in 120 genera (Platnick 2013. The World Spider Catalog. Version 12.0 www.research.amnh.org, accessed 8 January 2012). It comprises mainly hunting spiders that occur in significant numbers in virtually every terrestrial habitat. This report contributes to the knowledge of predation interactions of the non-native lizard H. mabouia by native spiders in Brazil, and also suggesting that spiders of different guilds, such as orbweavers (Nephilengys cruentata) and hunting spiders (Ctenidae, Lycosidae) may represent a potential mortality source for populations of this gekkonid.

We thank the Kumar family for their great company during the trip to Costa Rica, and L. W. Porrás for his comments on this note.

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On 5 June 2012 at 1746 h one of us (LM) observed a lycosid spider (29 mm, cephalothorax + abdomen length) on leaf litter attached to and feeding on a juvenile of H. mabouia (SVL = 50.5 mm). The spider bit the prey and remained attached to it until the lizard’s death, this process lasting approximately 30 minutes. The family Lycosidae, typically referred to as wolf spiders, is one of the most diverse groups of spiders, with 2393 currently described species in 120 genera (Platnick 2013. The World Spider Catalog. Version 12.0 www.research.amnh.org, accessed 8 January 2012). It comprises mainly hunting spiders that occur in significant numbers in virtually every terrestrial habitat. This report contributes to the knowledge of predation interactions of the non-native lizard H. mabouia by native spiders in Brazil, and also suggesting that spiders of different guilds, such as orbweavers (Nephilengys cruentata) and hunting spiders (Ctenidae, Lycosidae) may represent a potential mortality source for populations of this gekkonid.

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LEPOSTERTON MICROCEPHALUM. PREDATION. Leposternon is a very specialized genus of Amphisbaenidae (Gans 1974. Biomechanics: an Approach to Vertebrate Biology. J. B. Lippincott, Philadelphia. x + 261 pp.) with a broad distribution in South America (Gans 2005. Bull. Amer. Mus. Nat. Hist. 289:11–30), including Atlantic Forest areas in Southeastern Brazil. Leposternon microcephalum is common prey for some terrestrial snakes, especially Micrurus spp. (Marques and Sazima 1997. Herpetol. Nat. Hist. 5:88–93), but it is typically not known to be preyed upon by birds. Here we report on a specimen of L. microcephalum being caught and consumed by a White-necked Hawk (Amadonastur lacernulatus) (Fig. 1), an endemic and threatened species of the Brazilian Atlantic Forest (and so only photographed, not collected) (Thiollay 1994. In del Hoyo et al. [eds.], Handbook of the Birds of the World. Vol. 2. pp. 252–205. Lynx Edicions, Barcelona). The predation event was observed by one of us (HR) at Jardim Botânico do Rio de Janeiro, Brazil (the Botanical Garden at Rio de Janeiro City, Brazil: 43.2290°S, 22.9688°W, WGS84; elev. 50 m) at 0900 h on 3 June 2012. The identification of L. microcephalum was possible through the pholidosis observed by a specialist (JDBF) and available data on the known distributions of amphisbaenian
species. The photograph in Fig. 2 shows the hawk detaching the amphisbaenian skin from adjacent musculature to eat only the exposed flesh. To our best knowledge, this is the first record of such a behavior for an amphisbaenian predator. Bird predators of amphisbaenians are considered mainly as opportunistic. Zamprogno and Sazima (1993. Herpetol. Rev. 24:82–83) reported four birds of prey as predators of L. wucheiweri: Turkey Vulture (Cathartes aura), Crested Caracara (Caracara plancus), Yellow-Headed Caracara (Milvago chimachima), and an unidentified species of hawk (Buteo sp.). Additional reports of birds as predators of amphisbaenians include: Southern Lapwing (Vanellus chilensis) (Gans 1971. Amer. Mus. Nov. 2475:1–32) and Maguari Stork (Ciconia maguari) (Tozzetti et al. 2011. Panamjas 6:65–67), which had specimens of Mesobaena huebneri and Amphisbaena trachura in their stomachs, respectively; chickens and the Roadside Hawk (Rupornis magnirostris) feeding on Amphisbaena (darwinii) heterozonata (Gallardo 1967. Ciencia e Investigación 23:406–411); chickens feeding on Amphisbaena (=Bronia) be- dal (Vanzolini 1991. Pap. Avul. Zool. 37:347–361). However, the present record suggests some specialization of A. lacernulatus, regarded as a “ground searcher” species, for its skill in separating and rejecting the skin of L. microcephalum before swallowing the head and body. Amadonastur lacernulatus is apparently a broad generalist, its recorded prey items including snakes, mammals, birds and invertebrates (mainly arthropods) (Thiollay, op. cit.).

This is the first documentation of the consumption of an amphisbenian by A. lacernulatus.

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Three adult specimens of Mabuya frenata collected by DV in an area of rock outcrops (22.933333°S, 46.919167°W) in Valinhos, state of São Paulo, Brazil, expressed tail bifurcation. Two of them, a male (MNRJ 6727; SVL = 71.6 mm) and a female (MNRJ 6728; SVL = 84.4 mm), were collected on 19 December 1993; the male had an original (non-regenerated) portion of tail 51.6 mm long, followed by a regenerated portion extending 18 mm before bifurcating into two sub-equal tips about 10 mm long each. The female had 30 mm of original tail followed by a regenerated portion extending to 31.4 mm before bifurcating into a smaller lateral (7 mm) and a larger (14 mm) axial branch. In the third specimen, an adult male (MNRJ 6800; SVL = 66 mm) collected on 21 March 1994, the original portion of the tail extended 8 mm from the cloaca, then a regenerated portion extended to 10 mm and then bifurcated into a left and a right branch (respectively, 47.8 mm and 37.6 mm long) (Fig. 1). On the left branch, 17 mm from the tip, a second tip (1.7 mm long) was present (Fig. 1), suggesting that another bifurcation could result if it kept growing. The right branch showed evidence of having been broken and re-regenerated.

One specimen of M. macrorhyncha (MNRJ 15686) collected in the “restinga” of Barra de Maricá (22.960556°S, 42.86222°W), state of Rio de Janeiro, Brazil, on 30 April 1992 also expressed tail
bifurcation. The specimen, an adult male (SVL = 66.3 mm), had an original tail portion of 41.3 mm long. The regenerated portion extended 38 mm and then bifurcated into left (20.7 mm long) and right (24.7 mm long) branches (Fig. 2).

It is interesting that, in all cases above, bifurcation apparently occurred after a secondary break of an already regenerated tail portion. In one of the cases (MNRJ 6800), the two branches of the bifid tail were considerably long (each being more than half the total length of the tail, which was as long as the lizard's head and body), indicating that this particular animal was not substantially impaired by this anomaly. This same specimen had a third tail tip which, had it kept growing, could have resulted in a trifid tail (which could possibly result in greater impairment for its mobility).

Van Sluys et al. (2002. Stud. Neotrop. Fauna Environ. 37:227–231) examined 216 individuals of M. frenata from Valinhos, São Paulo, and found evidence of tail regeneration in 178 of them (including the three specimens mentioned above). Thus, the frequency of tail bifurcation as a consequence of regeneration can be estimated as 1.7% (3/178) in that population. For the population of M. macrorhyncha from Maricá, Rio de Janeiro, D. Vrcibradic (in Van Sluys et al., op. cit.) found that 78.3% (i.e., 83) of the 106 individuals examined had regenerated tails (including MNRJ 15686). This gives an estimated frequency of bifurcation of 1.2% (1/83), which is similar to that of M. frenata from Valinhos.

These are, to our knowledge, the first published estimates of the frequency of tail bifurcation in any species of Neotropical lizards.

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NOROPS FUSCOAURATUS (Slender Anole). PREDATION. No-rops fuscoauroatus is a small arboreal anole, active in the shade during the day, but early in the day can be seen briefly exposed to the sun. Individuals are often observed sleeping at night on leaves or on the ends of branches (Bannerman et al. 2001. Mamirauá: A Guide to the Natural History of the Amazon Flooded For-est. Instituto de Desenvolvimento Sustentável Mamirauá, Tefé, Brazil. 175 pp.; Duellman 2005. Cusco Amazónico, the Lives of Amphibians and Reptiles in an Amazonian Rainforest. Comstock Books in Herpetology, Ithaca, New York. 433 pp.; Vitt et al. 2003. Can. J. Zool. 81:142–156). I am unaware of any reports of predation on N. fuscoauroatus by an arachnid. I report here an instance of predation on N. fuscoauroatus by an actenid spider (Ctenus sp.).

During a herpetofaunal survey conducted for SINCHI Institute on 15 September 2010 in Colombian Amazonian region (location troche tres Salados, Resguardo Indígena Úitora, munici-pality of Solano, Caquetá state, southeast Colombia; 0.172°N, 74.651°W; WGS84 datum Bogota), I observed an actenid spider Ctenus sp. feeding on a juvenile individual of Norops fuscoauroatus (SLV 28 mm). The predation event occurred at 2253 h in a trail in the secondary Amazonian rainforest (Fig. 1), the attack on the anole was not observed. The spider may have encountered the anole at night while it was asleep. I found the spider and anole on the leaf of a shrub at 120 cm above the forest floor.

Records of Ctenus spiders preying upon vertebrate taxa available in the literature are mainly on anurans in the Amazonian region (Menin et al. 2005. Phyllomedusa 4:39–47) and in the Atlantic Forest of southeast Brazil (Barbo et al. 2009. Herpetol. Notes 2:99–100; Centeno 2009. Diversidade e Uso de Ambiente Pelos Anfíbios e Répteis de São Sebastião, Ilhabela, SP. Unpubl. Master's thesis. Universidade de São Paulo, Brazil). Barbo et al. (op. cit.) suggested that these spiders could be important predators of the abundant arboreal and leaf litter-dwelling species, but detailed studies are needed in order to support this hypothesis.

The record presented here increases our knowledge of the relationship between spiders and reptiles and the existence of...
important trophic connections between these groups. This field work was supported by Amazon Institute of Scientific Research SINCHI.

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A sample of 24 P. laevis was examined, consisting of 9 males (mean SVL = 62.2 mm ± 3.9 SD; range = 58–68 mm), 12 females (mean SVL = 62.6 mm ± 5.9 SD; range = 53–72 mm), 2 subadult females (mean SVL = 46.5 mm ± 2.1 SD; range = 45–48 mm) and 1 unsexed juvenile (SVL = 36 mm) collected 1949 to 1998 in Israel and deposited in the Zoological Museum of Tel Aviv University (TAUM), Tel Aviv, Israel by district: Haifa District: 4417, 12237, and deposited in the Zoological Museum of Tel Aviv University 1 unsexed juvenile (SVL = 36 mm) collected in Israel and stored in the Zoological Museum of Tel Aviv University. Eight males (mean SVL = 49.8 mm ± 4.7 SD, range = 40–56 mm), 6 females (mean SVL = 50.0 mm ± 5.8 SD, range = 43–59 mm), and 1 neonate (SVL = 26 mm SVL) were examined. One gonad was removed for histological examination. Histological sections were removed and embedded in paraffin, cut at 5µm, mounted on glass slides and stained by Harris’ hematoxylin followed by eosin counterstain. Histological slides are deposited at TAUM.

Two stages were noted in the testicular cycle: 1) regressed = post breeding (seminiferous tubules contain spermatogonia and Sertoli cells); 2) spermiogenesis (seminiferous tubules lined by clusters of sperm or metamorphosing spermatids). Monthly stages in the testicular cycle are in Table 1. The smallest reproductively active male (spermiogenesis) measured 58 mm SVL (TAUM 2174) and was collected in April.

Four stages were noted in the ovarian cycle (Table 2); 1) quiescent, (no yolk deposition); 2) early yolk deposition (vitellogenic granules in the cytoplasm); 3) enlarged follicles (> 4 mm); (4) oviductal eggs. The smallest reproductively active female measured 53 mm (3 oviductal eggs) (TAUM 5374) and was collected in September. Two reproductively inactive females from November (SVL = 45 mm, TAUM 15764) and SVL = 48 mm, TAUM 15484) were considered as subadults. Another subadult of undetermined sex (SVL = 36 mm, TAUM 16437) was collected in September and may have been born earlier the same year. Mean clutch size for 5 females was 3.6 ± 1.1 SD, range = 2–5. There was no evidence (oviductal eggs and concomitant yolk deposition in the same female) to suggest P. laevis females produced multiple clutches in the same reproductive season. However, there is sufficient time for production of multiple clutches as reproductively active females were collected from March to September, excluding April (N = 1) and males produce sperm starting in November. Multiple egg clutches are produced by P. laevis in Jordan (Disi et al. op. cit.). Males of the congener A. schmidtii in Saudi Arabia also exhibited spermiogenesis in November (Al-Johany and Spellerberg 1988. J. Arid. Environ. 15:197–207).

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Specimens were examined from the San Diego Natural History Museum (SDNHM 66870, 68703–704, 68706) and the University of Arizona (UAZ 22977–986, 23386). Eight males (mean SVL = 49.8 mm ± 4.7 SD, range = 40–56 mm), 6 females (mean SVL = 50.0 mm ± 5.8 SD, range = 43–59 mm), and 1 neonate (SVL = 26 mm SVL) were examined. One gonad was removed for histological examination. Histological sections were removed and embedded in paraffin, cut at 5µm, mounted on glass slides and stained by Harris’ hematoxylin followed by eosin counterstain. The only stage noted in the ovaries of P. lagunensis was quiescence in which no yolk deposition occurred in the follicles. The female samples were from June (N = 1), July (N = 5), and October (N = 1). Three stages of the testicular cycle were observed: 1) regressed (i.e., seminiferous tubules contain spermatogonia

| Table 1. Monthly stages in the testicular cycle of 9 adult Phoenicolacerta laevis from Israel. |
|---|---|---|---|
| Month | N | Regressed | Spermiogenesis |
| March | 2 | 0 | 2 |
| April | 2 | 0 | 2 |
| May | 2 | 0 | 2 |
| August | 1 | 1 | 0 |
| November | 2 | 0 | 2 |

| Table 2. Monthly stages in the ovarian cycle of 12 adult Phoenicolacerta laevis from Israel. |
|---|---|---|---|---|
| Month | N | Quiescent | Early yolk deposition | Enlarged follicles > 4 mm | Oviductal eggs |
| March | 2 | 0 | 1 | 0 | 1 |
| April | 1 | 1 | 0 | 0 | 0 |
| May | 1 | 0 | 0 | 1 | 0 |
| June | 1 | 0 | 0 | 0 | 1 |
| July | 3 | 0 | 1 | 1 | 1 |
| September | 2 | 1 | 0 | 0 | 1 |
| November | 1 | 1 | 0 | 0 | 0 |
| December | 1 | 1 | 0 | 0 | 0 |
and sertoli cells), 2) early recrudescence (i.e., slightly increased cellularity due to dividing spermatogonia and the appearance of some primary spermatocytes), and 3) recrudescence (i.e., marked increased cellularity with abundant primary spermatocytes). The male samples were from June (N = 3: regressed), July (N = 2: early recrudescence), and October (N = 1: regressed, N = 2: recrudescence).


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On 21 May 2010 at the La Malinche volcano in Tlaxcala, Mexico (19.227122°N, 97.2124083°W, WGS84, 2700 m elev.), we found a female Sceloporus aeneus (SVL = 57.31 mm; weight = 4.4 g) perched on a rock in direct sunlight at 1230 h. During capture we discovered lizard toes protruding from outside of its mouth; we extracted the prey item with tongs. Upon extraction we found a partially digested juvenile of Sceloporus graminicus (SVL = 33.74 mm; weight = 1 g). The SVL of the prey corresponded to 58% total length and to 22% total weight of the female S. aeneus. Sceloporus aeneus is generally considered an insectivorous opportunistic species (Urbano-Lozano 2008. Unpubl. Bachelor’s Thesis, Universidad Nacional Autónoma de México, FES-Iztacala). Thus, we document the first record of S. aeneus feeding on a lizard and show that this species has the capability to feed on proportionally-sized prey. This could be an uncommon event induced by malnutrition subsequent to oviposition, when females lose a large portion of body mass.

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SCELOPORUS LINEATULUS (Isla Santa Catalina Spiny Lizard). DIET AND ACCIDENTAL MORTALITY. Sceloporus lineatulus is endemic to Isla Santa Catalina, Baja California Sur, Mexico. Virtually nothing is known of the natural history of S. lineatulus (Grismer 2002. Amphibians and Reptiles of Baja California, Including its Pacific Islands and the Islands of the Sea of Cortez. Univ. California Press, Berkeley. 399 pp.). On 26 May 2011 several specimens of S. lineatulus were observed at the base of a large Pachycreus pringlei (Cardón Cactus) feeding on the seeds of the cactus’s fallen fruit. Closer observation revealed a deceased individual whose head had become stuck in the seed pod while feeding, and presumably succumbed to the midday heat. To our knowledge this is the first record of the natural diet of S. lineatulus and subsequent mortality by seed pod.

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SCLEOPORUS UNDULATUS (Eastern Fence Lizard). FEEDING BEHAVIOR. Eastern Fence Lizards obtain a substantial portion of their diet from ants, particularly as juveniles (Parker 1994.COPEIA 1994:136–152). Solenopsis invicta (Red-imported Fire Ant; hereafter fire ant) was introduced through the port of Mobile, Alabama in the 1930s and has now invaded much of the southeastern United States (Wojcik et al. 2001. Amer. Entomol. 47:16–23). It is likely that Eastern Fence Lizards consume fire ants while foraging and fire ants are considered a novel, toxic prey as they can sting fence lizards when eaten and ultimately cause death in smaller individuals (Langkilde and Friedenfelds 2010. Wildl. Res. 37:566–573). To date, all observations of fence lizards consuming...
fire ants of which I am aware occurred when individuals were under attack, or possibly opportunistically (e.g., Boronow and Langkilde 2010, J. Exp. Zool. 331A:17–23; Robbins and Langkilde 2012, J. Evol. Biol. 25:1937–1946). Moreover, Robbins and Langkilde (op. cit.) indicate uncertainty regarding whether fence lizards consume fire ants during regular foraging activity.

I observed a juvenile Eastern Fence Lizard (SVL = 22 mm) on top of an active fire ant mound on 10 October 2012 between 1730 h and 1759 h at the Joseph Jones Ecological Research Center in Newton, Georgia, USA. I observed and recorded the lizard actively moving on the mound to forage for 30 minutes and watched it consume three fire ants. Prior to this observation, on 12 September and 13 September 2012 at 1823 h and 1938 h, respectively, I observed an additional juvenile lizard on top of an active fire ant mound and, after monitoring the individual for 10 minutes, I observed the lizard consume one fire ant at 1833 h. A third juvenile lizard (SVL = 39 mm) was seen basking on an active fire ant mound by S. Greenspan on 8 October 2012 at 1118 h and I observed two more fence lizards basking on active fire ant mounds on 8 November 2012 at 1110 and 1445 h, but we did not stop to monitor their behavior. My observations indicate that Eastern Fence Lizards consume fire ants during regular foraging, rather than just opportunistically, and will use fire ant mounds as foraging sites. If fire ant consumption can lead to juvenile mortality, as found by Langkilde and Friedenfelds (op. cit.), this behavior could have a considerable influence on fence lizard population dynamics.

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SCLEPORUS UNIFORMIS (Yellow-backed Spiny Lizard). DIET. Sceloporus unifomis, recently elevated to species from within the S. magister complex (Crother [ed.] 2012. SSAB Herpetol. Circ. 39:1–92; Leaché and Mulcahy 2007. Mol. Ecol. 16:5216–5233), is a robust spiny lizard of the Mojave and Great Basin deserts. As with most Sceloporus, the species appears to be a generalist insectivore, feeding on ants, beetles, caterpillars, and other locally abundant arthropods as well as the occasional lizard (Knowlton and Nye 1946. Utah J. Econ. Entomol. 39:546; Parker and Pianka 1973. Herpetologica 29:143–152; Witt and Ohmart 1974. Herpetologica 30:410–417). Here we document a novel insect prey of S. unifomis, ladybird beetles (Coleoptera: Coccinellidae). This observation is noteworthy because ladybird beetles are chemically defended (King and Meinwald 1996. Chem. Rev. 96:1105–1122), and despite being conspicuous and often abundant, they are noticeably absent from the diet of nearly all North American lizards.

On 5 May 2011, along the eastern point of Anaho Island National Wildlife Refuge in Pyramid Lake, Washoe Co., Nevada, USA (39.94937°N, 119.49952°W; NAD83; 980 m elev.), we noosed several S. unifomis. While handling these lizards, two adult males (SCUN AI.005, SVL 85 mm; SCUN AI.008, SVL 95 mm) regurgitated their stomach contents, which were largely Seven-spotted Ladybird Beetles (Coccinella septempunctata). One lizard (SCUN AI.005) regurgitated ~17 ladybird beetles, the other (SCUN AI.008) ~12 ladybirds. The lizards were measured, marked and released, and the stomach contents retained for verification.

The absence of coccinellids in the diet of most lizards is striking, given the ubiquity, abundance, and visibility of these insects. Coccinellids possess formidable chemical defenses that may deter most arthropod and vertebrate predators (Happ and Eisner 1961. Science 134:329–331; Marples 1993. Chemoecology 4:33–38), including pyrazines that give an unpleasant odor (Marples et al. 1990. Chemoecology 1:43–51) and various toxic or distasteful alkaloids that ladybirds can exude from their haemolymph when threatened (King and Meinwald 1996, op. cit.). These chemicals are particularly effective against some birds, even inhibiting growth (Marples 1993, op. cit.). However, other vertebrates appear less affected; many amphibians seem tolerant of coccinellid toxins, and some bufonids and lizards consume significant quantities of ladybirds (Sloggett 2012. Insects 3:653–667). Among North American lizards, coccinellids have only been found as apparently accidental food items in the anguid Elgaria multicaudata (Cunningham 1956. Herpetologica 12:225–230) and xantusiid Xantusia vigilis (Brattstrom 1952. Copeia 1952:225–230). Copeia 1952:168–172, as well as the phrynosomatids Uta stansburiana (Knowlton and Thomas 1936. Copeia 1936:64–66) and S. occidentalis (Johnson 1965. Herpetologica 21:114–117). Only two phrynosomatids, S. undulatus and S. gracilis, appear to include ladybirds as a meaningful component of their diets, taking coccinellids with the same frequency as other similar-sized beetles (Johnson 1966. Am. Midl. Nat. 76:504–509; Knowlton 1948. Herpetologica 4:151; Knowlton and Thomas 1936, op. cit.; Knowlton et al. 1946. Utah J. Econ. Entomol. 39:382–383; Toliver and Jennings 1975. Southwest. Nat. 20:1–11). We suspect that our case of ladybird predation is purely incidental because earlier diet analyses of lizards in the S. magister complex have failed to turn up coccinellids as prey (e.g., Knowlton and Nye 1946, op. cit.; Parker and Pianka 1973, op. cit.; Witt and Ohmart 1974, op. cit.), and in our examination of several S. unifomis stomachs from Anaho Island we have never observed coccinellids. Nevertheless, it remains unclear whether the toxins in ladybirds are effective deterrents to lizard predation in general, and whether some lizard groups (e.g., Sceloporus) have evolved tolerance or other means of resistance to these defenses.

We thank D. Withers of the USFWS for permits and access to Anaho Island, and M. L. Forister for verifying the beetles.

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TROPIDURUS HYGOMI (Reinhardt’s Lava Lizard). COURTSHIP BEHAVIOR. Tropidurus hygomi is a heliothermic, generalist lizard, endemic to northeastern Brazil in restinga ecosystems of the north coast of Bahia from Salvador to the state of Sergipe (Rodrigues 1987. Arq. Zool., S. Paulo 31[3]:105–230). There are no records concerning the courtship behavior of the species.

On 13 March of 2013, around 0900 h, we recorded courtship behavior, followed by an attempted mating, between two T. hygomi within restinga of Reserva Imbassai (12.481616°S, 37.957193°W; datum WGS 84) using a Samsung WB100 digital camera. We kept a distance of 3 m from the lizards during filming. Air and substrate temperature were 36.6°C and 28°C, respectively. The adult female was foraging among leaf litter. When the female noticed the presence of the male, she elevated her tail (Fig. 1). Such behavior in some lizard species is performed during courtship or as a defensive action towards predators (Dial 1986. Amer. Nat. 127:103–111). The female then waved the tail.

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laterally for approximately one second and also raised her pelvis. The male, larger than the female, was at approximately 3 m away and approached her, directing his head to her cloaca region. The female refused copulation, moving away from the male, who then bit her right hind limb. The male stayed in the same place with his body stretched forward, watching her.

After the first attempt, there was a second attempt after three minutes. The female was on a dead bromeliad and raised the tail again and waved it laterally. Then, the female climbed into a bush, followed by the male, at which time we no longer able to continue observation.

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TAKYDROMUS SMARAGDINUS (Green Grass Lizard). OVER-WINTER SHELTER. Takydromus smaragdinus is a diurnal grass lizard occurring in subtropical forests and is endemic to the Central Ryukyu Islands, Japan (Ota et al. 2002. Biol. J. Linn. Soc. 76:493–509). Because the lizards are exposed to great predation pressures by a variety of species, including avian, mammalian, and snake predators, they exhibit several defensive behaviors, including sleeping and resting site selection. For example, during the active season (early spring to early winter), this lizard utilizes leaves located at the tips of thin branches as a nighttime sleeping site (unpubl. data), and such sleeping site selection by small lizards is believed to aid in nocturnal predation avoidance (see references in Ikeuchi et al. 2012. Current Herpetol. 31:107–116). Herein, we report that this lizard exploits insect galls as shelters during the inactive season. In winter, T. smaragdinus enters a temporary state of torpor, therefore, it has seldom been observed active during this time of year in the bushes, which are its natural habitats both day and night during the active season. During daylight hours, we collected seven galls, which had previously been abandoned by parasitic aphids, Sinonipponaphis monzeni, from five individual host plants (Distylism racemosum) in January 2013. The trees were located at the edge of the forests on Okinawajima Island (26.755°N, 128.297°E). In three out of the seven galls, we found two male lizards (SVL = 42.0 mm; head width = 5.0 mm; SVL = 32.9 mm; head width = 4.5 mm) and one female (SVL = 63.5 mm; head width = 5.7 mm). The largest diameters of three galls were 63.6, 56.4, and 55.3 mm, and the diameters of holes on these galls were 12.9, 12.1, and 11.8 mm, respectively. Galls were located at the heights of 4.5, 5.5, and 4.5 meters from the ground. Compared to the inhabited galls, there were bigger holes on the four galls that were not utilized by the grass lizards (diameters from 13.5 mm to 37.8 mm), but there appeared to be no differences in gall size and distance from the ground. Nocturnal mammals and snakes, which are common arboreal lizard feeders in the study area, would not have access to the lizards within these galls due to the small entrances. This shelter also protects the lizards against diurnal predators, such as birds, while lizards on the leaves at the tip of branches would present easy targets for them. In T. smaragdinus, insect galls potentially serve as optimum shelters against predators during both daytime and nighttime, although the number of galls might not be enough compared to the number of lizards in the area and they can only be utilized after autumn when the aphids leave.

This is a unique example of a secondary usage of shelter previously utilized by another animal.

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ingestion of a lizard previously unrecorded as prey for *T. hispidus* in the Forest Fragment of the University of Amapá, in the municipality of Macapá, Brazil. During an ecological study of a community of lizards in the Forest Fragment (0.006283°S; 51.08265°W; datum WGS84), a total of 25 stomachs were analyzed. A dactyloid lizard, *Norops australis* (SVL = 46.0 mm; total length = 63.0 mm; volume = 18.5 mm³) was found in the stomach contents of an adult female *T. hispidus* (SVL = 81.3 mm) captured on 26 September 2011, in addition to Hymenoptera, Coleoptera, Orthoptera, and plant matter (fruits and leaves). The voucher specimen of *T. hispidus* was deposited in the Collection of Laboratory of Zoology of the Universidade Federal do Amapá, Brazil (CDLABZOO 111). We thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support (Process 126528/2011-0). ICMBio provided a permit (Proc. Number 31814-2).

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**TROPIDURIUS HYGOMI. PREDATION.** Tropidurus hygomi is one of the few species of reptiles endemic to restinga habitat of coastal Brazil, occurring in discontinuous populations along the coast of Salvador, Bahia state, to Santo Amaro das Brotas, Sergipe (Vanzolini and Gomes 1979. Pap. Avul. Zool. 32:243–259). Data regarding the autecology of this species are lacking (Martins et al. 2010. Biotemas 23:71–75) and interspecific relationships with other species are not well understood, with the exception of a report on juvenile predation by *Amblyrhynchus cristatus* (Dias and Rocha 2004. Biotemas 23:71–75) and interspecific relationships with other species. Prior to this report, arthropods of the orders Orthoptera and Coleoptera have been reported as food items of *U. vautieri* diet of this lizard. Ingestion of shed skin by *T. hispidus* by Sazima and Haddad (1992. *In L. P. C. Morelato [ed.], História Natural da Serra do Japi: Ecologia e Preservação de uma Área Florestal no Sudeste do Brasil*, pp. 212–235. UNICAMP, Campinas), and by Condez et al. (2009, *op. cit.*).

In the current study we analyzed the stomach contents of five specimens of *U. vautieri* (two females: CRLZ 000065, 000256, and three males: CRLZ 000077, 000126, 000152) deposited in the Coleção de Répteis do do Laboratório de Zoologia, Centro Universitário de Lavras (CRLZ) - UNILAVRAS. All specimens are from the Reserva Biológica Unilavras Boqueirão (RBUB) (21.346°S, 44.990°W, datum WGS84; 1250 m elev.). In riparian forest associated with phytosociognomies of Cerrado, in the municipality of Ingá, Minas Gerais state, Brazil. We recorded body parts of specimens of arthropods of the orders Coleoptera (thorax, elytra, and abdomen), Hymenoptera (heads of wasps and ants, and wings), Blattodea (legs and abdomen), and Diptera (heads); and remains of shed skin of these specimens of *U. vautieri*. Hymenoptera, Blattodea and Diptera are novel arthropod taxa reported in the diet of this lizard. Ingestion of shed skin by *U. vautieri* has been previously observed by Ribeiro and Sousa (2006. Herpetol. Rev. 37:348–348).

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**VARANUS PANOPTES** (Yellow-spotted Monitor). CANNIBALISM. Intraspecific predation, or cannibalism, is common and widespread in animals, and is important in the ecology and evolution of many species (Polis 1981. Annu. Rev. Ecol. Syst 12:225–251). However, there is limited understanding of the implications of cannibalism for the behavior, ecology, and population dynamics of many species (Hämäläinen 2012. Amer. J. Primatol. 74:783–787).


On 6 May 2012 at approximately 1600 h, a medium-sized male *V. panoptes* (SVL = 40.6 cm; TL = 103.4 cm) was radio-tracked to an
area of open woodland along a permanent wetland at El Questro Wilderness Park in the east Kimberley region of Western Australia (15.98056°S, 127.45889°E). Upon approaching the animal, we noticed a juvenile V. panoptes (SVL: 192 mm, TL: 479 mm) in the mouth of the male. The male dropped the juvenile before fleeing a distance of approximately 30 m. The juvenile V. panoptes was dead upon discovery and exhibited wounds consistent with being mouthed by another monitor lizard.

On 8 June 2001, we observed a large V. panoptes on the bank of the Daly River near Oolloo Crossing, Northern Territory, Australia (14.004391°S, 131.240014°E). The lizard was a male, judging by its size (ca. 60 cm), and was in the act of swallowing a sub-adult V. panoptes that was about one-third the size of the cannibal. The head and front legs were inside the larger lizard. The smaller lizard was still struggling, raking at the head of the larger lizard with its hind legs. The larger lizard appeared to be struggling to swallow its prey, and would shake it from side-to-side occasionally. Once the prey stopped struggling, the larger monitor slowly swallowed it until just a portion of tail (ca. 15 cm) was left hanging out of its mouth. At this stage the larger lizard appeared to have difficulty walking, and we did not observe the last portion of the tail being swallowed. During the latter part of the swallowing, a third V. panoptes walked past that was a similar size to the one that was eaten.


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FIG. 1 Gravid adult female Zootoca vivipara with a record weight of 10.0 g (found on the island of Hiddensee, Germany).

Zootoca vivipara (Common Lizard). RECORD WEIGHT. On 25 June 2011 a very heavy adult female specimen of Zootoca vivipara was found on the island of Hiddensee near Vitte (54.563816°N, 13.112562°E) at the German coastline of the Baltic Sea underneath a dry-docked sailing boat. The female Z. vivipara reported here weighed 10.0 g (live weight), which makes it the heaviest gravid female specimen of the Common Lizard ever recorded (Fig. 1). The examined Z. vivipara measured 157 mm in total length (SVL = 72 mm; tail length = 85 mm). Most adult specimens of Z. vivipara express a total length of 110–140 mm with a maximum length of approximately 180 mm (Günther and Vöök 1996. In R. Günther [ed.], Die Amphibien und Reptilien Deutschlands, pp. 588–600. Fischer, Jena). Female individuals typically have a SVL measuring between 45 and 70 mm, seldom more than 75 mm (Günther and Vöök, 1996, op. cit.). Few reports regarding body weight data have been published for Z. vivipara.

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SQUAMATA — SNAKES

Agkistrodon contortrix (Copperhead). DIET. Agkistrodon contortrix is a widely-distributed viperid species that occurs in the eastern and central United States and northern Mexico. The species’ diet is known to include many species of small mammals, birds, snakes, lizards, frogs, salamanders, and invertebrates (Campbell and Lamar 2004. The Venomous Reptiles of the Western Hemisphere, Volume I. Cornell University Press, Ithaca, New York. 475 pp.). On 19 April 2012, at 2040 h, a male A. contortrix (SVL ca. 63.4 cm; Auburn University Museum [AUM] 39901) was collected injured on State Road 503 near CR 20 in Jasper Co., Mississippi, USA (32.13914°N, 89.06058°W; datum WGS84). The snake died overnight. While curating the specimen, the remains of an adult Pseudotus inexpectatus (Southeastern Five-lined Skink; AUM 39902) were found in the stomach. The lizard had been ingested headfirst. To our knowledge, this is the first record of A. contortrix consuming P. inexpectatus (Campbell and Lamar, op. cit.).

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Boigertophis subocularis (Trans-Pecos Ratsnake). OVERWINTERING BEHAVIOR. Colubrid snakes in North America, especially those inhabiting higher latitudes, typically hibernate during the cold winter months (Ernst and Ernst 2003. Snakes of
the United States and Canada. Smithsonian Inst. Press. Washington, D.C. 680 pp.). However, there is no information reported on the winter months, limiting the surface activity of most snakes, in which temperatures can reach freezing during the months, limiting the surface activity of most snakes, such as B. subocularis. This is the first documented sighting of B. subocularis basking during the winter months.

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**Bothrocophias campbelli** (Campbell’s Toad-headed Pit-viper, Víbora Boca de Sapo de Campbell). DIET/OPHIOPHAGY. The only documented prey item of Bothrocophias campbelli is a partly digested rat-sized rodent reported from Ecuador (Freire and Kuch 2000. Herpetol. Rev. 31:45). On 19 July 2012, ARR and KC collected a juvenile female B. campbelli (PSO-CZ 436; total length = 505 mm; SVL = 440 mm) on a tourist trail at Reserva Natural Rio Nambí (RNRÑ), municipality of Barbacoas, department of Nariño, Colombia (01.28592°N, 78.07433°W, datum WGS84; length = 1070 mm; 215.4 g) over a nine-month period on Indo Mountains Research Station (IMRS) (centered on 30.75°N, 105.00°W; datum WGS84).HUDspeth Co., Texas, USA. The landscape in the study area is represented by typical Chihuahuan Desert scrub. On 27 October 2010, at 1030 h, the female was observed basking outside its overwinterting microhabitat site after ingressing. The hibernaculum (elev. 1358 m) was located on a northeastern slope of part of the rimrock of Flat Top Mountain (Worthington et al. 2004. Biotic Resources of Indo Mountains Research Station, Southern Hudspeth County, Texas. University of Texas, El Paso. 85 pp.), which was composed of mostly trachyte rocks with sparse vegetation (Bouteloua grasses). The snake was visible until 1120 h, after which it went deeper in the hibernaculum. The body temperature of the snake was 13.5°C, and the ambient, substrate, and microhabitat temperatures were 12.5°C, 13.8°C, and 14°C, respectively. The Chihuahuan Desert has broad periods in which temperatures can reach freezing during the winter months. We thank H. García for assistance in the field, Fundación FELCA and their members M. F. Pai and C. F. Pai for permits and logistic help in the RNRÑ, and J. P. Hurtado for help with prey identification. PDAGC received Ph.D. funding from CAPES (bolsista da CAPES/CNPq – IEL Nacional - Brasil).

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**Coluber (=Masticophis) bilineatus** (Sonoran Whip-snake). DIET. The diet of the diurnally active, swift-moving Coluber bilineatus includes lizards, birds, and occasionally small mammals, frogs, and snakes (Stebbins 1985. A Field Guide to Western Reptiles and Amphibians. Houghton Mifflin Co., Boston Massachusetts. 336 pp.). On 25 July 2012 at 1320 h, while driving along the County Road south of Richards Road in southwestern New Mexico (31.6696°N, 108.8409°W; datum WGS 84) we encountered a DOR male C. bilineatus (total length = 1858 mm) that had recently ingested a C. flagellum (total length = 991 mm; Fig. 1). The C. flagellum had been ingested headfirst and completely consumed. This record is the first documentation of C. flagellum in the diet of C. bilineatus. The specimens (LACM 183338, 183339) and photo vouchers (LACM PC 1616, 1617) have been accessioned at the Natural History Museum of Los Angeles County, California.

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**COLUBER (=MASTICOPHIS) BILINEATUS** (Sonoran Whipsnake). **MAXIMUM LENGTH.** The maximum total length (TL) reported for *Coluber bilineatus* is ~1700 mm (Boundy 1995, Bull. Chicago Herpetol. Soc. 30:109–122). We captured and released a male *C. bilineatus* at ca. 1900 m elevation in the Peloncillo Mountains, Hidalgo Co., New Mexico, USA, that exceeds this length. Captured on 22 April 1995, at 1432 h, this snake measured precisely 1800 mm TL (SVL = 1265 mm) and weighed 460 g. We captured 15 *C. bilineatus* in the Peloncillo Mountains between 1995 and 2001. Males averaged 982 ± 70 (SE) mm SVL (N = 8, range 645–1265 mm). Females averaged 867 ± 48 mm SVL (N = 7, range 685–1076 mm).

A specimen collected from Portal, Cochise Co., Arizona, USA, and deposited in the American Museum of Natural History (AMNH 91620) measured 1331 mm SVL and 1486 mm TL but had an incomplete tail (measurements provided by D. Frost). Based on our small Peloncillo Mountains sample, where both males and females had mean tail/body length ratios of approximately 43% (t = 2.23, df = 10, p = 0.43), we calculate that AMNH 91620 would measure 1903 mm TL if the tail were complete.

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On 23 June 1999, at 0826 h, one of us (LK) saw a *S. variegatus* at a rocky tinaja in the streambed of a densely wooded canyon in the Animas Mountains, Hidalgo Co., New Mexico, USA. Immediately after the squirrel was frightened off, a *Coluber bilineatus* (SVL ca. 1200 mm) was found writhing approximately 8 m from the point where the squirrel was first observed. The snake had sustained numerous puncture wounds to the head and anterior 1/3 of the body consistent with those that would be made by rodent incisors. The tail was missing from approximately 60 mm posterior of the vent. When approached, the snake struck haphazardly. Despite the injuries, the snake appeared to be in good condition.

*Spermophilus variegatus* occasionally take live vertebrate prey (Hoffmeister 1986. The Mammals of Arizona. Univ. Arizona Press, Tucson. 602 pp.) and may have been preying on the *C. bilineatus*. However, in our area most *S. variegatus* give birth in June (Ortega 1990. J. Mammm. 71:448–457), so the squirrel may have been defending itself or its young against a predatory attack by the snake.

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**CROTALUS ATROX** (Western Diamondback Rattlesnake). **DIET AND FEEDING BEHAVIOR.** *Crotalus atrox* are generalist predators that prefer a diet of small mammals, but are also known to consume birds, lizards and in some cases, insects (Klauber 1956. Rattlesnakes: Their Life, Habits, History and Influence on Mankind. Vol. 1. Univ. California Press, Berkeley. 708 pp.). Though the natural history and feeding ecology of *C. atrox* has been well documented in captivity, relatively few observations have been made in their natural environment. The feeding behavior of *Crotalus* spp. is generally characterized by a strike, envenomation, and release of the prey item. The snake later tracks the dead prey item for consumption. However, certain stimuli, such as small prey size and prey type, may influence the snake to hold prey after the strike (Kardong 1986. J. Comp. Psychol. 100:304–314).

Here, I describe an in-situ observation of prey capture and consumption by a *C. atrox* in Taylor Co., Texas, USA. The observation documents a novel prey species for *C. atrox*, *Cophosaurus texanus texanus* (Texas Greater Earless Lizard), and is unusual in that the prey was not released after the strike.

On 20 May 2010, at 1005 h, a *C. texanus* was observed running off the side of a dirt road at the Horse Hollow Wind Energy Center (32.25834°N, 100.02678°W; datum WGS84). While the lizard was running, it was struck and held by a *C. atrox* that was basking on a rock, initially undetected by both the prey and observer. The *C. texanus* was struck head-first, with the initial strike reaching just past the front legs of the lizard (Fig. 1). Consumption of the lizard began approximately 50 sec later and was completed in approximately 7 min.

I thank Caleb Gordon, Normandeau Associates, NextEra Energy, Inc., and Turner Biological Consulting for the opportunity to observe this event.

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**Figure 1.** *Crotalus atrox* feeding on a *Cophosaurus texanus texanus* in Taylor Co., Texas, USA.
looking facial dermatitis (Fig. 1). Both individuals were pre-ecdysis when found and were held for approximately five weeks before biopsy samples were sent for analysis; during this time they completed ecdysis. Small biopsies from the head of Snake A and body of Snake B, as well as shed skins from both animals, were sent to the US Geological Survey – National Wildlife Health Center in Madison, Wisconsin for testing.

Tissue from the biopsies and affected areas of skin from the sheds were subjected to fungal culture at an incubation temperature of 24°C. Fungal isolates were examined microscopically for tentative identification. Most isolates were common environmental fungi that likely represented normal skin flora (e.g., *Aspergillus* and *Penicillium* spp.). However, two isolates (one from the biopsy of Snake A and one from the shed skin of Snake B) could not be identified by microscopic examination. A portion of the internal transcribed spacer region of the ribosomal RNA gene for both isolates was amplified and sequenced using universal primers. The sequences were identical to one another and >99.6% nucleotide match with *Chrysosporium ophiodiicola* (GenBank accession EU715819), a species isolated from a facial lesion; histopathology could not be performed on the remaining tissue of the skin from one of the biopsies using special stains for fungi. No fungal elements were observed, but the sample was taken from the edge of the biopsy and likely did not contain the actual mass of a *Chrysosporium* sp.; note facial dermatitis circled in red.

We thank Erica Hoaglund and Dan Lais for reviewing this note. We also thank Marc Bailey, Dv Kaufman, Dan Keyler, Jeffrey B. LeClere, Brian Potter, and Eric Thiss for their assistance in the field and Kevin McCurley for bringing this issue to our attention and providing technical guidance in the field. A special thank you goes to Tom Taggert and Valley Veterinary Clinic for voluntarily collecting biopsies from both snakes. We would also like to thank the USGS National Wildlife Heath Center in Madison, Wisconsin for testing samples and Carol U. Meteyer for examining the histopathology.

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**CROTALUS HORRIDUS** (Timber Rattlesnake). **REPRODUCTION.** *Crotalus horridus* is a widely distributed species native to the eastern United States; however, most research has focused on northern populations. In Georgia, *C. horridus* typically mates from August to October and gives birth from mid-August to mid-September. However, there have been reports of snakes at higher elevations delaying birth until early October (Jensen et al. 2008. The Amphibians and Reptiles of Georgia. Univ. Georgia Press, Athens. 575 pp.). On 19 October 2011, we collected a road killed female *C. horridus* with a distended lower body in Baker Co., Georgia, USA. No body size measurements were taken on the specimen due to its advanced state of decomposition. Upon dissection, we observed between 8–12 fetuses (SVL range = 291–330 mm) in the latter stages of development. This observation is evidence of late season pregnancy in *C. horridus* in the southeastern Coastal Plain.

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**CROTALUS VIRIDIS** (Prairie Rattlesnake). **DIET.** *Crotalus viridis* feeds on small mammals (mice, ground squirrels, rats, small rabbits); it will also consume lizards, amphibians, and other snakes. On 3 July 2012, an adult *C. viridis* was photographed attempting...

At 1130 h on 23 September 2008, 1 km W of the gap that leads to “El Vergel,” at km 304 of the Ciudad Juárez–Chihuahua Federal Highway 45, municipality of Juárez, Chihuahua, Mexico (31.20223889°N, 106.51834444°W, datum WGS 84; elev. 1285 m) one of us (EMR) encountered two male C. viridis (ca. 1100 mm SVL) engaged in combat (Fig. 1). The observation occurred in dune habitat with vegetation composed primarily of Prosopis glandulosa and Gutierrezia sarothrae, about 20 m away from the location of a female C. viridis and her newborn offspring. Combat continued for ca. 10 min, after which the defeated male withdrew. A film and photos of the combat are deposited in the scientific collection of vertebrates of the Autonomous University of Juárez UACJ (CHI-VER-189-08-06). The second combat event took place on 15 April 2003, at 1100 h, on the campus of the Autonomous University of Juárez (UACJ) (31.49132095°N, 106.790825°W; datum WGS84). These observations are unusual in that they occurred outside of the typical summer breeding season of the species.

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**DIPSAS ALTERNANS** (Jan’s Snail-Eater, Dormideira). DEFENSIVE BEHAVIOR. The genus Dipsas comprises small and nonvenomous Neotropical snakes that show several defensive strategies, some of which are thought to mimic venomous snakes of the genus Bothrops (Sazima 1992. In Campbell and Brodie Jr. [eds.], Biology of Pitvipers, pp. 199–216. Selva, Tyler, Texas). Recently, Maia-Carneiro et al. (2012. Biotemas 25:207–210) described three defensive behaviors in Dipsas alternans: immobility, spherical body coiling, and hiding the head among the body coils. In our long-term studies of snakes in the Atlantic forest region of the state of Paraná, southern Brazil, we have collected seven D. alternans. Five of these demonstrated the same defensive behaviors described by Maia-Carneiro et al. (op. cit.), but two exhibited a unique defensive behavior: spiral coiling. The two snakes were found moving within the leaf-litter on the ground of the forest. Both stayed immobile, but after manipulation, rolled their body into a perfect plain spiral, with their heads completely visible in the center (Fig. 1), displaying three spots on the dorsum of the head, as described by Maia-Carneiro et al. (op. cit.). In captivity, the specimens never showed any other defensive behaviors, but always forming the spiral when stimulated. Although the exact function of this behavior remains unknown, the spiral shape might confuse a potential predator or mimic the spiral-shaped dead leaves of common tree fern in the area, Dicksonia sellowiana (Cyatheaceae). The specimens are deposited in the herpetological collection of the Museu de História Natural Capão da Imbuia (MHNCL.691, Camarinhos, municipality of Campo Largo, Paraná; 25.43°S, 49.75°W, datum WGS 84).

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**Fig. 1.** Male-male combat between two Crotalus viridis observed in September in northern Chihuahua, Mexico.

**Fig. 1.** Dipsas alternans (MHNCL.691) from Paraná, Brazil, showing spiral defensive behavior.
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**EPICTIA TENELLUS** (Guyana Blind Snake). **PREDATION.** The vast majority of anurans, especially mid-sized and small species, feed on arthropods and other invertebrates (Duellman and 1994. Biology of Amphibians, 2nd ed. Johns Hopkins Univ. Press, Baltimore. 670 pp.). However, there are a few field observations of snake predation by frogs. *Leptodactylus labyrinthicus* (Pepper Frog) have been recorded to prey on several snake species: *Siby-nomorphus newiedi*, *Trialepida koppesi*, and *Tychlops brong-ersmanius* (Fonseca et al. 2012. Herpetol. Notes 5:167–168; Vaz-Silva et al. 2003. Herpetol. Rev. 34:359). During necropsy of 74 L. *labyrinthicus* deposited in Zoological Collection of the Universidade Federal do Mato Groasso, we found an adult *Epictia tenellus* (SVL = 156 mm; total length = 172 mm) in the large intestine of a male frog (SVL = 151 mm) from Mato Groasso State, Brazil. The fact that only one snake was recorded suggests that this frog is an opportunist feeder that infrequently feeds on uncommon snakes such as *E. tenellus*.

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**FICIMIA STRECKERI** (Tamaulipan Hook-nosed Snake). **REPRODUCTION.** *Ficimia streckeri* is distributed in extreme southern Texas, USA, and Mexico from Nuevo León, Tamaulipas, and San Luis Potosí to the central Mexican Plateau, Hidalgo and north of Veracruz (Wright and Wright. 1957. Handbook of Snakes of United States and Canada. Vol. 1. Cornell Univ. Press, Ithaca, New York. 564 pp.). It inhabits thorn forest, tropical deciduous forest, and cloud forest (Hardy 1976. Cat. Amer. Amphib. Rept. 181.1–181.2). It is seldom seen and little is known about its natural history, including reproduction (Werler and Dixon 2000. Herpetological Review 34:359). During necropsy of 74 L. *labyrinthicus* deposited in Zoological Collection of the Universidade Federal do Mato Groasso, we found an adult *Epictia tenellus* (SVL = 156 mm; total length = 172 mm) in the large intestine of a male frog (SVL = 151 mm) from Mato Groasso State, Brazil. The fact that only one snake was recorded suggests that this frog is an opportunist feeder that infrequently feeds on uncommon snakes such as *E. tenellus*.

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We conducted a field survey of homalopsid snakes in the intertidal zone of Sonadia Island, Bangladesh, from 9 to 17 July 2012. Sonadia Island is a roughly 4900-ha barrier island located in the far southeastern corner of Bangladesh, northwest of Cox’s Bazaar town. The island supports some of the last remaining patches of natural mangrove forest found in southeastern Bangladesh. On 15 July 2012, we found eight *F. leucobalia* in the early succession mangrove forest, in the landward side of the intertidal zone. Upon capture, one *F. leucobalia* (adult male; SVL = 52.8 cm, tail length = 7.8 cm, 92 g) defecated a *Cerithidea sp.* (Fig. 1; total length = 1.5 cm; 3 g). *Cerithidea sp.* is small, hard-shelled gastropod, abundant in the mudflats and mangrove forest in this region (Siddiqui et al. 2007. Encyclopedia of Flora and Fauna of Bangladesh: Volume 17: Molluscs. Asiatic Society of Bangladesh, Dhaka, Bangladesh. 415 pp.). Feeding on gastropods has not been previously recorded for any homalopsid snakes. Silva et al. (2011. Herpetol. Notes 4:373–375) recently reported an observation of a sea snake (*Lapemis curtus*) feeding on a gastropod in Sri Lanka, indicating that feeding on gastropods by aquatic snakes (homalopsid snakes and sea snakes) might be more common in this region than anticipated.

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A mature female *H. angulatus* (SVL = 297 mm) was captured on 9 November 2010, at 2200 h, on the edge of a stream in Atlantic Forest of Cruz do Espírito Santo municipality, Paraíba State, northeastern Brazil. Dissection revealed remains of an adult *Leptodactylus natalensis* (SVL = 49.4 mm) in the snake’s stomach. This is the first record of consumption of *L. natalensis* by *H. angulatus*. Because both species are sympatric and their habitats are similar, this type of interaction may be expected. The habit of making nests and vocalizing at the edge of slow-flowing streams (Amorim et al. 2009. Pap. Avul. Zool. 49:1–7) may make *L. natalensis* more vulnerable to predators such as *H. angulatus* during the breeding season. The snake and frog are housed in the Coleção Herpetológica da Universidade Federal da Paraíba, João Pessoa (CHUFPB 00005).

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**LAMPROPELGIS NIGRA** (Black Kingsnake). DIET. The diet of *Lampropeltis nigra* (taxonomy follows Pyron and Burbrink 2009. Zootaxa 2241:22–32) is diverse and includes a variety of lizard eggs, turtle eggs, snakes and their eggs, mammals, and birds (Ernst and Ernst 2003. Snakes of the United States and Canada. Smithsonian Books, Washington, D.C. 680 pp.; Green and Cobb 2011. Herpetol. Rev. 42:615). On 15 June 2010, we captured a male *L. nigra* (SVL = 104.2 cm; total length = 118.4 cm; 380 g) in a trap array located on the Camp Shelby Joint Force Training Center, De Soto National Forest, Perry County, Mississipi, USA. During transportation, the *L. nigra* regurgitated a juvenile *Cemophora coccinea* (Scarletsnake), an *Agkistrodon sp.*, and *Crotalus adamanteus* (Eastern Diamond-backed Rattlesnake) rattle segments. Rattle segments were identified as *C. adamanteus* due to the absence of *C. horridus* from the study area (Lee 2009. Southeast. Nat. 8:639–652) and the segments were too large to be those of *S. miliarius*. To the best of our knowledge this is the first documented occurrence of *C. coccinea* in the diet of *L. nigra*, and represents a novel food item for the genus *Lampropeltis* (Ernst and Ernst 2003, op. cit.).

**LAMPROPELGIS SPLENDIDA** (Desert Kingsnake). DIET. *Lampropeltis splendida* is a common Chihuahuan Desert species reported to feed on a variety of prey, including bird eggs and hatchlings (Degenhardt et al. 1996. The Amphibians and Reptiles of New Mexico. Univ. New Mexico Press, Albuquerque, New Mex- ico. 431 pp.). Avian nest predation by snakes has been reported infrequently, but may account for as much as 90% of all nest predation (Weatherhead and Blouin-Demers 2004. J. Avian Biol. 35:185–190). On 20 July 2012, at 0140 h, we recorded a *L. splendida* preying on an *Empidonax trailli extimus* (Southwestern Willow Flycatcher) nest with three nestlings (Fig. 1). The nest was located 1.5 m above the ground in a live 4.5-m tall *Salix exigua* (Coyote Willow). The locality was near San Marcial, Socorro Co., New Mexico, USA. A photo series from a trail camera with infrared capabilities documented four minutes of activity, although it is likely the predation event lasted much longer. To our knowledge, this is the first report of a Southwestern Willow Flycatcher...
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Fig. 1. Attempted predation by Leptodeira annulata on Leptodactylus cf. macrosternum in the Brazilian Caatinga.

Fig. 1. A Montatheris hindii consuming a Sylvirex granti mundus in a pitfall trap in Mt. Kenya National Reserve, Kenya.


At 1810 h on 25 October 2009 in the Fazenda Tanques, municipality of Santa Maria, state of Rio Grande do Norte, Brazil (05.87°S, 35.70°W, datum WGS84; elev. 137 m), we found an adult female L. annulata (SVL = 602 mm) in herbaceous vegetation on the border of a pond, biting the right hind limb of an adult Leptodactylus cf. macrosternum. The anuran continuously emitted open-mouthed distress calls (Fig. 1), and tried to escape from the snake. The L. annulata held the frog for approximately 15 min while anchoring its body by wrapping its caudal region around vegetation, but eventually the frog was able to escape.

Although we recognize that our presence may have disturbed the snake, the failed predation attempt may have occurred due to the large size and great vitality of the frog. Despite the batrachophagic habits of L. annulata, ingestion of large anurans does not seem to be common in this species. In an analysis of 66 specimens of L. annulata from the Brazilian Amazon, Vitt (op. cit.) reported only small frogs, with mean prey length (29.9 ± 3.9 mm) and width (11.0 ± 1.4 mm) much smaller than the L. cf. macrosternum we observed (estimated body length = 80 mm; body width = 39 mm).

The L. annulata (CHBEZ 2631) was vouchered in the herpetological collection of the Universidade Federal do Rio Grande do Norte, Natal, Brazil. This study was supported by research grants from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) to JSJ (process 107757/2010-9) and EMXF (process 309424/2011-9), and from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) to RFDS.

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MONTATHERIS HINDII (Kenya Montane Viper). DIET. Montatheris hindii is a small Kenyan viperid endemic to high altitude moorlands of the Aberdare Mountains and Mt. Kenya. Little is known about the natural history of this species although its diet consists of lizards and frogs, while small rodents have been suggested as prey (Spawls et al. 2004. A Field Guide to the Reptiles of East Africa. A & C Publishers Ltd., London. 543 pp.).

On 4 October 2011, during a small mammal survey in the Eastern Province of Kenya, Meru South District, Mt. Kenya National Reserve (00.16392°N, 37.44714°E, datum WGS 84; elev. 2980 m) an adult male M. hindii (total length = 299 mm; 16 g) was captured in a pitfall trap line. The pitfall line was situated in a transitional region between the upper montane forest zone and the Ericaceous zone along the eastern slope of Mt. Kenya. Vegetation in the immediate vicinity of the pitfall included tussock-forming grasses and herbaceous plants 0.5–1 m in height and this alpine grassland was bordered by a grove of Hagenia abyssinica trees ca. 100 m distant. While in the bucket trap, the snake had killed and half-consumed a Sylvirex granti mundus (5.0 g; Fig. 1). The M. hindii was deposited at the National Museum of Kenya, Mammalogy Section (TCD 3374) and the S. granti mundus is a voucher at the Field Museum of Natural History - Chicago (FMNH 216941). This is the first record of S. granti mundus in the diet of M. hindii. However, because the event occurred in a pitfall trap, the importance of this species as prey for M. hindii remains unknown.

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NERODIA FLORIDANA (Florida Green Watersnake). DIET. Although no diet studies have been completed (Gibbons and Dorcas 2004. North American Watersnakes: A Natural History. Univ. Oklahoma Press, Norman. 496 pp.), Nerodia floridana eat a wide variety of aquatic prey (Holbrook 2012. A Field Guide to the Snakes of Southern Florida. ECO Publ., Rodeo, New Mexico. 225 pp.). Though invasive species have the potential to cause harm to some species, there are cases where invasive fish have outcompeted native fish, increasing prey availability and ultimately benefiting watersnakes (Nerodia spp.) (King et al. 2006. Can. J. Zool. 84:108–115). During aquatic trapping efforts by the Center for Snake Conservation on 19 March 2012 in a tributary of Fishheating Creek, Glades Co., Florida, USA (26.909461°N, 81.329154°W; datum WGS84), a N. floridana (SVL = 595 mm) was accidentally drowned in an aquatic minnow trap. The snake contained a recently ingested Hoplosternum littorale (Brown Hoplo Catfish; total length = 110 mm). This is the first record of the native N. floridana feeding on this common nonnative species; however, it should be noted that several large N. floridana were encountered in the area, which supports dense populations of H. littorale (Center for Snake Conservation, unpubl. data). Both snake and fish were deposited together (FLMNH 166557) in the Florida Museum of Natural History Reptile and Amphibian (Herpetology) Collection.

PANTHEROPHIS OBSELOTUS (Texas Ratsnake). DIET AND FEEDING BEHAVIOR. Pantherophis spp. are a frequently documented predator of bird nests (Weatherhead and Blouin-Demers 2004. J. Avian Biol. 35:185–190) and are known to frequently use arboreal habitats (Mullin et al. 2000 Herpetol. Rev. 31:20–22). During a study of nest predation in Mississippi Kites (Ictinia mississippiensis) in White River National Wildlife Refuge, Arkansas, USA, we documented, using time-lapse video, the simultaneous visit of an active kite nest, 24.8 m high, by two P. obsoletus. At 1610 h (CST) on 13 June 2009, a single P. obsoletus entered the nest, struck the brooding adult, which flew from the nest, and immediately began consuming one of the two nestlings. While the snake tried to swallow the nestling, it was pulled out of the nest by an adult kite. Later that night (2107 h), a single P. obsoletus entered the same nest, again flushing the brooding adult, and immediately bit and coiled around the remaining nestling, which it swallowed within minutes. Following the consumption of the chick, this snake continued searching the nest for additional prey. At this point (2129 h), a second P. obsoletus entered the nest and began searching the nest in a similar manner. Both snakes continued searching the nest until 2206 h, when both departed. We do not know if either snake in the nest at 2129 was the same individual pulled out of the nest earlier in the day.

Since 2005, studies in Arkansas have documented P. obsoletus consuming both eggs and nestlings of Mississippi Kites (Bader and Bednarz 2009. Wetlands 29:598–606), which represented a previously unrecorded prey item. Additionally, whereas simultaneous visits by P. alleghaniensis and P. obsoletus have been observed at nests close to ground level (Carter et al. 2007. J. Field Ornithol. 78:390–394; Kukal and Cox 2010. Herpetol. Rev. 41:371–372), to our knowledge our observation is the first to document such an event in the forest canopy. The context of this event generates questions related to the mechanisms used by Pantherophis to locate nests as well as the frequency and significance of such social interactions during foraging. As the use of video systems to study nest predation in birds increases (Cox et al. 2012. Stud. Avian Biol. 43:185–210), researchers may discover that social interactions during foraging are more common among snakes than previously known.

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PANTHEROPHIS VULPINUS (Western Fox Snake). PREDATION. American Badgers (Taxidea taxus) are opportunistic feeders, and their diets include a number of small mammal species, a variety of reptiles, amphibians, birds, insects, and even fish (Hoodicoff 2003. Ecology of the Badger (Taxidea taxus jeffersonii) in the Thompson Region of British Columbia: Implications for Conservation. Univ. of Victoria, British Columbia. 126 pp.). On 7 July 2011, a T. taxus was observed depredating a nest of reptile eggs on Squaw Creek National Wildlife Refuge, Missouri, USA. The nest was located on the bank of a drainage ditch (40.1099°N, 95.2434°W; datum NAD83). Upon close inspection of the area after the badger retreated, several other excavated nest holes were located in the immediate vicinity. In total there were 220 exposed snake eggs and nine turtle eggs. Over 97% of the eggs had been depredated or were in poor (severely dented or smashed) condition. Six eggs were in moderate to good condition and were kept for incubation. All six eggs hatched and were identified as Pantherophis vulpinus. This represents the first known record of predation on P. vulpinus eggs by T. taxus.

We thank Mark Mills, Missouri Western State University, for assistance identifying the snakes. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.
PHILODRYAS NATTERERI (Paraguay Green Racer). DIET. Philodryas nattereri is a diurnal snake belonging to the family Dipsadidae and is widely distributed in the semiarid regions of Brazil. The diet of this species consists mainly of lizards, amphibians, birds, and small mammals (Vitt 1980. Pap. Avul. Zool. 34:87–98). Here we report the first documented predation of Leptodactylus vastus (Northeastern Pepper Frog) by P. nattereri and the encounter of a theraphosid spider in the snake’s stomach contents.

An adult male P nattereri (SVL = 845 mm) was collected alive in the Mocambinho community, City of Nossa Senhora de Nazaré, Piauí, Brazil (04.632667°S, 42.244694°W, datum SAD 69; elev. 117 m), on 04 July 2012 at 1630 h. During transport, the animal regurgitated its stomach contents, including a L. vastus and part of a theraphosid spider. We could not identify the species of spider because of its advanced digestion. We believe that the spider was preyed upon by the frog and some parts of the exoskeleton were released into the snake’s stomach. The snake and stomach contents were deposited in the Coleção Zoológica Delta do Paraíba (CZDP 0550) of Universidade Federal do Piauí-UFPI.

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PITUOPHIS CATENIFER (Gophersnake). DIET. Of 2600 Pituophis catenifer specimens examined by Rodriguez-Rohles (2002. Biol. J. Linn. Soc. 2002:165–183), 213 contained birds or their eggs. We herein provide the first verified report of P. catenifer preying on Lanius ludovicianus (Loggerhead Shrike) nestlings and eggs.

During a 2012 L. ludovicianus study we used remote-triggered wildlife cameras to monitor nests in southeastern New Mexico (Chaves, Eddy, and Lea counties). On 29 April 2012 a ca. 1.4 m (total length) P. catenifer was photographed at a nest located 1.7 m off the ground and initially containing six nestlings that were within a week of fledging (Fig. 1). The P. catenifer preyed on a nestling at ~2150 h and another at 2203 h. On 30 April 2012, a ca. 0.9 m (total length) P. catenifer was photographed eating L. ludovicianus eggs at 1345 h while being mobbed by both adult shrikes. The nest was located in a Prosopis glandulosa (mesquite tree) 1.1 m off the ground. The P. catenifer left after eating at least one egg; the female shrike continued incubation of the nest for the remainder of that day, according to subsequent images. The nest was empty the following day, suggesting that the P. catenifer may have returned during the night of 30 April 2012 (the camera on this nest was not capable of infrared nighttime photography).

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SISTRURUS CATENATUS CATENATUS (Eastern Massasauga). DIET. On 23 July 2012, at 2233 h, an adult female Sistrurus catenatus catenatus (SVL = 61 cm) was found on a road in the Magnetawan First Nation, Ontario, Canada, after being struck and killed by a vehicle. The snake had several feathers protruding anterior to the cloaca and a necropsy revealed two outer remiges (primary flight feathers) and several down feathers in the posterior portion of the gastrointestinal tract. In light of the time of year, location and surrounding habitat, coloration and vane width of the feathers, the bird was identified as a female Red-winged Blackbird (Agelaius phoeniceus). Based on the lengths of the two outer remiges (64.3 and 65.8 mm), we concluded that the bird was an adult female (average remige length for adult female A. phoeniceus is 67.0 mm, whereas average remige length for fledglings is 44.5 mm; Holcomb and Twiest 1968. Ohio J. Sci. 68:277–284).

Overall, S. c. catenatus is thought to be an ambush predation that preys upon small animals found within its wet habitat (swamps, marshes, bogs, fens, floodplains, and woods). The diet of adults predominately consists of small mammals (shrews, voles, and mice), but they are also known to consume crayfish, centipedes, insects, fish, amphibians, lizards, snakes, birds, and carrion (Ditmars 1908. The Reptile Book. Doubleday, Page and Company, New York. 307 pp.). Agelaius phoeniceus are common in wet, marshy areas but may rarely be encountered by an ambush predator like S. c. catenatus. Keenlyne and Beer (1973. J. Herpetol. 7:383–384) found that a S. c. catenatus in Wisconsin fed upon a fledgling A. phoeniceus; however, the fledgling blackbird was only one of 91 food items found. Our observation represents the first record of S. c. catenatus feeding on an adult A. phoeniceus.

We thank Chris Blomme and the Laurentian University Ver-tebrate Museum for their consultation and insight. Jenn Baxter-Gilbert, Sean Boyle, Ron Maleau, and Chris Neufeld assisted in the field. Financial support was provided by Magnetawan First Nation, Laurentian University, the Ontario Ministry of Natural
Lumbricus rubellus is the first account specifically identifying millipedes as a food item, as well as the diet of Storeria dekayi.


Small fish, and amphibians (Judd, 1994) are reported to consume slugs, insects, isopods, mites, spiders, earthworms (Judd, 1994) as having been consumed by S. dekayi include Arion hortensis, Deroceras laeve, and D. reticulatum (Judd 1954. Copeia 1954:62–64; Fitch 1999. A Kansas Snake Community: Composition and Changes over 50 Years. Krieger Publ. Co., Malabar, Florida. 165 pp.;) earthworms have not been identified to either genus or species. In addition to its preferred prey, S. dekayi has also been reported to consume snails, insects, isopods, mites, spiders, small fish, and amphibians (Judd, op. cit.; Wright and Wright 1957. Handbook of Snakes of the United States and Canada, Vol. 2. Cornell Univ. Press, Ithaca, New York. 441 pp; Langlois 1964. Ohio J. Sci. 64:11–25). Herein I report observations regarding the diet of S. dekayi from western Pennsylvania, USA, including the inaugural documentation of millipedes as a food item, as well as the first account specifically identifying Lumbricus rubellus (Red Marshworms) as having been consumed by S. dekayi.

While studying a population of S. dekayi at a site along the Hwy 832 bridge in Erie Co., Pennsylvania, USA (42.09375°N, 80.14180°W; datum WGS84), several observations were made regarding the species’ diet. At 1950 h on 24 August 2012 a juvenile female S. dekayi (SVL = 145 mm; 2.5 g) was discovered under a panel of particle board on a slope dominated by herbaceous vegetation. While being measured, the snake disgorged the following slugs: Arion hortensis complex (N = 1), Arion sp. (N = 1), Deroceras sp. (N = 2), and one unidentified slug. Also disgorged were two millipedes of the order Julida. The combined mass of the prey items was 0.12 g.

Between 31 May 2012 and 19 September 2012, dietary data were gathered from an additional eight S. dekayi (SVL = 114–225 mm; 1.5–7.5 g). Two S. dekayi had each consumed a single L. rubellus, while another disgorged an unidentified earthworm. The remaining five S. dekayi had consumed slugs, three each disgorged a single slug: Arion sp., Deroceras sp., and D. reticulatum, respectively. The remaining two S. dekayi regurgitated multiple slugs; one disgorged three D. reticulatum, the other disgorged two Arion sp., one Deroceras sp., and an unidentified slug.

Of the nine S. dekayi that disgorged prey, seven were found between 1838–2000 h. Three of these snakes disgorged prey that were still alive; two slugs and a L. rubellus. Ernst and Ernst (2003. Snakes of the United States and Canada. Smithsonian Books, Washington, DC. 668 pp.) noted that S. dekayi forage most often in the early evening or at night. The fact that live prey was disgorged in the evening suggests that this may be the case at the Erie Co. site as well. The remaining two S. dekayi were found in the morning between 0921–1124 h and only contained dead prey.

To my knowledge, this is the first report of millipedes in the diet of S. dekayi. The millipedes consumed by the S. dekayi captured on 24 August might have been consumed incidentally. Mucus secreted by Arion slugs during routine handling was especially sticky (pers. obs.). Millipedes were plentiful under cover objects with slugs and snakes, and it is foreseeable that nearby invertebrates could adhere to a slug being manipulated during predation. It is possible that the remains of insects and mites observed by Judd (op. cit.) might have also been ingested accidentally. Although earthworms have previously been reported in the diet of S. dekayi, this is the first report specifically identifying Lumbricus rubellus as a prey item. Lumbricus rubellus is a European exotic earthworm usually found in surface litter or under debris (Reynolds 1977. The Earthworms [Lumbricidae and Sparganophilidae] of Ontario. Life Sci. Misc. Publ., Royal Ontario Museum, Toronto, Canada. 141 pp.). Like L. rubellus, the slugs (Arion sp. and D. reticulatum) consumed by S. dekayi at the Erie Co. site were European exotics. Although it was not possible to identify most of the disgorged Arion slugs to species, A. subfuscus was the most prevalent species found at the site. Likewise, D. laeve was found at the site in very small numbers, while D. reticulatum was much more abundant. Snakes were released at the site of capture; prey items were preserved and will be deposited in the invertebrate collection of the Natural History Museum at the Tom Ridge Environmental Center, Erie, Pennsylvania, USA.

I wish to offer my gratitude to both Jeff Beane and George Pisani for suggestions and comments that improved the manuscript.

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Zamenis situla (Leopard Snake). Diet and Feeding Behavior. On 22 August 2012, at 0053 h, one of us (PC) observed an adult female Z. situla (SVL = 590 mm; tail length = 140 mm; 52 g) preying on a subadult Musculus (House Mouse). The observation took place on a roadside separated from an olive grove by a blackberry bush, ca. 1 km SW of the town of Cavallino, Province di Lecce, Italy (40.30°N, 18.18°E, datum WGS84; elev. 41 m). The snake was not preserved, but its morphological examination leaves no doubt as to its specific identity (2 pre-ventrals + 231 ventrals, anal scale divided; 75 subcaudals, divided except for the first six; pupil round; dorsals smooth, vertebral row not enlarged; 25 dorsal scale rows at midbody; 8 supralabials on each side, 4th + 5th contacting the eye; 9 infralabials, 1 loreal, 1 preocular and 2 postoculurs on each side; spotted dorsal pattern). The snake was released at the place of capture and the mouse was deposited in the collections of the Museo di Storia naturale del Salento. Rare and poorly known, Z. situla is reputed to be diurnal or occasionally crepuscular (Fattizzo 1996. Anfibi e Rettili della Penisola Salentina. Physis Ed., Latiano. 125 pp.; Rugiero et al. 1998. J. Herpetol. 32:626–630). Our observation seems to represent the first reported case of nocturnal feeding by this snake in the wild.

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The sight of an amphibian or reptile manifests a curiosity that is usually expressed through two questions: "what is it" and "what does it do?" For the person who knows what "it" is and does, the sighting raises other questions about whether or not the observation is normal regarding its appearance, location, seasonal activity, reproduction and other aspects the animal’s natural history. Rarely is an informed individual present to answer those questions. Instead, guides that summarize the fauna of geographic regions and provide summary natural history data serve as vicarious experts to a state’s citizenry, and to that purpose Amphibians and Reptiles of the Carolinas and Virginia is exemplary.

The book’s format is standard for a regional summary. The introduction is only eight text pages long, without subheadings, but manages, in that short space, to inform the reader about the scope of the book. It outlines the herpetofaunal diversity of the covered area in a passionless two-page summary of taxonomy and nomenclature and continues with discussions of introduced species and conservation (with an unfortunate emphasis on "listings"). There is an admonition to be careful and conservation-minded when searching for and collecting animals, laws regulating take are mentioned (although no specific rules are detailed), and there is a reserved discussion of pet-keeping. The format and arrangement of species accounts are presented, clues useful in identifying animals are provided, and there is a solicitation of new records. Finally, there is a caution about snake bites (but no suggestions about what to do when bit).

The physical characteristics of the Carolinas and Virginia are described (eight pages of text, a map, and seven photographs of habitat) through discussion of physiographic provinces, characteristic vegetative associations, and climate. Another eight pages discuss the history of herpetology in the region. This section has the liveliest prose in the book. It begins with 16th century reports of the fauna, the serendipitous advent of 18th and 19th century resident naturalists, followed by the arrival in each state of one or more individuals whose observational skills and prolific writing form the foundation for continued research in the Carolinas and Virginia.

A list of the native and non-native species of amphibians and reptiles separates the introductory material from the species accounts. Classic generic assignments are retained, with current generic names listed in parentheses (e.g., Eumeces (Plestiodon) fasciatus). Each class, order, and suborder receives about one page of descriptive material that characterizes each from a global perspective. Each species account is likewise brief. The amount of text for each account, with few exceptions, appears to be governed by the amount of space available on a single page that also must accommodate a color photograph and range map. Where additional space is required for text, the size of the photographs suffer (e.g., Bufo americanus). The species text includes a description, comparison with similar species, description of geographic range and habitat, food (for some species), reproductive data, and conservation status. Description of calls are provided for anurans. All of the information is provided in a little over 200 words per species. Few species are illustrated by more than one photograph, and there is rare mention of subspecies. Species accounts are followed by a thorough glossary, 52 literature references, and a dozen websites for private organizations, museums and universities.

A notable inconsistency in the book is the difference in which species distributions are displayed on the maps. Those for North Carolina are the most precise, portraying a minimal known range, but those of South Carolina and Virginia often appear overgeneralized and stop abruptly at the North Carolina borders (e.g., Plethodon cinereus, Lampropeltis tri equivalent). I was curious about the discontinuity in ranges of some species (e.g., Hyla gratiosa, Pantherophis guttatus) in northern North Carolina, but found no explanation. The color photographs are excellent. Characteristic markings and morphological features for most species are evident, highlighted for example by photographer Dermid’s clever means of showing the color pattern of the inner thigh on Hyla femoralis, and his positioning of Rana catesbeiana and R. grylio to compare extent of the hind-foot webbing between the two species. For a few, however, diagnostic markings are not portrayed, such as the long neck, broad forearm bands and striped “pants” of Deirochelys.

For those familiar with the first edition of Amphibians and Reptiles of the Carolinas and Virginia (Martof et al. 1980), I provide the following comparisons. The number of species has increased from 159 to 189, nearly all through the discovery of cryptic salamander species. Except for three plethodontid species complexes, the second edition provides equal coverage for the new species that have been added during the span of 30 years, and the new species are illustrated by high quality, diagnostic photographs. The range maps show greater detail of distribution, primarily by reducing the broad-brush display of the first edition. The text size is smaller in the second edition, and is presented as two columns, allowing more text to be packed in per page. Some wording is changed (e.g., hellbenders are described as “ugly, slimy and large” in the first edition, vs. “impressive” in the second). The
second edition introduces the term “biodiversity” and has eliminated the first edition’s statement that amphibians and reptiles “do well in captivity and make amusing pets.” Standard photograph size is 10.5 × 7 cm in the first, vs. 10 × 6 cm in the second edition. Most of Dermeid's photographs are retained in the second edition, including some new ones. However, several dozen have been replaced, I suppose to better portray diagnostic features. The new *Rana palustris* photo shows the bright yellow undersurface of the tibia, but the paired, square dorsal blotches are better featured in the first edition. The new *Rana sphenoecephala* photo is more typical in coloration of the species, though the characteristic white tympanic spot is obscure.

Except for the history chapter, the book is devoid of personality despite (or perhaps because of) being authored by seven individuals. The text has been masterfully crafted to eliminate all excess wording, and is concisely informative about each topic the authors have elected to cover. It presents a lesson in being succinct—descriptive biology in the form of “one-liners.” The citizens of the Carolinas and Virginia can now arm themselves with an updated, highly portable means of identifying and learning about that which creeps or slithers into their comfort zone.

This is a fantastic book. Anyone who has had the pleasure of hearing author Aaron Bauer give a lecture will find here eloquent, clear, easy to understand, yet packed with information. I could hear Aaron’s voice in my head while I read this book. As the introductory pages make clear, this book is not a husbandry guide for pet enthusiasts because there are plenty of those available. Nonetheless, there are frequent mentions of topics central to the interests of pet enthusiasts and this book will be well valued by the burgeoning ranks of people keeping geckos as pets, as well as any general naturalist, and all persons interested in herpetology at any level. Honestly, I don’t personally know a whole lot about geckos and I learned quite a bit from this book. For example, I have worked a bit with *Thecadactylus rapicauda* in the field for about 20 years, and learned from this book that they parachute between branches, using their extensively webbed feet. Bauer has a gifted approach here that is fully readable by enthusiasts of almost any age and background, yet he includes depth in his text that will inform the practicing comparative biologist. That is not an easy balance to achieve in writing, and Bauer got it impressively right in this book.

The question-and-answer format of the Johns Hopkins Press *Animal Answer Guide* series veers this book refreshingly away from a standard textbook format, yet the organization and well prepared index make information easy to find. The book has handy internal references, to guide readers to related topics appearing in other sections of the book. The style of the book does not allow for traditional academic in-line literature, but a suitably complete bibliography appears at the end. An unusual chapter entitled “Geckology” reviews the history of scholarly study of geckos. This is a very nice nod to the tradition of science that could well encourage a young herpetologist to explore the academic literature. Similarly, an appendix includes the names of virtually all relevant professional societies and journals. I would have greatly benefitted from a list like this when I was first trying to navigate the academic world while in high school. Another scholarly nod is the index including the current taxonomy of geckos, nicely including their IUCN Red List rankings. The chapter on geckos in human culture has far more depth than the after-thought feel that similar chapters in other books often have. Similarly, I greatly appreciated the double perspective approach used to treat the topics of “influences of geckos on humans” and “influences of humans on geckos” as I found it refreshingly original and perfectly balanced. These sorts of attentions are testament to Bauer’s evident attempts to positively encourage gecko enthusiasts toward the basic academic efforts that inform this very book. Bauer is being inclusive here, and clearly wants everybody to feel like they can join and contribute to the fascinating world of discovering the mysteries of geckos. This is a gracious approach that really allows this book to bring very technical information across to every interested reader. A particular jargon-packed sentence here or there may serve to make the reader want to learn more, rather than dissuade anyone. As a singular example, I will point to the concise and perfectly accurate summary of the different types of squamate chromatophores and pigments presented on page 42. I’ve never seen this admittedly complex topic better simplified and summarized, with no loss of basic information; very impressive. I nominate Aaron Bauer to write an *Animal Answer Guide* for every major clade of reptiles and amphibians, and then we will collectively have the ultimate useful textbook for our herpetology courses, and one that the students will actually read.

The production values are generally excellent. I found no spelling typos, and only a handful of awkward spacing/justification issues. Assumedly to keep prices affordable, most images appear in black-and-white, with two sets of well-chosen color plates to highlight certain appropriate taxa. Images are credited to many photographers, but those by Tony Gamble and Lee Grismer really stand out as especially well composed. A few of the black-and-white images are a bit dark and the image discussing the camouflauge value of green coloration in *Nautilinus grayi* does not work well in black and white imagery. The image of the inverted hemipenis is well lit, but its close-in perspective makes it a bit disorienting; a related image of the cloacal spur in males of some species (described well in the text) would have been a useful addition. But overall, the black and white images are perfectly suitable to their task. The only information gap I found was in the excellent section describing vision and structure of the eye. I fully thought we were leading into a description of the functional difference between circular and elliptical pupils, but I didn’t see it. But I did see a great summary of the function of rod
and cone cells in squamates, and I learned for the first time that geckos see in color at night!

What really permeates this book is Bauer's life-long passion and experience with the geckos of the world. No one else could have written this book with both the top-tier academic authority and also the in-hand love of geckos that Aaron Bauer has. His first-hand experiences, his knowledge, and his admiration for the incredible animals make this book ultimately readable for the broadest range of audiences. This is a fine piece of work and I am really glad I read it in its entirety. While Bauer works on the companion volumes for the remaining clades, I strongly recommend this book for everyone, at any level of interest. No matter which taxa you claim to study, go read this book.

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Australian Lizards—A Natural History

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“Lizards are juicy and nutritious” begins Chapter 6 of this new book on Australian lizards. Not since Edgar Waite's (1929) description of geckos as “soft and flabby to handle” have I appreciated a herpetological turn of phrase this much! This may look like a picture book, but it is so much more. Steve Wilson is known for his excellent photographs of reptiles and amphibians (e.g., Wilson and Knowles 1988; Wilson 2005; Wilson and Swan 2010) and this book does not disappoint. More than 400 color photos strikingly capture the diversity of the Australian lizard fauna. In addition to standard portraits, there are many “action shots” of lizards eating arthropods, arthropods eating lizards, lizards hatching and being born, threatening, thermoregulating, and mating. Throughout the photos are of good to excellent quality. There are great photos of Pygopus feeding on a spider (p. 116), various lizards copulating (p. 143–145), a Central Military Dragon (Caenophorus isolepis) caught in the act of defecation (p. 133), and a Garden Skink (Lampropholis delicata) with an unimaginable mite load (p. 100).

A photo of fighting male Bulbifera robusta (p. 142) dramatically shows off the gekkotan ability to withdraw the eye deep into the socket and examples of geckos (Diplodactylus conspicillatus, D. tessellatus) using their tails in defensive postures (p. 107) are striking. Of special note are a series of photos illustrating camouflage in geckos and agamids (pp. 94–96); that of Phyllurus platarius shows one of the best color matches to substrate I have ever seen (p. 94). I am especially impressed by the photos of limbless and reduced-limbed taxa. These can look like so many pieces of spaghetti, but Wilson has brought out their character, and the diversity of these forms, especially Lerista, can really be appreciated.

Come for the photos, stay for the text; it is well-written, detailed without being off-putting to non-specialists, and it serves as a crash course in Australian lizards, their diversity and biology. Although the title of the book is rather similar to Greer's (1989) The Biology and Evolution of Australian Lizards, Wilson's book has much more in common with Greene's Snakes, The Evolution of Mystery in Nature (1997) or Pianka and Vitt's Lizards, Windows to the Evolution of Diversity (2003). Greer's book is a treasure trove of information for herpetologists, a concise summary of data on Australian lizards, but this book is aimed at a more general audience. It is a “gateway” book—the kind that can really spark the interest of budding herpetologists, or even convert the non-herpetologically inclined. I defy anyone with even the slightest interest in the natural world not to be interested in Australian lizards by the time they finish the book.

The book is organized topically rather than taxonomically. After “Meet the Lizards,” an introduction to diversity, the book is arranged into chapters such as “Senses: sight, scent and sound,” “How lizards manage their water,” and “The fate of Australian lizards.” The last of these discusses the effects of cane toads and fire ants on lizards, as well as the more familiar and universal issues of changing land use and habitat loss. A series of somewhat more detailed side lights are presented as “boxes.” One deals with the rediscovery of the Pygmy Blue-tongue skink, Tiliguana adelaidensis, in 1992 and another with the Pedra Branca Skink, Niveoscincus palfeaymani, Australia's southernmost totally terrestrial vertebrate, which lives on a tiny rock in the Southern Ocean. Yet another is devoted to the origin of the names “wood adder” and “stone adder” for certain species of Diplodactylus geckos. I will leave it to readers to discover the source.

Although the emphasis is definitely Australian, there are a few non-Australian taxa shown or discussed (e.g., Phrynosoma and Furcifer to illustrate lingual feeding). Taxonomy is as up to date as can be for the local taxa—several new Australian genera that were proposed in 2011 and 2012 (Uvidicolus, Nebulifera, etc.) are used. However it is less current for some extralimital taxa. For example, Cnemidophorus uniparnes is used instead of Aspidoscelis (p. 147). Typos and misstatements are few and far between in this book. I noted only a few instances each: Scelopus poinsettia is misspelled poinsettii (p. 64), Mertens’ Water Monitor is rendered as Mertens' (p. 167), the number of Australian varanid species, given as 27, is said to be “about half of the world’s total” (p. 8), but the current tally for varanids is actually 73, Rhacodactylus (now Correlophus) ciliatus can regenerate their tails (contra p. 90), although they often do not, and, in the Glossary, the term “pleurodont” is incorrectly defined as an attachment type in which teeth are “set in sockets.”

Unfortunately for those whose interests are piqued by particular topics, there are no citations in the text itself, making it difficult to track sources for specific information. However, the references section contains about 215 entries representing a diversity of sources up through 2011, so there is an access point into the literature. Interestingly, although some more general works are included among the technical papers listed, the ultimate classic of Australian herpetology, Cogger's Reptiles and Amphibians of Australia (2000) is not. The book concludes with a single index combining common names, scientific names and major subjects.

This book is an ideal gift for any novice herpetologist—in Australia or not. It is also appropriate for any Australian or visitor to Australia who wants to better understand the natural world. Even seasoned herpetologists, familiar with all of the topics discussed, will find new appreciation for Australian lizards through the stunning images.
Les Rainettes du Cameroun (Amphibiens Anoures)

... Students working on amphibians of western Equatorial Africa have been spoiled in recent years. Right after the publication of an identification key to the amphibians of Gabon and Equatorial Guinea (Frétey et al. 2011), here is a remarkable book on the treefrogs of Cameroon. It is authored by the French biologist Jean-Louis Amiet, who vies with the Swiss Jean-Luc Perret the title of the best and most productive specialist on Cameroon amphibians. Jean-Louis Amiet is not only an amphibian specialist, he is a living encyclopedia with an extensive knowledge and active research activities on the flora and fauna of tropical Africa. This new, voluminous, solidly bound book, entirely in French, is divided into four main parts: general remarks (pp. 9–50, including a key to genera, an introduction to the physical geography of Cameroon with 26 beautiful landscape photographs, and a methodology section), hyperoliid treefrogs (pp. 51–431), the genus Leptopolis (pp. 433–562), and finally a chapter on poorly known species and under-prospected geographical areas (563–569). The literature section (pp. 571–576) includes 150 references, 31 of them authored or co-authored by Amiet, the most recent dating from 2009. Taxa covered belong to the Arthroleptidae (Leptopolis Günther, 1859) and Hyperoliidae (Acanthixalus Laurent, 1944, Afrixalus Laurent, 1944, Alexeotono Perret, 1988, Arlequinus Perret, 1988, Cryptophrynos Perret & Combaz, 1950, Hyperolius Rapp, 1842, Kassina Girard, 1853, Opisthophrynos Perret, 1966, and Phlyctimantis Laurent & Combaz, 1950). The hyperoliid treefrogs Chirorhinia (represented in Cameroon by C. rufescens (Günther, 1868)) were not included “in order to preserve the taxonomic homogeneity of the opus.” In total, 62 species are covered, among them 24 Hyperolius spp. and 16 Leptopolis spp., i.e., a bit less than a third of the ca. 200 amphibian species currently known from Cameroon.

Species accounts systematically include references to the original description and sections on adult morphology, pattern and color, sexual dimorphism, eco-ethology, and distribution. Depending on the species, some accounts also include sections on tadpole morphology, parasitism, taxonomic issues, or phylogenetic relationships. Each species account is illustrated by one or two plates of color photographs taken by Amiet (with the exception of the photograph of Afrixalus schneideri (Boettger, 1889), in black and white and taken by Perret—this is the only species that is not illustrated alive in color in the book), one or two plates showing superb drawings made by Amiet (dorsal patterns, webbing, tadpole, vocal sacs, etc., depending on the species), activity cycle graphs, and a point locality distribution map. In all there are 667 photographs of live individuals, with up to ten individuals per photograph. The distribution maps, limited to Cameroon, also show the major vegetation zones and the areas above 600 m asl. Illustrated identification keys to Hyperolius and Leptopolis species are provided, as is comparative table for Alexeotono spp. that can be used as a key.

Attention should be drawn to some taxonomic points presented in the opus, especially because some of them might be overlooked by non-French speaking readers. Amiet describes a new subgenus of Afrixalus, Laurentixalus Amiet, 2012 with Afrixalus laevis (Ahl, 1930) as type-species. It is said to include, besides the type-species, A. lacteus Perret, 1976, A. dorsimacula-...
explained in the original description and the rediscovery of that species by Bell et al. (2010; see Pauwels and Chirio 2012). Amiet regards *Leptopelis macrotis* Schiøtz, 1967 as a subspecies of *L. milsoni* (Boulenger, 1895). The book additionally makes corrections to mistakes made in the literature, by Amiet himself or by others, especially with respect to species identifications.

The text of this new book is fluid, pleasant to read, and there are few typographical errors. It has two exceptional qualities. First, it is abundantly illustrated with drawings (about 900!), graphs, and color plates. The drawings are exceptionally accurate. They represent a huge effort; for example, drawings of foot webbing each required about six hours of work (Amiet, pers. comm., May 2013). All photos are outstanding, and they were all taken in Cameroon (their localities and dates are provided in an appendix). Morphological and pattern variations are well represented. Unusually-patterned specimens are shown as well, but they are always clearly indicated as such in the figure captions (the exceptional nature of these specimens could be overlooked by non French speaking readers).

Second, the book suggests numerous directions for future research. Several populations potentially representing new species or subspecies are discussed in detail, with photographs of representatives of these (Manki *Hyperolius riggenbachi* Nieden, 1910, Mount Cameroon *Kassina cf. maculosa* (Sternfeld, 1917), *Leptopelis cf. bocagii* Günther, 1864), *L. cf. christyi* (Boulenger, 1912), Mwandong *L. cf. modestus* (Werner, 1898), Lena *L. cf. notatus* (Buchholz & Peters, 1875), and many others), and all the available information that could help to locate the additional specimens that will eventually allow their taxonomic status to be resolved. Under-prospected areas that might reveal interesting records are listed. Amiet has literally spoon-fed future batrachologists and professors in need of subjects for their students the descriptions of numerous frog taxa. Hopefully this will be capitalized upon.

Jean-Louis Amiet is currently working on botanical publications and will then work on butterfly publications before working again on amphibians (Amiet, pers. comm., May 2013); one will thus have to curb one’s impatience to see the next publications of Amiet on Cameroonian amphibians. In the meantime, we encourage scientific libraries, batrachologists, and students to acquire and exploit this remarkable and beautiful book.

**Acknowledgments.**—We are grateful to Jean-Louis Amiet (Nyons) and Thierry Frétey (Médéac) for providing useful information and literature, respectively, and to Yves-Marie Allain of La Nef des Livres for sending a review copy of the book.

**Literature Cited**


INFORMATION FOR CONTRIBUTORS

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